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The epidemiological approach to sports injury: the case for rugby league

A Thesis Submitted for the Degree of Doctor of Philosophy

By

Conor Gissane
Department of Health and Social Care, Brunel University

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Abstract

In any sporting activity it is important to know how many injuries players might receive and also what type of injuries will be received, so that efforts can be made to reduce the risk of injury. This thesis examines the injury incidence associated with playing professional rugby league, and examines some of the risks associated with injury whilst playing the game.

The first paper describes the pattern of injury incidence in professional rugby league and noted that it is higher than in other popular team sports.

The second paper examines the different exposures of forward and back players and observes that forwards experience higher rates of injury.

The third and fourth papers examine the effect of moving the playing calendar to summer rugby. The risk of injury has increased 67%, and it is also shown that 13% of players experience a 2-3% body mass loss in 14 of 16 games played in excess of 19°C ambient temperature.

The next two papers look specifically at the number of collisions experienced by players during the course of a game. Forwards are involved in more collisions (55) than backs (29) during the course of each game. Also, backs have a significantly higher injury rate per 10,000 physical collisions compared to forwards.

The next paper proposes a cyclical operational model to examine the inter-relationship of a number of factors that are involved in sports injury epidemiology. The application of this proposed cyclical model may lead to greater success in understanding the multi-faceted nature of sports injuries.

The final study in the series summarise the injury rates in professional rugby league football from previously published studies. The overall injury rate is 40.3 injuries per 1,000 hours (95% CI 36.9 to 43.8). The majority of injuries are to the lower half of the body (20.7 per 1,000 hours, 17.7 to 24), with the trunk receiving the least (6.7 per 1,000 hours, 5 to 8.6).

Acknowledgements

When carrying out research of this size and this length, it is necessary to recognize to part played by other parties. Throughout the course of these investigations several others have been involved.

I would like to thank and acknowledge the assistance of my good friend John White, and also to Kate Kerr who were involved in large parts of this research. I would also like to acknowledge the role played by my two supervisors Alex Farrow and David Marsland, without them it would not have been possible to put this work into thesis format. Thank you to you both.

Periodically, it has also been necessary to involve other persons when specialist areas of expertise were needed to take the investigations into new areas. For this I would like to acknowledge and thank Angela Cumine, Sarah Stephenson and Susie Robertson, and Paul Standing.

As I am neither a medical nor a therapeutic practitioner, I have, throughout this research, been dependent upon the clinical diagnosis provided by others. None of this would have been possible without the clinical and record keeping skills of the medical officers of the London Broncos Rugby League team, De Jennings and Simon Jennings. I would like to offer my sincerest thanks to my good friend De Jennings whom I have known for 13 years, and with whom we began our injury register in July 1990.

Lastly, I want to thank every player who has played for the Fulham/London Crusaders/London Broncos team. Without those guys being prepared to put their bodies on the line, there would be very little to write about.

Contents

The importance of epidemiological methods in sports injury research

Introduction

Epidemiology is the branch of medicine that deals with the occurrence, causes and prevention of disease (Schootman et al., 1994b). It is based on the assumptions that diseases do not occur at random, and that diseases do have causal and preventative factors that can be identified through the systematic investigation of populations (Henekens and Buring, 1987). The overall aim of epidemiologist is to identify factors that are associated with the onset of the disease, and then make recommendations for control and prevention (Schootman et al., 1994b). Although the origins of epidemiology are rooted in human disease and public health medicine, the methods employed have a wider applicability, and the outcomes need not be restricted to disease (McNeil, 1996). Epidemiological methods have been used to investigate areas such as, occupational health and disease (Harber et al., 1994, Schilling and Walford, 1981) accidents (Gordon, 1949), injury control (Berger and Mohan, 1996), and sports traumatology or sports injury (Caine et al., 1996, Schootman et al., 1994b, Walter and Hart, 1990).

Indeed, it has long been recognised that injuries do have a number of similarities to diseases. They obey certain biological laws, and they can, therefore, be studied using basic epidemiological principles (Gordon, 1949). However, while there are similarities between diseases and accidents, there are also a number of differences. Many diseases have long latency periods, for example cancer, whereas injuries can take place in an instant, for example a fracture (Schootman et al., 1994b). Also, a specific disease can result from exposure to an unknown causative agent, which may or may not be present under a number of different circumstances. Injuries, however, only occur under specific circumstances, when an individual is exposed to that situation (Schootman et al., 1994b).

Sports injury epidemiology

Sporting injury has been described as one of the unwelcome by products of participating in sport (Lower, 1995). But the magnitude and type of injury depend upon the sport and the way it is practised (Tweller et al., 1996). For example, at the community level sports injuries have been reported to be responsible for 17% of all medically treated injuries (deLoes, 1990). While in professional sports, it has been reported that injuries in soccer cost clubs a 17% loss of all game hours in a season (Neilsen and Yde, 1989). In both situations, such injuries represent substantial economic costs either directly in terms of medical treatment expenses, and indirectly in the form of absence from work.

The study of sports injuries represents a unique case in terms of injury (Schootman et al., 1994b). They occur under specific conditions when individuals are participating or practising for sport. Sports people are also often willing to play in spite of the playing conditions, and players are also quite willing to challenge the healing process by wanting to return to competition before they have completely recovered from injury (Schootman et al., 1994b). Because of its peculiarities, it has been argued that sports medicine research needs to consider dimensions that other clinical research does not (Noyes, 1988).

Although some of the methodologies may be transferable from disease or injury epidemiology (Powell, 1994), there is some disagreement as to which techniques can be successfully applied to sports injury research (Schootman et al., 1994b). But, if sports injuries are to be reduced, a comprehensive approach needs to be taken to define the nature and magnitude of the problem (Waller et al., 1994).

Caine et al. (1996), has stated that every one involved in sports, whether they be players, parents or sports medicine practitioners need to have answers to certain questions such as the following: -

i. Is the risk of injury greater in some sporting activities than others?
ii. What types of injuries are most common in a given sport?
iii. What is the average time lost from injury, and what is the risk of permanent impairment?
iv. Are some athletes more injury prone than others?
v. Are particular physical and psychological characteristics associated with a greater risk of injury?

vi.How can injury be predicted or prevented?
vii.How effective are the preventative measures that are implemented?

In an attempt to provide answers to these questions an epidemiological approach can be employed, and to function efficiently in the field of sports medicine epidemiologists need to become better acquainted with the correct employment of these study designs and their inherent limitations (Schootman et al., 1994b). Until this has taken place, and the numerous messages contained in sports medicine literature have been examined, no one can claim to know very much about sports injuries (Caine et al., 1996).

Hunter and Levy (1988) stated that injury patterns from sports activities should be considered for all those who care for athletes. They added that, the objective of an epidemiological investigation is firstly to describe those deleterious patterns and, ultimately to relate them to causative factors, in the hope that strategies can be developed to influence the future pattern. For epidemiologists to be in a position to influence future patterns of morbidity by controlling and/or preventing injury, they need to be able to quantify the occurrence of injury, identify who would be affected by certain injuries, and distinguish where and which method is to be used to study the injury outcome.

Previously the ability to perform these tasks has been limited because investigations involving sports injuries have traditionally used clinical case series data (Walter et al., 1985, Walter and Hart, 1990). These are able to document unusual medical events, and often can represent the initial clues of adverse effects of exposures (Henekens and Buring, 1987). However, this provides no information as to how to identify and examine sports persons at risk of injury, or any risk factors associated with specific injury.

Descriptive epidemiology

Several authors have suggested that the role of descriptive epidemiology is to quantify the occurrence of the human condition under investigation (Henekens and Buring, 1987, Bonita et al., 1993). The initial investigative step in epidemiological investigation before searching for risk factors is to collect descriptive data with regard to the frequency, type and severity of injuries in specific populations (Schootman et al., 1994b). Descriptive studies are observational in design, allowing nature to take its course without regard to causal or other hypotheses (Last, 1995).

To investigate whether an exposure is a potential risk factor and is related to the frequency of a condition, these frequencies are compared among people with varying levels of exposure to the risk factor (Wickham, 1989). When attempting to describe the distribution of injuries it is necessary to relate this to the population at risk (Caine et al., 1996). To do this, the size of the source population must be known or, injury must be related to exposure time.

A number of descriptors have been used in the sports medicine literature to describe the occurrence of injury. Typically, they are attempting to describe incidence rates, which pertain to the number of new injuries that occur in the observation period, or prevalence, which refers to the total number of injuries both new and old in the study population at risk in a given time (Henekens and Buring, 1987, Schootman et al., 1994b, Caine et al., 1996, Last, 1995). Previous research has sought to generalise exposure into participant years, and injuries per 100 or 1000 participants (Mendryk and Kramer, 1978). But it has been suggested that this can lead to questionable conclusions, particularly when comparisons across sports are made (Caine et al., 1996). In rugby, there has been a trend to standardise rates per 1000 hours (equation 1), where exposure time can be either playing time or, practice time plus playing time (Gibbs, 1993a, Seward et al., 1993, Garraway and MacLeod, 1995, Estell et al., 1995). This has allowed comparison across sports (Edgar, 1995), and across age groups (Estell et al., 1995).

$$\text{Injuries per 1000 hours} = \frac{\text{Number of injuries}}{\text{Total hours exposure}} \times 1000 \qquad (1)$$

A major limitation of descriptive sports injury research is the lack of a common operational definition of what constitutes a sports injury (Caine et al., 1996). Powell (1994) reported that the two most popular procedures for developing a definition are the criteria of an accurate medical diagnoses and time lost from participation. The two have often been used in conjunction, but can still result in different overall definitions. For example, in rugby league injury research one operational definition that has been used defined a sports injury as an injury that required a player to miss a subsequent game or, required specific medical attention (Seward et al., 1993). Another interpretation has defined an injury specifically as an injury that occurred during match play and resulted in a player missing a subsequent game (Gibbs, 1993a). Both definitions require accurate medical diagnosis, but slightly different time determinations.

By using descriptive studies, an epidemiologist can observe statistical associations between a population characteristic and the occurrence of a disease or a condition. This information can then be used to generate hypotheses. However, it is not possible to determine the importance of specific characteristics until athletes or players with or without specific symptoms have been followed (Walter et al., 1985).

Analytical epidemiology

Once the injury or injuries have been described, the search for risk factors that affect the occurrence of injury can be investigated (Schootman et al., 1994b). The epidemiological approach is rooted in the assumption that injuries do not happen purely by chance, so an important part of sports injury epidemiology is in the identification of factors that contribute to the occurrence of athletic injury (Caine et al., 1996) Last (1995), suggested that analytical epidemiology is about investigating which subsets of a defined population who are, have been, or in future may be either exposed or unexposed, or exposed in a different degrees, to a factor(s) hypothesised to influence the probability of occurrence of a given disease or other outcome.

In public health epidemiology it has been suggested that analytical investigations fall into three broad categories; case-control studies, cohort studies, and intervention studies (Lilienfield and Stolley, 1994), while some include a fourth, cross-sectional studies (McNeil, 1996, Schootman et al., 1994b). Each of these designs seeks to investigate an explicit comparison between exposure and disease status (Henekens and Buring, 1987). It has been recognised by a number of investigators that intervention studies, specifically randomised clinical trials, are the strongest research design available in epidemiology (Caine et al., 1996), and they also provide the most reliable evidence (Henekens and Buring, 1987). They are followed in order of strength by cohort studies and case control studies (Caine et al., 1996, Wade, 1988a). However, depending upon the specific exposure, the condition under investigation and the availability of resources, each type of study design has its own merits.

Case-control studies

Case-control studies are particularly efficient for investigating relatively rare conditions, they are both relatively simple and economical to carryout

(Bonita et al., 1993). All case-controls studies are carried out retrospectively, with the subjects' exposure history being assessed for a period in the past (Lilienfield and Stolley, 1994). This study commences at the end rather than the beginning of the causal pathway (Wade, 1988b). This form of study seeks to compare a group of cases, for example injured players, with one or more control groups, uninjured players, with respect to one, or more preceding exposures (Schootman et al., 1994a). An example of this type of study sought to compare the level of flexibility and the musculoskeletal systems of female gymnasts with normal values obtained from non-athlete age-matched controls (Kirby et al., 1981).

The condition under investigation may be a specific injury (Wade, 1988b). After the condition has been clearly defined, subjects who have the condition must be identified to form the case group. It has been suggested that often the best source of cases for sports medicine will be persons who have sought specific medical care for an injury. Or, alternatively, injured players can be identified through medical surveillance systems (Schootman et al., 1994a).

When selecting the cases, medical epidemiologists have suggested that they should represent as homogenous a disease entity as possible (Henekens and Buring, 1987). This needs to be ensured by the use of strict diagnostic criteria. For example, Rovere and Bowden (1986) suggested that including players with medial collateral ligament (MCL) injuries and players with anterior cruciate ligament (ACL) injuries in the same control group to study the effects of preventive knee braces would be inappropriate. This was because knee braces were not expected to protect against ACL injuries. Similarly, there needs to be strict exclusion criteria for subjects. All cases and controls need to have the same potential for exposure, which will in part depend upon the risk factor under investigation (Schootman et al., 1994a). For example, not all rugby players will have a similar potential exposure, and therefore risk, for injury in scrum situations.

With all case-control studies recall bias is a very frequent problem (Sackett, 1979). Frequently studies are hindered by inaccurate or biased recall of exposure, (Walter et al., 1985) which should be determined in the same manner for both cases and controls (Bonita et al., 1993). There is also the potential for cases, because they are injured, to be more motivated to provide a more detailed exposure history than the controls (Walter and Hart, 1990). So, when the subjects, both cases and controls, are either interviewed or questioned, the interviewer should be blind as to their subject status, so that there is not a conscious or unconscious attempt to question cases in more detail. This can be difficult in certain instances such as a broken leg, or when a case is wearing a neck brace.

The case-control study design has great potential in sports medicine epidemiology (Schootman et al., 1994a). However, they do require careful planning before initiation, not least because of the very high potential for biased information on the past.

Cohort studies

A cohort is a designated group of persons who are followed over a period of time (Last, 1995). They provide the best information about the causal factors of a condition, and also the most direct measurement of the risk of acquiring a condition (Bonita et al., 1993). They also reduce recall bias, which is so common in case-control studies. Exposure information in a prospective cohort is ascertained either prior to or at the time of the adverse event.

Some authors have suggested that cohort designs are prospective, beginning with a disease free group of people and following them overtime (Schootman et al., 1994b, Bonita et al., 1993, Lilienfield and Stolley, 1994). While others have suggested that they can be either prospective or retrospective (Henekens and Buring, 1987, Rudicel, 1988), with the distinguishing feature being whether the outcome of interest has occurred at the point in time when the investigator(s) initiate(s) the study (Henekens and Buring, 1987). Furthermore, cohorts can be subdivided into fixed or closed cohorts, membership of which is restricted to a specific time period (Last, 1995, Checkoway et al., 1989), and open cohorts that can add to membership through the course of the follow-up (Checkoway et al., 1989).

A further variation in the design of cohort analysis is the use of non-concurrent cohorts (Lilienfield and Stolley, 1994). In this type of study it is not possible to compare two groups where data has been collected concurrently. So, data on a previous cohort is compared with that of a current cohort. This design is often used when industrial processes alter, and it is unfeasible to follow two cohorts simultaneously (Lilienfield and Stolley, 1994). In sports medicine epidemiology this is sometimes the only feasible method. For example, when comparing injury rates before and after the advent of professionalism in rugby union (Garraway et al., 2000).

In sports medicine cohorts have often been used to provide descriptive data with regard to the incidence and prevalence of injury over a period of one to several seasons (Gibbs, 1993a, Seward et al., 1993, Garraway and MacLeod, 1995, Estell et al., 1995, Gerrard et al., 1994, Hughes and Fricker, 1994). While some studies have used sub-cohort analysis, such as different playing levels (Lee and Garroway, 1996) or players' physiques (Lee et al., 1997) to assess risk factors for injury.

Intervention studies

Intervention studies, specifically randomised controlled trials, are widely regarded as the strongest level of information available in epidemiological research (Caine et al., 1996, Henekens and Buring, 1987, Wade, 1988a, Rudicel, 1988). They have been referred to as the 'gold standard' (Wade, 1988a), and are the criterion against which other study designs are contrasted (Rudicel, 1988). The primary advantage of this type of study is that the treatments to be investigated are allocated at random to subjects in a sample of sufficiently large size (Henekens and Buring, 1987). Because subjects are allocated to treatment groups randomly many of the effects of bias and confounding that could be associated with non randomised studies are controlled for (Walter and Hart, 1990). This is because the process of randomisation should ensure that the comparison groups are balanced, both in terms of known determinants for a condition and all possible risk factors (McNeil, 1996). This approach is most comparable to that of laboratory experiments in basic sciences (Lilienfield and Stolley, 1994, Henekens and Buring, 1987).

These studies can be sub classified by various factors including the types of subjects involved and the size of the study (McNeil, 1996). Several types of intervention study have been defined in the literature: therapeutic trials in which a therapeutic agent or procedure is given in an attempt to cure, relieve the symptoms, or prolong the survival of those with the condition being investigated; intervention trials in which the investigator intervenes prior to a condition developing in individuals with characteristics that increase their risk of developing the disease; preventive trials in which an attempt is made to determine the efficacy of a preventive agent or procedure among those without the condition. For example, adding fluoride to the water supply to prevent dental caries

(Kunzel and Fischer, 1997). These are also referred to as prophylactic trials (Lilienfield and Stolley, 1994).

It has been suggested that randomised control type of investigative design offers an effective method for evaluating acute therapeutic modalities (Wade, 1988a), and it has been used to investigate the effectiveness of operative versus non-operative treatment for knee injuries (Sandberg et al., 1987). But in spite of this, and the acknowledgement that this is the strongest available evidence, they have been relatively little used for evaluation of a proposed means of injury prevention, or hypothesised causes of injury (Caine et al., 1996). This may be because there are a number of practical reasons why the design cannot be utilised (Hart, 1996). Indeed, some texts on epidemiological methods in occupational epidemiology do not cover the design strategy (Checkoway et al., 1989, Hernberg, 1992).

There are four main components to a randomised controlled trial; the selection of subjects; the random allocation of treatments to subjects; the treatment period; and the statistical analysis (Tygstrup et al., 1982). To design a trial effectively, careful attention must be paid to each stage in turn. One problem associated with such studies in sports injury research may be the identification of a large enough population from which patients can be recruited. For example, Wade (1988a), has suggested that if the objective was to evaluate knee braces in the prevention of knee injuries, the incidence is relatively small so assembling a study group may not be feasible.

Often an essential feature of clinical trials is the blinding that is carried out. The purpose of blinding is to reduce the effect that knowledge of treatment may have on the outcome measures. Altman (1991), suggests that this can be done at three levels. Single blinding is where the patient is unaware of the treatment they have been given. A double-blind experiment is when neither the patient, nor the person evaluating the treatment knows which treatment was administered. A further extension to the double-blind study is to carry out the statistical analysis unaware of the treatment allocation, which is known as triple-blind (Last, 1995).

However, while such strict terminology is relatively easily applied to drug and surgical trials, when other forms of therapeutic treatment are evaluated, the situation is not quite so easy to define. The term 'clinical trial' can be applied to any planned experiment, which has been designed to elucidate the most appropriate treatment, and this may be conducted successfully with or without blinding (Pocock, 1983). For example, a trial to evaluate the treatments for low back pain was randomised, but not blinded (Meade et al., 1990). While a trial comparing treatments of shoulder complaints was referred to as single-blind (Winters et al., 1997). However, the masking in each of these studies was only to the physiotherapist carrying-out the follow-up examination. In the final analysis, the treatments were not allocated blindly, only the follow-up evaluation was carried out blindly.

In sports medicine epidemiology, the intervention study or clinical trial is primarily designed to evaluate the efficacy and safety of new treatments (Pocock, 1983), for example whether they are surgical or therapeutic. But to evaluate protective equipment, such as prophylactic strapping and gum shields, it is unlikely that subjects could be randomly allocated to groups, and it may be unethical to attempt it. Certainly, blinding of the subjects will be almost impossible, a gum shield wearer would know if it was in his or her mouth. Therefore, studies involving protective equipment could, at best, be prospective cohort studies, with a blind evaluative stage and a 'blind' analysis.

Nevertheless, authors have argued that they do have their place in sports medicine research (van Mechelen, 1998, Eston and Rowland, 2000). However, debate remains as to the extent and precise location of the blinding (Gissane, 2000, Gissane, 1999). But the small number that have been carried out are single blind, with the practitioner carrying out the evaluation, blinded to the subjects' treatment allocation (Pope et al., 2000).

The epidemiological evaluation of sports injuries is a valid investigative tool and although there has been some disagreement over the best methods to use (Caine et al., 1996), it appears clear that traditional methods often need to be adapted only slightly. This can be seen with the use of non-concurrent cohorts (Garraway et al., 2000), and single blind randomised controlled trials (Pope et al., 2000) in sports medicine epidemiology.

Descriptive statistics are always the first stage of a research process in order to identify whether there is a problem or trend. The methodology used in the first paper (Stephenson et al., 1996) (see pages 40 to 57) presented in the thesis lays the basis for describing injury incidence, and identifying trends in a sample of rugby league players over four seasons.

All injuries that were reported by players during the four seasons between July 1990 and May 1994 were recorded. A season ran from the beginning of pre-season training, to the last competitive match in either April or May. An injury was taken to be the onset of pain or a disability that occurred while playing Rugby League football (Gissane et al., 1993). The diagnosis and classification of injury was carried out by the club doctor and the physiotherapist. The site and injuries were categorised as described previously (Alexander et al., 1980). The following details were recorded about each injury:

- The position of the player
- The site of the injury
- The nature of injury
- Whether the injury occurred in playing or training
- The team played for (first or 'A' team)
- Activity at the time of injury
- Time off as a result of injury

The total number of games played during the four seasons were recorded. In total, there were 249 games played (138 first team, 111 'A' team), this included all competitions and friendlies. Playing hours at risk were calculated as the number of matches played × 1.33 (each match lasting 80 minutes). Thirteen players in a side constitute 17.29 playing hours at risk during a game. Training sessions took place at the rate of two or three per week, involving approximately 5 hours work on game skills, with minimal body contact.

Statistical analysis consisted of the calculation of rates per 1000 hours of play, percentages, and where appropriate rates were compared using the normal approximation as described by Clarke (1994). Significance was set at the $P<0.05$ level.

The methods in the second publication (Gissane et al., 1997a) (see pages 58 to 73) presented as part of this thesis, seek to describe the differences in the incidence of injury between rugby league forwards and backs. For this paper the exposure under investigation was whether players were playing in either the forwards or the backs.

The data used in this investigation have been described previously (Stephenson et al., 1996). All injuries that were reported by players during the four seasons between July 1990 and May 1994, at one professional

Rugby League club were recorded. A season ran from the beginning of pre-season training, to the last competitive match in either April or May. An injury was taken to be the onset of pain or a disability that occurred while playing Rugby League Football and resulted in the player missing either matches or training for a period of seven days. The diagnosis and classification of injury was carried out by the club doctor and the physiotherapist. The following details were recorded about each injury: The position of the player (forward or back), the site of the injury, the nature of injury, the team played for (first or 'A' team), activity at the time of injury, time off as a result of injury

During the time of the injury survey a total of 249 games were played, which included all pre-season, league, cup and post-season games. This represented a total of 4305.21 player hours at risk (13 players × 1.33 hours × 249 games), each game lasting 80 minutes. Since a team of 13 is comprised of six forwards and seven backs, forwards were at risk for a total of 1987.02 playing hours, and backs for 2318.19 hours.

The statistical analysis consisted of the calculation of injury rates per 1000 hours of play as a standardised rate of exposure, for both forwards and backs. The relative risk (RR) was calculated using the person time cohort method as described by Hennekens and Buring (1987):

$$RR = \frac{\text{no of forward injuries/exposure time (hrs)}}{\text{no of back injuries/exposure time (hrs)}}$$

The injury rates for the different playing units were compared using the normal approximation as described by Clarke (1994)

$$z = \frac{(r_1 - r_2) - 0}{\sqrt{r_1/t_1 + r_2/t_2}}$$

where r_1 and r_2 are the two rates being examined and t_1 and t_2 are the respective time periods.

The methodology for the third paper(Gissane et al., 1998) (see pages 74 to 87) allowed the comparison of two non-current cohorts, with regard to their exposure to summer and winter rugby league.

During the initial European Super League season all injuries that were reported for the first team at one professional rugby league club were recorded. The injury data were compared with first team data from a previous study on the same club over a period of four seasons reported previously (Stephenson et al., 1996). An injury was defined as a physical impairment received during a competitive match which prevented a player being available for selection for the next competitive game (Gibbs, 1993a). The games were 7(1.09) [Mean(SD)] days apart. The diagnosis and classification of injury was carried out by the club doctor and physiotherapist. The information recorded about each injury has been reported previously (Gissane et al., 1993, Gissane et al., 1997a, Stephenson et al., 1996).

The population at risk was defined as the players who were selected to play for the first team in a given match, and the defined time at risk for calculating injury rates was the duration of the games multiplied by the number of players (1.33 hrs. × 13 players), multiplied by the number of games played. The average number of games played during the winter seasons was 34.5 (596.5 player hours), with each player averaging 12.1 appearances per season, and during the summer season, 23 games (397.67 player hours) were played in the Super League of 1996, with each player averaging 8.3 appearances.

Statistical analyses consisted of the calculation of injury rate per 1000 hours of play as a standardised rate of exposure (Edgar, 1995). To calculate the relative risk (RR) of injury between winter and summer rugby league the method using the incidence density ratio (IDR) for the two cohorts was used as described by Hennekens and Buring (1987).

$$\text{RR (IDR)} = \frac{\text{no. of summer injuries/exposure time (hrs)}}{\text{no. of winter injuries/exposure time (hrs)}}$$

Confidence intervals (95%) were calculated using the method as described by McNeil (1996). Where the confidence interval did not contain the null value (RR = 1.0) the RR was taken as being significant at the $P<0.05$ level (Henekens and Buring, 1987).

The methodology for the fourth paper (Jennings et al., 1998) (see pages 88 to 97) is descriptive and investigates body mass loss during a competitive match. Simple correlations were used to determine associations between variables. The subjects for this study were the members of the playing squad at one Super League Club, whose physical characteristics are displayed in table 1.

Table 1. Physical characteristics of players [mean±SD].

	Age (yrs)	Mass (kg)	Height (cm)
All players (n=28)	24.7±4.0	90.9±11.8	181.8±7.2
Backs (n=15)	25.1±4.3	84.6±7.5	178.4±2.1
Forwards (n=13)	24.3±3.8	98.1±12.1	185.4±7.7

The members of the squad who were selected for a given game took part in the assessment procedure on that occasion. Players' body mass was determined in the standard position before starting each game in underwear only, after they were towel dried. Each measurement was recorded to the nearest 100 g using a calibrated Seca 770 model scales. A similar procedure was completed on the players' completion of the game with minimal time delay. During the game the mean ambient temperature (°C) and mean relative humidity (%) was recorded using a Casella polymeter (Model M 112050: Reliability; humidity ±5% between 30% and 90% RH, Temperature ±1%).

For each game played, each player that played was treated as an independent event making a total of 268 player appearances. Therefore, all data were collected with body mass being determined as the difference between pre-game mass and post-game mass. Players were allowed to drink water ad libitum after pre-game body mass determination, during the game and at half time. For the purposes of analysis, only players who completed each full game of 80 minutes were included in the analysis (n=120).

The methodology used in the fifth publication (Gissane et al., 2001c) (see pages 98 to 112) makes use of video to examine the number and type of physical collisions experienced by players during competitive matches. Using video recordings provides the researcher with a detailed observation of what takes place during a game. Players representing one professional rugby league comprised subjects for the present study (N=35, forwards n= 15, backs n= 20). In order to assess the number and type of physical collisions in which players were involved while playing, video recordings of all 22 regular season games played during the 1996 Super League season were analysed. This represents a total of 29.3 hours of match play or 380.4 player hours (13 players x 1.33 hrs x 22 games). The video tapes used were master copies of recordings produced by two T.V. media broadcasting companies (British Sky Broadcasting, Isleworth and Micron Video, Wigan), and permission to use the material was granted by the Rugby Football League.

Each video was a standard VHS (25 frames.sec^{-1}) and was analysed by the principal investigator. Each physical collision that took place was classified into one of the following categories:

Defence (defending collisions)

1. Tackles - where the defending player(s) halted the progress of the ball carrier, and as a result the ball carrier had to play the ball.
2. Incomplete tackles - where the defending player(s) made contact with the ball carrier, but failed to prevent forward progress, or were unable to stop the passing of the ball.

Attack (attacking collisions)

3. "Tackled in possession" - where the ball carrier was tackled whilst in possession of the ball, forward progress was halted and the ball carrier had to play the ball.
4. "Broken tackles" - where the ball carrier was able to break through the tackle and continue forward progress.
5. Passes out of the tackle - where the ball carrier was tackled but was able to pass the ball.

Following this analysis it was possible to calculate each player's total defensive involvement (the sum of tackles and incomplete tackles), total attacking involvement (the sum of "tackled in possession", "broken tackles" and passes out of the tackle), and total physical involvement (in defence and attack) in each game analysed.

In order to determine the reliability of the physical collision analysis, three videos were analysed twice (each one week apart) by the principal author and the 95% limits of agreement were calculated using previously recommended methods (Nevill and Atkinson, 1997, Bland and Altman, 1986). Because the differences between readings did not vary in a systematic way across the all values, it was necessary to log transform the original data (Bland and Altman, 1986). Descriptive statistics (mean and 95% CI) for each physical collision category were computed for each playing position. To determine differences in the number and type of physical collision between forwards and backs, and between attacking involvement and defensive involvement, further analysis was undertaken using a proportion test (Altman, 1991).

The sixth publication (Gissane et al., 2001a) (see pages 113 to 126) presented in this thesis sought to make use of data collected from an injury register and combine this with the detailed observations regarding collisions from video analysis.

All injuries that were reported for the first team of one professional super league rugby club were recorded over one season. An injury was defined as a physical impairment received during a competitive match, which prevented a player being available for selection for the next competitive game (Gibbs, 1993a). The position of the player; the site of the injury; the nature of injury; the activity at the time of injury and the time off as a result of injury were recorded for each game played over the full season. The details of each category have been described previously (Gissane et al., 1993, Gissane et al., 1998, Gissane et al., 1997a).

The population at risk was defined as the players who were selected to play for the first team in a given match, and the defined time at risk for calculating injury rates was the duration of the games multiplied by the number of players (1.33 hrs. × 13 players), multiplied by the number of games played. A total of 23 games (22 regular season plus one play-off game) were played during one season (397.7 player hours).

In order to assess the number and type of collisions that players were involved in while playing, video recordings of 22 regular season games played during the 1996 Super League season were analysed (29.3 hours of match-play, 380.4 player hours). The video tapes used for analysis were master copies of recordings produced by two TV media broadcasting companies (British Sky Broadcasting, Isleworth and Micron Video, Wigan), and permission to use the material was granted through the Rugby Football League. The categorisation of physical collisions was carried out as outlined previously (Gissane et al., 2001c).

Following the analysis of physical collision categories, it was possible to calculate the following; 1) each player's total defensive involvement (the sum of tackles and incomplete tackles), 2) total attacking involvement (the sum of "tackled in possession", "broken tackle" and passes out of the tackle), 3) total physical involvement (defensive plus attack) in each game analysed, and 4) the differences in physical collisions incurred by backs and forwards.

Statistical analyses consisted of the calculation of injury rate per 10,000 physical collisions as standardised rates of exposure, and descriptive statistics for physical collisions (mean and 95% CI). In order to compare differences between the proportions of physical collisions a single proportion test was used (Altman, 1991), while a test for differences between injury rates used the method of Clarke (Clarke, 1994), and the relative risk (RR and 95% CI) was computed. In order to analyse the differences between forwards and backs in the number of games missed by injured players, the Mann Whitney U and Kruskal Wallis tests were employed since the data were not normally distributed

The seventh publication (Gissane et al., 2001b) (see pages 127 to 146) develops an operational model to investigate contact sports injuries.

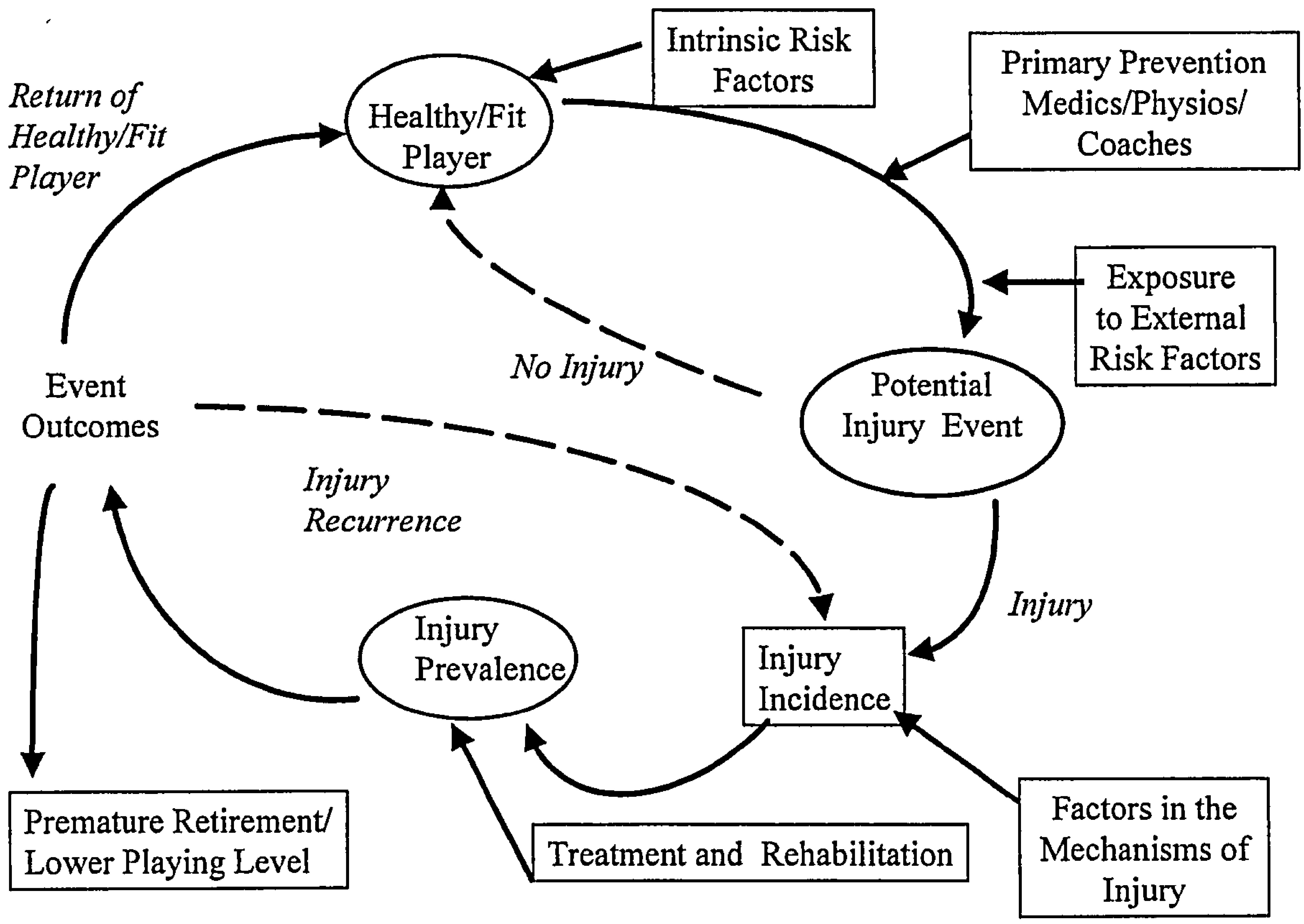
Traditional approaches to the epidemiological investigation of sports injuries have tended to focus on the incidence and prevalence of injury, applied both to individual sports, and to overall national statistics. The model developed in the work reported in the thesis aims to expand this traditional approach to take into consideration the multitude of factors which may predispose to injury, and which may determine the ultimate outcome of the injury for the contact sport athlete.

The cyclical model consists of five linked stages. First the ostensibly ***healthy/fit athlete*** may be at risk of injury from a number of predisposing factors. These may, with or without the additional exposure to external risk factors, in the presence of a ***potential injury event***, result in ***injury incidence***. The duration of time that the injury persists, during treatment and rehabilitation, contribute to the ***prevalence*** of the injury, and the ultimate ***outcome*** may be a return to sport at the original level, thus completing the cycle, or a return at a different level, or even premature retirement (figure 2). Each of the elements of the model are now described in greater detail.

The healthy fit player

Inherent within the ostensibly healthy/fit player, exist a myriad of ***intrinsic risk factors*** that have been suggested by the literature (Meeuwisse, 1994). For example, it has been reported that field hockey, soccer and lacrosse players exhibited an increased risk for ankle sprain when they displayed an increased eversion:inversion strength ratio (Barker et al., 1997).

Figure 2. A cyclical operational model for the investigation of contact sports injuries.



At this stage in the cycle the strategies for intervention may be termed 'primary prevention' (Lysens et al., 1991), with the aim of preventing injuries from occurring in the first instance (Fletcher et al., 1996). Knowledge of the individual's risk factors may be of benefit in primary prevention. These strategies amongst others, might include such measures as appropriate warm up, adequate hydration, prophylactic taping. They might also include the wearing protective equipment such as gum shields in rugby (Jennings, 1990), hurling (Crowley et al., 1995) and ice hockey (Rampton et al., 1997), or head guards in hurling (Crowley et al., 1995) and ice hockey (Kujala et al., 1995, Rampton et al., 1997). Such strategies would also include the coaching of proper technique in contact sports when either making or receiving a tackle (Corcoran, 1979), and teaching correct falling technique in judo (Kujala et al., 1995). Coaches and sports medicine practitioners seek to prevent injury, and it is the most logical and least costly method of health care (Meeuwisse, 1994). Additionally, prevention screening could take place to assess intrinsic risk factors that could lead to sports injury problems (McKeag, 1985). For example, it has been shown that postural and mechanical factors can predispose female basketball players (Garraway and MacLeod, 1995), rugby and soccer (Watson, 1995) players to injury, while screening has been advocated for groin injury prevention in rugby league football (O'Connor, 1995b).

Potential Injury Event

In addition to the intrinsic factors, extrinsic factors will play an important part in the potential for injury. The exposure to ***extrinsic risk factors*** will undoubtedly vary across sports and may vary within positions in certain sports, as well as the conditions under which sport is played. For example, both field hockey (Jamison and Lee, 1989) and American football (Skovron et al., 1990) have reported increased injury rates when games are played on astroturf. In American Football, both the risk of knee (RR = 1.18) and ankle (RR = 1.39) injuries are increased when the game is played on artificial compared with real grass (Powell and Schootman, 1992).

The event that initiates an injury is one of the most identifiable parts of the injury process and has been the focus of much research (Meeuwisse, 1994). In contact team sports these events are likely to be highly game specific, and indeed position specific. It has been suggested there are a high number of thigh injuries in professional soccer (Inklaar, 1994), and that are commonly result from physical contact with an opponent (Ekstrand and Gillquist, 1983). It has also been suggested that with the exception of goalkeepers, there are few upper body injuries that prevent soccer players from playing (McKeag, 1985).

At this stage in the cycle, a player that is not injured can continue to play whilst still exhibiting the same intrinsic risk factors, whereas if he/she becomes injured the player progresses to the next stage of the model.

Injury Incidence

In descriptive sports medicine epidemiological terminology incidence has been defined by the number of new events or cases of injury that develop in a population of individuals at risk during a specified time interval (Henekens and Buring, 1987). The incidence of injury in specific sports is an area that has received much attention (Garraway and MacLeod, 1995, Hickey et al., 1997, Kujala et al., 1995). However, the comparison across studies is often difficult due to the varying definitions of injury that have been employed (van Mechelen et al., 1996). Nevertheless, where comparisons can be made, there is a range of injury incidence rates among contact sports as demonstrated in table 2.

Table 2. Injury incidence rates across team sports.

Sport	Injuries per 1000 player hours	Reference
Rugby League	34*	Stephenson et al., 1996
Rugby Union	20*	Hughes and Fricker, 1994
Australian Rules	35	Seward et al., 1993
Soccer	22.6	Inklaar et al., 1996

*Injuries requiring a player to be unable to play for more than one week

Injury Prevalence

In descriptive sports epidemiology, injury prevalence has been quantified by the proportion of individuals in a population who have an injury at a specific instant. It provides an estimate of the probability or risk that an individual will be injured at some point in time (Henekens and Buring, 1987). Injury prevalence depends upon both the incidence rate of an injury, and the period of time between the initiating event to the return to full fitness. In sporting terms the prevalence of an injury is an important consideration, since the treatment and rehabilitation of injuries takes time, and this is often a major factor in injury prevalence. It has been suggested that because professional sport is a business, it is often desirable on the part of both the team and the player to keep time lost from playing to a minimum (Lewin, 1989). Prevalence can also be influenced by game regulations, for example in rugby union football a player who is concussed is required not to either play or train for a period of 21 days (International Rugby Football Board resolution 5.7), whereas in rugby league football there is a sliding scale of required abstinence for the severity of injury based on the symptom severity of concussion. Therefore, concussions that are considered relatively minor in rugby league football, would have a far higher prevalence in rugby union football, which could contribute to a distortion in specific injury prevalence among similar sports.

The type and duration of treatment of the athlete is dependent upon each specific injury which the player is has sustained. For example it has been reported that 44% of rugby injuries only require treatment with RICE (rest, ice, compression and elevation) (Hughes and Fricker, 1994), while others may require surgical intervention (Thomas and Thomas, 1999).

During the rehabilitation process, both secondary and tertiary prevention can take place. The aim of secondary prevention is to restore health when it is impaired (Last, 1995). In sports medicine it is defined as the process of preventing or delaying the development of irreversible structural damage, by therapeutic intervention (Lysens et al., 1991). These measures can influence the prevalence of injury by reducing the amount of time that a person remains injured, but not the incidence. Appropriate and early management of soft tissue injury in particular, has been shown to promote early recovery (MacLeod, 1993).

Therapy that seeks to limit the injury process from becoming either chronic or persistent has been termed tertiary prevention (Lysens et al., 1991). The aim of tertiary prevention is to reduce both the incidence and prevalence of long term disability (Lysens et al., 1991). Sound treatment and rehabilitation have been suggested to be one of the most adequate preventive measures for secondary and tertiary prevention (Lysens et al., 1984).

Event Outcomes

In the proposed cyclical operational model for the investigation of sports injuries (figure 2), an injury has three possible ***event outcomes.*** A player can return to a healthy/fit state, the injury can recur, and either, the player can retire from competition at that level, or continue participating at a lower level The obvious ideal is to return to playing at the pre-injury level of performance. In order for an athlete to be regarded as healthy they must be able to take part fully in both training and playing.(Lysens et al., 1991) However, professional athletes are unlike a number of other occupational groups in that they are often quite willing to train and play in spite of injury, compared with others, who normally return to work only when they are completely recovered (Schootman et al., 1994b).

Recurrent injuries are also a major problem in sport and have been reported to account for 16.5% of all injuries in rugby union football (Garraway and MacLeod, 1995). Recurrent injuries increase the ***incidence rate*** and the amount of time lost for an injured player, thus also increasing the ***prevalence rate*** of injury. Furthermore, one of the greatest risk factors for injury is the history of previous injury (Watson, 1997).

In extreme circumstances professional sport players are sometimes forced into premature retirement because of injury. In such cases, it has been reported that rugby league football players who suffered long term consequences of injury after their playing careers, experienced difficulties, which included job limitations, reduced income earning potential and increased personal medical costs (Meir et al., 1997).

In certain situations players will be unable to return to playing and the management of such an injury may seek to maximise the quality of life rather than fully remediate the injury (Lysens et al., 1984). Previous work has described cervical spine injuries of two rugby union football players who could no longer return to play (Secin et al., 1999). These players are now members of the Rugby Amistat Foundation, which is dedicated to the well being of players who have suffered physical and mental trauma following disabling injury (Secin et al., 1999).

The overall design of the proposed operational model is cyclical because even if a player returns to health/fitness, the sports injury itself may constitute an intrinsic risk factor for the predisposition of future injury. Even if a player is fortunate enough to avoid an injury, the individual's intrinsic risk factors are unlikely to remain the same over time. For example, at the beginning of every season a player has another year of experience and is another year older, both of which have been described as potential sports injury risk factors (Lysens et al., 1991, Watson, 1997). This will serve to alter the nature of intrinsic risk factors present. In addition to this, coaches in contact sports often emphasise increasing muscle bulk during the closed season (Meir, 1993), which may also serve to alter an individual's intrinsic risk factors.

The eighth publication (Gissane et al., 2002) (see pages 148 to 162) uses pooled data analysis of injury incidence in rugby league football. To carry out a pooled data analysis of injury in rugby league football methods included the development of a search strategy to locate relevant papers investigating injury in the game. Inclusion/exclusion criteria were developed to ensure compatibility of the data, and finally the combined analysis was performed. Databases identified for searching included Medline, Sports Discus and Web of Science databases, covering the period from 1985 to 2000 and 18 studies were identified. The terms used were, rugby *with* league *and* injury.

Inclusion criteria for the present analysis were Studies published later than 1990; data collection carried out prospectively on professional players; a definition of a recordable injury being one that required an injured player to miss the subsequent game; and finally a count of the number of games studied to allow the calculation of person time injury rates.

A total of 18 articles were identified that reported prospective data collection of rugby league injury, and details of these studies are shown in table 1. Of these, only ten satisfied the inclusion criteria,(Gissane et al., 1993, Seward et al., 1993, Estell et al., 1995, Gibbs, 1993a, Gissane et al., 1997a, Gissane et al., 1998, Hodgson-Phillips et al., 1998, Stephenson et al., 1996) two of these studies were excluded (Hodgson-Phillips, 1998, Hodgson-Phillips et al., 1997) because of reporting the same source data as in a previous paper.(Hodgson-Phillips et al., 1998) A further two studies were also excluded as the same common baseline data set had been used to highlight further trends. For example, Stephenson et al. (Stephenson et al., 1996) and Gissane et al. (Gissane et al., 1997a) used the same baseline data, only the former reported the overall incidence of injury in rugby league (Stephenson et al., 1996), while the latter sought to highlight the differences in injury rates between forwards and backs (Gissane et al., 1997a). Therefore a total of six studies were included in the final pooled analysis which are highlighted in table 1, three of which reported both first team and reserve grade information (Stephenson et al., 1996, Estell et al., 1995, Gibbs, 1993a).

Since many studies did not include all areas of interest for analysis, it was necessary to extract specific information from individual studies at different stages of the analytical process.

The data from individual studies were combined using the method described by Breslow and Day (Breslow and Day, 1987). Person-time incidence rates and 95% confidence intervals were calculated using Confidence Interval Analysis Software (Altman et al., 2000). To test for significant differences, proportion tests (z), chi-squared (χ^2) goodness of fit tests were used, along with relative risk (RR) where appropriate.

Table 1. Summary of rugby league injury studies which reported prospective data collection.

Author(s) *italicised studies used*	Study Design	Seasons	Grade/Level	Participating Clubs
Alexander et al., 1979	Prospective	1	1st, Reserve, U21	1
Alexander et al., 1980	Prospective	2	1st, Reserve, U21	1
Estell et al., 1995	Prospective	1	1st, Reserve, U21, U19, U17, U15	1
Gabbett 1999	Prospective	3	Amateur	3
Gibbs 1994	Prospective	3+2	1st, Reserve, U21	1
Gibbs 1993	Prospective	3	1st, Reserve, U21	1
Gissane et al., 1998	Prospective	5	1st	1
Gissane et al., 1997	Prospective	4	1st, Reserve	1
Gissane et al., 1993	Prospective	1	1st, Reserve	1
Gissane et al., 1997	Prospective	1	1st	2
Hodgson-Phillips 1998	Prospective	4	1st	1
Hodgson-Phillips et al., 1998	Prospective	4	1st	1
Hodgson-Phillips et al., 1997	Prospective	4	1st	1
Lythe and Norton 1992	Mixed	1	--	Not stated
Norton and Wilson 1995	Prospective	1	1st, Reserve, Senior B, Open age amateur	24
Seward et al., 1993	Prospective	1	1st, Reserve, U21	9
Stephenson et al., 1996	Prospective	4	1st, Reserve	1
Walker 1985	Prospective	5	--	1

Injury in rugby league: a four year prospective survey

Abstract

Objective - To investigate the incidence of injury in English professional Rugby League over a period of four playing seasons.

Methods - All injuries that were received by players during match play were recorded. Each injury was classified according to site, type, player position, team playing for, activity at the time of injury, and time off as a result of injury.

Results - The overall injury rate was 114 (95% CI 105 - 124) per 1000 playing hours, the most frequent type of injury were muscular injuries (34 [29 - 40] per 1000 playing hours), while the most frequently injured site was the head and neck region (38 [16 - 25] per 1000 playing hours). Players received the largest percentage of injuries when being tackled (46.3% [41.9 - 50.7]), most injuries required less than one week away from playing and training (70.1% [66.1 - 74.2]) and forwards had a higher injury rate than backs (139 vs. 93 injuries per 1000 hours).

Conclusions - The high rates of injury in Rugby League are undoubtedly due to the high amount of bodily contact in the game. Being tackled has the highest risk of injury, because of being hit forcibly by other players. Forwards suffer higher injury rates than backs probably because they are involved in a greater number of physical collisions.

Key words: rugby league, injury, injury rate, prospective study

Introduction

Rugby League is a physical game in which players are required to demonstrate speed, stamina, strength and agility (Gibbs, 1993a). It has been suggested that injury rates in Rugby League are higher than in other main body contact sports such as, Rugby Union (Seward et al., 1993, Gissane et al., 1993), Australian rules football and soccer (Seward et al., 1993). The possible reasons for the high injury rate are that players are involved in 20 to 40 physical 'confrontations' per game, and that players wear minimal protective equipment (Gibbs, 1994), such as padding, which is designed to protect the soft tissues but not the bones and joints (Doran and Dunn, 1987), or padded supports and sleeves for which, it has been suggested, there is no evidence of protection for injured muscles (MacLeod, 1993).

However, it is acknowledged that research into many aspects of Rugby League is extremely limited (Brewer and Davis, 1995), not least the incidence of injury. Previous investigations have reported on short time periods (Alexander et al., 1980, Gissane et al., 1993), and the only longitudinal investigations have been carried out in the Australian game (Gibbs, 1993a, Gibbs, 1994). These studies also report widely differing findings, which could be due to the playing conditions, the skill level of players, the design of the studies, or the definition of what constitutes an injury. Therefore, the purpose of this study was to describe the incidence of injury in one professional Rugby League club over a period of four seasons.

Methodology

All injuries that were reported by players during the four seasons between July 1990 and May 1994 were recorded. A season ran from the beginning of pre-season training, to the last competitive match in either April or May. An injury was taken to be the onset of pain or a disability that occurred while playing Rugby League football (Gissane et al., 1993). The diagnosis and classification of injury was carried out by the club doctor and the physiotherapist. The site and injuries were categorised as described previously (Alexander et al., 1980). The following details were recorded about each injury:

- The position of the player
- The site of the injury
- The nature of injury
- Whether the injury occurred in playing or training
- The team played for (first or 'A' team)
- Activity at the time of injury
- Time off as a result of injury

The total number of games played during the four seasons were recorded. In total, there were 249 games played (138 first team, 111 'A' team), this included all competitions and friendlies. Playing hours at risk were calculated as the number of matches played × 1.33 (each match lasting 80 minutes). Thirteen players in a side constitute 17.29 playing hours at risk during a game. Training sessions took place at the rate of two or three per week, involving approximately five hours work on game skills, with minimal body contact.

Statistical analysis consisted of the calculation of rates per 1000 hours of play, percentages, and where appropriate rates were compared using the normal approximation as described by Clarke (Clarke, 1994). Significance was set at the $P<0.05$ level.

Results

During the four seasons under investigation a total of 599 medical conditions that prevented a player from either playing or taking part in club training for Rugby League were recorded. Of these, 27 were illnesses and conditions such as sickness, and were excluded from the analysis. This left a total of 572 sports injuries, 492 (82.1%) of which were received during match play and 80 (13.9%) during training.

Of the 492 match injuries, 297 (60.4%) were to first team players and 195 (39.6%) to Alliance ('A' team) players. This equates to an overall incidence rate of 114 injuries per 1000 hours of match play (first team, 124; A team, 102; $z = 2.2$, $P<0.05$).

The type of injuries sustained during match play are displayed in table 1, which indicated that the highest injury rates are for muscular injuries (haematomas and strains) (34 per 1000 hours). When examining the first and A teams separately the same type of injury was the most common (first team 37, A team 31 per 1000 hours; $z = 4.7$, $P<0.05$). The types of injuries that were least common were abrasions & skin infections and 'others' (both 2 per 1000 hours)

The site of injuries sustained by players are displayed in table 2, which indicated that the region of the body that suffers the highest injury rates is the head and neck (38 per 1000 hours). The same site was also the most injured when comparing the first and A teams, although the two rates are markedly different (47 vs. 28 per 1000 hours; first team vs. A team; $z = 3.2$, $P<0.05$). The next most commonly injured site in the body was the thigh and calf, but the injury rate was less than half that of the head and neck (20 per 1000 hours). The least injured sites of the body were the arm and the 'others' category, which included such areas as fingers and toes (both 7 per 1000 hours).

Table 1. Type of injury sustained in matches.

Type of injury	All players			1st team			A Team		
	Number	Rate per 1000 hrs	95% CI	Number	Rate per 1000 hrs	95% CI	Number	Rate per 1000 hrs	95% CI
haematomas	68	16	12 - 20	37	16	11 - 20	32	17	11 - 22
muscle strains	79	18	14 - 22	51	21	29 - 44	27	14	9 - 19
Muscular injuries (total)	147	34	29 - 40	88	37	25 - 37	59	31	23 - 39
joint sprain	117	27	22 - 32	61	26	16 - 27	56	29	22 - 37
laceration	85	20	16 - 24	66	28	21 - 34	19	10	6 - 14
contusion	51	12	9 - 15	28	12	7 - 16	23	12	7 - 17
fracture & dislocation	40	9	6 - 12	25	10	6 - 15	15	8	4 - 12
concussion	35	8	6 - 11	18	8	4 - 11	17	9	5 - 13
abrasion & skin infection	10	2	1 - 4	7	3	1 - 5	3	2	1 - 5
others	7	2	1 - 3	4	2	1 - 4	3	2	1 - 5
all types	492	114	105-124	297	124	111-138	195	102	88-115

Table 2. Site of injury sustained in matches.

Type of injury	All players			1st team			A Team		
	Number	Rate per 1000 hrs	95% CI	Number	Rate per 1000 hrs	95% CI	Number	Rate per 1000 hrs	95% CI
head & neck	165	38	33 - 44	111	47	38 - 55	54	28	21 - 36
thigh & calf	88	20	16 - 25	49	21	15 - 26	39	20	14 - 27
knee	50	12	8 - 15	28	12	7 - 16	22	11	7 - 16
thorax & abdomen	45	10	7 - 14	24	10	6 - 14	21	11	6 - 16
shoulder	41	10	7 - 12	26	11	7 - 15	15	8	4 - 12
ankle	40	9	6 - 12	24	10	6 - 14	16	8	4 - 12
arm	32	7	5 -10	19	8	4 - 12	13	7	3 - 10
others	31	7	5 - 10	16	7	3 - 10	15	8	4 - 12
All types	492	114	105-124	297	124	111-138	195	102	88-115

The figures for the first and 'A' teams are displayed in table 3 and tended to be quite similar. Of all the playing injuries the largest percentage were received when a player was being tackled (46.3%), while a tackler was injured in 21.3% of the injury events. The remaining 32.3% were classified as others, which included injuries during such activities as running and scrummaging.

The amount of time off taken by players as a result of injury is shown in table 4. It can be seen that more than two-thirds of all injuries sustained required a player to take less than one week away from playing and training, a relatively small proportion of injuries (7.5%) required a player to be away from training for more than four weeks.

The incidence of injury for forwards and backs is shown in table 5. From this it can be seen that forwards are injured more frequently than backs in absolute terms (56.3 vs. 43.7%, both first and A teams). When the rate is standardised for the number of players (six forwards and seven backs), the injury rate differences are even larger (forwards 139 vs. backs 93 per 1000 hours; $z = 4.5$, $P<0.05$).

Table 3. Activity at the time of being injured.

activity	All players			1st team			A Team		
	Number	Percent	95% CI	Number	Percent	95% CI	Number	Percent	95% CI
tackled	228	46.3	41.9 - 50.7	138	46.5	40.8 - 52.1	90	46.2	39.2 - 53.2
other	159	32.3	28.2 - 36.4	99	33.3	28.0 - 38.7	60	30.8	24.3 - 53.2
tackler	105	21.3	17.7 - 25.0	60	20.2	15.6 - 24.8	45	23.1	17.2 - 29.0
Total	492	100.0	99.3 - 100	297	100.0	98.8 -100	195	100.0	98.1 -100

Table 4. Time off as a result of being injured.

Time off	All players			1st team			A Team		
	Number	Percent	95% CI	Number	Percent	95% CI	Number	Percent	95% CI
< 1 week	345	70.1	66.1 - 74.2	225	75.8	70.9 - 80.6	120	61.5	54.7 - 68.4
1-2 weeks	67	13.6	10.6 - 16.6	32	10.8	7.3 - 14.3	35	17.9	12.6 - 23.3
2-3 weeks	32	6.5	4.3 - 8.7	14	4.7	2.3 -7.1	18	9.2	5.2 - 13.3
3-4 weeks	11	2.2	0.9 - 3.5	5	1.7	0.6 - 3.9	6	3.1	0.6 - 5.5
4-5 weeks	37	7.5	5.2 - 9.6	21	7.1	4.2 - 10.0	16	8.2	4.4 - 12.1
Total	492	100.0	99.3 - 100	297	100.0	98.8 - 100	195	100.0	98.1 -100

Table 5. Distribution of injury between forwards and backs.

position	All players			1st team			A Team		
	Number	Rate per 1000 hrs	95% CI	Number	Rate per 1000 hrs	95% CI	Number	Rate per 1000 hrs	95% CI
forwards	277	139	124 -155	169	153	113 - 150	108	122	100 - 144
backs	215	93	81 - 105	128	100	83 - 116	87	84	67 -101
Total	492	114	105 - 124	297	124	111 - 138	195	102	88 - 115

Discussion

The study found an overall injury incidence rate in Rugby League of 114 injuries per 1000 man hours of play. It has been suggested that the high injury rate is due to repeated hard body contact (Gibbs, 1994). The injury rate in the current study is higher than the rate of 14 that has been reported for Rugby Union (Garraway and MacLeod, 1995), and also higher than the rate of 45 per 1000 hours that has been reported for Australian Rugby League (Gibbs, 1993a). One probable reason for the differing rates between Australian and English Rugby League, and League and Union was the decision of previous studies (Gibbs, 1993a, Garraway and MacLeod, 1995) to only include injuries that required a player to miss a subsequent game, the games being played on a weekly basis. If in the present study injuries requiring less than one week to recover from are excluded the overall rate is reduced to 34 per 1000 hours (first team 30, A team 39 per 1000 hours). However, this may not strictly be comparable, as situations such as whether conditions in England may result in more than a week between games. Then postponed games, which must be played later in the season could result in a fixture backlog requiring more than one game a week to be played.

Muscular injuries accounted for 29.9% of all injury types. This is similar to values that have previously been reported (Walker, 1985, Alexander et al., 1979). Injuries of this type to the quadriceps have been reported to be common as this is the first point of contact in the tackle (Gibbs, 1994). It could be argued that a game that has been likened to being mugged 30 times in 80 minutes (O'Hare, 1995), which involves a player in 20 to 40 physical 'confrontations' per game (Larder, 1992) predisposes players to this type of injury.

The site of the body to which most injuries took place was the head and neck region with 33.3% of all injuries. This is higher than has been previously reported, with studies quoting values ranging from 5.8% (Gibbs, 1993a) to 28.8% (Alexander et al., 1980) of all injuries. Again, the decision to include minor injuries may account for part of the difference. But at least one other study chose to include minor injuries (MacLeod, 1993), and commented that head and neck injuries were on the increase. While another reported that head lacerations were very common although they did not require players to miss games (Gibbs, 1994).

The observation that a majority of injuries are caused in the tackle is common to both rugby codes (Gissane et al., 1993, Garraway and MacLeod, 1995, Addley and Farren, 1988, Inglis and Stewart, 1981, Lythe and Norton, 1992). The findings of the present study also showed that the player being tackled was more likely to be injured (46.3%), this is also in agreement with previous research (Lythe and Norton, 1992, Gissane et al., 1993). In Rugby League, the tackle is a very prominent part of the game, which carries inherent dangers such as, being knocked over backwards, whiplash and the clashing of heads (Larder, 1992).

This study also reported that 32.3% of players were injured in situations classified as 'others', this must be considered to be a limitation of this study. With almost one third of injuries falling into this category, it is clear that it is too large as a general classification, and that future research should attempt to break this down into more component parts. For example, some injuries may have occurred as a result of foul play but were not recorded as such. Nevertheless, the sport is concerned about such incidents, which was emphasised by the Rugby League issuing a directive in January 1995 specifically making lifting a player and 'spear tackling' him a sending off offence under Law 15.1d regarding illegal throws.

The vast majority of injuries recorded in this study (70.1%) required that a player be absent from training and playing for less than a week. Part of the reason for this high figure was the decision to include all injures received while playing. Gibbs (1993a), who defined an injury as an event that required a player to miss the next week's game, reported that the largest proportion (38%) of injuries required players to miss the next game. If the injuries requiring less than one week are excluded from the current analysis, the largest proportion required 1-2 weeks absence (46%). However, classifying injuries in this way can be shown to miss a lot of minor injuries (Inklaar, 1994). Also, it should be pointed out that 17% of the injuries recorded in this study were lacerations. The majority of these would have involved the 'blood-bin', which began in the 1991-2 season after concern over such injuries. Furthermore, one investigation reported that such injuries rarely cause a player to miss a game, but counted 101 over five seasons (Gibbs, 1994). If they were counted, they would add considerably to both the numbers of, and the injury rates.

A possible explanation for differences between the League and Union codes might be the specific regulations regarding concussions. The International Rugby Football Board resolution (5.7) requires a concussed player to refrain from playing and training for a period of at least three weeks from the injury, and subject to being cleared by a proper examination (MacLeod, 1993). However, in Rugby League concussion is graded by severity as shown in table six. This could result in injuries being recorded but players requiring less time away from playing and training.

Finding that backs are injured much more frequently than forwards, has been observed by others (Gibbs, 1993b, Garraway and MacLeod, 1995, Seward et al., 1993). It has also been reported that forwards received a higher than expected number of injuries, based on the number of player positions (Gibbs, 1993b). As backs run the ball more and forwards tend to be involved in more collisions (Larder, 1992), then perhaps they should be more susceptible to injuries. It has also been suggested that the pattern of injury between forwards and backs might change with an alteration in the style of play (Garraway and MacLeod, 1995).

Table 6. Classification of concussions

Severity of concussion	Action
Mild: no loss of consciousness (L.O.C.)	
i. Full memory of event	can usually continue playing (after being checked)
ii. Memory deficit of event	must cease playing: no training or playing for 48 hours, and only after medical check by the club doctor.
Moderate: (L.O.C.) of up to 2 minutes	must cease playing: no playing or training for 15 days and only after a medical check by the club doctor.
Severe:	
i. L.O.C. of up to 3 minutes	must cease playing: no playing or training for 22 days and only after a medical check by the club doctor.
ii. L.O.C. of over 3 minutes	must cease playing: and be admitted to hospital for observation: no playing or training for 29 days and only after a medical check by the club doctor.

All cases of SEVERE concussion should have X-rays of the skull and cervical spine.

Source: Rugby Football League (1993).

The results from the present study show that Rugby League has very high injury rates. This is undoubtedly due to the large amount of physical body contact between players. Injury rates were shown to be higher at the highest standards of play. Forwards experience greater rates of injury than backs, which is probably due to them being involved in more repetitive body contact than backs. Perhaps future research should examine the differing injury rates between forwards and backs in relation to their game specific workloads, and also to analyse what types of injury these respective groups receive during the course of a game.

Acknowledgements

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Postscript

During the peer review of this paper, the reviewers made some extremely useful and helpful comments. With some of the points, the authors had the necessary information available and could address the issues. While, unfortunately, for others we could not.

One of these points was the incidence of foul play, which was not collected. The reason for this was that when the register was begun back in 1990, we collected what we thought was relevant at the time. At that time, there were almost no studies available on Rugby League and an overall picture of the injury situation was needed. This is not to say that foul play is not an extremely important issue, but with the advent of the Super League concern has shifted. The Rugby League Medical Association is currently more concerned with the effect playing on hard ground will have on overall injury rates, and, also, what is the potential for heat stress injuries?

Differences in the incidence of injury between rugby league forwards and backs

Abstract

Evidence with regard to the incidence of injury to forwards and backs in the game of rugby league is extremely limited. A four year prospective study of all the injuries from one professional Rugby League club was conducted. All injuries that were received during match play were recorded, and those for forwards and backs compared. Forwards had a higher overall rate of injury than backs (139.4 [124.2 - 154.6] vs. 92.7 [80.9 - 104.6] per 1000 player hours, P<0.00006). Forwards had a higher rate of injuries to all body sites with the exception of the ankle and the 'others' category of injury. They had significantly higher rates for the arm (11.6 [6.9 - 16.3] vs. 3.9 [1.4 - 6.4] per 1000 player hours, P = 0.005) and, the head and neck (53.9 [43.9 - 63.8] vs. 25.0 [18.7 - 31.4] injuries per 1000 player hours, P<0.00006). Forwards had significantly more injuries than backs for contusions (17.1 vs. 7.3 per 1000 player hours, z = 2.85, P = 0.0044), lacerations (26.7 vs. 13.8 per 1000 player hours, z = 2.92, P = 0.0035) and haematomas (20.6 vs. 11.6 per 1000 player hours, z = 2.29, P = 0.02). Forwards were also more likely to be injured when in possession of the ball (70.5 [59.2 - 81.7] vs. 38.0 [30.2 - 45.7]), and also when tackling (33.2 [25.3 - 41.1] vs. 16.8 [11.6 - 22.1]). The higher rates of injury experienced by forwards were most likely as a result of their greater physical involvement in the game, both in attack and in defence.

Introduction

In many team sports, different demands are made on different player positions. Within Rugby League there has been a trend to reduce specialisation, so that the work carried out by players varies less from position to position (Larder, 1992) and it has been suggested that fitness training is uniform for all positions (O'Connor, 1995a). Nevertheless, match analysis has demonstrated that backs cover greater distances in a game than forwards (7336 vs. 6647m (Meir et al., 1993)), and also that forwards are involved in a larger number of physical collisions than backs (36.3 vs. 19.14) (Larder, 1992). It can be said that the forwards' main role in possession is to gain ground quickly and to put the opposition on the back foot, while backs attempt to move the ball wide and exploit space. Similarly when defending, forwards do the majority of the tackling, attempting to stop the opposition gaining ground, and so denying them space in which to operate.

With these variations in physical effort demanded of the two playing units within a team it was hypothesised that there is a differing risk of injury, and that the injuries received by members of these playing units might also differ. It has been demonstrated that forwards do experience higher rates of injury than backs (Gibbs, 1993a, Gissane et al., 1993, Norton and Wilson, 1995) while in Rugby Union, it has been reported that 80% of injuries to backs took place whilst players were involved in the tackle situation (Garraway and MacLeod, 1995). But to date, the specific question of whether, and how, differing roles in game situations alters the risk of injury has not been addressed.

The purpose of this study was to describe the differences in the incidence of injury to forwards and backs, and to determine if there is a greater risk of injury when playing as a forward or a back in a professional Rugby League club over a period of four seasons.

Methods and procedures

The data to be used in this investigation have been described previously (Stephenson et al., 1996). All injuries that were reported by players during the four seasons between July 1990 and May 1994, at one professional Rugby League club were recorded. A season ran from the beginning of pre-season training, to the last competitive match in either April or May. An injury was taken to be the onset of pain or a disability that occurred while playing Rugby League Football (Gissane et al., 1993), which has been reported to best correspond with daily reality (Tweller et al., 1996). The diagnosis and classification of injury were carried out by the club doctor and the physiotherapist. The site and type of injuries were categorised as described previously (Alexander et al., 1980). The following details were recorded about each injury: The position of the player (forward or back), the site of the injury, the nature of injury, the team played for (first or 'A' team), activity at the time of injury, time off from playing and training as a result of injury.

During the time of the injury survey a total of 249 games were played, which included all pre-season, league, cup and post-season games. This represented a total of 4305.21 player hours at risk (13 players × 1.33 hours × 249 games), each game lasting 80 minutes. Since a team of 13 is comprised of six forwards and seven backs, forwards were at risk for a total of 1987.02 playing hours, and backs for 2318.19 hours. The age of a player was taken as the age at the beginning of the season (1st September). Based on this, the mean age (±SE) was 24.3±0.27 yrs.

The statistical analysis consisted of the calculation of injury rates per 1000 hours of play as a standardised rate of exposure, for both forwards and backs. The injury rates for the different playing units were compared using the normal approximation as described by Clarke (1994):

$$z = \frac{(r_1 \quad r_2) \quad 0}{\sqrt{r_1/t_1 + r_2/t_2}}$$

where r_1 and r_2 are the two rates being examined and t_1 and t_2 are the respective time periods.

Results

During the four years of the study a total of 492 injuries were recorded, 277 to forwards and 215 to backs. The overall injury rate for all players was 114.3 injuries per 1000 player hours (95% CI 104.8 to 123.8). The rates for forwards and backs were 139.4 (124.2 to 154.6) and 92.7 (80.9 to 104.6) per 1000 player hours ($z = 4.45$, $P < 0.0006$). The relative risk of injury when comparing forwards and backs was 1.50 (1.32 to 1.68).

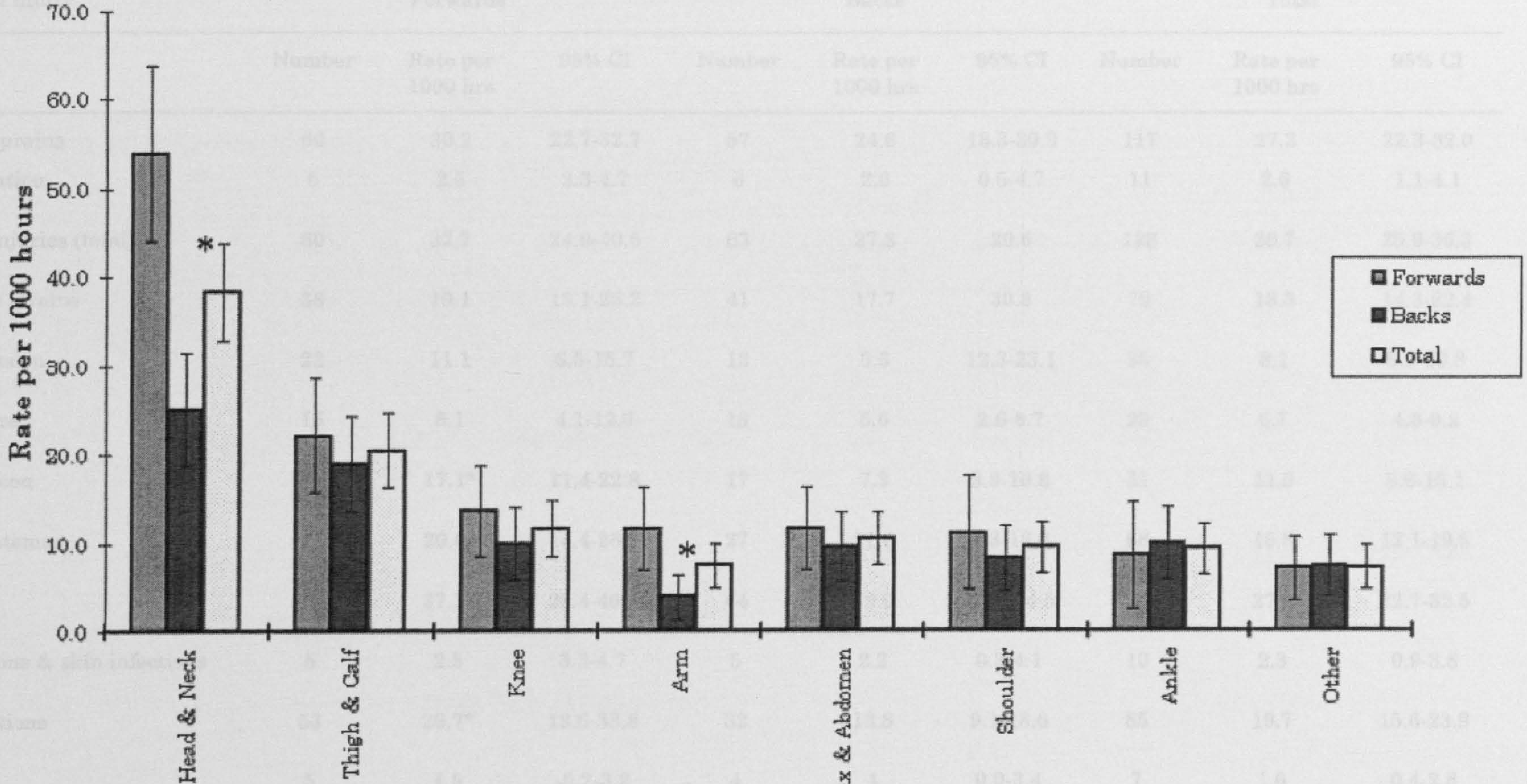
Injuries to different sites of the body are displayed in Figure 1. Forwards had higher rates of injury in all categories than backs, with the exception of the ankle and the 'others' category of injury. Forwards also demonstrated higher injury rates in six of the eight site category classifications, and had significantly higher injury rates for head and neck injuries (53.9 vs. 25.0 injuries per 1000 player hours, $z = 9.32$, $P<0.00006$), and arm injuries (11.6 vs. 3.9 per 1000 player hours, $z = 2.81$, $P = 0.005$). The two categories in which backs recorded higher injury rates were ankle (9.9 vs. 8.6 per 1000 player hours, $z = 0.46$, $P = 0.65$) and 'others' (7.3 vs. 7.1 per 1000 player hours, $z = 0.11$, $P = 0.91$), although these were not statistically significant.

Analysis of the types of injuries sustained (Table 1), demonstrated that forwards and backs had significantly different rates of injury for contusions (17.1 vs. 7.3 per 1000 player hours, $z = 2.85$, $P = 0.0044$), lacerations (26.7 vs. 13.8 per 1000 player hours, z = 2.92, P = 0.0035) and haematomas (20.6 vs. 11.6 per 1000 player hours, z = 2.29, P = 0.02). It was observed that forwards exhibited higher injury rates for each type of injury with the exception of the dislocations and the others category. However, in both cases the observed rates were small and the differences non-significant (dislocations z = 0.05, P = 0.96; others z = 0.18, P = 0.86).

Activity at the time of receiving an injury is shown in Table 2. From this it can be seen that the tackle is the phase of play associated with most injury. The results indicated that forwards had significantly higher rates of injury than backs when they were the tackler, i.e. defending (33.2 vs. 16.8 per 1000 player hours, z = 3.35, P = 0.00082), and when they were being tackled i.e. attacking (70.5 vs. 38.0 per 1000 player hours, z =4.52, P<0.0006). It was also found that when incidence rates for being tackled and tackling were compared directly, both forwards (tackler 33.2, tackled 70.5 per 1000 player hours, z = 5.16, P<0.0006) and backs (tackler 16.8, tackled 38.0 per 1000 player hours, z = 4.35, P<0.0006), were significantly more likely to be injured when being tackled.

Finally, when the rates for time off as a result of injury (Figure 2) were analysed, the only category in which there were significant differences between forwards and backs was the rate of injury requiring less than one

Figure 1. Comparison of injury sites for forwards and backs (rate with 95% CI).



*Significant differences between forwards and backs, P<0.05

Table 1. Type of injury sustained in matches.

Type of injury	Forwards			Backs			Total		
	Number	Rate per 1000 hrs	95% CI	Number	Rate per 1000 hrs	95% CI	Number	Rate per 1000 hrs	95% CI
Joint sprains	60	30.2	22.7-32.7	57	24.6	18.3-30.9	117	27.2	22.3-32.0
Dislocation	5	2.5	3.3-4.7	6	2.6	0.5-4.7	11	2.6	1.1-4.1
Joint injuries (total)	60	32.7	24.9-40.5	63	27.2	20.6	128	29.7	25.9-36.3
Muscle strains	38	19.1	13.1-25.2	41	17.7	30.8	79	18.3	14.3-22.4
Concussion	22	11.1	6.5-15.7	13	5.6	12.3-23.1	35	8.1	5.5-10.8
Fracture	16	8.1	4.1-12.0	13	5.6	2.6-8.7	29	6.7	4.3-9.2
Contusion	34	17.1*	11.4-22.8	17	7.3	3.9-10.8	51	11.8	8.6-15.1
Haematomas	41	20.6*	14.4-26.9	27	11.6	7.3-16.0	68	15.8	12.1-19.5
Total	75	37.7*	29.4-46.1	44	19.0	13.4-24.5	119	27.6	22.7-32.5
Abrasions & skin infections	5	2.5	3.3-4.7	5	2.2	0.3-4.1	10	2.3	0.9-3.8
Lacerations	53	26.7*	19.6-33.8	32	13.8	9.1-18.6	85	19.7	15.6-23.9
Other	5	1.5	-0.2-3.2	4	4	0.0-3.4	7	1.6	0.4-2.8
Total	277	139.4	124-2-154.6	215	215	80.9-104.6	492	114.3	104.8-123.8

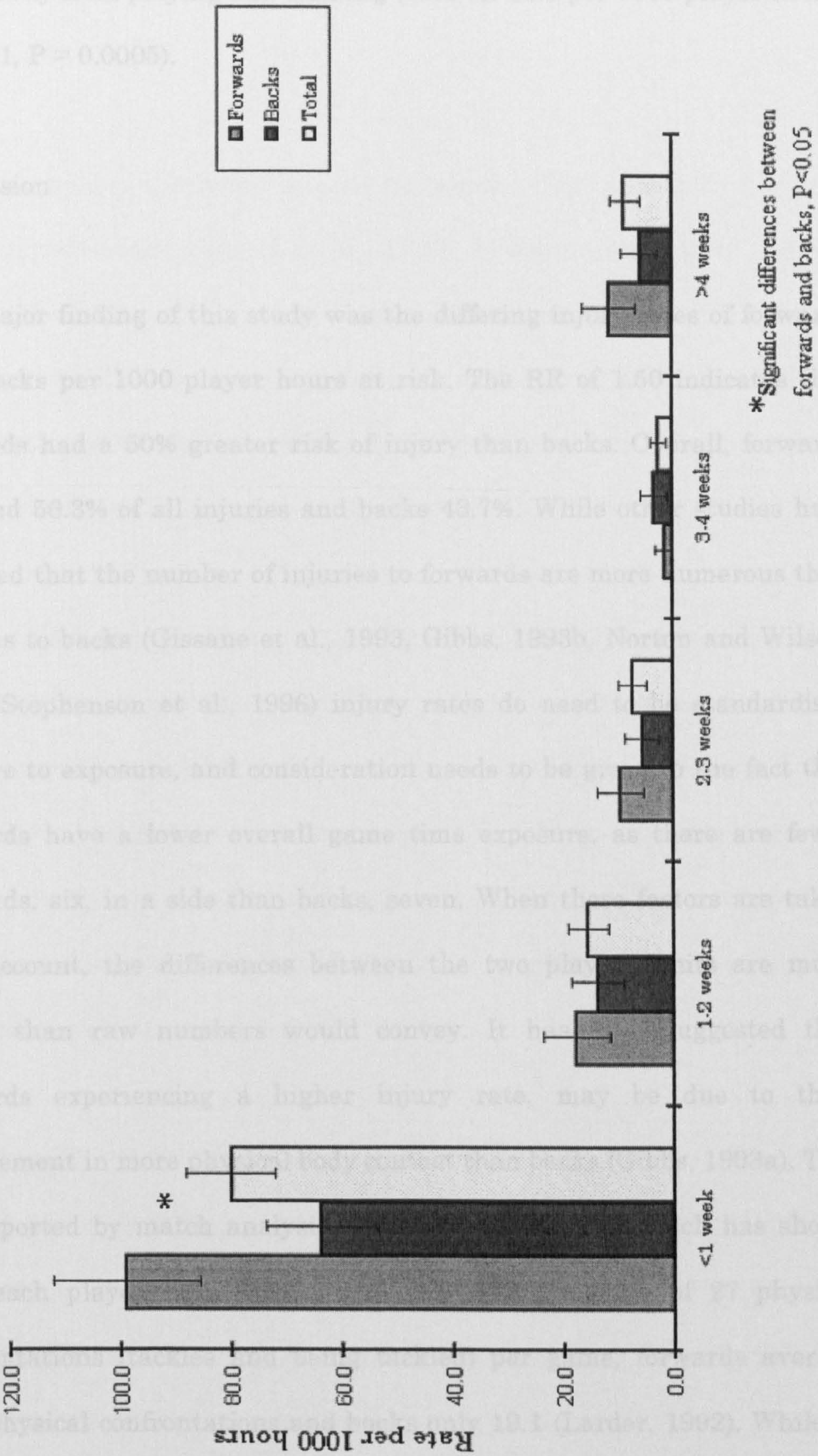
* significantly different from backs (P<0.05)

Table 2. Activity at the time of injury.

	Forwards			Backs			Total		
	Number	Rate per 1000 hrs	95% CI	Number	Rate per 1000 hrs	95% CI	Number	Rate per 1000 hrs	95% CI
Tackler	66	33.2*	25.4-41.1	39	16.8	11.6-22.1	105	24.2	19.8-29.0
Tackled	140	70.5*†	59.2-81.7	88	38.0†	30.2-45.7	228	53.0†	46.3-59.6
The tackle	206	103.7*	90.3-117.1	127	54.8	45.5-64.1	333	73.5	69.4-85.3
Other	71	35.7	27.6-43.9	88	38.0	30.2-45.7	159	36.9	31.3-42.6
Total	277	139.4	124.2-154.6	215	92.7	80.9-104.6	492	114.3	104.8-123.8

* significantly different from backs (P<0.05) † significantly different from tackling (P<0.05)

Figure 2. Time off as a result of injury for forwards and backs (rate with 95%CI).



week away from playing and training (99.1 vs. 63.9 per 1000 player hours, $z = 4.01$, $P = 0.0005$).

Discussion

The major finding of this study was the differing injury rates of forwards and backs per 1000 player hours at risk. The RR of 1.50 indicates that forwards had a 50% greater risk of injury than backs. Overall, forwards received 56.3% of all injuries and backs 43.7%. While other studies have reported that the number of injuries to forwards are more numerous than injuries to backs (Gissane et al., 1993, Gibbs, 1993b, Norton and Wilson, 1995, Stephenson et al., 1996) injury rates do need to be standardised relative to exposure, and consideration needs to be given to the fact that forwards have a lower overall game time exposure, as there are fewer forwards, six, in a side than backs, seven. When these factors are taken into account, the differences between the two playing units are much larger than raw numbers would convey. It has been suggested that forwards experiencing a higher injury rate, may be due to their involvement in more physical body contact than backs (Gibbs, 1993a). This is supported by match analysis at international level, which has shown that each player in a side is involved in an average of 27 physical confrontations (tackles and being tackled) per game, forwards average 36.3 physical confrontations and backs only 19.1 (Larder, 1992). While at club level Robinson (1996), reported that forwards and backs were involved in 32.4±1.2 and 19.0±0.8 (mean±SE) physical confrontations per game respectively.

The higher rates of forward injuries for specific sites of the body has been reported previously (Seward et al., 1993). In the present study, the site that received the most injuries was the head and neck area, with forwards receiving significantly more injuries than backs. Injuries to the head and facial areas, particular lacerations, have been suggested to be much more common in forwards than in backs (Seward et al., 1993).

Forwards experienced higher rates of injury in each of the type category in this study, with the exception of the dislocation and 'others' category. They recorded significantly higher rates for contusions, haematomas and lacerations. The higher rates for lacerations could be as a result of more injuries to the facial region (Seward et al., 1993). In spite of their high incidence, it may be considered fortunate that is rare for such injuries to cause players to miss games (Gibbs, 1993a).

In this study 67.7% of all injuries took place in the tackle, which is a slightly lower than figures than have been previously reported (77.2%) (Norton and Wilson, 1995). The injury rates were significantly higher when players were carrying the ball and being tackled. It has previously been reported that of all injuries that take place in the tackle, 56.6% of them are to the ball carrier (Norton and Wilson, 1995), whereas the figure in the present study was 68.5%. It has already been reported how forwards tend to be in more physical confrontations than backs in the game, and when examining the activity whilst in possession, (Larder, 1992) reported that forwards were tackled an average of 13.5 times per game, while backs were tackled only times per game. While Robinson (1996), reported that forwards were tackled 14.2±0.8 (mean±SE), and backs 10.4±0.5 times per game The process of being tackled is an area of the game that carries inherent dangers, including whiplash injuries, the clashing of heads and being knocked over backwards (Larder, 1992). Several authors have suggested that stricter enforcement of high tackle regulations could reduce the number of injuries (Seward et al., 1993, Milburn, 1995, Gibbs, 1994).

Similarly, forwards perform on average over twice as many tackles per game as backs (22.8 vs. 10.1) (Larder, 1992), which exposes them to a greater risk of injury and accounts for their significantly higher injury rates than backs. Outside of the tackle situation, backs demonstrated higher injury rates than forwards, which may appear surprising since they are not involved in scrummages, which average 19.4 per game (Larder, 1992). However, there is evidence that they cover greater distances than forwards (7336 vs. 6647m) (Meir et al., 1993), and knee injuries have been reported to occur in non-contact hyperextension and side stepping manoeuvres (Gibbs, 1994). Furthermore, they would tend to be involved in relatively more situations where they were required to gather a high ball, in circumstances where they may be required to jump for the ball, with the opposition approaching towards them. If more than one player is jumping for the ball there is an obvious risk of injury from collision or landing awkwardly, without a tackle taking place. Similar situations have also been described in Rugby Union where the 'Garryowen' kick is used as an attacking ploy (O'Brien, 1992).

The only time off category in which there were significant differences between forwards and backs were injuries that require less than one week away from playing and training. The reason for this would most probably be the higher numbers of overall injuries received by forwards. When examining injuries in this way, one characteristic of Rugby League is the larger numbers of injuries requiring one week away from playing and training, compared with other team sports (Seward et al., 1993). Arguably, a sizeable proportion of these are lacerations, which some studies have chosen not to include. Gibbs (1993b) reported 61 lacerations over a three year period, that did not require a player to miss subsequent games. If they were included they would have increased the overall injuries by 43%.

In Rugby League forward players experience higher rates of injury than backs, in spite of the fact that backs out number forwards seven to six. It has been suggested that if the differing playing units do have different injury profiles, then perhaps specific prevention programmes would be appropriate (Norton and Wilson, 1995). The results of this study support this proposition and offer further evidence as to the different areas of the body, and the specific situations in which forwards and backs receive injuries. Such considerations should be taken into account when designing player conditions and training programmes (Seward et al., 1993). Fitness profiles have shown forwards to be heavier than backs, with greater amounts of body fat (Brewer et al., 1994). It has been argued that forwards need to have such body composition to provide them with protection from the extra collisions in which they are involved (Meir, 1993). Rugby League may have recently demonstrated a trend toward less specialisation (Larder, 1992), and fitness training may be uniform across positions (O'Connor, 1995a), but evidence suggests that forwards' greater physical involvement, places them at a much higher risk of injury. Some investigators have argued that the best way to standardise injury rates in rugby football is to quote incidence and prevalence per 1000 player hours (Edgar, 1995, Lower, 1995). While others have commented that getting a true reflection of actual exposure time at risk may prove too difficult (van Mechelen et al., 1992). In Rugby League, future research could possibly address the questions of how physical involvement (tackles and being tackled) influences injury rates, and are their particular tackle situations that expose players to higher injury risks? Why this is the case may be difficult to pinpoint 'why does one tackle cause an injury when the previous 50 did not?' (MacLeod, 1993). Furthermore, within the two playing units of forwards and backs, there are specialist positions such as hooker and half-back, so that future research could be directed towards examining specific injuries that occur across the full range of positions, rather than the two playing units within a team.

Conclusion

The limitations of this study notwithstanding, it is clear that forward players in rugby league demonstrate a higher incidence of injury than back players. Forwards appear to have a higher injury rates because of their greater physical involvement compared to backs. But, to provide a more complete answer, specific analysis of physical involvement in relation to injury rates is required.

Injury in summer rugby league football - the experiences of one club

Abstract

Objective - To investigate whether the movement of the playing season would alter the risk of injury whilst playing first team European professional rugby league.

Methods - The study design was a historical cohort design comparing winter and summer seasons in first team European rugby league, which recorded injuries received by players during match play. Each injury was classified according to site, type, player position, activity at the time of injury, and time off as a result of injury.

Results - The risk of injury when playing summer rugby league was higher than in winter rugby league (RR = 1.67 [95% confidence interval 1.18 to 2.17]). Both forwards (1.08 [0.28 to 1.88]) and backs (2.36 [2.03 to 2.69]) demonstrated an increased risk of injury for summer rugby over winter rugby league.

Conclusions - Summer rugby could have resulted in a shift of injury risk factors as exhibited by a change in injury patterns. This may be due to playing conditions, but there were also some law changes. Also, changes in playing style, team tactics, player equipment, fitness preparations and the reduced preseason break may have had confounding effects on injury risk.

Key words: rugby league, injury, injury risk, summer rugby, cohort study

Introduction

Injury studies in rugby league football have previously reported high rates of injury (Gibbs, 1993a, Gissane et al., 1993, Stephenson et al., 1996, Seward et al., 1993), higher than many other team sports (Seward et al., 1993). The reason for this high injury rate is probably the high number of physical collisions in which players are involved during the course of a game (Gibbs, 1993a). With increasing professionalism in the sport, player injuries are an important issue, both in terms of team success and the livelihood of the players themselves (Seward et al., 1993).

The year of 1996 saw a bold move with European Rugby League playing in the spring and summer months, as opposed to its more traditional playing time of the autumn, winter and spring. This move meant playing games in higher temperatures (London temperature (mean[range]) - September to April 9.5 °C [6 - 14], April to September 18.6 °C [13 - 22]) and on harder surfaces. There would however, be one third fewer competitive matches to be played, due to the restructuring of the league (12 teams) and the elimination of two cup competitions. Injury studies carried out in Australia (Seward et al., 1993, Gibbs, 1993a, Estell et al., 1995), have consistently reported higher injury rates than English studies (Stephenson et al., 1996, Gissane et al., 1993), and it has been surmised that this might be due to the game being played on harder surfaces (Stephenson et al., 1996). Playing rugby league in the summer months may also increase the likelihood of players suffering from thermal injuries and heat stroke, due to the combination of higher temperatures and relative humidities (Savdie et al., 1991, Meir et al., 1994b, Meir et al., 1994a).

It is an unusual event for a sport to completely change the time of its playing calendar, and this move may result in an alteration in the risk of injury to players. Therefore, the purpose of the present study was to ascertain whether or not the movement of the playing season from the autumn and winter months to the spring and summer months would alter the risk of injury whilst playing professional rugby league, in the new European Super League established in March 1996.

Methodology

During the initial European Super League season all injuries that were reported for the first team at one professional rugby league club were recorded. The injury data were compared with first team data from a previous study on the same club over a period of four seasons reported previously (Stephenson et al., 1996). An injury was defined as a physical impairment received during a competitive match which prevented a player being available for selection for the next competitive game (Gibbs, 1993b). The games were 7(1.09) [Mean(SD)] days apart. The diagnosis and classification of injury were carried out by the club doctor and physiotherapist. The information recorded about each injury has been reported previously (Gissane et al., 1993, Gissane et al., 1997a, Stephenson et al., 1996).

The population at risk was defined as the players who were selected to play for the first team in a given match, and the defined time at risk for calculating injury rates was the duration of the games multiplied by the number of players (1.33 hrs. × 13 players) multiplied by the number of games played. The average number of games played during the winter seasons was 34.5 (596.5 player hours), with each player averaging 12.1 appearances per season, and during the summer season, 23 games (397.67 player hours) were played in the Super League of 1996, with each player averaging 8.3 appearances.

Statistical analyses consisted of the calculation of injury rate per 1000 hours of play as a standardised rate of exposure. To calculate the relative risk (RR) of injury between winter and summer rugby league the method using the incidence density ratio (IDR) for the two cohorts was used as described by Hennekens and Buring (1987).

$$\text{RR (IDR)} = \frac{\text{no. of summer injuries/exposure time (hrs)}}{\text{no. of winter injuries/exposure time (hrs)}}$$

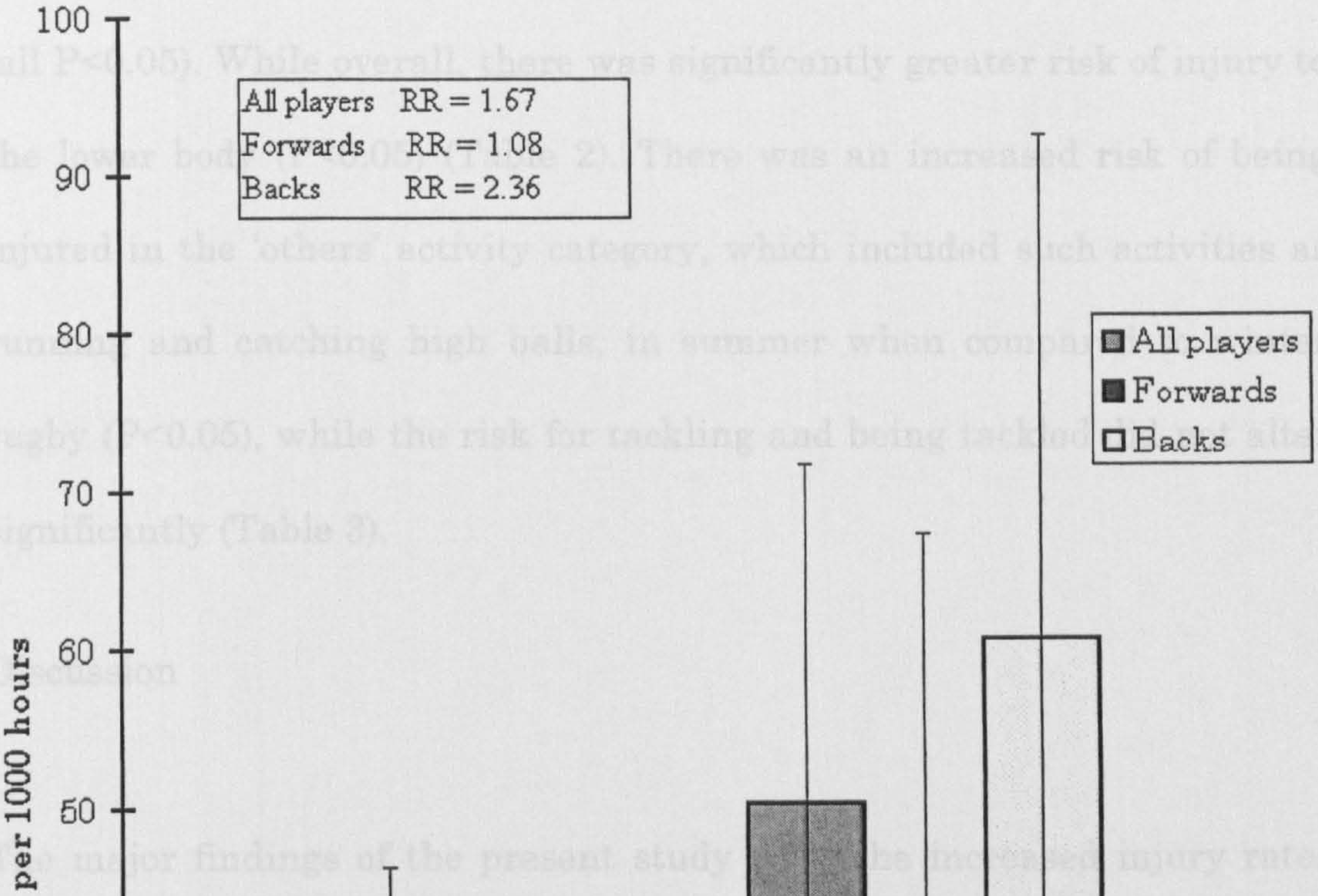
Confidence intervals (95%) were calculated using the method as described by McNeil (1996). Where the confidence interval did not contain the null value (RR = 1.0) the RR was taken as being significant at the $P<0.05$ level.

Results

There was no significant difference between the ages of the two cohorts of players investigated (winter 24.2(2.5), summer 25.7(3.9) yr. [mean(sd)], (t = 0.76, df = 69, P = 0.448). The injury rates for summer and winter rugby league for all players are displayed in Figure 1, in which it can be seen that summer rugby league had a higher injury rate than winter rugby league. Furthermore, the actual risk of injury in summer rugby league was 67% higher than in winter rugby league (RR = 1.67 [95% confidence interval 1.18 to 2.17]).

The injury rates for forwards and backs were analysed separately (Figure 1). From this it can be seen that the forwards' injury rate was slightly higher for summer rugby league, with an increase in the risk of injury for summer rugby of eight percent higher over winter rugby league (RR = 1.08 [0.28 to 1.88]). In comparison, the backs had a much larger increase in injury rates when playing rugby league in the summer, with a resulting higher risk of injury when playing rugby league in the summer. The RR of 2.36 (2.03 to 2.69) indicated that the risk of injury increased 136% from winter to summer rugby.

Figure 1. Comparison of injury rates for winter and summer rugby league (with 95% CI).



In table 1 it can be seen that there were significantly increased risks of injury during summer rugby for haematomas, fractures and dislocations, joint injures and others (all P<0.05). Similarly, there were significantly increased risks of injury to the shoulder, arm and 'others' sites of the body (all P<0.05). While overall, there was significantly greater risk of injury to the lower body (P<0.05) (Table 2). There was an increased risk of being injured in the 'others' activity category, which included such activities as running and catching high balls, in summer when compared to winter rugby (P<0.05), while the risk for tackling and being tackled did not alter significantly (Table 3).

Discussion

The major findings of the present study were the increased injury rates and the increased risk of injury associated with summer rugby league in both forward and back players, but the data suggest that the increased risk of injury was proportionately greater in backs than forwards.

The data for this study were collected prospectively as part of an ongoing investigation, which is a necessary process so that changing injury rates can be taken into account when designing playing conditions, training and fixtures (Seward et al., 1993). It allowed the comparison of the winter and summer cohorts, to assess changes in injury risk as a result of moving the playing calendar. It has been suggested that historical cohort study designs decrease the comparability of the data (Rudicel, 1988).

Table 1. Relative risk of types of injury.

	Winter		Summer			
	Number	Rate per 1000 hrs	Number	Rate per 1000 hrs	RR	95% CI
Haematomas	4	1.68	2	5.03	3.00*	1.3-4.7
Muscle strains	18	7.54	1	2.51	0.33	-1.7-2.4
Muscular injuries (total)	*22*	*9.22*	*3*	*7.54*	*0.82*	*-0.4-2.0*
Joint sprain	25	10.48	8	20.12	1.92*	1.1-2.7
Laceration	4	1.68	0	--	--	--
Contusion	4	1.68	0	--	--	--
Fracture & dislocation	8	3.35	7	17.60	5.25*	4.2-6.3
Concussion	8	3.35	1	2.51	0.75	-1.3-2.8
Others	1	0.42	1	2.51	6.00	3.2-8.8
All injuries	72	30.18	20	50.29	1.67*	1.2-2.2

*P<0.05

Table 2. Relative risk of injury to anatomical sites of the body.

	Winter		Summer			
	Number	Rate per 1000 hrs	Number	Rate per 1000 hrs	RR	95% CI
Thigh & Calf	13	5.45	2	5.03	0.90	-0.6-2.4
Knee	9	3.77	3	7.54	2.00	0.7-3.3
Ankle	8	3.35	1	2.51	0.75	-1.3-2.8
Shoulder	7	2.93	3	7.54	2.57*	1.2-3.9
Arm	3	1.26	2	5.03	4.00*	2.2-5.8
Head & Neck	19	7.96	3	7.54	0.95	-0.3-2.2
Thorax & abdomen	11	4.61	2	5.03	1.09	-0.4-2.6
Others	2	0.84	4	10.06	12.00*	10.3-3.7
Upper body	41	17.18	10	25.15	1.46	0.8-2.1
Lower body	31	12.99	10	25.15	1.94*	1.2-2.6

*P<0.05

Table 3. Activity at the time of being injured.

	Winter		Summer			
	Number	Rate per 1000 hrs	Number	Rate per 1000 hrs	RR	95% CI
Tackled	15	6.29	7	17.60	2.7	0.9-3.7
Tackler	39	16.35	7	17.60	1.1	0.3-1.9
Other	18	7.54	6	15.09	2.0*	1.1-2.9

*P<0.05

However similar data, by the present investigators, were collected for both summer rugby league (current cohort) and winter rugby league (historical cohort), but only three players were present in both the winter and summer cohorts

Injury rates for the summer cohort increased although exposure time was decreased by one third, which may have been due to the playing conditions of warmer temperatures and harder playing surfaces. In support of this, Australian studies (Gibbs, 1993a, Estell et al., 1995, Seward et al., 1993), where temperatures during the playing season are 18.2 [16 - 22] °C (mean [range]), have often reported higher injury rates than British studies (Stephenson et al., 1996, Gissane et al., 1993), even though fewer games were played (1994-95 English League, 30 games vs. 1994 Australia, 22 games). There is also the possibility that some injuries may have been carried over from the previous season. The last winter season prior to the beginning of Super League finished in the first week of February, with the Super League beginning at the end of March. This was a 51 day period, much shorter than the three and half month time period between seasons previously, which would not allow players the recuperation period that they had previously enjoyed. Furthermore, the move to full time professionalism could have served to predispose players to injury, since full time training, with increased training would allow players much less time for recovery (Arhheim, 1989).

Forwards have been reported to receive more injuries than backs (Gibbs, 1993a, Gissane et al., 1993, Norton and Wilson, 1995, Seward et al., 1993), as a result of being involved in more physical contact (Stephenson et al., 1996, Gissane et al., 1997b). It is therefore unusual to find a higher rate of injury amongst backs, and the subsequently very high relative risk comparing summer and winter rugby. Alexander (1980) found more injuries to backs when the style of play changed to move the ball wider sooner, giving the backs a greater role in the game. Previous research has shown that the ball carrier is the person who is most likely to receive an injury (Gissane et al., 1997b), which would increase the risk of injury to back players by involving them in more physical collisions, and at the same time reduce the amount of physical contact experienced by forwards.

Another possible reason for backs having a higher injury rate than forwards could be the introduction of the zero tackle law, which was not in place when the winter rugby data was collected. The law (2.3.1) states "When a player gathers the ball from an opposition kick in general play and does not subsequently pass or kick the ball himself, the initial tackle will be counted as a zero tackle" (RFL, 1996). Which effectively gives a team seven 'play the balls' or possessions. When the ball is kicked, it is often kicked deep in the field of play and is gathered by a back player, who runs to gain ground, and since the ball carrier is at the highest risk of injury in a tackle (Gissane et al., 1993, Stephenson et al., 1996), these law changes and playing styles could increase the risk of injury in back players.

The findings of the present study also demonstrated that there was an alteration in the risk of injury when injuries were examined by both type and site of the body. Injury investigations in other sports have reported alterations in injury patterns when changing playing surface, in which hockey (Jamison and Lee, 1989) and American Football (Skovron et al., 1990) have reported increased injury rates on astroturf. In American Football the risk of knee (RR = 1.18) and ankle (RR = 1.39) injuries has also been shown to increase as a result of the change of playing surface (Powell and Schootman, 1992). The changing relative risks in specific injuries seen in the present study may be due to similar mechanisms seen in hockey and American Football. Specifically, Fuller (Fuller, 1990) claimed that the hard surface of artificial grass allows players to achieve higher speed, but there is a decreased shock absorption capacity, and the same situation could be suggested about summer rugby league. The site category 'others' (RR=12.0) contained a number of foot injuries which previously were extremely rare (Jennings, 1990), but their onset could be associated with turning and being tackled on the harder surface.

The first season of Super League has exhibited a change in injury patterns, and could have resulted in a shift of injury risk factors. This cannot be exclusively explained by the playing conditions, as there are a number of other factors that need to be considered as athletic injuries are likely multifactorial in aetiology, making the identification of simple risk factors difficult (Meeuwisse, 1994). Between the end of data collection for the first cohort and the beginning of data collection for the second cohort, law changes were instituted which could serve to alter the risk of injury. The shorter preseason break and the increased training volume might influence the factors that predispose a player to injury. Additionally, playing style, team tactics and player equipment may also have altered. Any of these factors could have a confounding effect on the incidence of injury and further investigation is needed to determine their influence.

Epidemiological investigations are needed to determine the extent of injury rates as an initial investigative step in epidemiology. However, rugby league has taken the very unusual step of moving its playing season, with the result that descriptive investigations need to continue to document the accompanying injury risk. Preliminary findings suggest that it has increased, but surveillance needs to continue, as sport is a dynamic, changeable entity. The 1997 season will see further changes, which will affect the game, the players and almost certainly the risk of injury associated with such exposure.

Body mass loss as an indicator of dehydration in summer rugby league

Abstract

Objective - To determine the body mass losses experienced by summer rugby league players.

Methods - Players at one club who took part in 16 summer games had body mass determined before and after playing.

Results - There was a low overall correlation between percentage body mass loss and ambient temperature ($r = 0.29$, $p = 0.02$), but as playing temperature increased, 13% of players experienced a 2-3% body mass loss in 14 of 16 games played in excess of 19°C ambient temperature.

Conclusions - With the seasonal change new physiological challenges have been placed on players, some of who are demonstrating body mass losses which can affect on field performance and thermoregulatory mechanisms.

Introduction

During exercise the metabolic heat produced by the body can increase by 15 to 20 times above that produced at resting levels (Mitchell, 1994), and taking part in activity in hot conditions can cause the body temperature to rise even more quickly (Brewer, 1997). Moving the English professional rugby league season from the period September through to April, to March until September allowed it to be played in parallel to the Australian rugby league season. However, for players in the European Super League it meant that the game was to be played in much higher temperatures than previously, and for a certain portion of the season (June, July and August) the temperature would be higher than in Sydney, Australia (Pearce and Smith, 1993). The movement of the season places a responsibility on the game's administrators, as well as the players, coaches, and sports medicine teams at club level to define and implement strategies which will help players to cope with these new playing conditions. The Rugby League Medical Association (RLMA) expressed concern for the potential problems associated with heat stress at its 1996 meeting (Stephenson et al., 1996), and the Rugby Football League has responded by producing guidelines for players and coaches to avoid dehydration (Brewer, 1997).

A near-fatal accident was reported in Australian Rugby League (ARL) where a player who suffered heat stroke whilst playing (ambient temperature 24.1 °C, relative humidity 73%), spent 10 days in a coma and suffered Disseminated Intravascular Coagulation (DIC), along with renal and heptatic disturbances (Savdie et al., 1991). Strategies to prevent heat stress are important in order to maintain optimal cardiovascular function and thermoregulation (Gonzalez-Alsonso et al., 1992), as well as prevent dehydration by as little as three percent of body mass which has a detrimental effect on performance (Brack and Ball, 1998), and has been described as medically dangerous (Mitchell, 1994). At dehydration levels slightly below this level (2-3%) the body's ability to sweat is decreased, and with it the capability of the thermoregulatory system to maintain core temperature (Sawka et al., 1985). It has also been reported that dehydration resulting in body mass decreases as low as 2% can noticeably impair performance by compromising the circulatory and thermoregulatory functions (Saltin, 1964). The aim of the present investigation was to determine the extent to which players' body mass changes may be used as an indicator of dehydration state whilst playing summer rugby league.

Methodology

The subjects for this study were the members of the playing squad at one Super League Club, whose physical characteristics are displayed in table 1.

Table 1. Physical characteristics of players [mean±SD].

	Age (yrs)	Mass (kg)	Height (cm)
All players (n=28)	24.7±4.0	90.9±11.8	181.8±7.2
Backs (n=15)	25.1±4.3	84.6±7.5	178.4±2.1
Forwards (n=13)	24.3±3.8	98.1±12.1	185.4±7.7

Procedure

The members of the squad who were selected for a given game took part in the assessment procedure on that occasion. Players' body mass was determined in the standard position before starting each game in underwear only, after they were towel dried. Each measurement was recorded to the nearest 100 g using a calibrated Seca 770 model scales. A similar procedure was completed on the players' completion of the game with minimal time delay. During the game the mean ambient temperature (°C) and mean relative humidity (%) was recorded using a Casella polymeter (Model M 112050: Reliability; humidity ±5% between 30% and 90% RH, Temperature ±1%).

For each game played, each player that played was treated as an independent event making a total of 268 player appearances. Therefore, all data were collected with body mass being determined as the difference between pre-game mass and post-game mass. Players were allowed to drink water ad libitum after pre game body mass determination, during the game and at half time. For the purposes of analysis, only players who completed each full game of 80 minutes were included in the analysis (n=120).

The statistical analysis consisted of Pearson's correlation to determine associations between variables, and independent t tests to determine differences between forwards and backs. All tests were carried out using SPSS for Windows 6.1.2.

Results

Data were recorded in a total of 16 games, and the overall mean temperature was 22.9±5.3 °C, and the mean relative humidity 73±13.6 %. During these games a total of 36 forwards and 84 backs completed whole game(s). The mean body mass loss for all the players was 1.1 (95% CI 0.98 to 1.22) kg, in which the forwards and backs had mean body mass losses of 1.48 (1.25 to 1.7) kg, and 0.94 (0.82 to 1.06) kg respectively (mean difference = 0.54 (0.3 to 0.78) kg, t = 4.48, df = 118 P = 0.001). Overall mean loss for all players was 1.22 (1.1 to 1.34) % of body mass, in which forwards and backs had mean losses of 1.51 (1.29 to 1.74) % and 1.09 (0.95 to 1.24) % respectively (mean difference = 0.42 (0.16 to 0.69) %, t = 3.18, df = 120 P=0.002).

The overall relationship between the playing temperature and percentage body mass loss revealed a low correlation (r = 0.29, p = 0.02). There were non significant negative correlations between relative humidity and percentage mass loss (r = -0.28, p = 0.08) and relative humidity and temperature (r = - 0.15, p = 0.59). From table two it can be observed that as the ambient playing temperature increased the number and percentage of players reaching body mass loss relative to the level of dehydration where performance could become impaired increased. Of the players who experienced 2-3% dehydration, one experienced it four times, three other players twice, with four players experiencing a single incident.

Discussion

The major finding of this study was that an increase in ambient temperature resulted in a greater proportion of players reaching levels of body mass decrease relative to a state of dehydration which could compromise thermoregulatory control system (Sawka et al., 1985).

In this study there was no attempt to control for specific variables that might influence the test results, such as water intake and exposure to direct sunlight (Mitchell, 1994). The main aim was to describe the body mass losses during the course of playing typical rugby league games in the summer. Although none of the players reached the 3% loss in body mass that has been shown to be medically dangerous

Table 2. Ambient temperature and players body mass losses during rugby league games

			Players completing games			2 - 3% body mass loss		
Temperature	Games	Players	number	percentage	95% CI	number	percentage	95% CI
18°C or below	2	34	16	47.1	29.8 - 64.9	0	0.0	--
19 - 23°C	5	83	37	44.6	33.7 - 55.9	1	2.7	0.1 - 14.2
24 - 28°C	8	134	60	44.8	53.2 - 63.2	10	16.7	8.3 - 28.5
29+°C	1	17	7	41.2	18.4 - 67.1	5	71.4	29.0 - 96.3
Total	18	268	120	44.8	39 - 51	16	13.3	7.8 - 20.7

(Mitchell, 1994), 13 % (16/120) of players lost between 2-3% body mass in 14 of the 16 games played in excess of 19°C ambient temperature. Thermoregulation mechanisms can be compromised at such levels of body mass change (Mitchell, 1994, Sawka et al., 1985),] and the associated level of dehydration may adversely affect physical performance by reducing endurance times (Craig and Cummings, 1966).

Previous studies in other sports have monitored fluid intake of players during match play (Kirkendall, 1993, Goodman et al., 1985). They have also involved far fewer subjects than the present study. There are also practical difficulties with measuring fluid intake during matched play. Water in drinking bottles is used for other purposes such as, rinsing out mouth, washing gum shields, and cooling heads. All of which can lead to errors in estimation.

A number of measures are in place which are designed to assist players in minimising dehydration. Shirts are now made of much lighter material than previously and weigh about 40% less than before (376.8 vs. 218 g) (Meir et al., 1994a). The Rugby Football League has also issued some guidelines for players and coaches about training and playing in hot environments (Brewer, 1997). These guidelines advise players that they "need to hydrate before a game and rehydrate properly after a game." They also warn that those players with higher percentage body fat are most at risk of thermal stress, and since it has been reported that forwards carry more body fat than backs (O'Connor, 1996, Meir, 1993), this may partly explain why forwards are noted to have a greater percentage body mass loss than backs.

The player observed in 1990 who suffered from DIC was febrile, which served to decrease the amount of heat which could be dissipated before overheating (Savdie et al., 1991). The Rugby League have warned players who have been ill or are suffering from a virus that they are more prone to heat stress, and have advised them to seek advice from the club medical personnel before playing or training. Similarly, the RFL warn about excessive use of taping and protective equipment, which can inhibit the thermoregulatory process (Brewer, 1997). The player who suffered from DIC, had been wearing his kit and a neoprene thigh guard, in total 70% of his body surface area was covered (Savdie et al., 1991). There is also the practice of support staff entering the field of play at stoppages giving the players water, something not enjoyed in other sports (Cullen, 1998), which serves to aid the rehydration process.

In this study the variable examined was body mass loss as a proxy measure for dehydration. This should be considered as a conservative measure of fluid loss as neither fluid intake or urine excretion were measured. There are also other factors beyond those examined in the present study which could exert an influence on body mass loss during games. For example, previous research has reported that percentage body fat can influence the efficiency of thermoregulation (Meir, 1992).

The results of this study demonstrated that players appear to be experiencing new physiological challenges from the heat encountered whilst playing summer rugby league. Although for the majority of cases seen in the present study this did not represent a problem, 13% of players experienced 2-3% body mass loss during a game, which can effect both on field performance and thermoregulatory mechanisms (Sawka et al., 1985, Saltin, 1964). Research from other sports and Australian rugby league can provide direction for strategies to help overcome the problem. Devising and adopting strategies such as these was formerly the domain of touring teams. Now, however, it is required in the European playing season due to the switch to summer competition.

Physical collisions in professional super league rugby, the demands on different player positions

Abstract

Objective - To determine the total number and nature of physical collisions experienced by players in differing positions in professional rugby league.

Methods - Video recordings of all the regular season games (N=22) played by one professional super league rugby club were examined. Physical collisions were classified into tackles, incomplete tackles, "tackled in possession", "broken tackles" and passes out of the tackle.

Results - Forwards were involved in significantly more collisions (55) than backs (29) during the course of each game (z=2.73, P <0.0001). Eight player positions (forwards (n=6) and two half backs (scrum half and stand off)) were involved in significantly more collisions while defending as compared to attacking (all P<0.005). The differences for all back three quarter positions and the full back were not significant.

Conclusions - Players, both backs and forwards experienced more physical collisions than previously reported, which may be linked to operational definitions, rule changes and the advent of summer rugby league. Players were involved in more physical collisions whilst defending, since over two thirds of tackles involved more than one player tackling the ball carrier.

Key words: professional rugby league, physical collisions, forwards, backs, tackle

Introduction

Rugby League is a game of physical collisions (Kear et al., 1996), in which the tackle has a greater prominence than in rugby union (Gissane et al., 1993). The high number of physical collisions encountered by players has been suggested as a possible reason why they experience such high injury rates (Gibbs, 1993a). It has been further suggested that the collisions in which players are involved are important from both a physiological as well as an injury prevention perspective (Kear et al., 1996, O'Hare, 1995). A survey of international players found that the two aspects of the game that players found most tiring were being tackled, and tackling other players (Kear et al., 1996). Many coaches acknowledge that it is important to control these aspects of the game since they have a major influence on the outcome of a match (Larder, 1988, Kear et al., 1996). Within team sports players have different demands placed upon them according to the requirements of their position (O'Connor, 1996), and for optimal performance it is necessary to identify the specific characteristics of successful play relative to playing position (O'Connor, 1995a).

To this end, previous research in rugby league has investigated the movement patterns of players during matches (Meir et al., 1993), and the differing injury rates of forwards and backs (Gissane et al., 1997a). However, while other work reported the number of physical collisions in which players are involved during the course of a game, the studies were limited and were often based on data reported from small numbers of matches (Larder, 1992, Robinson, 1996). Furthermore, when examining the physical collisions from an injury prevention point of view, it may be important to take all physical contacts into account, which might include for example, situations where the tackle was not necessarily successful, because it still involved physical contact.

The purpose of the present study was to determine the number and type of physical collisions that rugby league players experience during typical match play. In addition the study determined how total physical collisions were distributed between attack (while in possession of the ball) and defence, and among playing positions.

Methodology

Players representing one professional rugby league comprised subjects for the present study (N=35, forwards n= 15, backs n= 20). In order to assess the number and type of physical collisions in which players were involved while playing, video recordings of all 22 regular season games played during the 1996 Super League season were analysed. This represents a total of 29.3 hours of match-play or 380.4 player hours (13 players x 1.33 hrs x 22 games). The video tapes used were master copies of recordings produced by two T.V. media broadcasting companies (British Sky Broadcasting, Isleworth and Micron Video, Wigan), and permission to use the material was granted by the Rugby Football League.

Each video was a standard VHS (25 frames.sec^{-1}) and was analysed by the principal investigator. Each physical collision that took place was classified into one of the following categories:

Defence (defending collisions)

1. Tackles - where the defending player(s) halted the progress of the ball carrier, and as a result the ball carrier had to play the ball.
2. Incomplete tackles - where the defending player(s) made contact with the ball carrier, but failed to prevent forward progress, or were unable to stop the passing of the ball.

Attack (attacking collisions)

3. "Tackled in possession" - where the ball carrier was tackled whilst in possession of the ball, forward progress was halted and the ball carrier had to play the ball.
4. "Broken tackles" - where the ball carrier was able to break through the tackle and continue forward progress.
5. Passes out of the tackle - where the ball carrier was tackled but was able to pass the ball.

Following this analysis it was possible to calculate each player's total defensive involvement (the sum of tackles and incomplete tackles), total attacking involvement (the sum of "tackled in possession", "broken tackles" and passes out of the tackle), and total physical involvement (in defence and attack) in each game analysed.

Statistical analysis

In order to determine the reliability of the physical collision analysis, three videos were analysed twice (each one week apart) by the principal author and the 95% limits of agreement were calculated using previously recommended methods (Bland and Altman, 1986, Nevill and Atkinson, 1997). Because the differences between readings did not vary in a systematic way across the all values, it was necessary to log transform the original data (Bland and Altman, 1986). Descriptive statistics (mean and 95% CI) for each physical collision category were computed for each playing position. To determine differences in the number and type of physical collision between forwards and backs, and between attacking involvement and defensive involvement, further analysis was undertaken using a proportion test (Altman, 1991).

Results

Reliability of video tape analyses

The reliability of the physical collision analysis demonstrated that the 95% limits of agreement calculated were 0.92 to 1.08, which indicated that the retest analyses were between eight percent above and below the original readings.

Collision analysis

The mean number of physical collisions for attack, defence and total collisions experienced by player positions is shown in table 1. All players were involved in both defensive collisions (while attempting to tackle the ball carrier) and attacking collisions (being tackled when carrying the ball), which resulted in an average of 41 physical collisions per player per game (27 in defence and 14 in attack). Forward players were involved in an average of 55 physical collisions during a game (39 defence, 16 attack), which was significantly more than the backs who were involved in an average of 29 physical collisions (16 defence, 13 attack) [$z = 2.73$, $p<0.0032$]. All of the forwards, plus the scrum half and the stand off were involved in a significantly greater number of physical collisions when defending (all $p< 0.05$) as compared to attacking. Only three player positions, the two wings and the full back, were involved in more attacking than defensive physical collisions but the differences were not significant ($z = 1.66$, $P> 0.09$).

The mean number of defensive physical collisions (complete and incomplete tackles) performed by player positions is presented in figure 1. There were significantly more complete than incomplete tackles (290 vs. 59, $z= 12.3$, $P <0.00006$). Overall, only 17% (59/349) of the defensive physical collisions carried out by the players in this study allowed an opponent to break through the tackle or off load the ball. Backs were involved in a significantly greater number of incomplete tackles than forwards (22% vs. 15%, $z = 6.14$, $P <0.00006$)

Table 1. Physical collisions experienced by player positions during match-play.

	Defence		Attack		Total collisions	
Position	Mean	95% CI	Mean	95% CI	Mean	95% CI
Full back	10	8 - 13	18	16 - 20	28	26 - 31
Right wing	10	7 - 12	13	11 - 15	23	19 - 25
Right centre	18	15 - 22	12	10 - 14	30	27 - 34
Left Centre	18	15 - 20	14	13 - 15	32	29 - 34
Left Wing	7	5 - 9	11	10 - 13	18	16 - 20
Stand off	29**	26 - 32	13	12 - 15	42	38 - 45
Scrum half	23**	19 - 27	10	8 - 11	33	28 - 36
Openside prop	44**	39 - 49	23	20 - 26	67	60 - 74
Hooker	43**	39 - 47	6	4 - 8	49	45 - 53
Blindside prop	37**	31 - 41	20	17 - 24	57	48 - 66
Openside 2nd row	45**	40 - 50	19	15 - 23	64	56 - 72
Blindside 2nd row	39**	36 - 43	16	14 - 17	55	51 - 59
Loose forward	27**	24 - 30	11	11 - 13	38	35 - 43
Backs	16	15 - 18	13	12 - 14	29	28 - 31
Forwards	39**	37 - 41	16	15 - 17	55*	52 - 58
All players	27	25 - 29	14	13 - 15	41	39 - 43

* significantly different from backs
** significantly different from attack

The mean number of attacking physical collisions ("tackled in possession", "broken tackles" and passes out of the tackle) is presented in figure 2. There were significantly more "tackled in possession", than passes out of the tackle and "broken tackles" (153 vs. 34, z=8.6, P<0.00006) Overall, the ball carrying players under investigation were able to either "bust" a tackle or off load the ball in 18% (34/187) of the attacking physical collisions. There was no significant difference between the forward and back ball players in the proportion of passes out of the tackle and "broken tackles" (19% vs. 18%, z = 0.74, P =0.4593)

Discussion

The present study indicated that rugby league players were involved in an average of 41 (95% CI 39 to 43) physical collisions per game, which is above the upper limit of a previous estimate of 20-40 per game (Larder, 1992). This may be due in part to the decision in the present study to include incomplete tackles in the observations which were not reported in previous estimates. If incomplete tackles were removed, the figure would be reduced to an average 37 physical collisions per game (forwards 50 per game, backs 26 per game). However this would still suggest that the current figures were higher than previously reported (Larder, 1992).

Figure 1. Proportion of complete and incomplete tackles made by player position.

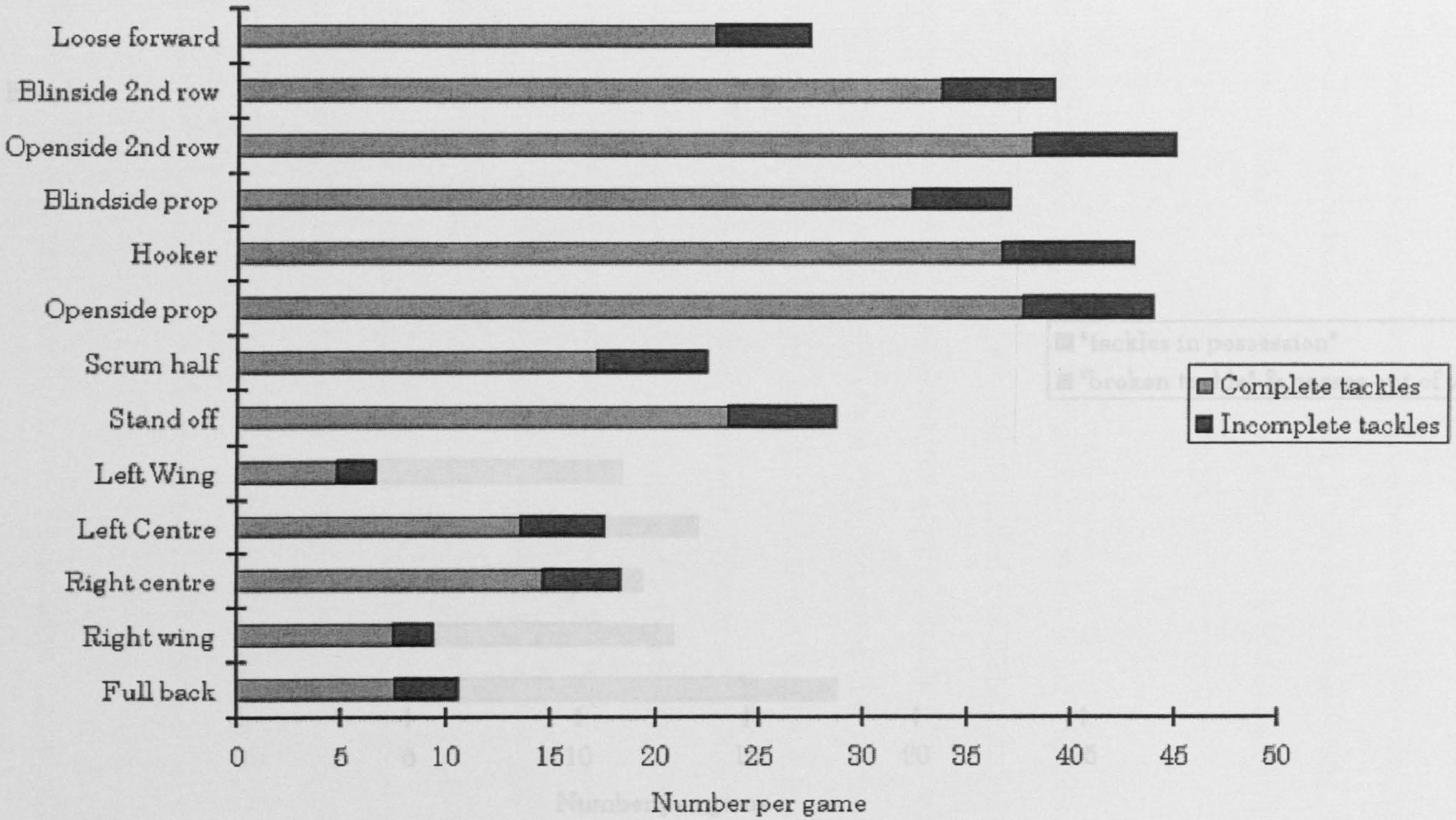
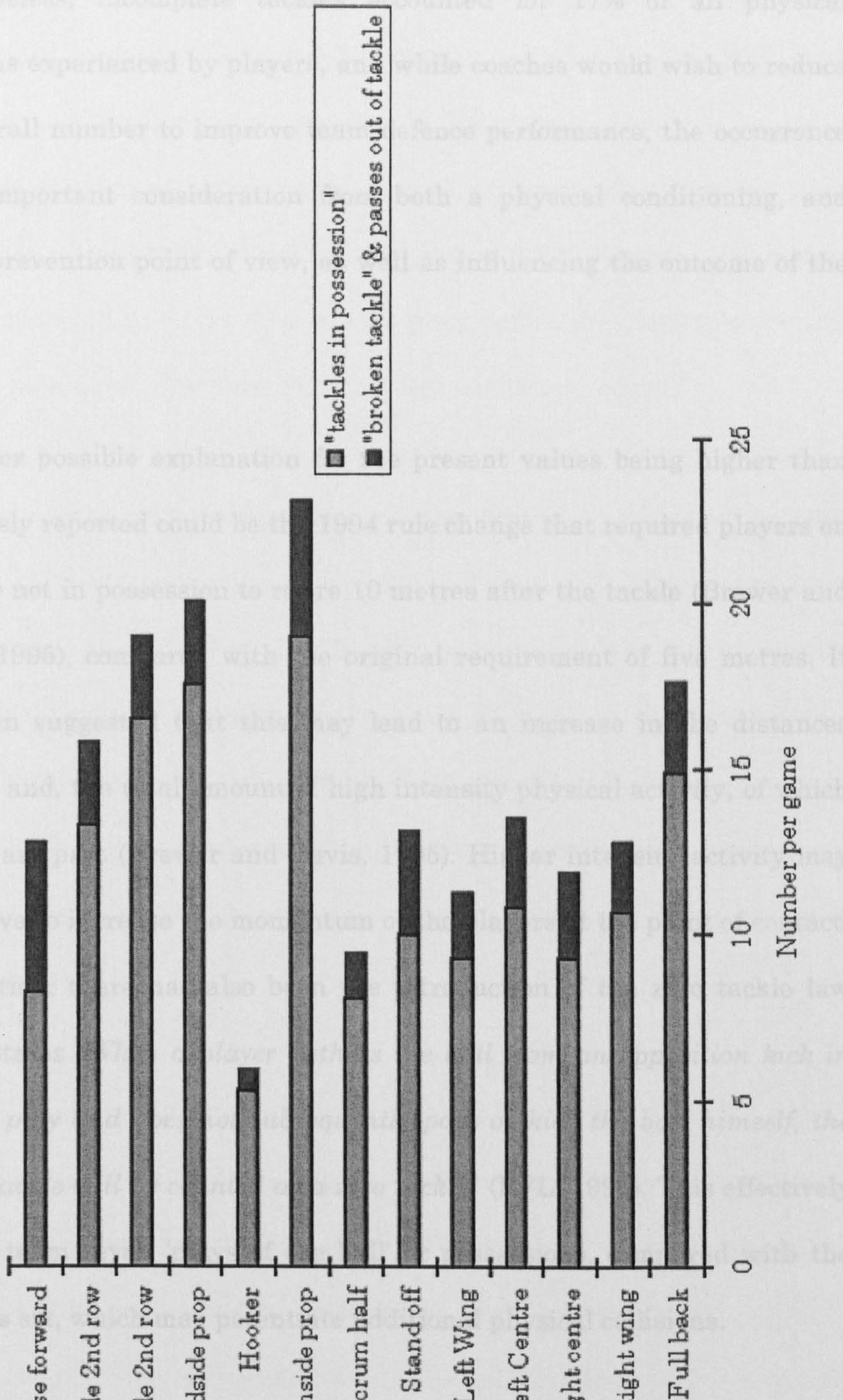


Figure 2 Proportions of "tackled in possession" and "broken tackles", and passes out of tackles experienced by position.



Nevertheless, incomplete tackles accounted for 17% of all physical collisions experienced by players, and while coaches would wish to reduce the overall number to improve team defence performance, the occurrence is an important consideration from both a physical conditioning, and injury prevention point of view, as well as influencing the outcome of the game.

A further possible explanation for the present values being higher than previously reported could be the 1994 rule change that required players on the side not in possession to retire 10 metres after the tackle (Brewer and Davis, 1995), compared with the original requirement of five metres. It has been suggested that this may lead to an increase in the distances covered and, the total amount of high intensity physical activity, of which tackles are part (Brewer and Davis, 1995). Higher intensity activity may also serve to increase the momentum of the players at the point of contact. In addition, there has also been the introduction of the zero tackle law which states "*When a player gathers the ball from an opposition kick in general play and does not subsequently pass or kick the ball himself, the initial tackle will be counted as a zero tackle*" (RFL, 1996). This effectively gives a team seven 'plays of the ball' or possessions, compared with the previous six, which may potentiate additional physical collisions.

Forwards were involved in a greater number of collisions than backs (55 vs. 29) which is in agreement with previously reported work (Robinson, 1996, Larder, 1992), although again the figures in the present study are higher than previously reported. One study reported that at club level forwards were involved in 32 physical collisions per game and backs 19 per game (Robinson, 1996), while at international level forwards were involved in 36 and backs 19 collisions (Larder, 1992). However, the games analysed in both previous studies took place before the 1994 rule change, the zero tackle law, and prior to the advent of summer rugby.

Several authors have suggested that the higher numbers of injuries received by forwards during match play (139.4 vs. 92.7 injuries per 1000 player hours) (Gissane et al., 1997a), may be because of the higher number of physical contacts (Gissane et al., 1997a, Gissane et al., 1993, Gibbs, 1993b, Norton and Wilson, 1995). However, if as a result of recent changes in the laws of the game both forwards and backs are experiencing more physical collisions, then the risk of injury should rise proportionately for all players.

It was also interesting to note that eight of the 13 player positions were involved in significantly more physical collisions in defence than attack. A previous study reported that props and hookers spent a greater amount of the time (4.5%) performing defensive tackling than backs (1.8%), and that forwards spent 2.7% of the time taking the ball into the tackle, compared with 1.8% for backs (Meir et al., 1993). This may account for the greater number of physical collisions by forwards made while defending. It should be noted that more than one player can be involved in the tackle, but only one player is carrying the ball whilst being tackled. Previous research on the number and type of contact experienced by individual players found that two thirds of tackles involved more than one defender tackling the ball carrier (Clarke, 1993). However, unlike the present study, previous work did not seek to examine how many players were involved in a given tackling situation on a ball carrier. If more than one player is involved in the tackle this could potentially increase the risk of injury to a player, as well as the number of physical collisions in which that player is involved.

The present findings have implications for both physical conditioning and injury prevention in rugby league. Coaches have recently suggested that the high injury rates reported in the game (Gibbs, 1993a, Gissane et al., 1993, Gissane et al., 1997a) are due to the ferocity of the physical collision situation (Jones, 1998). However, coaches have also been also been careful to emphasise the importance of safety and self protection when either tackling or being tackled (Corcoran, 1979). The findings of the present study emphasise the different incidence of physical collisions experienced by different player positions. This could serve as an indication to alter the training strategies of different positions and/or playing units, by either increasing or decreasing the number of physical collisions in training in proportion to those experienced in the game. Rugby League has shown a recent trend towards less specialisation between playing positions (Larder, 1992), and there is the suggestion that fitness training for professional rugby league is uniform for all positions (O'Connor, 1995a). However, it has also been argued that training procedures should reflect the breakdown of match play activities, and that these should be position specific (Meir et al., 1993). Similarly, injury prevention strategies could place a differing emphasis on players who are going to be involved in a greater number of physical collisions than others (RFL, 1996).

Conclusion

The present study has provided data on the number and type of physical collisions experienced by players during professional rugby league play. It should be recognised that playing style might also exert an influence on the number and types of physical collisions experienced. However, empirical data as to the specific nature of the physical collisions that players incur during a game is important. Training needs to conform to the principle of specificity, and the sheer volume of physical collisions encountered by some players may influence their injury risk, both from the physical impact and the possibility of cumulative fatigue. The numbers of physical collisions documented in the present study are higher than previously reported, which could be due to the inclusion of incomplete tackles. However it could be also be due to a change in the nature of play. The 1994 rule changes moved the defensive line back further by 5 metres, and the advent of summer rugby league probably resulted in firmer playing surfaces which allow faster running speeds and increased momentum at the point of contact in the tackle. Differences in the running speeds of players have been reported to be an important risk factor in rugby union tackles (Garraway et al., 1999). A further study has examined the numbers of players involved in specific tackles, in an attempt to determine if this has an influence on the risk of injury to the ball carrier and/or the tackler. In addition the follow up study has attempted to determine if the number of physical collisions experienced by players has a direct influence on the incidence of injury in playing units and positions (Gissane et al., 2001a).

Acknowledgement

The authors would like to thank Glen Workman and Tony Currie for their assistance with this investigation.

Physical collisions and injury rates in professional super league rugby

Abstract

Objective - To determine if there was a relationship between exposure to physical collisions and injury rates in professional super league rugby football.

Methods - All injuries received during one season's match play were recorded for all games played by one professional super league rugby club. Each injury was classified according to player position and activity at the time of injury. Physical collisions were determined from video and classified into tackles, incomplete tackles, "tackled in possession", "broken tackle" and passes out of the tackle.

Results - Forwards were involved in significantly more physical collisions per game than backs (55 vs. 29, P = 0.003). Overall backs had a significantly higher injury rate per 10,000 physical collisions (16.3 vs. 7.2, P = 0.0015), but there were no significant differences between the two playing units for injuries received whilst attacking or defending.

Conclusions - This study demonstrated that backs have higher standardised injury rates (per 10,000 collisions) than forwards, in spite of being involved in fewer physical collisions per game played. The observed differences could be due to the nature of specific physical collisions experienced by the respective playing units or intrinsic injury risk factors among the players involved.

Key words: Rugby League, injury rates, physical collisions

Introduction

Injury rates in rugby league football have been reported to be higher than those experienced in other contact team sports (Gissane et al., 1993, Seward et al., 1993). It has also been reported that the injury rates experienced by players have increased as a result of the recent move to a summer competition (Gissane et al., 1997b, Gissane et al., 1997a, Hodgson-Phillips et al., 1998). In addition many authors have reported that forward players receive far more injuries that back players (Lythe and Norton, 1992, Norton and Wilson, 1995, Gissane et al., 1993, Seward et al., 1993, Gibbs, 1993a, Gissane et al., 1997a, Gissane et al., 1998). One reason that is often put forward to explain this finding is that forwards are involved in much more physical contact than backs (Gibbs, 1993a, Gissane et al., 1997b).

Forwards may be involved in more physical contact because of their role in the game, although it has been suggested that there has been a recent trend towards much less specialisation between positions (Larder, 1992), which may have an influence on the contact rates experienced by forwards It has also been suggested that when the numbers of player positions involved are taken into account, forwards receive relatively more injuries and backs relatively fewer, than might be expected (Gibbs, 1993a).

Front row forwards spend more of their time taking the ball into the tackle than backs (2.7% vs. 1.8%), and over twice as much time tackling

(4.5% vs. 1.8%) (Meir et al., 1993). The amount of time spent in these activities is an important consideration since research has shown that between 67% and 77% of injuries take place in the tackle (Norton and Wilson, 1995, Gissane et al., 1997b, Gissane et al., 1997a). It has further been reported that both forwards and backs receive significantly more injuries while being tackled than when tackling, and that forwards receive significantly more injuries than backs when either tackling or being tackled (Gissane et al., 1997a). If injuries are to be reduced, it is necessary to establish if there is a relationship between the exposure risk factors, such as the number and type of physical collisions, and the incidence of injury in rugby league football.

The purpose of the present investigation was to examine the relationship between the rate of injury in rugby league football, and the number and type of physical collisions in games in which players are involved during the course of a full playing season by one professional super league rugby club.

Methods

All injuries that were reported for the first team of one professional super league rugby club were recorded over one season. An injury was defined as a physical impairment received during a competitive match which prevented a player being available for selection for the next competitive game (Gibbs, 1993a). The position of the player; the site of the injury; the nature of injury; the activity at the time of injury and the time off as a result of injury were recorded for each game played over the full season. The details of each category have been described previously (Gissane et al., 1998, Gissane et al., 1997a, Gissane et al., 1993).

The population at risk was defined as the players who were selected to play for the first team in a given match, and the defined time at risk for calculating injury rates was the duration of the games multiplied by the number of players (1.33 hrs. × 13 players) multiplied by the number of games played. A total of 23 games (22 regular season plus one play off game) were played during one season (397.7 player hours).

In order to assess the number and type of collisions that players were involved in while playing, video recordings of 22 regular season games played during the 1996 Super League season were analysed (29.3 hours of match-play, 380.4 player hours). The video tapes used for analysis were master copies of recordings produced by two TV media broadcasting companies (British Sky Broadcasting, Isleworth and Micron Video, Wigan), and permission to use the material was granted through the Rugby Football League. The categorisation of physical collisions was carried out as outlined previously (Gissane et al., 2001c).

Following the analysis of physical collision categories, it was possible to calculate the following; 1) each player's total defensive involvement (the sum of tackles and incomplete tackles), 2) total attacking involvement (the sum of "tackled in possession", "broken tackle" and passes out of the tackle), 3) total physical involvement (defensive plus attack) in each game analysed, and 4) the differences in physical collisions incurred by backs and forwards.

Statistical analyses consisted of the calculation of injury rate per 10,000 physical collisions as standardised rates of exposure, and descriptive statistics for physical collisions (mean and 95% CI). In order to compare differences between the proportions of physical collisions a single proportion test was used (Altman, 1991), while a test for differences between injury rates used the method of Clarke (Clarke, 1994), and the relative risk (RR and 95% CI) was computed. In order to analyse the differences between forwards and backs in the number of games missed by injured players, the Mann Whitney U and Kruskal Wallis tests were employed since the data were not normally distributed

Results

The descriptive statistics of the number of physical collisions incurred by forwards and backs are shown in table 1, which indicates that forwards were involved in significantly more physical collisions during defensive tackling than backs ($z = 2.73$, $P = 0.0032$). Furthermore, forwards were involved in a significantly greater total number of physical collisions ($z =$

2.97 P=0.0015). This was largely as a result of the increased defensive tackling demands by forwards, since there was no significant difference in the number of attacking collisions incurred by forwards and backs.

The number of injuries received, sub-divided by activity at the time of injury and the standardised injury rates per 10,000 physical collisions among forwards and backs are shown in table 2. There were no significant differences between forwards and backs in the total number of injuries received (7 vs. 13, z = 1.12, P = 0.26). However, examination of the standardised injury rates revealed that backs had a higher total standardised injury rate than forwards (z = 2.21, P= 0.027). When injuries that were received in the tackle (either to the tackler or the player being tackled) were examined, there was no significant difference in injury rate between forwards and backs. The forward playing unit demonstrated higher injury rates for physical collisions when attacking (RR = 3.68 [95%CI 0.62 - 22.1]), compared with the back playing unit (RR 1.01 [0.27 - 3.77]). It was also noted that backs had higher injury rates than forwards in both attack and defence, but these differences were not significant. Overall, the tackle situation accounted for a majority (14/20) of all injuries observed.

In the act of tackling an opponent, the upper body incurred the greatest proportion of injuries (5/7, z= 0.76, P= 0.44), in which there were two arm injuries (both forwards) and three shoulder injuries (all to backs). The only

Table 1. Mean number of physical collisions incurred per game by forwards and backs.

	Tackling (defence)		Tackled (Attack)		Total Physical Collisions	
Position	Mean	95% CI	Mean	95% CI	Mean	95% CI
Backs	16	15-18	13	12-14	29	28-31
Forwards	39*	37-41	16	15-17	55**	52-58
All Players	27	25-29	14	13-15	41	39-43

*Significantly different from attack
**Significantly different from backs

Table 2. Injury rates per 10,000 physical collisions for forwards and backs.

	Collisions			Injuries				Injury rate per 10,000 collisions		
	Attack	Defence	Total	Tackled	Tackling	Other	Total	Attack	Defence	Total
Backs	1892	2394	4286	4	5	4	13*	21.14	20.88	16.33
Forwards	2016	4592	6968	3	2	2	7	14.88	14.88	7.17
Team	3908	7346	11254	7	7	6	20	17.91	17.91	12.44

* Significantly different to forwards

other two injuries observed were to the foot and both were incurred by backs. In contrast, when being tackled the lower body received the greatest proportion of all injuries (5/7), with the only two upper body injuries being incurred one to the head (concussion) and the other to the rib area.

Injuries that were received by players and categorised as 'other' which did not occur in the tackle included three joint sprains to backs, that were received whilst running and changing direction quickly i.e. not resulting from physical collisions, as well as two incidences of foul play which were also included in this category.

Overall backs missed more games in total as a result of injury incurred than forwards (45 vs. 23). However, forwards had higher median scores for games missed when their injuries were incurred in tackling (five games vs. two games [Median scores]), and in being tackled (four games vs. two games), although neither of these differences were significant (P>0.05)

Discussion

The present study revealed a similar findings to other work (Norton and Wilson, 1995, Gissane et al., 1997a), in that the majority (14/20) of injuries occurred in the tackle. Half of these (7/14) were to the person being tackled, which is lower than reported previously (Lythe and Norton, 1992).

However, while previous investigations have suggested that injury was probably related to the number of physical collisions that players were involved in during a game (Norton and Wilson, 1995, Gissane et al., 1997a), the unique finding of the present study was that when the injury rate was standardised, backs had a significantly higher overall injury rate per 10,000 collisions than forwards, suggesting that positional play has an influence on injury rate. However, when the injuries received in the tackle were examined separately, the difference in injury rates between forwards and backs was removed. Nevertheless, in the present study backs experienced higher rates of injury than forwards (per 10,000 physical collisions), whilst being involved in significantly less physical collisions. This suggests that backs are more likely to be injured outside of the tackle situation.

The collision in rugby league is considered to be a major risk factor (Norton and Wilson, 1995, Gissane et al., 1997a). It has been argued that extrinsic risk factors are independent of the injured person, and are related to the types of activity during the incident of injury (Taimela et al., 1990), and the manner in which sport is practised (Lysens et al., 1991). These observations may be true of the physical collisions experienced in rugby league, especially when there is usually more than one person involved in the physical collision such as the tackle (Clarke, 1993). Therefore, self protection and safety of both the tackler and the person being tackled are important techniques that coaches teach to players (Gissane et al., 1998, Corcoran, 1979).

Since the tackle is the activity in rugby league in which so many injuries take place, some authors have suggested that injury prevention strategies directly aimed at making the tackle safer, should be considered (Lythe and Norton, 1992). Recent developments have seen certain types of physical contact outlawed (e.g. the spear tackle) and the banning of contact with a player who has jumped to catch a high ball (RFL, 1996). However due to the markedly different number of physical collisions in which players are involved, it may be necessary to develop specific injury prevention programmes for the different positional playing units (Lythe and Norton, 1992).

It is also necessary to consider some intrinsic risk factors which may influence injury rates in rugby league players. Several authors have reported that forward players have a greater body mass, with larger overall fat-free mass but possess more body fat than backs (O'Connor, 1996, Brewer and Davis, 1995, Meir, 1993). While it has been suggested that increased body fat may have a protective effect in the collision (Meir, 1993), the larger fat-free mass of forwards would result in these players being relatively stronger, more difficult to tackle and thus halt progress. Furthermore both upper and lower body strength has been reported to be significantly higher in forwards than backs; upper body strength is important for making tackles, while leg strength is important for breaking them (O'Connor, 1996). However, increased body fat could also be a disadvantage in terms of energy expenditure and workload (O'Connor, 1996, Meir, 1993), especially with the game now being played in higher temperatures. Since backs possess lower levels of upper and lower body strength than forwards, this could make them more susceptible to injury in the physical collision. Furthermore backs may also be more predisposed to non-collision injury as a result of their style of play which involves more turning and changing direction during running than forward play.

Not withstanding the injury associated with physical contact, almost one third (6/20) of injuries in the present study did not take place during physical contact. Four of these injuries were to backs (three ligament sprains and a muscle strain) and two to forwards (one joint sprain and one dislocation). Nevertheless such injuries will undoubtedly have specific causes, for example backs may be more susceptible to ligament sprains and muscle strains because they are involved in more changes of direction during running. In some instances video evidence suggested a likely possible cause, for example a back player who injured a hamstring whilst sprinting with the ball.

Recently, concern has been expressed about the ferocity of tackles and the role this might play in the incidence of injury (Jones, 1998). It has already been stated that the defending team usually has more than one player tackling the ball carrier (Clarke, 1993), and the implications of this need to be investigated in future research. The present study demonstrated that backs have slightly higher standardised injury rates than forwards, in spite of being involved in fewer physical collisions. The difficulty appears to be deciding why a player gets injured in a particular collision situation (MacLeod, 1993). If it takes more tacklers to halt the progress of a particular player, is that player at greater risk of being injured? Or, could it be the specific types of tackle that backs receive that results in them receiving more injuries per 10,000 physical collisions? Alternatively, the intrinsic injury risk factors such as strength, body composition and flexibility which influence injury incidence, need to be considered. Another important consideration is the momentum of the players at the point of contact. Momentum results from a combination of strength, speed, body mass and distance covered which can serve to increase the force of a given collision and thereby increase the risk of injury. In rugby union it has been suggested that the momentum of the players is an important factor in determining whether a player is injured in a tackle, with most injuries occurring at running or sprinting speeds (Garraway et al., 1999).

Conclusion

The present study found that there was no relationship between the number of individual physical collisions which players incurred, and the incidence of injury. It is possible that the lack of an observed relationship may be due to the small number of injuries in the present study, or because of the confounding effect of an increased number of non collision injuries in backs. Future research into injury in rugby league football needs to continue to monitor injury incidence and prevalence. The game has undergone a number of changes in recent years, such as modifications in the laws of the game and movement of the playing calendar, which have undoubtedly influenced injury patterns (Gissane et al., 1998). Therefore, any further changes might have a similar influence and need to be monitored. Future investigations also need to examine the evidence with regards to intrinsic injury risk factors exhibited by players. If injury prevention programmes are to be put in place, they need to be based on the knowledge of both intrinsic and extrinsic aetiological risk factors that contribute to increased injury risk (van Mechelen et al., 1996).

Acknowledgement

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An operational model to investigate contact sports injuries

Abstract

Purpose: A cyclical operational model is proposed to examine the inter-relationship of a number of factors that are involved in sports injury epidemiology. In sports injury research, investigations often attempt to identify a unique risk factor that distinguishes an injured player. However a wide variety of factors can contribute to a sports injury occurring and an understanding of the cause of injury is important to advance knowledge. **Methods:** The proposed model identifies a healthy/fit player initially, although the player may exhibit a number of intrinsic risk factors for sports injury. Prior to exposure to extrinsic risk factors, there is the opportunity for implementation of prevention strategies by coaching personnel and the sports medicine team. These strategies might include, among others, appropriate warm up, adequate hydration, wearing protective equipment and prophylactic taping. Additionally, preventative screening could take place to assess the various intrinsic and extrinsic risk factors that could lead to sports injury. **Discussion:** Two examples of how the operational model relates to contact sports injury cases are presented. Participating in sport inevitably exposes the player to external risk factors which predispose towards injury. The treatment of the injured player aims to restore the player to pre-injury playing status and to prevent the injury from becoming chronic. **Conclusions:** It is suggested that the application of this proposed cyclical model may lead to greater success in understanding the multi-faceted nature of sports injuries, and

furthermore help minimise injury risk and support the rehabilitation of injured contact sports participants.

Key words: epidemiology, injury, incidence, prevalence, risk factors, predisposition

Introduction

In sports injury research the aim of inquiries has often been to find a unique marker or risk factor that will identify injured players (Meeuwisse, 1991). Usually the frequency of injury is examined in relation to the presence or absence of a specific risk factor (Powell and Schootman, 1992). However, most sports injuries are rarely attributed to a single risk factor. Although injuries may sometimes appear to be random accidents, many factors play a role before the actual occurrence of an injury event (Meeuwisse, 1991). An understanding of the aetiology of injury is also important for the advancement of knowledge (Meeuwisse, 1994).

While sports participation is acknowledged as having a health-promoting benefit, it can also have deleterious effects on health in the form of injuries and accidents (van Mechelen et al., 1992). Action to prevent sports injuries should be based on the knowledge of aetiological factors that contribute to increased injury risk (van Mechelen et al., 1996). Various authors have described many risk factors which are usually grouped into intrinsic (subject related) factors and extrinsic (externally related) factors (Lysens et al., 1991, Lysens et al., 1984, Caine et al., 1996).

Intrinsic factors have been defined as individual biological, biomechanical and psychosocial characteristics predisposing a person to the outcome of injury (Caine et al., 1996). Extrinsic risk factors are independent of the injured person and are related to the types of activity during the incident of injury (Taimela et al., 1990), and the manner in which sport is practised (Lysens et al., 1991). A summary of both intrinsic and extrinsic risk factors documented in the sports injury literature is presented in table 1. However, even the classification of risk factors into intrinsic and extrinsic could be criticised as being artificial (Lysens et al., 1984), since injuries that result from participation are multi-risk phenomena, with a variety of risk factors interacting at a given time (Lysens et al., 1991).

Since sports injuries do not occur independently, previous research has suggested strategies for the investigation of sports injuries (van Mechelen et al., 1992, Watson, 1997), using a sequence of events with four stages (van Mechelen et al., 1992);

1. The initial stage involves the identification of the problem and the description of injury in terms of injury incidence and the severity of injury.

2. The next stage identifies the risk factors and mechanisms that play a part in sports injury episodes.

3. Once these have been identified, measures that will have the likely effect of reducing sports injuries can be introduced. These measures are based on the injury mechanisms and risk factors that have been identified in stage two.

4. The final stage of the sequence is to repeat the initial stage with the preventive measures in place, in order to determine the extent to which such measures are effective.

Later work proposed a multifactorial model for the investigation of sports injuries (Meeuwisse, 1994), in which an indefinite number of intrinsic risk factors may predispose an individual to injury (figure 1). If an athlete is predisposed to injury, extrinsic factors could exert their influence i.e. extrinsic risk superimposed upon intrinsic factors.

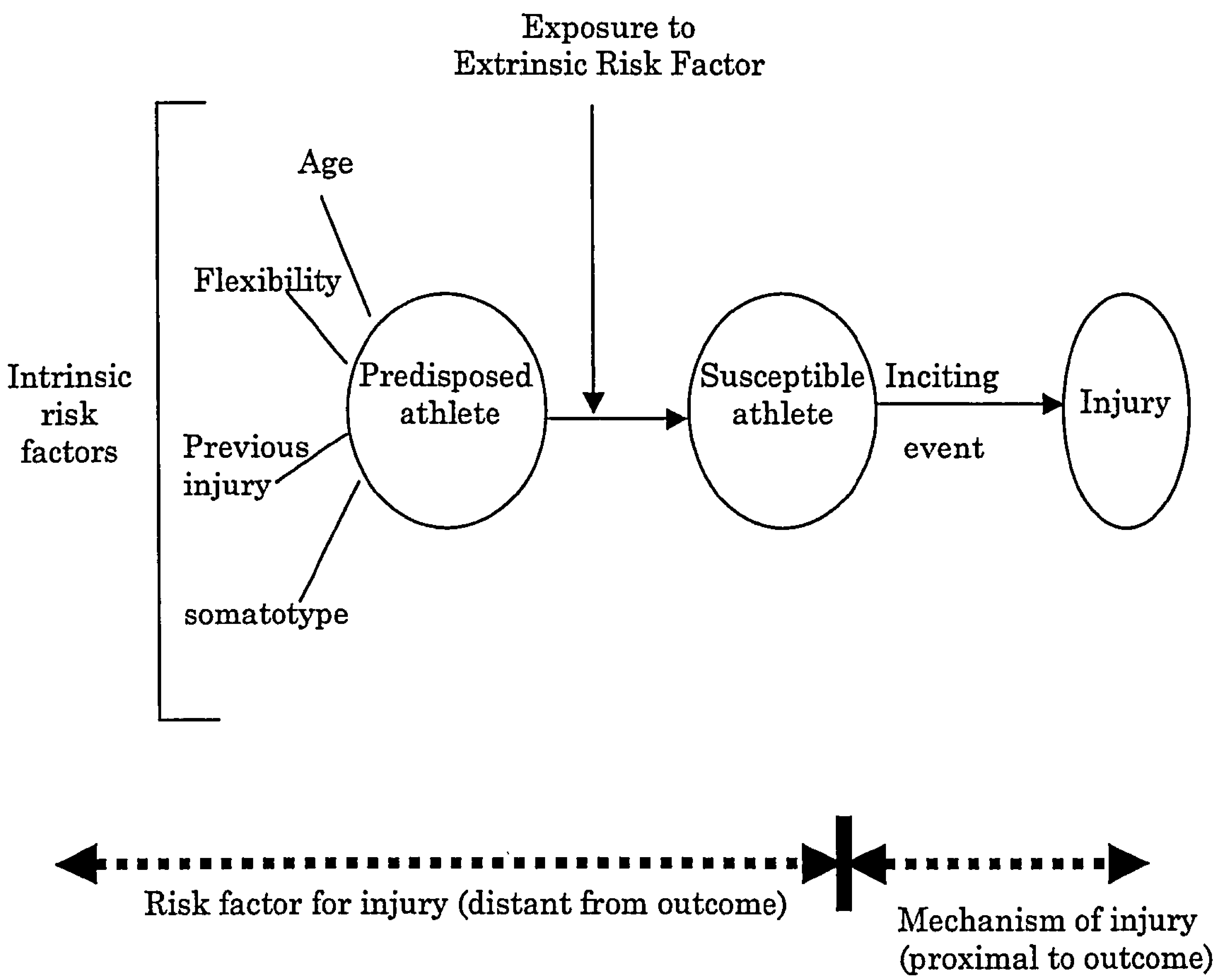
However, an injury may require a further "initiating event", such as a collision or sudden change of direction. These "initiating events" may be focused on by the practitioner, with little attention being paid to those factors that were more distant from the event, e.g. how does an athlete become susceptible to injury?

Both the strategy for injury prevention (van Mechelen et al., 1992) and the multifactorial model of aetiology (Meeuwisse, 1994), have valid and important contributions to make for the investigation of sports injuries. However, a linear model with a beginning and an end point may be too simplistic, since it is logical to assume that these intrinsic risk factors are not fixed and that they can vary over time. Furthermore figure 1 is a linear model which does not account for what happens following injury, how the athlete may return to sport and how the susceptibility to injury changes.

Table 1. Intrinsic and extrinsic risk factors reported in the literature.

Intrinsic risk factors	**Extrinsic risk factors**
Physical characteristics	Exposure (Meeuwisse, 1991)
Age(Meeuwisse, 1991, Powell and Schootman, 1992)	Type of sports (Meeuwisse, 1991)
Sex (Meeuwisse, 1991, Powell and Schootman, 1992)	playing time (Meeuwisse, 1991)
Somatotype(Meeuwisse, 1991)	position in the team (Meeuwisse, 1991)
Body size (Powell and Schootman, 1992)	level of competition (Meeuwisse, 1991)
Previous injury (Meeuwisse, 1991, Powell and Schootman, 1992)	warm up (Powell and Schootman, 1992)
Physical fitness (Meeuwisse, 1991)	personal equipment (Powell and Schootman, 1992)
Joint mobility (Meeuwisse, 1991, Powell and Schootman, 1992)	
Muscle tightness (Meeuwisse, 1991, Powell and Schootman, 1992)	Training (Meeuwisse, 1991)
Ligamentous laxity (Meeuwisse, 1991)	
Malalignment of lower extremities (Meeuwisse, 1991, Powell and Schootman, 1992)	Coaching (Powell and Schootman, 1992)
Dynamic strength (Powell and Schootman, 1992)	
Static strength (Powell and Schootman, 1992)	Refereeing (Powell and Schootman, 1992)
Skill level (Powell and Schootman, 1992)	control of game (Powell and Schootman, 1992)
Psychological characteristics (Meeuwisse, 1991)	
Psychosocial characteristics(Meeuwisse, 1991)	Opponents
Skill level (Powell and Schootman, 1992)	foul play (Powell and Schootman, 1992)
Willingness to take risks (Powell and Schootman, 1992)	opponent's physique (Powell and Schootman, 1992)
Interaction with other players (Powell and Schootman, 1992)	Environment (Meeuwisse, 1991)
	Type & condition of playing surface (Meeuwisse, 1991, Powell and Schootman, 1992)
Experience of sport (Powell and Schootman, 1992)	weather conditions (Meeuwisse, 1991, Powell and Schootman, 1992)
	Time of day (Meeuwisse, 1991)
	time of season (Meeuwisse, 1991)
	Equipment
	protective equipment (Meeuwisse, 1991)
	Footwear (Meeuwisse, 1991)
	Orthotics (Meeuwisse, 1991)

Figure 1. A new multifactorial model of athletic injury etiology.



Source: Meeuwisse WH. Assessing causation in sports injury: a multifactorial model. Clin J Sport Med 1994; 4: 166-70.

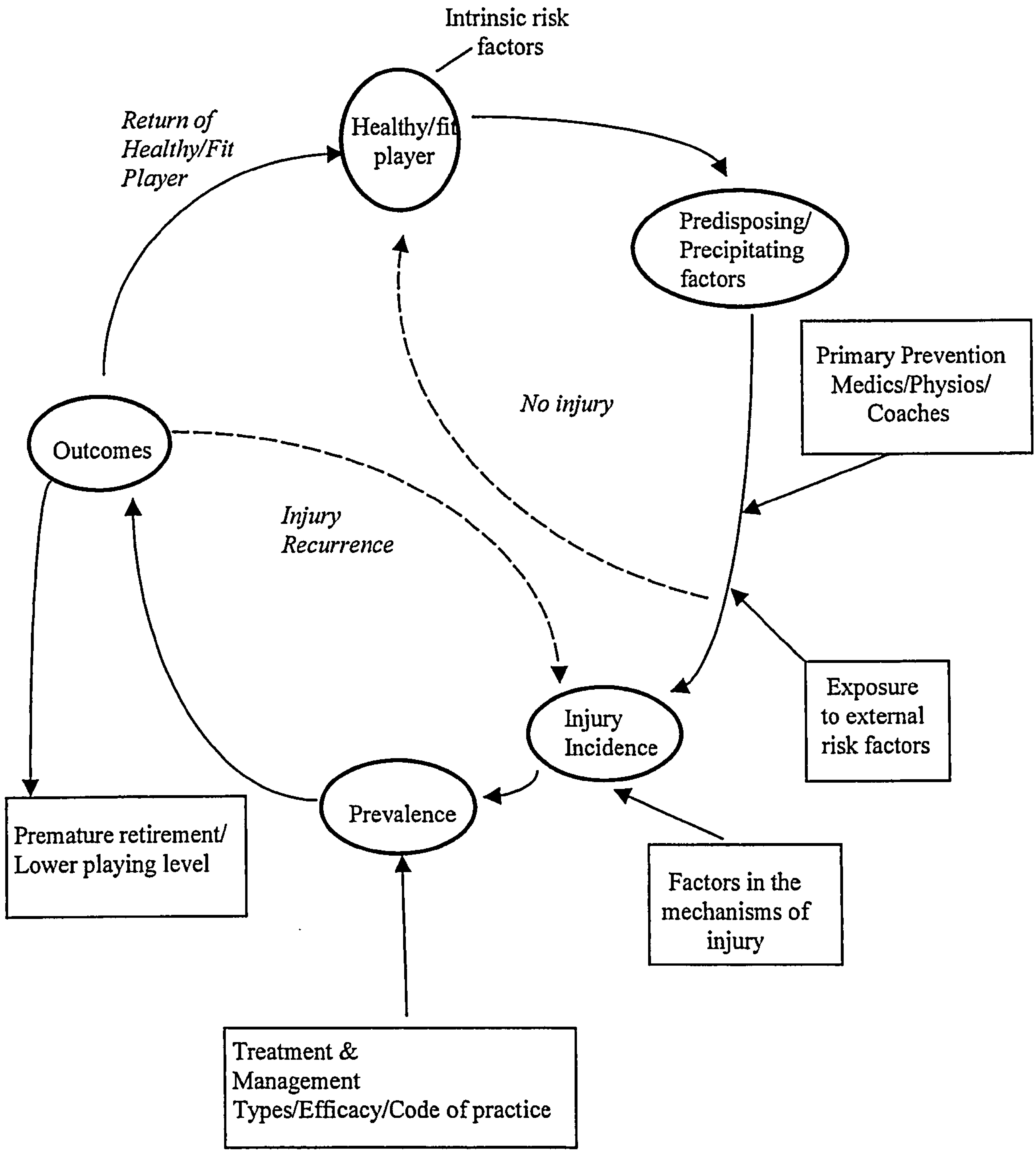
Materials and Methods

A proposed cyclical operational model for the investigation of contact sports injuries

Traditional approaches to the epidemiological investigation of sports injuries have tended to focus on the incidence and prevalence of injury, applied both to individual sports, and to overall national statistics. The model developed here aims to expand this traditional approach to take into consideration the multitude of factors which may predispose to injury, and which may determine the ultimate outcome of the injury for the contact sport athlete.

The cyclical model consists of five linked stages. First the ostensibly ***healthy/fit athlete*** may be at risk of injury from a number of predisposing factors. These may, with or without the additional exposure to external risk factors, in the presence of a ***potential injury event***, result in ***injury incidence***. The duration of time that the injury persists, during treatment and rehabilitation, contribute to the ***prevalence*** of the injury, and the ultimate ***outcome*** may be a return to sport at the original level, thus completing the cycle, or a return at a different level, or even premature retirement (figure 2). Each of the elements of the model are now described in greater detail.

Figure 2. A cyclical operational model for the investigation of sports injuries.



The *healthy/fit player*

Inherent within the ostensibly healthy/fit player, exist a myriad of ***intrinsic risk factors*** that have been suggested by the literature (Meeuwisse, 1994). For example, it has been reported that field hockey, soccer and lacrosse players exhibited an increased risk for ankle sprain when they displayed an increased eversion:inversion strength ratio (Barker et al., 1997).

At this stage in the cycle the strategies for intervention may be termed 'primary prevention' (Lysens et al., 1991), with the aim of preventing injuries from occurring in the first instance (Fletcher et al., 1996). Knowledge of the individual's risk factors may be of benefit in primary prevention. These strategies amongst others might include such measures as appropriate warm up, adequate hydration and prophylactic taping. They might also include the wearing of protective equipment such as gum shields in rugby, hurling (Crowley et al., 1995) and ice hockey (Rampton et al., 1997), or head guards in hurling (Crowley et al., 1995) and ice hockey (Rampton et al., 1997, Kujala et al., 1995). Such strategies would also include the coaching of proper technique in contact sports when either making or receiving a tackle (Corcoran, 1979), or teaching correct falling technique in judo (Kujala et al., 1995). Coaches and sports medicine practitioners seek to prevent injury, and it is the most logical and least costly method of health care (Meeuwisse, 1991). Additionally, prevention screening could take place to assess intrinsic risk factors that could lead to sports injury problems (McKeag, 1985). For example, it has been shown that postural and mechanical factors can predispose female basketball players (Garraway and MacLeod, 1995), rugby and soccer (Watson, 1995) players to injury, while screening has been advocated for groin injury prevention in rugby league football (O'Connor, 1995b).

Potential Injury Event

In addition to the intrinsic factors, extrinsic factors will play an important part in the potential for injury. The exposure to ***extrinsic risk factors*** will undoubtedly vary across sports and may vary within positions in certain sports, as well as the conditions under which sport is played. For example, both field hockey (Jamison and Lee, 1989) and American football (Skovron et al., 1990) have reported increased injury rates when games are played on astroturf. In American Football, both the risk of knee (RR = 1.18) and ankle (RR = 1.39) injuries are increased when the game is played on artificial compared with real grass (Powell and Schootman, 1992).

The event that initiates an injury is one of the most identifiable parts of the injury process and has been the focus of much research (Meeuwisse, 1994). In contact team sports these events are likely to be highly game specific, and indeed position specific. It has been suggested there are a high number of thigh injuries in professional soccer (Inklaar, 1994), and that these are commonly result from physical contact with an opponent

(Ekstrand and Gillquist, 1983). It has also been suggested that with the exception of goalkeepers, there are few upper body injuries that prevent soccer players from playing (McKeag, 1985).

At this stage in the cycle, a player that is not injured can continue to play whilst still exhibiting the same intrinsic risk factors, whereas if he/she becomes injured the player progresses to the next stage of the model.

Injury Incidence

In descriptive sports medicine epidemiological terminology incidence has been defined by the number of new events or cases of injury that develop in a population of individuals at risk during a specified time interval (Henekens and Buring, 1987). The incidence of injury in specific sports is an area that has received much attention (Kujala et al., 1995, Hickey et al., 1997, Garraway and MacLeod, 1995). However, the comparison across studies is often difficult due to the varying definitions of injury that have been employed (van Mechelen et al., 1996). Nevertheless, where comparisons can be made, there is a range of injury incidence rates among contact sports as demonstrated in table 2.

Injury Prevalence

In descriptive sports epidemiology, injury prevalence has been quantified by the proportion of individuals in a population who have an injury at a specific instant. It provides an estimate of the probability or risk that an individual will be injured at some point in time (Henekens and Buring, 1987). Injury prevalence depends upon both the incidence rate of an injury, and the period of time between the initiating event to the return to full fitness. In sporting terms the prevalence of an injury is an important consideration, since the treatment and rehabilitation of injuries takes time, and this is often a major factor in injury prevalence. It has been suggested that because professional sport is a business, it is often desirable on the part of both the team and the player to keep time lost from playing to a minimum (Lewin, 1989). Prevalence can also be influenced by game regulations, for example in rugby union football a player who is concussed is required not to either play or train for a period of 21 days (International Rugby Football Board resolution 5.7), whereas in rugby league football there is a sliding scale of required abstinence for the severity of injury based on the symptom severity of concussion. Therefore, concussions that are considered relatively minor in rugby league football, would have a far higher prevalence in rugby union football, which could contribute to a distortion in specific injury prevalence among similar sports.

The type and duration of treatment of the athlete is dependent upon each specific injury which the player is has sustained. For example it has been reported that 44% of rugby injuries only require treatment with RICE (rest, ice, compression and elevation), while others may require surgical intervention (Stephenson et al., 1996).

Table 2. Injury incidence rates across team sports.

Sport	Injuries per 1000 player hours	Reference
Rugby League	34*	Stephenson et al., 1996
Rugby Union	20*	Hughes and Fricker, 1994
Australian Rules	35	Seward et al., 1993
Soccer	22.6	Inklaar et al., 1996

*Injuries requiring a player to be unable to play for more than one week

During the rehabilitation process, both secondary and tertiary prevention can take place. The aim of secondary prevention is to restore health when it is impaired (Last, 1995). In sports medicine it is defined as the process of preventing or delaying the development of irreversible structural damage, by therapeutic intervention (Lysens et al., 1991). These measures can influence the prevalence of injury by reducing the amount of time that a person remains injured, but not the incidence. Appropriate and early management of soft tissue injury in particular, has been shown to promote early recovery (MacLeod, 1993).

Therapy that seeks to limit the injury process from becoming either chronic or persistent has been termed tertiary prevention (Lysens et al., 1991). The aim of tertiary prevention is to reduce both the incidence and prevalence of long term disability (Lysens et al., 1991). Sound treatment and rehabilitation have been suggested to be one of the most adequate preventive measures for secondary and tertiary prevention (Lysens et al., 1984).

Event Outcomes

In the proposed cyclical operational model for the investigation of sports injuries (figure 2), an injury has three possible ***event outcomes***. A player can return to a healthy/fit state, the injury can recur, and either, the player can retire from competition at that level, or continue participating at a lower level The obvious ideal is to return to playing at the pre-injury level of performance. In order for an athlete to be regarded as healthy they must be able to take part fully in both training and playing (Lysens et al., 1991). However, professional athletes are unlike a number of other occupational groups in that they are often quite willing to train and play in spite of injury, compared with others, who normally return to work only when they are completely recovered (Schootman et al., 1994b).

Recurrent injuries are also a major problem in sport and have been reported to account for 16.5% of all injuries in rugby union football (Garraway and MacLeod, 1995). Recurrent injuries increase the ***incidence rate*** and the amount of time lost for an injured player, thus also increasing the ***prevalence rate*** of injury. Furthermore, one of the greatest risk factors for injury is the history of previous injury (Watson, 1997).

In extreme circumstances professional sport players are sometimes forced into premature retirement because of injury. In such cases, it has been reported that rugby league football players who suffered long term consequences of injury after their playing careers, experienced difficulties, which included job limitations, reduced income earning potential and increased personal medical costs (Meir et al., 1997).

In certain situations players will be unable to return to playing and the management of such an injury may seek to maximise the quality of life rather than fully remediate the injury (Lysens et al., 1984). Previous work has described cervical spine injuries of two rugby union football players who could no longer return to play (Secin et al., 1999). These players are now members of the Rugby Amistat Foundation, which is dedicated to the well being of players who have suffered physical and mental trauma following disabling injury (Secin et al., 1999).

The overall design of the proposed operational model is cyclical because even if a player returns to health/fitness, the sports injury itself may constitute an intrinsic risk factor for the predisposition of future injury. Even if a player is fortunate enough to avoid an injury, the individual's intrinsic risk factors are unlikely to remain the same over time. For example, at the beginning of every season a player has another year of experience and is another year older, both of which have been described as potential sports injury risk factors (Lysens et al., 1991, Watson, 1997). This will serve to alter the nature of intrinsic risk factors present. In addition to this, coaches in contact sports often emphasise increasing muscle bulk during the closed season (Meir, 1993), which may also serve to alter an individual's intrinsic risk factors.

Discussion

The advantage of the cyclical model over the previous linear model (Meeuwisse, 1994) is that knowledge and awareness of the factors involved at each stage of the model, allows for the development of appropriate strategies for the prevention of injury at the primary, secondary and tertiary levels. Therefore, the practical application of this model may help the sports medicine practitioner deal more effectively with the injury problems of athletes in contact sports.

This paper proposes to provide an example of the application of this model to two specific sports situations in the contact sport of rugby union football.

Case 1. First Rib Synchondrosis

An injury to the first rib synchondrosis in a rugby football player is an example of an acute injury, caused primarily as a consequence of extrinsic factors (Kemp and Targett, 1999). However, the muscle bulk in the shoulder area and the strength of the muscles represent the player's internal (intrinsic) risk factors. The external exposure to a (extrinsic) risk factor would be the contact with the opposing player, and the opposing player's physique.

In this example the specific injury incidence was a first rib synchondrosis. The injury contributed to the incidence as an injury event, and the treatment which t was described as conservative, and lasting for 12 weeks contributed to the prevalence throughout the recovery period. At the end of the treatment, the event outcome was that the player was pain free and a repeated CT scan showed that the injury had healed. The player was then allowed to resume contact sport at the same level, which would return him to the start of the cycle, where this injury may or may not represent an intrinsic risk factor to future injury.

Case 2. Incarcerated Hernia

An incarcerated hernia during a lineout (Thomas and Thomas, 1999) might fit into the model as follows; this is an acute injury superimposed upon an intrinsic weakness. For this injury, the intrinsic risk factors would include the pre-existing hernia, the player's position, somatotype and gender, while the predisposing external risk factors would include the fact that it took place in a lineout. This is an area of the game that has recently been the subject of some rule changes, which has resulted in lineout jumpers being supported and lifted by adjacent players. This is a technique that is coached and rehearsed during practice sessions. The act of being supported in an unstable mid air position could be considered to be an external risk factor. The exertion of jumping may have increased the intra-abdominal pressure, thus increasing the size of the hernia. This would be compounded by the increased external pressure to the groin area, transmitted through the shorts, with the action of two other players lifting and holding the lineout jumper.

The particular injury was the hernia, which required treatment with surgery. The prevalence of the injury was for a period of five weeks in total, after which the event outcome was the player being able to return to play, again completing the cycle.

Conclusions

The model that has been proposed seeks to acknowledge the multifactorial nature of sports injury. It further recognises that the sports injury is not an endpoint (Meeuwisse, 1994), since rehabilitation and recovery are part of the continuing process. In so doing, it attempts to bridge the gap between descriptive and analytical sports injury epidemiology. Sports participants almost always seek to return to play, but on their return their intrinsic risk factors and the external risk factors will undoubtedly be different. While the model has been applied to rugby football and the myriad of factors that can influence injury, the situation will undoubtedly be different in other sports and needs to be investigated further.

The previously published work underpinning the development of the proposed cyclical model (figure 2) has been presented in order to illustrate the application to sports injury research and demonstrate the advantages over the previously proposed linear model (figure 1). Furthermore, it is envisaged that the new model may be used to further develop current descriptive and future analytical epidemiological approaches to sports injury research.

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A pooled data analysis of injury incidence in rugby league football:

Summary

The aim of this study was to summarise the injury rates in professional Rugby League Football. Previously published studies were identified from database searches of literature from Medline, Sports Discus, and Web of Science. A total of 18 articles, which reported the prospective injury data collection for at least one playing season in professional rugby league worldwide, were included. The definition of injury adopted required an injured player to miss the subsequent game through injury. Ten studies satisfied the injury definition criteria for inclusion. A review of articles and extraction of relevant data was carried out independently by two authors. A total of 517 injuries were reported during 12,819 man hours exposure (753 games), which resulted in an overall injury rate of 40.3 injuries per 1,000 hours (95% CI 36.9 to 43.8). The majority of injuries were to the lower half of the body (20.7 per 1,000 hours, 95%CI 17.7 to 24), with the trunk receiving the least (6.7 per 1,000 hours, 95%CI 5 to 8.6). Injury rates in professional rugby league are higher than some other contact sports, probably due to the large number of physical collisions that take place. This pooled data analysis provides more accurate estimates of injury incidence in the game of professional Rugby League Football.

Introduction

Rugby League football has been described as a fast moving contact sport (Alexander et al., 1980), and as a collision sport (Larder, 1988). It is an invasion game, whereby one team attempts to invade the territory of the other team with the object of scoring points, while the opposition uses physical force, within the laws of the game, to try and stop them. To do this, the internal structure of the game demands that the side that is not in possession tackles their opponents who are in possession of the ball. Tackling can be described as the act of preventing a ball carrier running with the ball, or passing or kicking the ball to another member of the attacking team. The ball carrier can be tackled by any number of the opposing teams players (Federation, 2001).

A Rugby League team consists of 13 players (six forwards and seven backs) who have six possessions to advance the ball down field. The ball must be passed backwards, but can be carried or kicked down field. Unlike American Football, there are no special teams or sub-units within a team (other than forwards and backs), so each player has a role to play in both attack and defence.

Research into the incidence of injury in rugby league has shown that injury incidence is high compared to other sports, for example Rugby Union (Gissane et al., 1993, Seward et al., 1993). However, one shortcoming of many of these studies is that they deal with a relatively small number of players and often only one club, thus reducing their generalisability.

One strategy to enhance the information provided from epidemiological studies is to combine the information from multiple studies into a single estimate (Checkoway, 1991). For this technique to be successful it is important that the studies that are included have compatible structure with respect to inclusion criteria, follow up, and exposure history. The combined data from these individual studies can then be statistically reanalysed to provide more precise injury data (Blettner et al., 1999).

The purpose of the present study was to provide pooled estimates of injury incidence in rugby league football from published studies; more specifically, this will include estimates of injury incidence, injury severity, site of injury, and the comparison of injury rates between forward players and back players.

Methods

These included the development of a search strategy to locate papers investigating injury in rugby league. Inclusion/exclusion criteria were developed to ensure compatibility, and finally, combined analysis was performed.

Search strategy for identification of databases

Searching Medline, Sports Discus and Web of Science databases, covering the period from 1985 to 2000 identified 18 studies. The following terms were used, rugby *with* league *and* injury.

Inclusion criteria

In the present analysis the authors collated published studies that reported the incidence of injury in rugby league football. The inclusion criteria were: -

- Studies published later than 1990;
- Data collection carried out prospectively on professional players;
- A definition of a recordable injury being one that required an injured player to miss the subsequent game;
- A count of the number of games studied to allow the calculation of person time injury rates.

Procedure

A total of 18 articles were identified that reported prospective data collection of rugby league injury, and details of these studies are shown in table 1. Of these, only ten satisfied the inclusion criteria (Gissane et al., 1993, Seward et al., 1993, Estell et al., 1995, Gibbs, 1993b, Gissane et al., 1997a, Gissane et al., 1998, Hodgson-Phillips et al., 1998, Stephenson et al., 1996), but two of these studies had to be excluded (Hodgson-Phillips et al., 1997, Hodgson-Phillips, 1998) for re-reporting the same source data to a previous paper (Hodgson-Phillips et al., 1998).

Upon further examination, it was also apparent that in some of the remaining eight studies that satisfied the inclusion criteria, authors had used the same common baseline data sets to highlight further trends in their data. For example, the data reported by Gissane et al., (Gissane et al., 1993), are contained within the data reported in a later paper (Stephenson et al., 1996), while, Stephenson et al. (1996) and Gissane et al. (1997) used the same baseline data. But one reported the overall incidence of injury in rugby league (Stephenson et al., 1996), while the other sought to highlight the differences in injury rates between forwards and backs (Gissane et al., 1997a).

This resulted in a total of six studies being included in the final pooled analysis which are highlighted in table 1, three of which reported both first team and reserve grade information (Estell et al., 1995, Gibbs, 1993b, Stephenson et al., 1996).

Since many studies did not include all areas of interest for analysis, it was necessary to extract specific information from individual studies at different stages of the analytical process.

Statistical methods

The data from individual studies were combined using the method described by Breslow and Day (Breslow and Day, 1987), Person-time incidence rates and 95% confidence intervals were calculated using Confidence Interval Analysis Software (Altman et al., 2000), To test for significant differences, proportion tests (z), chi-squared (χ^2) goodness of fit tests were used, along with relative risk (RR) where appropriate.

Results

The included studies reported injury data from a total of 753 games, 548 first team and 205 at reserve grade. The total number of hours observation for injury exposure was calculated as 13 players x length of the game x number of games played (two teams of 13 playing for one hour constitute 26 man hours). Games, are usually 80 minutes in length, but in two studies (Estell et al., 1995, Gibbs, 1993a) reserve grade games were 70 minutes long. There was a total of 12,819 man-hours across the six studies, 9474 at first team and 3118 at reserve grade

The injury incidence figures are shown in table 2. There was an overall injury rate of 40.3 injuries per 1000 man-hours. First team players experienced a slightly higher, injury rate than reserve grade players, although the difference was not significant ($z = 0.49$, $p = 0.62$).

Table 1. Summary of rugby league injury studies which reported prospective data collection.

Author(s) *italicised studies used*	Study Design	Seasons	Grade/Level	Participating Clubs
Alexander et al., 1979	Prospective	1	1st, Reserve, U21	1
Alexander et al., 1980	Prospective	2	1st, Reserve, U21	1
Estell et al. 1995	Prospective	1	1st, Reserve, U21, U19, U17, U15	1
Gabbett 1999	Prospective	3	Amateur	3
Gibbs 1994	Prospective	3+2	1st, Reserve, U21	1
Gibbs 1993	Prospective	3	1st, Reserve, U21	1
Gissane et al., 1998	Prospective	5	1st	1
Gissane et al., 1997	Prospective	4	1st, Reserve	1
Gissane et al., 1993	Prospective	1	1st, Reserve	1
Gissane et al., 1997	Prospective	1	1st	2
Hodgson-Phillips 1998	Prospective	4	1st	1
Hodgson-Phillips et al., 1998	Prospective	4	1st	1
Hodgson-Phillips et al., 1997	Prospective	4	1st	1
Lythe and Norton 1992	Mixed	1	--	Not stated
Norton and Wilson 1995	Prospective	1	1st, Reserve, Senior B, Open age amateur	24
Seward et al., 1993	Prospective	1	1st, Reserve, U21	9
Stephenson et al., 1996	Prospective	4	1st, Reserve	1
Walker 1985	Prospective	5	--	1

It was possible to pool data on the site of injury from four studies, which totalled 8365 exposure hours (Seward et al., 1993, Stephenson et al., 1996, Gibbs, 1993a, Gissane et al., 1998) and figure 1 displays the injury rates to the different sites of the body from these studies. There were significant differences between these injury rates ($\chi^2 = 12.34$, df = 3, $p<0.01$) with injuries to the lower limb accounting for 46.4% of the total, followed by, upper limb (20%), head and neck (18.7%) and trunk (14.7%).

Only two studies (Gibbs, 1993a, Gissane et al., 1997a) have reported a comparison between forward and back players for injury rates, which totalled 3673 man-hours of exposure (forwards = 1811.39, backs = 1861.9), giving injury rates of 66 (95%CI 55 to 79) and 61 (50 to 73) for forwards and backs, respectively. The relative risk (RR) of 1.09 demonstrated that playing as a forward increased the risk of injury by only 9%, although the 95% confidence interval for the RR (0.85 to 1.40) indicated that the increased risk was not significant.

Injury severity was graded according to the criteria used by Gibbs (1993a). An injury was classified as minor (one game missed), moderate (two to four games missed), or major (five or more games missed). It was possible to pool the results from three studies (Gibbs, 1993a, Hodgson-Phillips et al., 1998, Stephenson et al., 1996) that covered a total of 9437 hours of exposure, and the injury rates are shown in table 3. Overall minor injuries accounted 43% of the total, with moderate and severe accounting for 32.9%

and 25% respectively. However, the differences between the injury categories were not significant ($\chi^2 = 5.37$, $df = 2$, $p > 0.05$)

Discussion

The major findings of the analysis were; 1) that there was no difference between the injury rates of first and reserve grade players; 2) there were significant differences between the injury rates for different sites of the body, with the lower limb having the highest injury rate; 3) there was a small but not significant increased risk of injury when playing as a forward compared to playing as a back, and 4) there was no significant difference among the degree of severity of injuries sustained by players.

Pooling data from a number of studies of similar design is a technique that can produce an overall estimate which incorporates the information provided by those studies (Elwood, 1998). Therefore, the major strength of the present pooled analysis is the fact that it provides more accurate estimates of injury rates than the individual studies which provide the initial raw data. Therefore injury rates from the present study can be compared with injury rates from previous studies.

Table 2. Pooled injury incidence data of included studies.

Study	Grade/Level	Seasons reported	Injuries (no)	Games played	Exposure time (hrs)	Injury rate per 1000 hrs	95% CI
Hodgson-Phillips et al., 1998	1st	4	77	115	1988.4	38.7	30.1-47.4
Seward et al., 1993	1st	1	151	178	3077.6	49.1	41.2-56.9
Gissane et al. 1998	1st	1	20	23	397.7	50.3	28.3-72.3
Stephenson et al. 1996	1st	4	72	138	2386.0	30.2	23.2-37.1
Estell et al. 1995	1st	1	20	28	484.1	41.3	23.2-59.4
Gibbs 1993	1st	3	47	66	1141.1	41.2	29.4-53.0
Combined	1st		387	548	9474.9	40.8	36.8-44.8
Gibbs 1993	Reserve	3	41	66	1001.0	41.0	29.4-55.6
Stephenson et al. 1996	Reserve	4	75	111	1919.2	39.1	30.7-49.0
Estell et al. 1995	Reserve	1	14	28	424.7	33.0	15.7-50.2
Combine	Reserve		130	205	3344.9	38.9	32.2-45.6
Overall			517	753	12819.8	40.3	36.9-43.8

Figure 1. Pooled data for site of injury (rates per 1000 hrs with 95%CI).

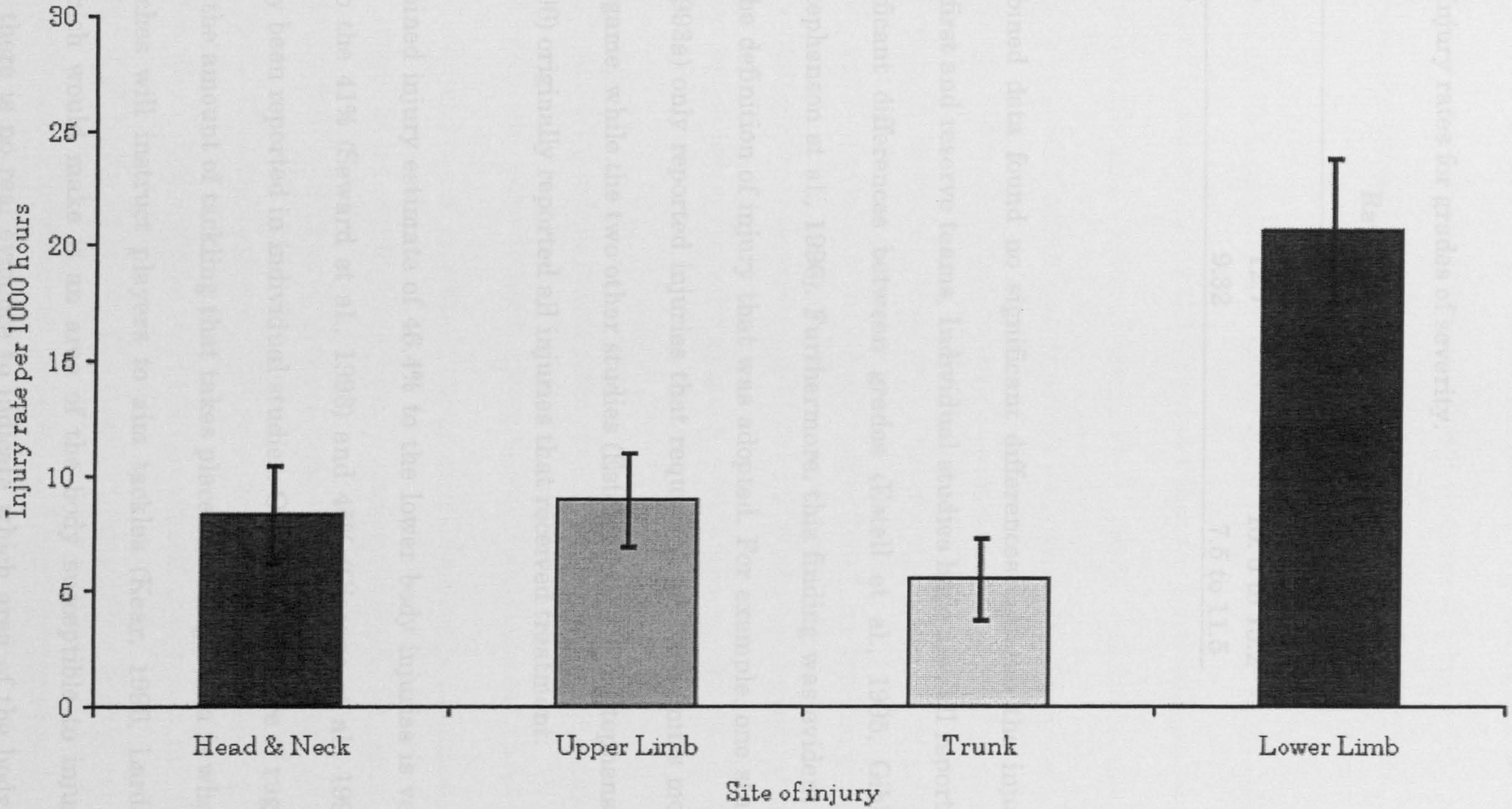

Table 3. Injury rates for grades of severity.

	Rate per 1000 hours	95% CI
Minor	16.64	14.1 to 19.5
Moderate	12.7	10. 5 to 15.2
Major	9.32	7.5 to 11.5

The combined data found no significant differences between the injury rates for first and reserve teams. Individual studies have also all reported non-significant differences between grades (Estell et al., 1995, Gibbs, 1993a, Stephenson et al., 1996). Furthermore, this finding was evident in spite of the definition of injury that was adopted. For example, one study (Gibbs, 1993a) only reported injuries that required a player to miss more than one game, while the two other studies (Estell et al., 1995, Stephenson et al., 1996) originally reported all injuries that received treatment.

The combined injury estimate of 46.4% to the lower body injuries is very similar to the 41% (Seward et al., 1993) and 45% (Gissane et al., 1998) previously been reported in individual studies. One major feature of rugby league is the amount of tackling that takes place. The thigh area is where most coaches will instruct players to aim tackles (Kear, 1996, Larder, 1988), which would make it an area of the body susceptible to injury. However, there is no real evidence to indicate which area of the body is contacted first, or with how much force, in the tackle. But, when tackles are aimed at the upper part of the body, arms and shoulders can be used to protect such areas as the trunk and head, whereas the lower limb will remain somewhat exposed to contact.

Almost half of the injuries in the pooled data analysis were to the lower limb, whereas it has been reported elsewhere that the head and neck were the most frequently injured sites (Gissane et al., 1993). This discrepancy is also likely to be due to differences in injury definition. If all injuries that required treatment were included, then lacerations that require suturing would be counted, however, these would not require a player to miss a subsequent game. Indeed, it has been suggested that including such injuries in addition to those requiring a player to miss a subsequent game, would increase the injury count by as much as 43% (Gibbs, 1993a).

If this study had adopted an injury definition for all injuries that received treatment, it would have limited the number of studies that could be utilised. However, the injury pattern would probably have been somewhat different. Injury rates would have been somewhat higher, for example combining the first and reserve grade estimates of Estell (Estell et al., 1995), Hodgson-Phillips (Hodgson-Phillips et al., 1998), and Stepehenson (Stephenson et al., 1996) would increase the overall injury rate to 116.6 injuries per 1000 hours. It is also likely that the site of the body that was most injured would also change to the head and neck (Stephenson et al., 1996, Gissane et al., 1993). This definition would then include all minor concussions and sutures that would not prevent a player from playing in the next match.

One recognised limitation when compiling the present analysis was that it was not possible to provide an accurate estimate of the phase of play in which injury took place. Although two previous studies (Gissane et al., 1997a, Stephenson et al., 1996) have suggested that most injuries are received by the ball carrier whilst being tackled, both reported the same baseline data, and furthermore no other investigators have reported injury occurrence in relation to the phase of play.

The aggregation of two data sets (Gibbs, 1993a, Gissane et al., 1997a) revealed that there was no increased *risk* of injury when playing as a forward compared to playing as a back. Recent work (Gissane et al., 2001c) has shown that forwards are involved in many more physical collisions than backs during the course of a game (55 vs. 29) This situation is similar in forwards compared in both attack (16 vs. 13) and defence (39 vs. 16). These increased numbers of physical collisions experienced by forwards do not appear to predispose them injury.

The pooled data analysis of three studies (Stephenson et al., 1996, Hodgson-Phillips et al., 1998, Gibbs, 1993a) indicated that there were no significant differences between categories of severity of injury. Nevertheless, although 43% of injuries required players to miss only one game, it was disturbing to note that one in every four injuries required a player to miss five or more games. Since recent changes in playing calendars and league structures, five games now represents almost 20% of a season, which will require increased numbers of players to cover for the playing time lost as a result of injury.

Conclusion

Within the limits of the definition of injury used in the present study (an injury requiring a player to miss a subsequent game), the pooled analysis has allowed the calculation of more accurate estimation of injury rates in professional rugby league and has attempted to make the results more generalisable. The resulting combined analysis reduces the variability associated with imprecise estimates and potential biases associated with individual studies. It also removes the influence of individual sub-cohort characteristics, such as playing style (Checkoway, 1991).

To date, rugby league is a sport that has not undergone a comprehensive scientific investigation. However, it may be possible in future to add subsequent studies to the present pooled analysis with a view to improving the understanding of the factors surrounding injury incidence in rugby league football.

In order to provide more comprehensive data on injury incidence in rugby league football further prospective studies are required. Furthermore, these studies should use common definitions of injury, the phases of play in which injury occurs, and the precise mechanism of injury. Such approaches would be best facilitated by the adoption of a standardised injury surveillance system that would allow further in depth analyses to be performed.

Overall Discussion and Recommendations

When beginning the investigation of injury in rugby league football, it was observed by De Jennings and myself, that there was very little literature on the subject. Also, when our data collection began (July, 1990), the most recent paper at that time was five years old (Walker, 1985).

The first piece of work published was a simple one-season survey of injuries (Gissane et al., 1993). As it only covered one season, it was almost cross-sectional in design and the findings of this could be somewhat distorted. As pointed out by Alexander et al. (1980), the situation had the potential to change markedly from season to season.

The first article presented in this thesis (Stephenson et al., 1996) (see pages 40 to 57) was designed to be a descriptive study so that the injury situation within the English game could be illustrated. Describing the current situation is usually the starting point with epidemiology. The data collection period of four seasons would allow the more accurate determination of injury estimates than the one-year investigation (Gissane et al., 1993), and reduce the possibility of marked variation between individual seasons.

From descriptive epidemiological studies, hypotheses can be generated to be tested in later analytical studies (Henekens and Buring, 1987, Hart, 1996, Caine et al., 1996). One hypothesis put forward by Stephenson et al. (Stephenson et al., 1996), was that the exposure of forward and backs was different, and that this differing exposure would result in different injury patterns. Gissane et al. (1997a) examined this hypothesis further (see pages 58 to 73), demonstrating that the injury pattern for the two playing units was indeed different, with forwards experiencing much higher rates of injury that backs.

Events within the game itself largely dictated the direction of the next two studies. The decision was made to move the playing calendar in 1996, from the autumn and winter months to the spring and summer months. Because of previous research in this field, the opportunity presented itself to examine the hypothesis that the injury rate would change along with the move of the playing calendar. Because the injury register was already in place, there was going to be the opportunity to examine the hypothesis using the same data collection techniques, prior to and after the change. This would mean the minimisation of potential biases, by using the same data collection tool. The hypothesis was tested using a non-concurrent cohort (Gissane et al., 1998) (see pages 74 to 87), and demonstrated that the risk of injury in summer rugby was 67% higher in spite of players being involved in much fewer games.

Similarly, with the move to summer rugby league, it was unclear what effect the environment, namely the temperature, was going to have on players. The calendar move meant that the game was going to be played in much higher temperatures than European players had previously experienced. In epidemiological terms, the specific situation had to be described to determine if there was a potential health problem. So Jennings et al. (1998) (see pages 88 to 97), seek to describe the how many players were experiencing dehydration during match play. Ideally, it would have been better to have had a comparison group for body mass losses during winter rugby league. But prior to the calendar change, no one had considered it to be a problem.

However, this paper has had a far-reaching effect. The game's administrators are aware of the need for players to hydrate properly, but at the same time they do not want coaches and trainers constantly running on the field of play. This presents a problem, in as much as the investigation can is viewed by the RLMA as a risk assessment. Its findings suggest that we need more people on the field carrying water, rather than less. To compromise an amendment was placed in the laws (Appendix C Rule 11) that states: -

On Field Trainers - Only two trainers are permitted on the field at any one time and must enter the field from behind their own team. If both teams obtain permission from the referee prior to the commencement of the game, then another trainer will be allowed for the match if the playing conditions would require, e.g., heat (RFL, 2001).

This allows an extra water carrier to be used. Also, with prior consultation with the referees they will in junior games (U 18, U 19 and U 21), stop the game for at approximately halfway through each half.

Several authors have suggested that injury rates in rugby league are high because of the volume of physical collisions in which players are involved (Stephenson et al., 1996, Gibbs, 1993a, Kear et al., 1996, O'Hare, 1995). The next two papers in this thesis (Gissane et al., 2001c, Gissane et al., 2001a) (see pages 98 to 112 and pages 113 to 126), sought to describe the amounts and types of physical collisions and then determine if there was a relationship between collisions and injury rates. The task was made much easier by the move to summer rugby league. The change was brought about by the opportunity for greatly increased media exposure. From a research point of view, this meant that there were professional video recordings of each game available. Using video recordings meant that both the amounts and types of physical collisions could be determined much more accurately. Also, as tapes could be rewound and reviewed, the chances of measurement errors could be very much reduced. All tapes that were used in this study were recorded from a position at approximately the half way line. This view allows the most uninterupted and least obscured scrutiny of the events taking place.

As a result of this research, speculation about which players were involved in the most physical work was partially laid to rest. Forwards were involved in almost twice as much physical contact as backs, and also players got involved in more physical contact while their side was defending. From this it was possible to determine that backs had a significantly higher injury rate per 10,000 physical collisions than forwards (Gissane et al., 2001a) (see pages 113 to 126).

The Operational Model (Gissane et al., 2001b) (see pages 127 to 146) was a culmination of many years reading and researching in the area of injury incidence. Quite often injuries are looked at in relation to one factor. But, injuries can come about as a result of many factors and there are many points in the process where injury incidence, prevalence and outcome can be influenced. Its major difference to other proposed models (Meeuwisse, 1994) was that the model was cyclical, which did not see injury as an end point. By doing this, it allowed the inclusion of a player's previous playing and injury experience into the model. Whereas previous authors (Watson, 1997), had included it as an intrinsic risk factor.

It has been suggested that it is often useful to have information from several epidemiological studies combined into a single estimate (Checkoway, 1991). Typically there are two ways of carrying out this task. Firstly, a meta-analysis is the process of using statistical methods to combine the results of different studies. Secondly, when possible the raw data from several studies can be pooled together and re-analysed. To carryout a pooled data analysis it is necessary to have the raw data

(Blettner et al., 1999). Because of the way that injury data are reported in sports medicine studies, it is often possible to pool the raw data without having access to the original data.

This is possible because an injury rate is calculated using the following formula: -

$$\text{rate} = \frac{\text{cases}}{\text{player hours at risk}} \times 10^{n}$$

Because it is a division sum, if any of the two components are known, the third can be calculated as shown below.

$$\text{rate} = \left(\frac{\text{injuries}}{\text{player hours at risk}}\right) \times 10^{n}$$

$$\text{injuries} = \left(\frac{\text{rate}}{10^{n}}\right) \times \text{player hours at risk}$$

$$\text{player hours at risk} = \left(\frac{\text{injuries}}{\text{rate}}\right) \times 10^{n}$$

Many studies report the number of injuries that players receive and the number of games played during the course of the study, along with the injury rate. So, it is possible to break the information down to its component parts and combine the data together. This allows research a great deal of scope to combine the information reported in a number of small studies. When it is carried out it will allow much more accurate estimates to be presented and will increase the generalisability of the findings.

With the knowledge of both how rates were constructed and the information reported in the literature, it was possible to write the final paper in the series (Gissane et al., 2002) (see pages 148 to 62).

This series of papers has produced evidence that is valuable to a variety of professions in rugby league football. Those who are involved in preventing and treating injuries now have information on the number of type of injuries that occur during the course of match play. This can serve to inform and guide training of health professions within the game. Also, information is available to coaches about how often injuries occur and how this can influence player selection. For both the health professionals and the coaches, information is available on the risk of dehydration. This not only has effects detrimental to health, but also to a player's skills ability.

In addition to this, the work has resulted in rule amendments (RFL 2001), and some of the most detailed investigations of individual player's activities during match play (see pages 98 to 112 and pages 113 to 126). Beyond this, the technique of pooling data that was employed (Gissane et al., 2002) (see pages 148 to 62) could be used in many other sports to provide an overall view of a number of studies that have been published. This technique has never been used before in sports injury research, and it could be used to examine conflicting findings between studies.

Future research

In spite of the work that has been carried out over the last 12 years, there is still a lot of scope for future research, both in sports injury incidence and in rugby league.

Once upon a time, the editor of a paper called the 'Rugby Leaguer' interviewed me about some of my research. He asked me why I had stated in the paper that more research needed to be done (Gissane et al., 1993). I replied that it was for the same reason that he published a paper each week. The game, in the same way as any other sport, is a living thing that is constantly changing and evolving. The game changes, and as it changes it presents opportunities for future research.

Injury research of the game has in recent years focussed on the move to summer rugby. But, in epidemiological terms there are many things that still remain to be investigated. For example, for clear evidence on risk factors they need to be examined in a prospective study, with data collected about specific factors prior to the collection of injury data (Waller et al., 1994). This type of research has been carried out in rugby union

(Quarrie et al., 2001) and soccer (Inklaar et al., 1996). Prospective cohort studies such as these would allow targets and strategies for prevention to be established and implemented. Over the last few years in rugby league, the changes seem to have taken place, and then the investigations as to whether they have hindered or helped players' health have come later. However, the move to summer was eight seasons ago, and it now looks permanent. So possibly now the time is right to investigate ways in which players' injury experiences can be reduced.

The task today would be somewhat easier in terms of data collection. When De Jennings and I first began to collect data on 4th July 1990., neither of us really had any idea how long we would be going about this task. All the data was collected in a hand written register. If we were to start again we would undoubtedly use a purpose written database, which would make our data much more flexible and the task of data management much easier. For any sports medicine epidemiology investigation to function efficiently and to produce high quality research, information technology is going to be essential.

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Injury in rugby league: a four year prospective survey

Sarah Stephenson, Conor Gissane, Deanna Jennings

Abstract

***Objective*—To investigate the incidence of injury in English professional rugby league over a period of four playing seasons.**

***Methods*—All injuries that were received by players during match play were recorded. Each injury was classified according to site, type, player position, team playing for, activity at the time of injury, and time off as a result of injury.**

***Results*—The overall injury rate was 114 (95% confidence interval 105 to 124) per 1000 playing hours, the most frequent type of injury were muscular injuries [34 (29 to 40) per 1000 playing hours], while the most frequently injured site was the head and neck region [38 (16 to 25) per 1000 playing hours]. Players received the largest percentage of injuries when being tackled [46.3% (41.9 to 50.7)], most injuries required less than one week away from playing and training [70.1% (66.1 to 74.2)], and forwards had a higher injury rate than backs (139 *v* 93 injuries per 1000 hours).**

***Conclusions*—The high rates of injury in rugby league are undoubtedly due to the high amount of bodily contact in the game. Being tackled has the highest risk of injury, because of being hit forcibly by other players. Forwards suffer higher injury rates than backs, probably because they are involved in a larger number of physical collisions.**

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Key terms: rugby league; injury; injury rate; prospective study

Physiotherapy Department, West Middlesex University Hospital, Isleworth, Middlesex, United Kingdom
S Stephenson, physiotherapist

Department of Health Studies, Brunel University College, Isleworth, Middlesex, United Kingdom
C Gissane, research officer

Reigate, Surrey, United Kingdom
D Jennings, general practitioner

Correspondence to:
C Gissane, Department of Health Studies, Brunel University College, Isleworth, Middlesex TW7 5DU.

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Rugby league is a physical game in which players are required to demonstrate speed, stamina, strength, and agility.[1] It has been suggested that injury rates in rugby league are higher than in other main body contact sports such as rugby union,[2-3] Australian rules football, and soccer.[2] The possible reasons for the high injury rate are that players are involved in 20 to 40 physical "confrontations" per game,[4] and that players wear minimal protective equipment,[5] such as padding, which is designed to protect the soft tissues but not the bones and joints,[6] or padded supports and sleeves for which, it has been suggested, there is no evidence of protection for injured muscles.[7]

However, it is acknowledged that research into many aspects of rugby league is extremely limited,[8] not least on the incidence of injury. Previous investigations have reported on short time periods,[3 9] and the only longitudinal investigations have been carried out in the Australian game.[1 5] These studies also report widely differing findings, which could be due to the playing conditions, the skill level of players, the design of the studies, or the definition of what constitutes an injury. The purpose of this study was therefore to describe the incidence of injury in one professional rugby league club over a period of four seasons.

Methods

All injuries that were reported by players during the four seasons between July 1990 and May 1994 were recorded. A season ran from the beginning of preseason training to the last competitive match in either April or May. An injury was taken to be the onset of pain or a disability that occurred while playing rugby league football.[3] The diagnosis and classification of injury was carried out by the club doctor and the physiotherapist. The site and injuries were categorised as described previously.[9] The following details were recorded about each injury:

- The position of the player
- The site of the injury
- The nature of injury
- Whether the injury occurred in playing or training
- The team played for (first or "A" team)
- Activity at the time of injury
- Time off as a result of injury

The total number of games played during the four seasons was recorded. In total, there were 249 games played [first team 138, alliance ("A") team 111]. This included all competitions and friendlies. Playing hours at risk were calculated as the number of matches played × 1.33 (each match lasting 80 minutes). Thirteen players in a side constitute 17.29 playing hours at risk during a game. Training sessions took place at the rate of two or three per week, involving approximately five hours work on game skills, with minimal body contact.

Statistical analysis consisted of the calculation of rates per 1000 hours of play and percentages; where appropriate rates were compared using the normal approximation as described by Clarke.[10] Significance was set at the $P < 0.05$ level.

Results

During the four seasons under investigation, 599 medical conditions that prevented a player from either playing or taking part in club train-

Table 1 Type of injury sustained in matches

	All players			1st Team			A Team		
Type of injury	Number	Rate per 1000 hours	95% CI	Number	Rate per 1000 hours	95% CI	Number	Rate per 1000 hours	95% CI
Haematomas	68	16	12-20	37	16	11-20	32	17	11-22
Muscle strains	79	18	14-22	51	21	29-44	27	14	9-19
Muscular injuries (total)	147	34	29-40	88	37	25-37	59	31	23-39
Joint sprain	117	27	22-32	61	26	16-27	56	29	22-37
Laceration	85	20	16-24	66	28	21-34	19	10	6-14
Contusion	51	12	9-15	28	12	7-16	23	12	7-17
Fracture and dislocation	40	9	6-12	25	10	6-15	15	8	4-12
Concussion	35	8	6-11	18	8	4-11	17	9	5-13
Abrasion and skin infection	10	2	1-4	7	3	1-5	3	2	1-5
Others	7	2	1-3	4	2	1-4	3	2	1-5
All types	492	114	105-124	297	124	111-138	195	102	88-115

CI, confidence interval.

Table 2 Site of injury sustained in matches

	All players			1st Team			A Team		
Site of injury	Number	Rate per 1000 hours	95% CI	Number	Rate per 1000 hours	95% CI	Number	Rate per 1000 hours	95% CI
Head and neck	165	38	33-44	111	47	38-55	54	28	21-36
Thigh and calf	88	20	16-25	49	21	15-26	39	20	14-27
Knee	50	12	8-15	28	12	7-16	22	11	7-16
Thorax and abdomen	45	10	7-14	24	10	6-14	21	11	6-16
Shoulder	41	10	7-12	26	11	7-15	15	8	4-12
Ankle	40	9	6-12	24	10	6-14	16	8	4-12
Arm	32	7	5-10	19	8	4-12	13	7	3-10
Others	31	7	5-10	16	7	3-10	15	8	4-12
All sites	492	114	105-124	297	124	111-138	195	102	88-115

CI, confidence interval.

Table 3 Activity at the time of being injured

	All players			1st Team			A Team		
Activity	Number	Rate per 1000 hours	95% CI	Number	Rate per 1000 hours	95% CI	Number	Rate per 1000 hours	95% CI
Tackled	228	46.3	41.9-50.7	138	46.5	40.8-52.1	90	46.2	38.2-53.2
Other	159	32.3	28.2-36.4	99	33.3	28.0-38.7	60	30.8	24.3-37.2
Tackler	105	21.3	17.7-25.0	60	20.2	15.6-24.8	45	23.1	17.2-29.0
Total	492	100.0	99.3-100	297	100.0	98.8-100	195	100.0	98.1-100

CI, confidence interval.

ing for rugby league were recorded. Of these, 27 were illnesses and conditions such as sickness, and were excluded from the analysis. This left a total of 572 sports injuries, 492 (82.1%) of which were received during match play and 80 (13.9%) during training.

Of the 492 match injuries, 297 (60.4%) were to first team players and 195 (39.6%) to A team players. This equates to an overall incidence rate of 114 injuries per 1000 hours of match play (first team, 124; A team, 102; $z = 2.2$, $P < 0.05$).

The types of injuries sustained during match play are shown in table 1. The highest injury rates were for muscular injuries (haematomas and strains) (34 per 1000 hours). When examining the first and A teams separately, the same type of injury was the most common (first team 37, A team 31 per 1000 hours; $z = 4.7$, $P < 0.05$). The types of injury that were least common were abrasions and skin infections and "others" (both 2 per 1000 hours).

The sites of injuries sustained by players are shown in table 2, which indicated that the region of the body that suffers the highest injury rates is the head and neck (38 per 1000 hours). The same site was also the most injured when comparing the first and A teams, although the two rates are markedly different (47 *v* 28 per 1000 hours; first team *v* A team; $z = 3.2$, $P < 0.05$). The next most commonly injured site in the body was the thigh and calf, but the injury rate was less than half that of the head and neck (20 per 1000 hours). The least injured sites of the body were the arm and the "others" category, which included such areas as fingers and toes (both 7 per 1000 hours).

The figures for the first and A teams are given in table 3 and tended to be quite similar. Of all the playing injuries the largest percentage was received when a player was being tackled (46.3%), while a tackler was injured in 21.3% of the injury events. The remaining 32.3% were classified as "others", which included injuries during such activities as running and scrummaging.

The amount of time off taken by players as a result of injury is shown in table 4. It can be seen that more than two thirds of all injuries sustained required a player to take less than one week away from playing and training, a relatively small proportion of injuries (7.5%) required a player to be away from training for more than four weeks.

Table 4 Time off as a result of being injured

	All players			*1st Team*			*A Team*		
Time off	*Number*	*Rate per 1000 hours*	*95% CI*	*Number*	*Rate per 1000 hours*	*95% CI*	*Number*	*Rate per 1000 hours*	*95% CI*
< 1 week	345	70.1	66.1-74.2	225	75.8	70.9-80.6	120	61.5	54.7-68.4
1-2 weeks	67	13.6	10.6-16.6	32	10.8	7.3-14.3	35	17.9	12.6-23.3
2-3 weeks	32	6.5	4.3-8.7	14	4.7	2.3-7.1	18	9.2	5.2-13.3
3-4 weeks	11	2.2	0.9-3.5	5	1.7	0.6-3.9	6	3.1	0.6-5.5
> 4 weeks	37	7.5	5.2-9.6	21	7.1	4.2-10.0	16	8.2	4.4-12.1
Total	492	100.0	99.3-100	297	100.0	98.8-100	195	100.0	98.1-100

CI, confidence interval.

Table 5 Distribution of injury between forwards and backs

	All players			*1st Team*			*A Team*		
Position	*Number*	*Rate per 1000 hours*	*95% CI*	*Number*	*Rate per 1000 hours*	*95% CI*	*Number*	*Rate per 1000 hours*	*95% CI*
Forwards	277	139	124-155	169	153	113-150	108	122	100-144
Backs	215	93	81-105	128	100	83-116	87	84	67-101
Total	492	114	105-124	297	124	111-138	195	102	88-115

CI, confidence interval.

Table 6 Classification of concussions

Severity of concussion	*Action*
Mild: no loss of consciousness (LOC)	
i. Full memory of event	Can usually continue playing (after being checked)
ii. Memory deficit of event	Must cease playing: no training or playing for 48 hours, and only after medical check by the club doctor
Moderate: (LOC) of up to 2 minutes	Must cease playing: no playing or training for 15 days and only after a medical check by the club doctor
Severe:	
i. LOC of up to 3 minutes	Must cease playing: no playing or training for 22 days and only after a medical check by the club doctor
ii. LOC of over 3 minutes	Must cease playing: and be admitted to hospital for observation: no playing or training for 29 days and only after a medical check by the club doctor

All cases of SEVERE concussion should have *x* rays of the skull and cervical spine.
Source: The Rugby Football League (1993).

The incidence of injury for forwards and backs is shown in table 5. From this it can be seen that forwards are injured more frequently than backs in absolute terms (56.3 *v* 43.7%, both first and A teams). When the rate is standardised for the number of players (six forwards and seven backs), the injury rate differences are even larger (forwards 139 *v* backs 93 per 1000 hours; $z = 4.5$, $P < 0.05$).

Discussion

In this study we found an overall injury incidence rate in rugby league of 114 injuries per 1000 man hours of play. It has been suggested that the high injury rate is due to repeated hard body contact.[5] The injury rate in the current study is higher than the rate of 14 that has been reported for rugby union,[11] and also higher than the rate of 45 per 1000 hours that has been reported for Australian rugby league.[1] One probable reason for the differing rates between Australian and English rugby league, and League and Union was the decision of previous studies[1 11] only to include injuries that required a player to miss a subsequent game, the games being played on a weekly basis. If in the present study injuries requiring less than one week to recover from are excluded the overall rate is reduced to 34 per 1000 hours (first team 30, A team 39 per 1000 hours). However, this may not strictly be comparable, as situations such as weather conditions in England may result in more than a week between games. Then postponed games, which must be played later in the season, could result in a fixture backlog requiring more than one game to be played per week.

Muscular injuries accounted for 29.9% of all injury types. This is similar to values that have previously been reported.[12 13] Injuries of this type to the quadriceps have been reported to be common as this is the first point of contact in the tackle.[5] It could be argued that a game which has been likened to being mugged 30 times in 80 minutes,[14] which involves a player in 20 to 40 physical "confrontations" per game,[4] predisposes players to this type of injury.

The site of the body to which most injuries took place was the head and neck region, with 33.3% of all injuries. This is higher than has been previously reported, with studies quoting values ranging from 5.8%[1] to 28.8%[9] of all injuries. Again, the decision to include minor injuries may account for part of the difference. But at least one other study chose to include minor injuries,[17] and commented that head and neck injuries were on the increase. While another reported that head lacerations were very common, although they did not require players to miss games.[5]

The observation that a majority of injuries are caused in the tackle is common to both rugby codes.[3 11 15-17] The findings of the present study show that the player being tackled is more likely to be injured (46.3%), and this is also in agreement with previous research.[3 17] In rugby league, the tackle is a very prominent part of the game, which carries inherent dangers such as being knocked over backwards, whiplash, and the clashing of heads.[4]

This study also reported that 32.3% of players were injured in situations classified as "others"; this must be considered a limitation of the study. With almost one third of injuries falling into this category, it is clear that it is too large as a general classification, and that future research should attempt to break this down into more component parts. For example, some injuries may have occurred as a result of foul play but were not recorded as such. Nevertheless, the sport is concerned about such incidents, and this was emphasised by the Rugby League issuing a directive in January 1995 specifically making lifting a player and "spear tackling" him a sending off offence under Law 15.1d regarding illegal throws.

The vast majority of injuries recorded in this study (70.1%) required that a player be absent from training and playing for less than a week. Part of the reason for this high figure was the decision to include all injures received while playing. Gibbs,[1] who defined an injury as an event that required a player to miss the next week's game, reported that the largest proportion (38%) of injuries required players to miss the next game. If the injuries requiring less than one week off play are excluded from the current analysis, the largest proportion required one to two weeks absence (46%). However, classifying injuries in this way can be shown to miss many minor injuries.[18] Also, it should be pointed out that 17% of the injuries recorded in this study were lacerations. The majority of these would have involved the "blood-bin", which began in the 1991-2 season after concern over such injuries. Furthermore, one investigation reported that such injuries rarely cause a player to miss a game, but counted 101 over five seasons.[5] If they were counted, they would add considerably to both the numbers of, and the injury rates.

A possible explanation for differences between the League and Union codes might be the specific regulations regarding concussions. The International Rugby Football Board resolution (5.7) requires a concussed player to refrain from playing and training for a period of at least three weeks after the injury, and subject to being cleared by a proper examination.[7] However, in rugby league, concussion is graded by severity, as shown in table 6. This could result in injuries being recorded but players requiring less time away from playing and training.

The finding that backs are injured much more frequently than forwards has been observed by others.[1 2 11] It has also been reported that forwards received a larger than expected number of injuries, based on the number of player positions.[1] As backs run the ball more and forwards tend to be involved in more collisions,[4] then perhaps they should be more susceptible to injuries. It has also been suggested that the pattern of injury between forwards and backs might change with an alteration in the style of play.[11]

The results from our study show that rugby league has very high injury rates. This is undoubtedly due to the large amount of physical body contact between players. Injury rates were shown to be higher at the highest standards of play. Forwards experience greater rates of injury than backs, which is probably due to their being involved in more repetitive body contact than backs. Perhaps future research should examine the differing injury rates between forwards and backs in relation to their game-specific work loads, and also analyse what types of injury these respective groups receive during the course of a game.

We would like to thank Dr J A White, Dr L Rushton, Dr J C G Pearson, and Ms C A C Coupland for their assistance while writing this paper.

Postscript

During the peer review of this paper, the reviewers made some extremely useful and helpful comments. For some of these points, we had the necessary information available and could address the issues, while unfortunately for others we could not do so.

One of these points was related to information on the incidence of foul play, which was not collected. The reason for this was that when the register was begun back in 1990, we collected what we thought was relevant at the time. At that time, there were almost no studies available on rugby league and an overall picture of the injury situation was needed. This is not to say that foul play is not an extremely important issue, but with the advent of the Super League concern has shifted. The Rugby League Medical Association is currently more concerned with the effect that playing on hard ground will have on overall injury rates and with the potential for heat stress injuries.

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Differences in the Incidence of Injury Between Rugby League Forwards and Backs

Gissane C,[1] Jennings D.C.,[2] Cumine A.J.,[3] Stephenson S.E.,[4] & White J.A.[5]
[1]Department of Health Studies, Brunel University College, Isleworth, Middlesex, UK.
[2]General Practitioner, Reigate, Surrey, UK.
[3]Department of Sport Science and Physical Education, St Mary's University College Strawberry Hill, Twickenham, Middlesex, UK.
[4]Department of Physiotherapy, West Middlesex University Hospital, Isleworth, Middlesex, UK.
[5]Department of Public Health Medicine and Epidemiology, Queen's Medical Centre, University Hospital, Nottingham, UK.

ABSTRACT
Gissane C, Jennings D.C., Cumine A.J., Stephenson S.E., & White J.A. (1997) Differences in the incidence of injury between rugby league forwards and backs. ***The Australian Journal of Science and Medicine in Sport*** *29 (4): 91-94*

Evidence with regard to the incidence of injury to forwards and backs in the game of rugby league is extremely limited. A four year prospective study of all the injuries from one professional Rugby League club was conducted. All injuries that were received during match play were recorded, and those for forwards and backs compared. Forwards had a higher overall rates of injury than backs (139.4 [124.2 - 154.6] vs. 92.7 [80.9 - 104.6] per 1000 player hours, P<0.00006). Forwards had a higher rate of injuries to all body sites with the exception of the ankle and the 'others' category of injury. They had significantly higher rates for the arm (11.6 [6.9 - 16.3] vs. 3.9 [1.4 - 6.4] per 1000 player hours, P = 0.005) and, the head and neck (53.9 [43.9 - 63.8] vs. 25.0 [18.7 - 31.4] injuries per 1000 player hours, P<0.00006). Forwards had significantly more injuries than backs for contusions (17.1 vs. 7.3 per 1000 player hours, z = 2.85, P = 0.0044), lacerations (26.7 vs. 13.8 per 1000 player hours, z = 2.92, P = 0.0035) and haematomas (20.6 vs. 11.6 per 1000 player hours, z = 2.29, P = 0.02). Forwards were also more likely to be injured when in possession of the ball (70.5 [59.2 - 81.7] vs. 38.0 [30.2 - 45.7]), and also when tackling (33.2 [25.3 - 41.1] vs. 16.8 [11.6 - 22.1]). The higher rates of injury experienced by forwards were most likely as a result of their greater physical involvement in the game, both in attack and in defence.

INTRODUCTION

In many team sports, different demands are made on different player positions. Within Rugby League there has been a trend to reduce specialisation, so that the work carried out by players varies less from position to position (Larder, 1992) and it has been suggested that fitness training is uniform for all positions (O'Connor, 1995). Nevertheless, match analysis has demonstrated that backs cover greater distances in a game than forwards (7336 vs. 6647m [Meir et al., 1993]), and also that forwards are involved in a larger number of physical collisions than backs (36.3 vs. 19.14) (Larder, 1992). It can be said that the forwards main role in possession is to gain ground quickly and to put the opposition on the back foot, while backs attempt to move the ball wide and exploit space. Similarly, when defending forwards do the majority of the tackling, attempting to stop the opposition gaining ground, and so denying them space in which to operate.

With these variations in physical effort demanded of the two playing units within a team it was hypothesised that there is a differing risk of injury, and that the injuries received by members of these playing units might also differ. It has been demonstrated that forwards do experience higher rates of injury than backs (Gibbs, 1993; Gissane et al., 1993; Norton & Wilson, 1995) while in Rugby Union, it has been reported that 80% of injuries to backs took place whilst players were involved in the tackle situation (Garroway and Macleod, 1995). But to date, the specific question of whether, and how, differing roles in game situations alters the risk of injury has not been addressed.

The purpose of this study was to describe the differences in the incidence of injury to forwards and backs, and to determine if there is a greater risk of injury when playing as a forward or a back in a professional Rugby League club over a period of four seasons.

METHODS AND PROCEDURES

The data to be used in this investigation have been described previously (Stephenson et al., 1996). All injuries that were reported by players during the four seasons between July 1990 and May 1994, at one professional Rugby League club were recorded. A season ran from the beginning of pre-season training, to the last competitive match in either April or May. An injury was taken to be the onset of pain or a disability that occurred while playing Rugby League Football (Gissane et al., 1993). Which has been reported to best correspond with daily reality (Twellaar et al., 1996). The diagnosis and classification of injury was carried out by the club doctor and the physiotherapist. The site and type of injuries were categorised as described previously (Alexander et al., 1980). The following details were recorded about each injury: The position of the player (forward or back), the site of the injury, the nature of injury, the team played for (first or 'A' team), activity at the time of injury, time off from playing and training as a result of injury.

During the time of the injury survey a total of 249 games were played, which included all pre-season, league, cup and post-season games. This represented a total of 4305.21 player hours at risk (13 players x 1.33 hours x 249 games), each game lasting 80 minutes. Since a team of 13 is comprised of six forwards and seven backs, forwards were at risk for a total of 1987.02 playing hours, and backs for 2318.19 hours. The age of a player was taken as the age at the beginning of the season (1st September). Based on this, the mean age(±SE) was 24.3±0.27 yrs.

The statistical analysis consisted of the calculation of injury rates per 1000 hours of play as a standardised rate of exposure, for both forwards and backs. The injury rates for the different playing units were compared using the normal approximation as described by Clarke (1994):

$$z = \frac{(r_1 - r_2) - 0}{\sqrt{r_1/t_1 + r_2/t_2}}$$

where r_1 and r_2 are the two rates being examined and t_1 and t_2 are the respective time periods.

RESULTS

During the four years of the study a total of 492 injuries were recorded, 277 to forwards and 215 to backs. The overall injury rate for all players was 114.3 injuries per 1000 player hours (95% CI 104.8 to 123.8). The rates for forwards and backs were 139.4 (124.2 to 154.6) and 92.7 (80.9 to 104.6) per 1000 player hours (z = 4.45; P < 0.0006). The relative risk of injury when comparing forwards and backs was 1.50 (1.32 to 1.68).

Injuries to different sites of the body are displayed in Figure 1. Forwards had higher rates of injury in all categories than backs, with the exception of the ankle and the 'others' category of injury. Forwards also demonstrated higher injury rates in six of the eight

Figure 1: Comparison of injury sites for forwards and backs (rate with 95% CI).

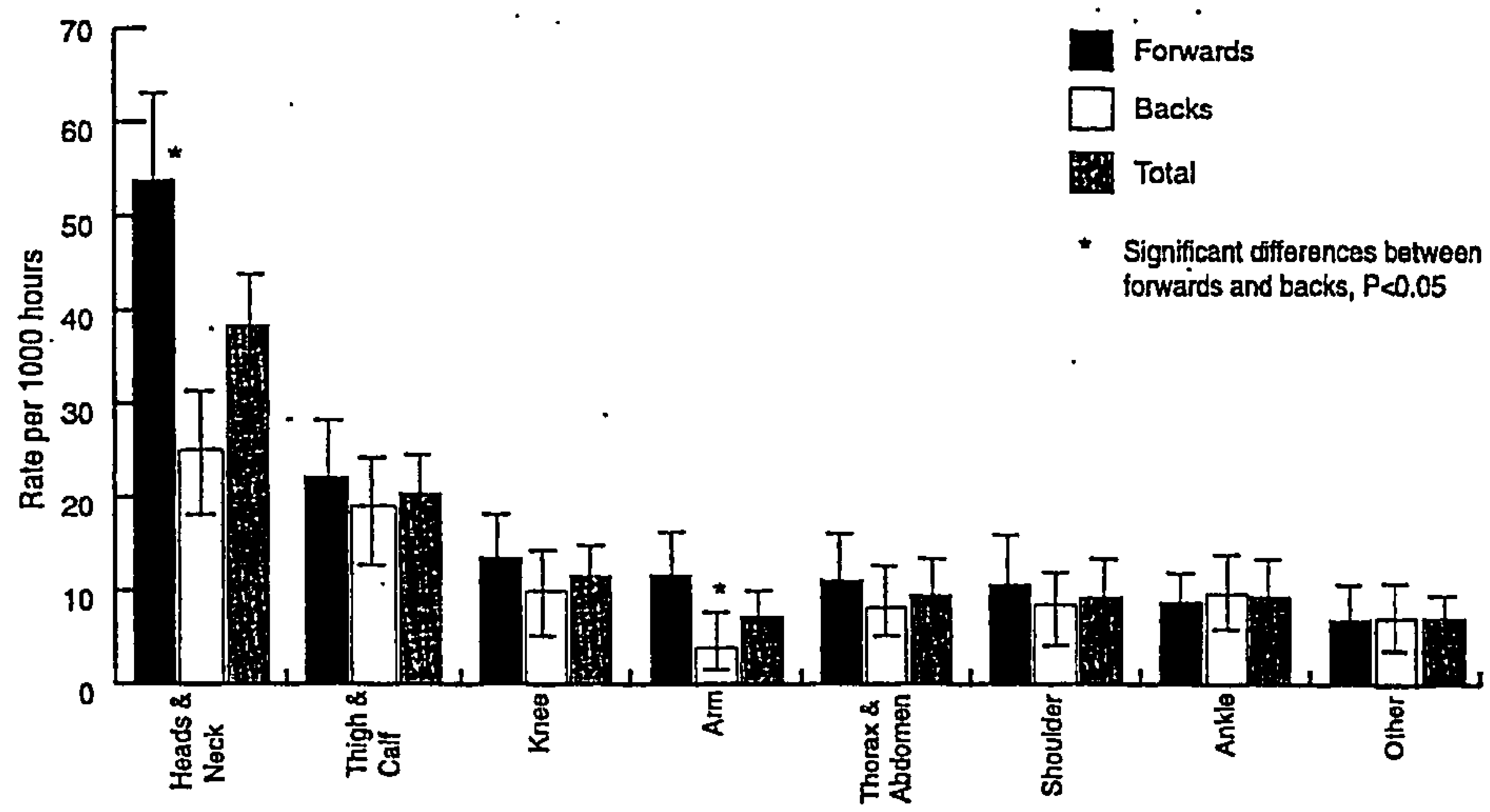


Table 1: Type of injury comparison of forwards and backs.

	FORWARDS			BACKS			TOTAL		
	Number	Rate per 1000 hours	95% CI	Number	Rate per 1000 hours	95% CI	Number	Rate per 1000 hours	95% CI
Joint Sprains	60	30.2	22.7 - 37.7	57	24.6	18.3 - 30.9	117	27.2	22.3 - 32.0
Dislocation	5	2.5	3.3 - 4.7	6	2.6	0.5 - 4.7	11	2.6	1.1-4.1
Joint injuries (total)	65	32.7	24.9 - 40.5	63	27.2	20.6 - 30.8	128	29.7	25.9 - 36.3
Muscle strains	38	19.1	13.1 - 25.2	41	17.7	12.3 - 23.1	79	18.3	14.3 - 22.4
Concussions	22	11.1	6.5 - 15.7	13	5.6	2.6 - 8.7	35	8.1	5.5 - 10.8
Fracture	16	8.1	4.1 - 12.0	13	5.6	2.6 - 8.8	29	6.7	4.3-9.2
Contusions	34	17.1*	11.4 - 22.8	17	7.3	3.9 - 10.8	51	11.8	8.6- 15.1
Haematomas	41	20.6*	14.4 - 26.9	27	11.6	7.3 - 16.0	68	15.8	12.1 - 19.5
Total	75	37.7*	29.4 - 46.1	44	19.0	13.4 - 24.5	119	27.6	22.7 - 32.5
Abrasions & Skin infect.	5	2.5	3.31 - 4.72	5	2.2	0.3 - 4.1	10	2.3	0.9 - 3.8
Lacerations	53	26.7*	19.6 - 33.8	32	13.8	9.1 - 18.6	85	19.7	15.6 - 23.9
Other	3	1.5	-0.2 - 3.2	4	1.7	0.0 - 3.4	7	1.6	0.4 - 2.8
Total	**277**	**139.4**	**124.2 - 154.6**	**215**	**92.7**	**80.9 - 104.6**	**492**	**114.3**	**104.8- 123.8**

* signficantly different from backs (P<0.05)

site category classifications, and had significantly higher injury rates for head and neck injuries (53.9 vs. 25.0 injuries per 1000 player hours, z = 9.32, P<0.00006), and arm injuries (11.6 vs. 3.9 per 1000 player hours, z = 2.81, P = 0.005). The two categories in which backs recorded higher injury rates were ankle (9.9 vs: 8.6 per 1000 player hours, z = 0.46, P = 0.65) and 'others' (7.3 vs. 7.1 per 1000 player hours, z = 0.11, P = 0.91), although these were not statistically significant.

Analysis of the types of injuries sustained (Table 1), demonstrated that forwards and backs had significantly different rates of injury for contusions (17.1 vs. 7.3 per 1000 player hours, z = 2.85, P = 0.0044), lacerations (26.7 vs. 13.8 per 1000 player hours, z = 2.92, P = 0.0035) and haematomas (20.6 vs. 11.6 per 1000 player hours, z = 2.29, P = 0.02). It was observed that forwards exhibited higher injury rates for each type of injury with the exception of the dislocations and the others category. However, in both cases the observed rates were small and the differences non-significant (dislocations z = 0.05, P = 0.96; others z = 0.18, P = 0.86).

Activity at the time of receiving an injury is shown in Table 2. From this it can be seen that the tackle is the phase of play associated with most injury. The results indicated that forwards had significantly higher rates of injury than backs when they were the tackler, i.e. defending (33.2 vs. 16.8 per 1000 player hours, z = 3.35, P = 0.00082), and when they were being tackled i.e. attacking (70.5 vs. 38.0 per 1000 player hours, z =4.52, P<0.0006). It was also found that when incidence rates for being tackled and tackling were compared directly, both forwards (tackler 33.2, tackled 70.5 per 1000 player hours, z = 5.16, P<0.0006) and backs (tackler 16.8, tackled 38.0 per 1000 player hours, z = 4.35, P<0.0006), were significantly more likely to be injured when being tackled.

Finally, when the rates for time off as a result of injury (Figure 2) were analysed, the only category in which there were significant differences between forwards and backs was the rate of injury requiring less than one week away from playing and training (99.1 vs. 63.9 per 1000 player hours, z = 4.01, P = 0.0005).

DISCUSSION

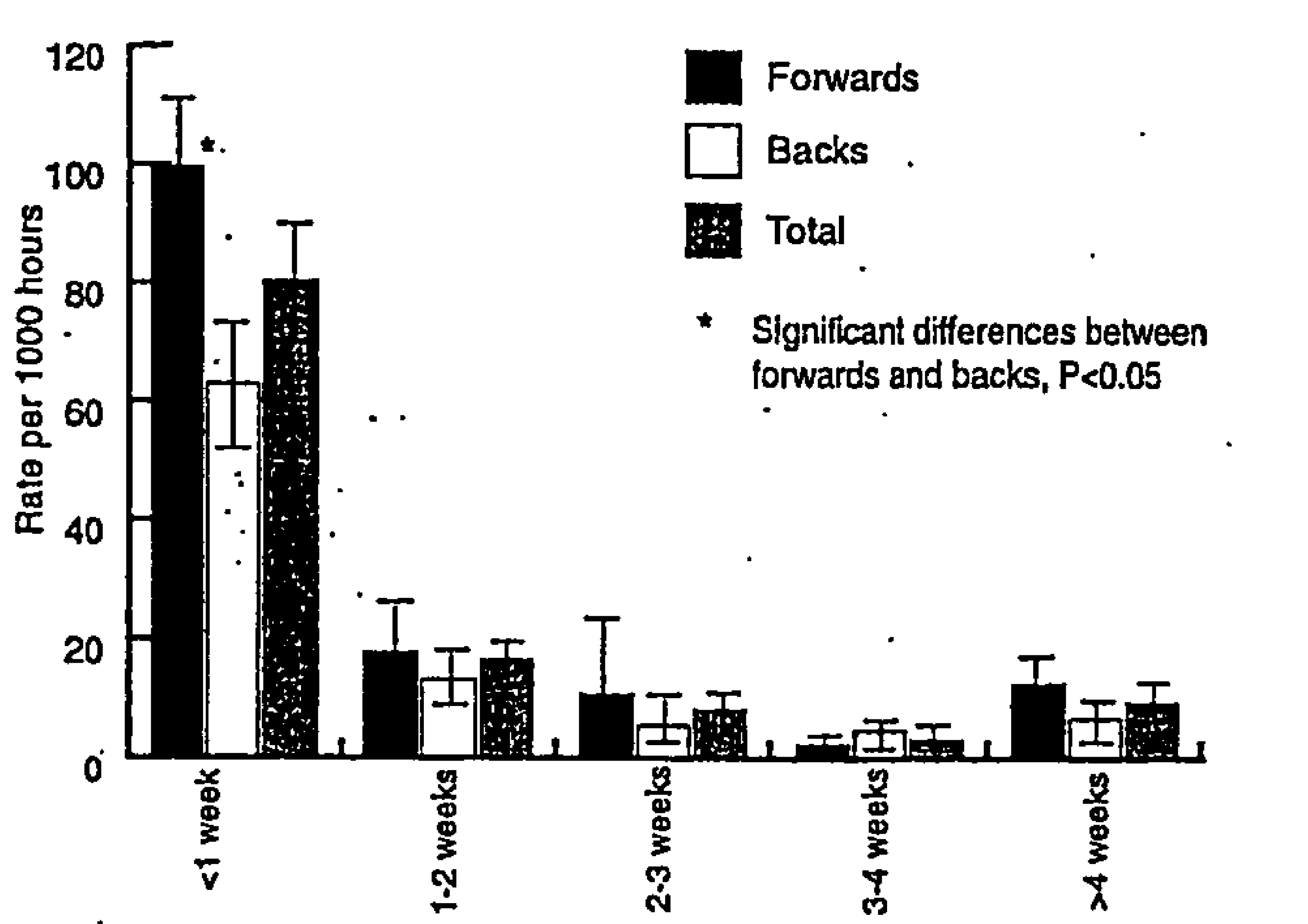
The major finding of this study was the differing injury rates of forwards and backs per 1000 player hours at risk. The RR of 1.50

Table 2: Activity at the time of injury.

	FORWARDS			BACKS			TOTAL		
	Number	Rate per 1000 hours	95% CI	Number	Rate per 1000 hours	95% CI	Number	Rate per 1000 hours	95% CI
Tackler	66	33.2*	25.4 - 41.1	39	16.8	11.6 - 22.1	105	24.4	19.8-29.0
Tackled	140	70 5*#	59.2 - 81.7	88	38.0#	30.2 - 45.7	228	53.0#	46.3 - 59.6
The tackle	206	103.7*	90.3 - 117.1	127	54.8	45.5 - 64.1	333	73.5	69.4 - 85.3
Other	71	35.7	27.6 - 43.9	88	38.0	30.2 - 45.7	159	36.9	31.3 - 42.6
Total	**277**	**139.4**	**124.2 - 154.6**	**215**	**92.7**	**80.9 - 104.6**	**492**	**114.3**	**104.8 - 123.8**

* significantly different from backs (P<0.05)
# significantly different from tackling (P<0.05)

Figure 2: Time off as a result of injury for forwards and backs (rate with 95% CI).



indicates that forwards had a 50% greater risk of injury than backs. Overall, forwards received 56.3% of all injuries and backs 43.7%. While other studies have reported that the number of injuries to forwards are more numerous than injuries to backs (Gibbs, 1993; Gissane et al., 1993; Norton & Wilson; 1995; Stephenson et al., 1996), injury rates do need to be standardised relative to exposure, and consideration needs to be given to the fact that forwards have a lower overall game time exposure, as there are fewer forwards, six, in a side than backs, seven. When these factors are taken into account, the differences between the two playing units are much larger than raw numbers would convey. It has been suggested that forwards experiencing a higher injury rate, may be due to their involvement in more physical body contact than backs (Gibbs, 1993). This is supported by match analysis at international level which has shown that each player in a side is involved in an average of 27 physical confrontations (tackles and being tackled) per game, forwards average 36.3 physical confrontations and backs only 19.1 (Larder, 1992). While at club level Robinson (1996), reported that forwards and backs were involved in 32.4±1.2 and 19.0±0.8 (mean±SE) physical confrontations per game respectively.

The higher rates of forward injuries for specific sites of the body has been reported previously (Seward et al., 1993). In the present study, the site that received the most injuries was the head and neck area, with forwards receiving significantly more injuries than backs. Injuries to the head and facial areas, particular lacerations, have been suggested to be much more common in forwards than in backs (Seward et al., 1993).

Forwards experienced higher rates of injury in each type category in this study, with the exception of the dislocation and 'others' category. They recorded significantly higher rates for both contusions, haematomas and lacerations. The higher rates for lacerations could be as a result of more injuries to the facial region (Seward et al., 1993). In spite of their high incidence, it may be considered fortunate that is rare for such injuries to cause players to miss games (Gibbs, 1994).

In this study 67.7% of all injuries took place in the tackle, which is a slightly lower than figures that have been previously reported (77.2%) (Norton & Wilson, 1995). The injury rates were significantly higher when players were carrying the ball and being tackled. It has previously been reported that of all injuries that take place in the tackle, 56.6% of them are to the ball carrier (Norton & Wilson, 1995), whereas the figure in the present study was 68.5%. It has already been reported how forwards tend to be in more physical confrontations than backs in the game, and when examining the activity whilst in possession, Larder (1992) reported that forwards were tackled an average of 13.5 times per game, while backs were tackled only 9 times per game. Robinson (1996) reported that forwards were tackled 14.2±0.8 (mean±SE), and backs 10.4±0.5 times per game. The process of being tackled is an area of the game that carries inherent dangers, including whiplash injuries, the clashing of heads and being knocked over backwards (Larder, 1992). Several authors have suggested that stricter enforcement of high tackle regulations could reduce the number of injuries (Seward et al., 1993; Gibbs, 1994; Milburn, 1995).

Similarly, forwards perform on average over twice as many tackles per game as backs (22.8 vs. 10.1) (Larder, 1992), which exposes them to a greater risk of injury and accounts for their significantly higher injury rates than backs. Outside of the tackle situation, backs demonstrated higher injury rates than forwards, which may appear surprising since they are not involved in scrummages, which average 19.4 per game (Larder, 1992). However, there is evidence that they cover greater distances than forwards (7336 vs. 6647m) (Meir et al., 1993), and knee injuries have been reported to occur in non-contact hyper-extension and side stepping manoeuvres (Gibbs, 1994). Furthermore, they would tend to be involved in relatively more situations where they were required to gather a high ball, in circumstances where they may be required to jump for the ball, with the opposition approaching towards them. If more than one player is jumping for the ball there is an obvious risk of injury from collision or landing awkwardly, without a tackle tacking place. Similar situations have also been described in Rugby Union where the 'Garryowen' kick is used as an attacking ploy (O'Brien, 1992).

The only time off category in which there were significant differences between forwards and backs were injuries that require less than one week away from playing and training. The

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reason for this would most probably be the higher numbers of overall injuries received by forwards. When examining injuries in this way, one characteristic of Rugby League is the larger numbers of injuries requiring one week away from playing and training, compared with other team sports (Seward et al., 1993). Arguably, a sizeable proportion of these are lacerations, which some studies have chosen not to include. Gibbs (1993), reported 61 lacerations over a three year period, that did not require a player to miss subsequent games. If they were included they would have increased the overall injuries by 43%.

In Rugby League forward players experience higher rates of injury than backs, in spite of the fact that backs out number forwards seven to six. It has been suggested that if the differing playing units do have different injury profiles, then perhaps specific prevention programmes would be appropriate (Norton & Wilson, 1995). The results of this study support this proposition and offer further evidence as to the different areas of the body, and the specific situations in which forwards and backs receive injuries. Such considerations should be taken into account when designing player conditions and training programmes (Seward et al., 1993). Fitness profiles have shown forwards to be heavier than backs, with greater amounts of body fat (Brewer et al., 1994). It has been argued that forwards need to have such body composition to provide them with protection from the extra collisions in which they are involved (Meir, 1994). Rugby League may have recently demonstrated a trend toward less specialisation (Larder, 1992), and fitness training may be uniform across positions (O'Connor, 1995), but evidence suggests that forwards' greater physical involvement, places them at a much higher risk of injury. Some investigators have argued that the best way to standardise injury rates in rugby football is to quote incidence and prevalence per 1000 player hours (Edgar, 1995; Lower, 1995). While others have commented that getting a true reflection of actual exposure time at risk may prove too difficult (van Mechelen et al., 1992). In Rugby League, future research could possibly address the questions of how physical involvement (tackles and being tackled) influences injury rates, and are their particular tackle situations that expose players to higher injury risks? Why this is the case may be difficult to pinpoint '..why does one tackle cause an injury when the previous 50 did not?' (Macleod, 1993). Furthermore, within the two playing units of forwards and backs, there are specialist positions such as hooker and half-back, so that future research could be directed towards examining specific injuries that occur across the full range of positions, rather than the two playing units within a team.

CONCLUSION

The limitations of this study not with standing, it is clear that forward players in rugby league demonstrate a higher incidence of injury than back players. Forwards appear to have a higher injury rates because of their greater physical involvement compared to backs. But, to provide a more complete answer, specific analysis of physical involvement in relation to injury rates is required.

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Injury in summer rugby league football: the experiences of one club

C Gissane, D Jennings, J White, A Cumine

Abstract

***Objective*—To investigate whether the movement of the playing season from winter to summer would alter the risk of injury to players taking part in first team European professional rugby league.**

***Methods*—The study design was a historical cohort design comparing winter and summer seasons in first team European rugby league, which recorded injuries received by players during match play. Each injury was classified according to site, type, player position, activity at the time of injury, and time off as a result of injury.**

***Results*—The risk of injury when playing summer rugby league was higher than when playing winter rugby league (relative risk = 1.67 (95% confidence interval 1.18 to 2.17)). Both forwards (1.08 (0.28 to 1.88)) and backs (2.36 (2.03 to 2.69)) experienced an increased risk of injury.**

***Conclusions*—Summer rugby may have resulted in a shift of injury risk factors as exhibited by a change in injury patterns. This may be due to playing conditions, but there were also some law changes. Changes in playing style, team tactics, player equipment, fitness preparation, and the reduced preseason break may also have had confounding effects on injury risk.**

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Keywords: rugby league; injury; injury risk; summer rugby; cohort study

Department of Health Studies, Brunel University, Isleworth, Middlesex TW7 5DU, United Kingdom
C Gissane

Reigate, Surrey, United Kingdom
D Jennings

Department of Public Health Medicine and Epidemiology, University Hospital, Queen's Medical Centre, Nottingham NG7 2UH, United Kingdom
J White

Division of Sport Science and Physical Education, St Mary's University College, Strawberry Hill, Twickenham, Middlesex TW1 4SX, United Kingdom
A Cumine

Correspondence to: C Gissane, Brunel University, Osterley Campus, Borough Road, Isleworth, Middlesex TW7 5DU, United Kingdom.

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Studies of injury in rugby league football have previously reported rates of injury[1-4] higher than for many other team sports.[3] The reason for this high injury rate is probably the high number of physical collisions in which players are involved during the course of a game.[1] With increasing professionalism in the sport, injuries are an important issue, both in terms of team success and the livelihood of the players themselves.[3]

The year of 1996 saw a bold move, with European rugby league taking place in the spring and summer months, as opposed to its more traditional time of autumn, winter, and spring. This move meant that matches would be played in higher temperatures (London temperature (mean (range)) in September to April 9.5 (6–14)°C and in April to September 18.6 (13–22)°C) and on harder surfaces. There would, however, be one third fewer competitive matches to be played, because of the restructuring of the league (12 teams) and the elimination of two cup competitions. Injury studies carried out in Australia[1 3 5] have consistently reported higher injury rates than English studies,[2 4] and it was surmised that this was due to the game being played on harder surfaces.[4] Playing rugby league in the summer months may also increase the likelihood of players suffering from thermal injuries and heat stroke, as the result of a combination of higher temperatures and relative humidities.[6-8]

It is unusual for a sport to completely change its playing calendar, and this move may result in an alteration in the risk of injury to players. Therefore the purpose of the present study was to ascertain whether or not the movement of the playing season from the autumn and winter months to the spring and summer months would alter the risk of injury to players taking part in professional rugby league in the new European Super League established in March 1996.

Methods

During the initial European Super League season all injuries that were reported for the first team at one professional rugby league club were recorded. The injury data were compared with first team data from a previous study on the same club over a period of four seasons.[4] An injury was defined as a physical impairment received during a competitive match which

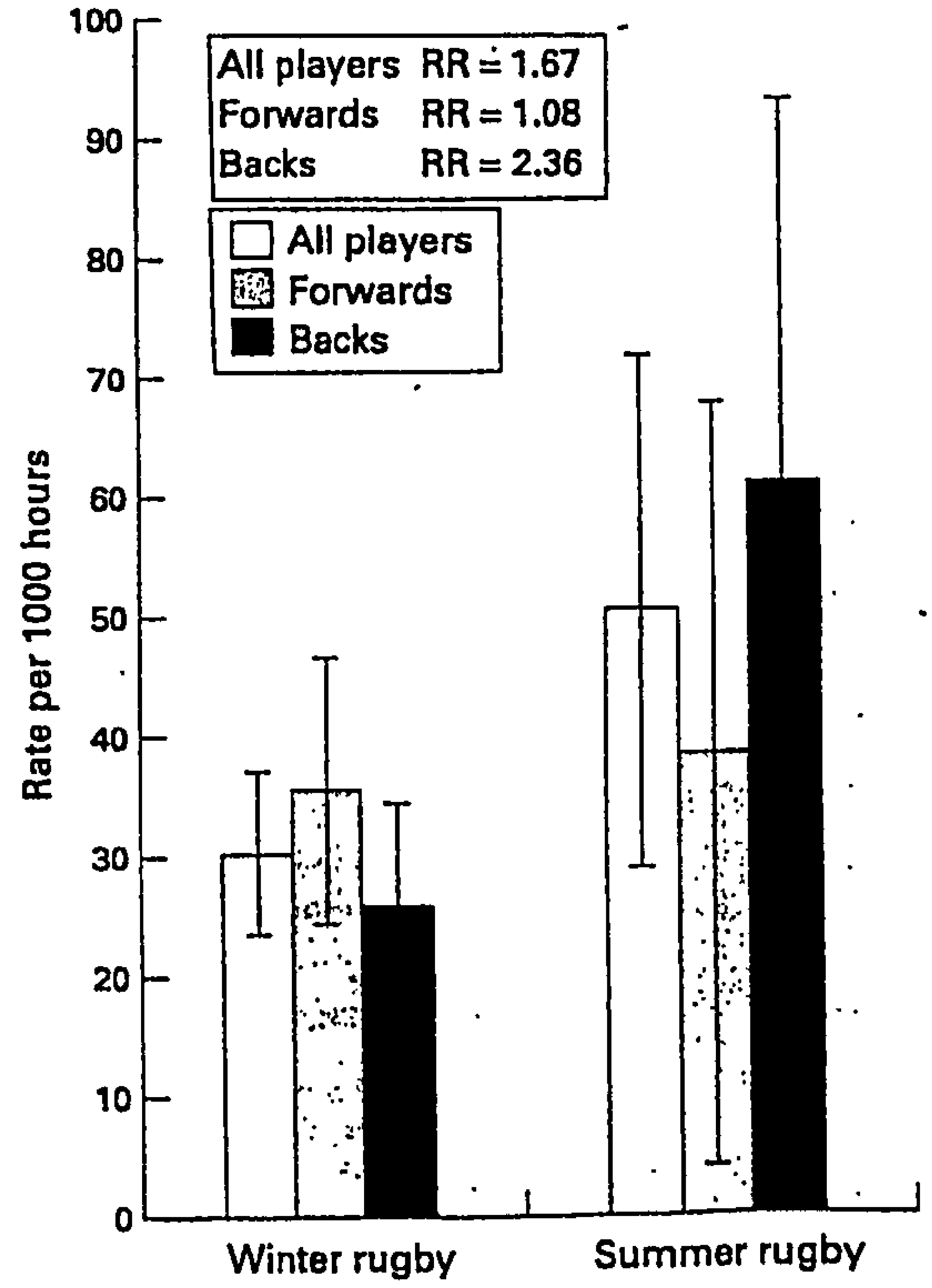

Figure 1 Comparison of injury rates for winter and summer rugby league (with 95% confidence interval).

Table 1 Relative risk of types of injury

	Winter		Summer			
	No	Rate per 1000 hours	No	Rate per 1000 hours	RR	95% CI
Haematomas	4	1.68	2	5.03	3.00*	1.3 to 4.7
Muscle strains	18	7.54	1	2.51	0.33	−1.7 to 2.4
Muscular injuries (total)	22	9.22	3	7.54	0.82	−0.4 to 2.0
Joint sprain	25	10.48	8	20.12	1.92*	1.1 to 2.7
Laceration	4	1.68	0	—	—	—
Contusion	4	1.68	0	—	—	—
Fracture and dislocation	8	3.35	7	17.60	5.25*	4.2 to 6.3
Concussion	8	3.35	1	2.51	0.75	−1.3 to 2.8
Others	1	0.42	1	2.51	6.00*	3.2 to 8.8
All injuries	72	30.18	20	50.29	1.67*	1.2 to 2.2

RR, relative risk; CI, confidence interval.
* $p < 0.05$.

prevented a player from being available for selection for the next competitive game.[1] The games were 7 (1.09) (mean (SD)) days apart. The diagnosis and classification of injury was carried out by the club doctor and physiotherapist. The type of information recorded for each injury has been described previously.[2 4 9]

The population at risk was defined as the players who were selected to play for the first team in a given match, and the defined time at risk for calculating injury rates was the duration of the games multiplied by the number of players (1.33 hours × 13 players) multiplied by the number of games played. The average number of games played during the winter season was 34.5 (596.5 player hours), with each player averaging 12.1 appearances per season, and during the summer season 23 games (397.67 player hours) were played in the Super League of 1996, with each player averaging 8.3 appearances.

Statistical analyses consisted of the calculation of injury rate per 1000 hours of play as a standardised rate of exposure.[10] To calculate the relative risk (RR) of injury between winter and summer rugby league, we used the incidence density ratio (IDR) method described by Hennekens and Buring[11] for the two cohorts.

$$\text{RR (IDR)} = \frac{\text{No of summer injuries/exposure time (hours)}}{\text{No of winter injuries/exposure time (hours)}}$$

Confidence intervals (95% CI) were calculated using the method described by McNeil.[12] Where the CI did not contain the null value (RR = 1.0), the RR was taken as being significant at the $p<0.05$ level.[11]

Results

There was no significant difference between the ages of the two cohorts of players investigated (winter 24.2 (2.5) years, summer 25.7 (3.9) years (mean (SD)) ($t = 0.76$, df = 69, $p = 0.448$). Figure 1 shows the injury rates for summer and winter rugby league for all players: summer rugby league had a higher injury rate than winter rugby league, the actual risk of injury in summer rugby league being 67% higher than in winter rugby league (RR = 1.67 (95% CI 1.18 to 2.17)).

The injury rates for forwards and backs were analysed separately (fig 1). The injury rate for forwards was slightly higher for summer rugby league (an 8% increase; RR = 1.08 (95% CI 0.28 to 1.88)). The backs had a much larger increase in injury rates when playing rugby league in the summer. The RR of 2.36 (95% CI 2.03 to 2.69) indicated that the risk of injury increased 136% on changing the playing season from winter to summer.

Table 1 shows that there were significantly increased risks during summer rugby of haematomas, fractures and dislocations, joint injuries, and others (all $p<0.05$). Similarly, there was significantly increased risk of injury to the shoulder, arm, and other sites of the body (all $p<0.05$), and overall, there was significantly greater risk of injury to the lower body ($p<0.05$) (table 2). There was an increased risk of being injured in the "others" activity category, which included such activities as running and catching high balls, in summer when compared with winter rugby ($p<0.05$), while the injury risk when tackling or being tackled did not alter significantly (table 3).

Table 2 Relative risk of injury to anatomical sites of the body

	Winter		Summer			
	No	Rate per 1000 hours	No	Rate per 1000 hours	RR	95% CI
Thigh and calf	13	5.45	2	5.03	0.90	−0.6 to 2.4
Knee	9	3.77	3	7.54	2.00	0.7 to 3.3
Ankle	8	3.35	1	2.51	0.75	−1.3 to 2.8
Shoulder	7	2.93	3	7.54	2.57*	1.2 to 3.9
Arm	3	1.26	2	5.03	4.00*	2.2 to 5.8
Head and neck	19	7.96	3	7.54	0.95	−0.3 to 2.2
Thorax and abdomen	11	4.61	2	5.03	1.09	−0.4 to 2.6
Others	2	0.84	4	10.06	12.00*	10.3 to 13.7
Upper body	41	17.18	10	25.15	1.46	0.8 to 2.1
Lower body	31	12.99	10	25.15	1.94*	1.2 to 2.6

RR, relative risk; CI, confidence interval.
* $p < 0.05$.

Table 3 Activity at the time of injury

	Winter		Summer			
	No	Rate per 1000 hours	No	Rate per 1000 hours	RR	95% CI
Tackler	15	6.29	7	17.60	2.7	0.9 to 3.7
Tackled	39	16.35	7	17.60	1.1	0.3 to 1.9
Other	18	7.54	6	15.09	2.0*	1.1 to 2.9

RR, relative risk; CI, confidence interval.
* $p < 0.05$.

Discussion

The major findings of the present study were the increased injury rates and the increased risk of injury associated with summer rugby league in both forward and back players, but the data suggest that the increased risk of injury was proportionately greater in backs than forwards.

The data for this study were collected prospectively as part of a continuing investigation, which is a necessary process so that changing injury rates can be taken into account when playing conditions, training, and fixtures are being designed.[3] It allowed the winter and summer cohorts to be compared, to assess changes in injury risk as a result of moving the playing calendar. It has been suggested that historical cohort study designs decrease the comparability of data.[13] However, similar data were collected by the present investigators for both summer rugby league (current cohort) and winter rugby league (historical cohort), but only three players were present in both the winter and summer cohorts.

Injury rates for the summer cohort increased even though exposure time was decreased by one third, which may have been due to the altered playing conditions of warmer temperatures and harder playing surfaces. In support of this, studies in Australia,[1 3 5] where temperatures during the playing season are 18.2 (16–22)°C (mean (range)), have often reported higher injury rates than British studies,[2 4] even though fewer games were played (30 games in the English league in 1994–1995 *v* 22 games in Australia in 1994). There is also the possibility that some injuries may have been carried over from the previous season. The last winter season before the beginning of the Super League finished in the first week of February, with the Super League beginning at the end of March. This was a 51 day period, much shorter than the three and half months between seasons as previously; players therefore did not have the time to recuperate that they had previously enjoyed. Furthermore, the move to full time professionalism could have predisposed players to injury, since full time increased training would allow players much less time for recovery.[14]

Forwards have been reported to receive more injuries than backs,[1-3 15] as a result of being involved in more physical contact.[4 9] It is therefore unusual to find a higher rate of injury among backs and the subsequently very high relative risk in summer rugby. Alexander *et al*[16] found more injuries to backs when the style of play changed to move the ball wider sooner, giving the backs a greater role in the game. Previous research has shown that the ball carrier is the person who is most likely to receive an injury.[9] Therefore increasing the amount of time that the backs are ball carriers involves them in more physical collisions and therefore increases their risk of injury; at the same time, the amount of physical contact experienced by the forwards is reduced.

Another possible reason for backs having a higher injury rate than forwards is the introduction of the zero tackle law, which was not in place when the winter rugby data were collected. The law (2.3.1) states "When a player gathers the ball from an opposition kick in general play and does not subsequently pass or kick the ball himself, the initial tackle will be counted as a zero tackle".[17] This effectively gives a team seven "play the balls" or possessions. When the ball is kicked, it is often deep in the field of play, and it is gathered by a back player, who runs to gain ground; since the ball carrier is at the highest risk of injury in a tackle,[2 4] these law changes and playing styles could increase the risk of injury in back players.

The findings of the present study also show that there was an alteration in the risk of injury when examined by both type and site of the body. Investigations in other sports have reported alterations in injury patterns when the playing surface has been changed; for hockey[18] and American Football[19] increased injury rates have been reported since the use of astroturf. In American Football the risk of knee (RR = 1.18) and ankle (RR = 1.39) injuries has also been shown to increase as a result of the change of playing surface.[20] The changing relative risks in specific injuries seen in the present study may be due to similar mechanisms. Specifically, Fuller[21] claimed that the hard surface of artificial grass allows players to achieve higher speed, but there is decreased shock absorption capacity, and the same could be suggested for summer rugby league. The site category "others" (RR = 12.0) contained a number of foot injuries which previously were extremely rare,[22] but their onset could be associated with turning and being tackled on the harder surface.

The first season of Super League has produced a change in injury patterns, and may have resulted in a shift of injury risk factors. This cannot be exclusively explained by the playing conditions, as there are a number of other factors that need to be considered; athletic injuries usually have many causes, making the identification of simple risk factors difficult.[23] Between the end of data collection for the first cohort and the beginning of data collection for the second cohort, law changes were instituted, which may have altered the risk of injury. The shorter preseason break and the increased amount of training may influence the factors that predispose a player to injury. In addition, playing style, team tactics, and player equipment may also have altered. Any of these factors may have a confounding effect on the incidence of injury, and further investigation is needed to determine their influence.

Epidemiological investigations are needed to determine the extent of injury rates as an initial investigative step. However, rugby league has taken the very unusual step of moving its playing season, and descriptive investigations need to continue to document the accompanying injury risk. Preliminary findings suggest that it has increased, but surveillance needs to continue, as sport is a dynamic entity. The 1997 season will see further changes which will affect the game, the players, and almost certainly the risk of injury.

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Body mass loss as an indicator of dehydration in summer rugby league

S. Jennings[1], S. Robertson[2], D. Jennings[3], J. White[4], C. Gissane[5]

[1]Department of Orthopaedics, Royal Free Hospital, Pond Street Hampstead, London NW3, UK.
[2]Department of Sport Science, St Mary's University College, Strawberry Hill Twickenham Middlesex, TW1 4SX, UK.
[3]General Practitioner, Reigate, Surrey, UK.
[4]Division of Public Health Medicine and Epidemiology, Queen's Medical Centre, University Hospital, Nottingham, NG7 2UH, UK.
[5]Department of Health Studies, Brunel University, Osterley Campus, Isleworth Middlesex, TW7 5DU, UK.

Abstract

Objective: To determine the body mass losses experienced by summer rugby league players.

Methods: Players at one club who took part in 16 summer games had body mass determined before and after playing.

Results: There was a low overall correlation between percentage body mass loss and ambient temperature (r=0.29, p=0.02), but as playing temperature increased, 13% of players experienced a 2-3% body mass loss in 14 of 16 games played in excess of 19°C ambient temperature.

Conclusions: With the seasonal change new physiological challenges have been placed on players, some of who are demonstrating body mass losses which can affect on field performance and thermoregulatory mechanisms.

Introduction

During exercise the metabolic heat produced by the body can increase by 15 to 20 times above that produced at resting levels, [1] and taking part in activity in hot conditions can cause the body temperature to rise even more quickly [2]. Moving the English professional rugby league season from the period September through to April, to March until September allowed it to be played in parallel to the Australian rugby league season. However, for players in the European Super League it meant that the game was to be played in much higher temperatures that previously, and for a certain portion of the season (June, July and August) the temperature would be higher than in Sydney, Australia [3]. The movement of the season places a responsibility on the game's administrators, as well as the players, coaches, and sports medicine teams at club level to define and implement strategies which will help players to cope with these new playing conditions. The Rugby League Medical Association (RLMA) expressed concern for the potential problems associated with heat stress at its 1996 meeting, [4] and the Rugby Football League has responded by producing guidelines for players and coaches to avoid dehydration [2].

A near-fatal accident was reported in Australian Rugby League (ARL) where a player who suffered heat stroke whilst playing (ambient temperature 24.1°C relative humidity 73%), spent 10 days in a coma and suffered Disseminated Intravascular Coagulation (DIC), along with renal and heptatic disturbances [5]. Strategies to prevent heat stress are important in order to maintain optimal cardiovascular function and thermoregulation, [6] as well as prevent dehydration by as little as three percent of body mass which has a detrimental effect on performance, [7] and has been described as medically dangerous [1]. At dehydration levels slightly below this level (2-3%) the body's ability to sweat is decreased, and with it the capability of the thermoregulatory system to maintain core temperature [8]. It has also been reported that dehydration resulting in body mass decreases as low as 2% can noticeably impair performance by compromising the circulatory and thermoregulatory functions [9]. The aim of the present investigation was to determine the extent to which players' body mass changes may be used as an indicator of dehydration state whilst playing summer rugby league.

Methodology

The subjects for this study were the members of the playing squad at one Super League Club, whose physical characteristics are displayed in Table 1.

Procedure

The members of the squad who were selected for a given game took part in the assessment procedure on that occasion. Players' body mass was determined in the

Correspondence: Conor Gissane
Tel 0181 891 0121 x 2636
Fax 0181 847 2030
E-mail: Conor.Gissane@Brunel. ac.uk

	Age (yrs)	Mass (kg)	Height (cm)
All players (n = 28)	24.7±4.0	90.9±11.8	181.8±7.2
Backs (n = 15)	25.1±4.3	84.6±7.5	178.4±2.1
Forwards (n = 13)	24.3±3.8	98.1±12.1	185.4±7.7

Table 1. Physical characteristics of players [Mean ± SD].

standard position before starting each game in underwear only, after they were towel dried. Each measurement was recorded to the nearest 100 g using a calibrated Seca 770 model scales. A similar procedure was completed on the players' completion of the game with minimal time delay. During the game the mean ambient temperature (°C) and mean relative humidity (%) was recorded using a Casella polymeter (Model M 112050: Reliability; humidity ±5% between 30% and 90% RH, Temperature ±1%).

For each game played, each player that played was treated as an independent event making a total of 268 player appearances. Therefore, all data was collected with body mass being determined as the difference between pre-game mass and post-game mass. Players were allowed to drink water ad libitum after pre game body mass determination, during the game and at half time. For the purposes of analysis, only players who completed each full game of 80 minutes were included in the analysis (n = 120).

The statistical analysis consisted of Pearson's correlation to determine associations between variables, and independent t tests to determine differences between forwards and backs. All tests were carried out using SPSS for Windows 6.1.2.

Results

Data were recorded in a total of 16 games, and the overall mean temperature was 22.9±5.3 °C, and the mean relative humidity 73±13.6%. During these games a total of 36 forwards and 84 backs completed whole game(s). The mean body mass loss for all the players was 1.1 (95% CI 0.98 to 1.22) kg, in which the forwards and backs had mean body mass losses of 1.48 (1.25 to 1.7) kg, and 0.94 (0.82 to 1.06) kg respectively (mean difference = 0.54 (0.3 to 0.78) kg, $t = 4.48$, $df = 118$ $P = 0.001$). Overall mean loss for all players was 1.22 (1.1 to 1.34) % of body mass, in which forwards and backs had mean losses of 1.51 (1.29 to 1.74)% and 1.09 (0.95 to 1.24)% respectively (mean difference = 0.42 (0.16 to 0.69)%, $t = 3.18$, $df = 120$ $P = 0.002$).

The overall relationship between the playing temperature and percentage body mass loss revealed a low correlation ($r = 0.29$, $p = 0.02$). There were non significant negative correlations between relative humidity and percentage mass loss ($r = -0.28$, $p = 0.08$) and relative humidity and temperature ($r = -0.15$, $p = 0.59$). From table two it can be observed that as the ambient playing temperature increased the number and percentage of players reaching body mass loss relative to the level of dehydration where performance could become impaired increased. Of the players who experienced 2-3% dehydration, one experienced it four times, three other players twice, with four players experiencing a single incident.

Discussion

The major finding of this study was that an increase in ambient temperature resulted in a greater proportion of players reaching levels of body mass decrease relative to a state of dehydration which could compromise thermoregulatory control system [8].

In this study there was no attempt to control for specific variables that might influence the test results, such as water intake and exposure to direct sunlight [1]. The main aim was to describe the body mass losses during the course of playing typical rugby league games in the summer. Although none of the players reached the 3% loss in body mass that has been shown to be medically dangerous, [1] 13% (16/120) of players lost between 2-3% body mass in 14 of the 16 games played in excess of 19°C ambient temperature. Thermoregulation mechanisms can be compromised at such levels of body mass change, [1, 8] and the associated level of dehydration may adversely affect physical performance by reducing endurance times [10].

Previous studies in other sports have monitored fluid intake of players during match play [11, 12]. They have also involved far fewer subjects than the present study. There are also practical difficulties with measuring fluid intake during matched play. Water in drinking bottles is used for other purposes such as, rinsing out mouth, washing gum shields, and cool heads. All of which can lead to errors in estimation.

A number of measures are in place which are designed to assist players in minimising dehydration. Shirts are now made of much lighter material than previously and weigh about 40% less than before (376.8 vs. 218 g) [13]. The Rugby Football League has also issued some guidelines for players and coaches about training and playing in hot environments [2]. These guidelines advise players that they "need to hydrate before a game and rehydrate properly after a game". They also warn that those players with higher percentage body fat are most at risk of thermal stress, and since it has been reported that forwards carry

			Players completing game			2 - 3% body mass loss		
Temperature	Games	Players	number	percentage	95% CI	number	percentage	95% CI
18°C or below	2	34	16	47.1	29.8 - 64.9	0	0.0	—
19 - 23°C	5	83	37	44.6	33.7 - 55.9	1	2.7	0.1 - 14.2
24 - 28°C	8	134	60	44.8	63.2 - 53.6	10	16.7	8.3 - 28.5
29 +°C	1	17	7	41.2	18.4 - 67.1	5	71.4	29.0 - 96.3
Total	16	268	120	44.8	39 - 51	16	13.3	7.8 - 20.7

Table 2. Ambient temperature and players' body mass losses during rugby league games.

more body fat than backs, [14, 15] this may partly explain why forwards are noted to have a greater percentage body mass loss than backs.

The player observed in 1990 who suffered from DIC was febrile, which served to decrease the amount of heat which could be dissipated before overheating [5]. The Rugby League have warned players who have been ill or are suffering from a virus that they are more prone to heat stress, and have advised them to seek advice from the club medical personnel before playing or training. Similarly, the RFL warn about excessive use of taping and protective equipment which can inhibit the thermoregulatory process [2]. The player who suffered from DIC, had been wearing his kit and a neoprene thigh guard, in total 70% of his body surface area was covered [5]. There is also the practice of support staff entering the field of play at stoppages giving the players water, something not enjoyed in other sports, [16] which serves to aid the rehydration process.

In this study the variable examined was body mass loss as a proxy measure for dehydration. This should be considered as a conservative measure of fluid loss as neither fluid intake or urine excretion were measured. There are also other factors beyond those examined in the present study which could exert an influence on body mass loss during games. For example, previous research has reported that percentage body fat can influence the efficiency of thermoregulation [17].

The results of this study demonstrated that players appear to be experiencing new physiological challenges from the heat encountered whilst playing summer rugby league. Although for the majority of cases seen in the present study this did not represent a problem, 13% of players experienced 2-3% body mass loss during a game, which can effect both on field performance and thermoregulatory mechanisms [8, 9]. Research from other sports and Australian rugby league can provide direction for strategies to help overcome the problem. Devising and adopting strategies such as these was formerly the domain of touring teams. Now, however, it is required in the European playing season due to the switch to summer competition.

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Physical Collisions in Professional Super League Rugby, The Demands on Different Player Positions

C. Gissane MSc†, J. White PhD‡, K. Kerr PhD, D. Jennings MB BS*

†Department of Health Studies, Brunel University, Osterley Campus, Isleworth, Middlesex, TW7 5DU. ‡Division of Public Health Medicine and Epidemiology, University Hospital, Queen's Medical Centre, Nottingham, NG7 2UH. Division of Physiotherapy Education, University of Nottingham, Hucknall Road, Nottingham, NG5 1PG. *General Practitioner, Reigate, Surrey.

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Address for correspondence:

Conor Gissane
Department of Health Studies
Brunel University
Osterley Campus
Isleworth
Middlesex
TW7 5DU
Tel 0181 891 0121 x 2636
Fax 0181 847 2030
conor.gissane@brunel.ac.uk

SUMMARY

Objective - To determine the total number and nature of physical collisions experienced by players in differing positions in professional rugby league.

Methods - Video recordings of all the regular season games (N=22) played by one professional super league rugby club were examined. Physical collisions were classified into tackles, incomplete tackles, "tackled in possession", "broken tackles" and passes out of the tackle.

Results - Forwards were involved in significantly more collisions (55) than backs (29) during the course of each game ($z=2.73$, $P < 0.0001$). Eight player positions (forwards (n=6) and two half backs (scrum half and stand off)) were involved in significantly more collisions while defending as

compared to attacking (all P<0.005). The differences for all back three quarter positions and the full back were not significant.

Conclusions - Players, both backs and forwards experienced more physical collisions than previously reported, which may be linked to operational definitions, rule changes and the advent of summer rugby league. Players were involved in more physical collisions whilst defending, since over two thirds of tackles involved more than one player tackling the ball carrier.

Key words: professional rugby league, physical collisions, forwards, backs, tackle

INTRODUCTION

Rugby League is a game of physical collisions,[1] in which the tackle has a greater prominence than in rugby union.[2] The high number of physical collisions encountered by players has been suggested as a possible reason why they experience such high injury rates.[3] It has been further suggested that the collisions in which players are involved are important from both a physiological as well as an injury prevention perspective.[1,4] A survey of international players found that the two aspects of the game that players found most tiring were being tackled, and tackling other players.[1] Many coaches acknowledge that it is important to control these aspects of the game since they have a major influence on the outcome of a match.[1,5] Within team sports players have different demands placed upon them according to the requirements of their position,[6] and for optimal performance it is necessary to identify the specific characteristics of successful play relative to playing position.[7]

To this end, previous research in rugby league has investigated the movement patterns of players during matches,[8] and the differing injury rates of forwards and backs.[9] However, while other work reported the number of physical collisions in which players are involved during the course of a game, the studies were limited and were often based on data reported from small numbers of matches.[5,10] Furthermore, when examining the physical collisions from an injury prevention point of view, it may be important to take all physical contacts into account, which might include for example, situations where the tackle was not necessarily successful, because it still involved physical contact.

The purpose of the present study was to determine the number and type of physical collisions that rugby league players experience during typical match play. In addition the study determined how total physical collisions were distributed between attack (while in possession of the ball) and defence, and among playing positions.

METHODOLOGY

Players representing one professional rugby league comprised subjects for the present study (N=35, forwards n= 15, backs n= 20). In order to assess the number and type of physical collisions in which players were involved while playing, video recordings of all 22 regular season games played during the 1996 Super League season were analysed. This represents a total of 29.3 hours of match-play or 380.4 player hours (13 players x 1.33 hrs x 22 games). The video tapes used were master copies of recordings produced by two T.V. media broadcasting companies (British Sky Broadcasting, Isleworth and Micron Video, Wigan), and permission to use the material was granted by the Rugby Football League.

Each video was a standard VHS (25 frames.sec^{-1}) and was analysed by the principal investigator. Each physical collision that took place was classified into one of the following categories:

Defence (defending collisions)

1. *Tackles* - where the defending player(s) halted the progress of the ball carrier, and as a result the ball carrier had to play the ball.
2. *Incomplete tackles* - where the defending player(s) made contact with the ball carrier, but failed to prevent forward progress, or were unable to stop the passing of the ball.

Attack (attacking collisions)

1. "*Tackled in possession*" - where the ball carrier was tackled whilst in possession of the ball, forward progress was halted and the ball carrier had to play the ball.
2. "*Broken tackles*" - where the ball carrier was able to break through the tackle and continue forward progress.
3. *Passes out of the tackle* - where the ball carrier was tackled but was able to pass the ball.

Following this analysis it was possible to calculate each player's total defensive involvement (the sum of tackles and incomplete tackles), total attacking involvement (the sum of "tackled in possession", "broken tackles" and passes out of the tackle), and total physical involvement (in defence and attack) in each game analysed.

STATISTICAL ANALYSIS

In order to determine the reliability of the physical collision analysis, three videos were analysed twice (each one week apart) by the principal author and the 95% limits of agreement were calculated using previously recommended methods.[11,12] Because the differences between readings did not vary in a systematic way across the all values, it was necessary to log transform the original data.[11] Descriptive statistics (mean and 95% CI) for each physical collision category were computed for each playing position. To determine differences in the number and type of physical collision between forwards and backs, and between attacking involvement and defensive involvement, further analysis was undertaken using a proportion test.[13]

RESULTS

Reliability of video tape analyses

The reliability of the physical collision analysis demonstrated that the 95% limits of agreement calculated were 0.92 to 1.08, which indicated that the retest analyses were between eight percent above and below the original readings.

Collision analysis

The mean number of physical collisions for attack, defence and total collisions experienced by player positions is shown in table 1. All players were involved in both defensive collisions (while attempting to tackle the ball carrier) and attacking collisions (being tackled when carrying the ball) which resulted in an average of 41 physical collisions per player per game (27 in defence and 14 in attack). Forward players were involved in an average of 55 physical collisions during a game (39 defence, 16 attack), which was significantly more than the backs who were involved in an average of 29 physical collisions (16 defence, 13 attack) [$z = 2.73$, $p<0.0032$]. All of the forwards, plus the scrum half and the stand off were involved in a significantly greater number of physical collisions when defending (all $p< 0.05$) as compared to attacking. Only three player positions, the two wings and the full back, were involved in more attacking than defensive physical collisions but the differences were not significant ($z = 1.66$, $P> 0.09$).

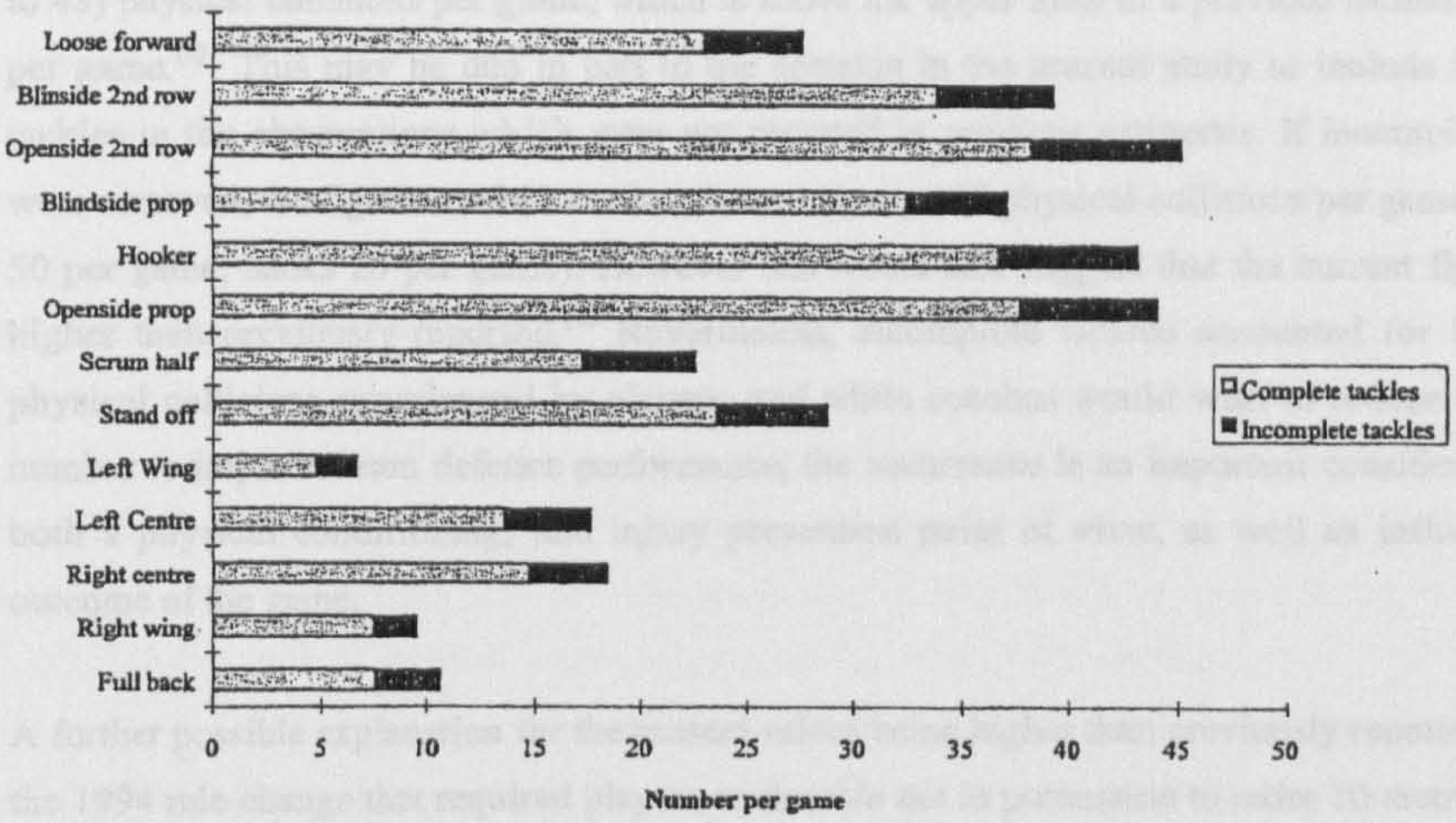
Table 1. Physical collisions experienced by player positions during match-play.

	Defence		Attack		Total collisions	
Position	Mean	95% CI	Mean	95% CI	Mean	95% CI
Full back	10	8 - 13	18	16 - 20	28	26 - 31
Right wing	10	7 - 12	13	11 - 15	23	19 - 25
Right centre	18	15 - 22	12	10 - 14	30	27 - 34
Left Centre	18	15 - 20	14	13 - 15	32	29 - 34
Left Wing	7	5 - 9	11	10 - 13	18	16 - 20
Stand off	29**	26 - 32	13	12 - 15	42	38 - 45
Scrum half	23**	19 - 27	10	8 - 11	33	28 - 36
Openside prop	44**	39 - 49	23	20 - 26	67	60 - 74
Hooker	43**	39 - 47	6	4 - 8	49	45 - 53
Blindside prop	37**	31 - 41	20	17 - 24	57	48 - 66
Openside 2nd row	45**	40 - 50	19	15 - 23	64	56 - 72
Blindside 2nd row	39**	36 - 43	16	14 - 17	55	51 - 59
Loose forward	27**	24 - 30	11	11 - 13	38	35 - 43
Backs	16	15 - 18	13	12 - 14	29	28 - 31
Forwards	39**	37 - 41	16	15 - 17	55*	52 - 58
All players	27	25 - 29	14	13 - 15	41	39 - 43

* significantly different from backs
** significantly different from attack

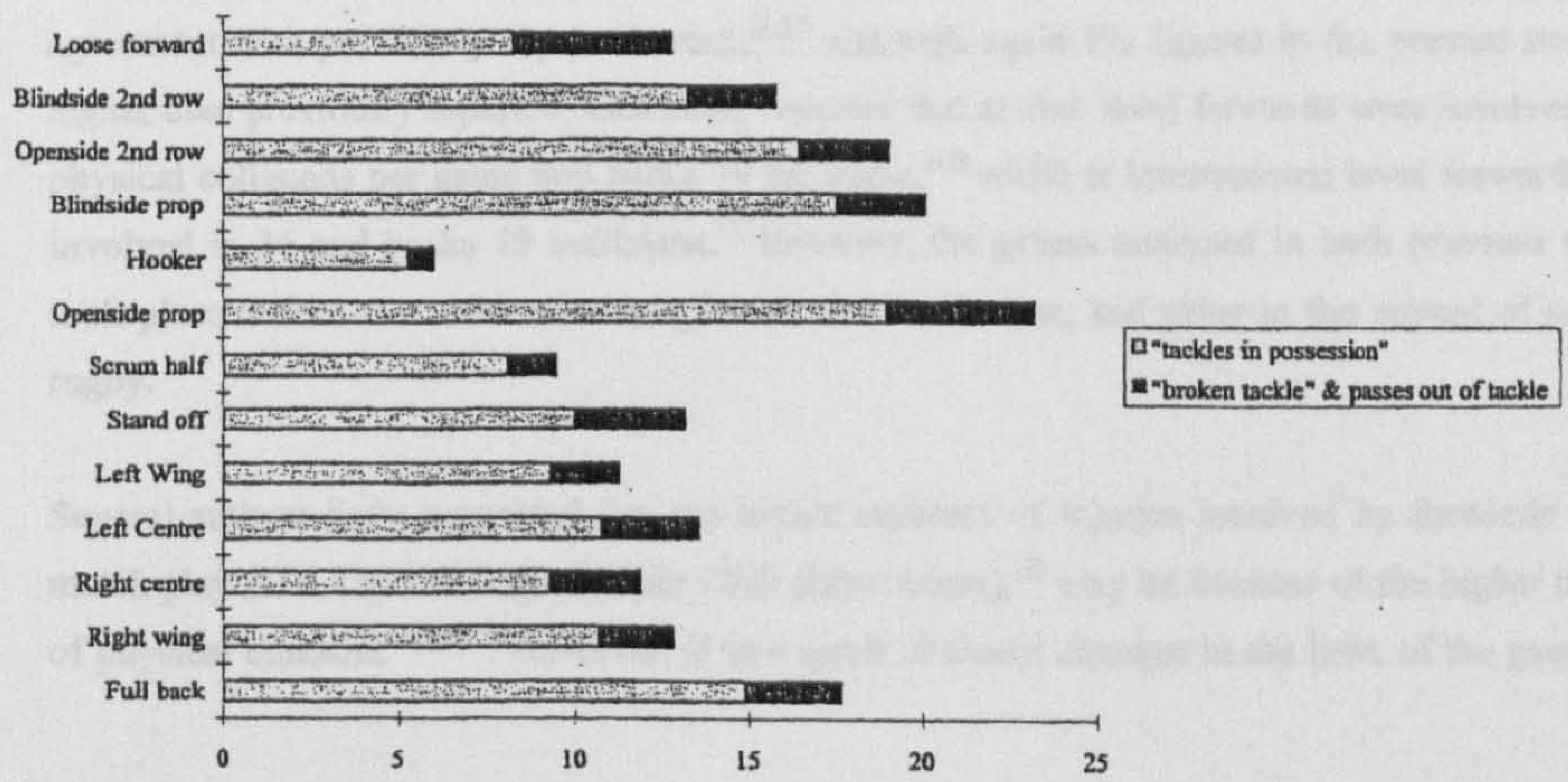
The mean number of defensive physical collisions (complete and incobut the differences were not significant incomplete tackles) performed by player positions is presented in figure 1. There were significantly more complete than incomplete tackles (290 vs. 59, z= 12.3, P <0.00006). Overall, only 17% (59/349) of the defensive physical collisions carried out by the players in this study allowed an opponent to break through the tackle or off load the ball. Backs were involved in a significantly greater number of incomplete tackles than forwards (22% vs. 15%, z = 6.14, P <0.00006)

Figure 1. Proportion of complete and incomplete tackles made by player position.



The mean number of attacking physical collisions ("tackled in possession", "broken tackles" and passes out of the tackle) is presented in figure 2. There were significantly more "tackled in possession", than passes out of the tackle and "broken tackles" (153 vs. 34, $z=8.6$, $P<0.00006$). Overall, the ball carrying players under investigation were able to either "bust" a tackle or off load the ball in 18% (34/187) of the attacking physical collisions. There was no significant difference between the forward and back ball players in the proportion of passes out of the tackle and "broken tackles" (19% vs. 18%, $z = 0.74$, $P = 0.4593$)

Figure 2. Proportions of "tackled in possession" and "broken tackles", and passes out of tackles experienced by position.



DISCUSSION

The present study indicated that rugby league players were involved in an average of 41 (95% CI 39 to 43) physical collisions per game, which is above the upper limit of a previous estimate of 20-40 per game.[5] This may be due in part to the decision in the present study to include incomplete tackles in the observations which were not reported in previous estimates. If incomplete tackles were removed, the figure would be reduced to an average 37 physical collisions per game (forwards 50 per game, backs 26 per game). However this would still suggest that the current figures were higher than previously reported.[5] Nevertheless, incomplete tackles accounted for 17% of all physical collisions experienced by players, and while coaches would wish to reduce the overall number to improve team defence performance, the occurrence is an important consideration from both a physical conditioning, and injury prevention point of view, as well as influencing the outcome of the game.

A further possible explanation for the present values being higher than previously reported could be the 1994 rule change that required players on the side not in possession to retire 10 metres after the tackle,[14] compared with the original requirement of five metres. It has been suggested that this may lead to an increase in the distances covered and, the total amount of high intensity physical activity, of which tackles are part.[15] Higher intensity activity may also serve to increase the momentum of the players at the point of contact. In addition, there has also been the introduction of the zero tackle law which states "*When a player gathers the ball from an opposition kick in general play and does not subsequently pass or kick the ball himself, the initial tackle will be counted as a zero tackle*".[16] This effectively gives a team seven 'plays of the ball' or possessions, compared with the previous six, which may potentate additional physical collisions.

Forwards were involved in a greater number of collisions than backs (55 vs. 29) which is in agreement with previously reported work,[5,10] although again the figures in the present study are higher than previously reported. One study reported that at club level forwards were involved in 32 physical collisions per game and backs 19 per game,[10] while at international level forwards were involved in 36 and backs 19 collisions.[5] However, the games analysed in both previous studies took place before the 1994 rule change, the zero tackle law, and prior to the advent of summer rugby.

Several authors have suggested that the higher numbers of injuries received by forwards during match play (139.4 vs. 92.7 injuries per 1000 player hours),[9] may be because of the higher number of physical contacts.[2,3,9,17] However, if as a result of recent changes in the laws of the game both forwards and backs are experiencing more physical collisions, then the risk of injury should rise proportionately for all players.

It was also interesting to note that eight of the 13 player positions were involved in significantly more physical collisions in defence than attack. A previous study reported that props and hookers spent a greater amount of the time (4.5%) performing defensive tackling than backs (1.8%), and that forwards spent 2.7% of the time taking the ball into the tackle, compared with 1.8% for backs.[8] This may account for the greater number of physical collisions by forwards made while defending. It should be noted that more than one player can be involved in the tackle, but only one player is carrying the ball whilst being tackled. Previous research on the number and type of contact experienced by individual players found that two thirds of tackles involved more than one defender tackling the ball carrier.[18] However, unlike the present study, previous work did not seek to examine how many players were involved in a given tackling situation on a ball carrier. If more than one player is involved in the tackle this could potentially increase the risk of injury to a player, as well as the number of physical collisions in which that player is involved.

The present findings have implications for both physical conditioning and injury prevention in rugby league. Coaches have recently suggested that the high injury rates reported in the game[2,3,9] are due to the ferocity of the physical collision situation.[19] However, coaches have also been also been careful to emphasise the importance of safety and self protection when either tackling or being tackled.[20] The findings of the present study emphasise the different incidence of physical collisions experienced by different player positions. This could serve as an indication to alter the training strategies of different positions and/or playing units, by either increasing or decreasing the number of physical collisions in training in proportion to those experienced in the game. Rugby League has shown a recent trend towards less specialisation between playing positions,[5] and there is the suggestion that fitness training for professional rugby league is uniform for all positions.[7] However, it has also been argued that training procedures should reflect the breakdown of match play activities, and that these should be position specific.[8] Similarly, injury prevention strategies could place a differing emphasis on players who are going to be involved in a greater number of physical collisions than others.[16]

CONCLUSION

The present study has provided data on the number and type of physical collisions experienced by players during professional rugby league play. It should be recognised that playing style might also exert an influence on the number and types of physical collisions experienced. However, empirical data as to the specific nature of the physical collisions that players incur during a game is important. Training needs to conform to the principle of specificity, and the sheer volume of physical collisions encountered by some players may influence their injury risk, both from the physical impact and the possibility of cumulative fatigue. The numbers of physical collisions documented in the present study are higher than previously reported, which could be due to the inclusion of incomplete tackles. However it could be also be due to a change in the nature of play. The 1994 rule changes moved the defensive line back further by 5 metres, and the advent of summer rugby league probably resulted in firmer playing surfaces which allow faster running speeds and increased momentum at the point of contact in the tackle. Differences in the running speeds of players have been reported to be an important risk factor in rugby union tackles.[21] A further study has examined the numbers of players involved in specific tackles, in an attempt to determine if this has an influence on the risk of injury to the ball carrier and/or the tackler. In addition the follow up study has attempted to determine if the number of physical collisions experienced by players has a direct influence on the incidence of injury in playing units and positions.[22]

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Physical Collisions and Injury Rates in Professional Super League Rugby

C. Gissane MSc*, D. Jennings MB BS†, S. Jennings‡, J. White PhD** and K. Kerr PhD††

*Department of Health Studies, Brunel University, Osterley Campus, Isleworth, Middlesex, TW7 5DU. †General Practitioner, Reigate, Surrey. ‡Department of Orthopaedics, Middlesex Hospital, Mortimer Street, London NW1. **Division of Public Health Medicine and Epidemiology, University Hospital, Queen's Medical Centre, Nottingham, NG7 2UH. ††Division of Physiotherapy Education, University of Nottingham, Hucknall Road, Nottingham, NG5 1PG.

Running Header: Collision and Injury in Rugby League

Address for correspondence:
Conor Gissane
Department of Health Studies
Brunel University
Osterley Campus
Isleworth
Middlesex
TW7 5DU
Tel 0181 891 0121 x 2636
Fax 0181 847 2030
conor.gissane@brunel.ac.uk

SUMMARY

Objective - To determine if there was a relationship between exposure to physical collisions and injury rates in professional super league rugby football.

Methods - All injuries received during one season's match play were recorded for all games played by one professional super league rugby club. Each injury was classified according to player position and activity at the time of injury. Physical collisions were determined from video and classified into tackles, incomplete tackles, "tackled in possession", "broken tackle" and passes out of the tackle.

Results - Forwards were involved in significantly more physical collisions per game than backs (55 vs. 29, P = 0.003). Overall backs had a significantly higher injury rate per 10,000 physical collisions (16.3 vs. 7.2, P = 0.0015), but there were no significant differences between the two playing units for injuries received whilst attacking or defending.

Conclusions - This study demonstrated that backs have higher standardised injury rates (per 10,000 collisions) than forwards, in spite of being involved in fewer physical collisions per game played. The observed differences could be due to the nature of specific physical collisions experienced by the respective playing units or intrinsic injury risk factors among the players involved.

Key words: Rugby League, injury rates, physical collisions

INTRODUCTION

Injury rates in rugby league football have been reported to be higher than those experienced in other contact team sports.[1,2] It has also been reported that the injury rates experienced by players have increased as a result of the recent move to a summer competition. [3,4,5] In addition many authors have reported that forward players receive far more injuries that back players.[1,2,5,6,7,8,9] One reason that is often put forward to explain this finding is that forwards are involved in much more physical contact than backs.[6,7]

Forwards may be involved in more physical contact because of their role in the game, although it has been suggested that there has been a recent trend towards much less specialisation between positions,[10] which may have an influence on the contact rates experienced by forwards It has also been suggested that when the numbers of player positions involved are taken into account, forwards receive relatively more injuries and backs relatively fewer, than might be expected.[6]

Front row forwards spend more of their time taking the ball into the tackle than backs (2.7% vs. 1.8%), and over twice as much time tackling (4.5% vs. 1.8%).[11] The amount of time spent in these activities is an important consideration since research has shown that between 67% and 77% of injuries take place in the tackle.[5,7,8] It has further been reported that both forwards and backs receive significantly more injuries while being tackled than when tackling, and that forwards receive significantly more injuries than backs when either tackling or being tackled.[7] If injuries are to be reduced, it is necessary to establish if there is a relationship between the exposure risk factors, such as the number and type of physical collisions, and the incidence of injury in rugby league football.

The purpose of the present investigation was to examine the relationship between the rate of injury in rugby league football, and the number and type of physical collisions in games in which players are involved during the course of a full playing season by one professional super league rugby club.

METHODS

All injuries that were reported for the first team of one professional super league rugby club were recorded over one season. An injury was defined as a physical impairment received during a competitive match which prevented a player being available for selection for the next competitive game [6]. The position of the player; the site of the injury; the nature of injury; the activity at the time of injury and the time off as a result of injury were recorded for each game played over the full season. The details of each category have been described previously.[1,5,7]

The population at risk was defined as the players who were selected to play for the first team in a given match, and the defined time at risk for calculating injury rates was the duration of the games multiplied by the number of players (1.33 hrs. × 13 players) multiplied by the number of games played. A total of 23 games (22 regular season plus one play off game) were played during one season (397.7 player hours).

To assess the number and type of collisions that players were involved in while playing, video recordings of 22 regular season games played during the 1996 Super League season were analysed (29.3 hours of match-play, 380.4 player hours). The video tapes used for analysis were master copies of recordings produced by two TV media broadcasting companies (British Sky Broadcasting, Isleworth and Micron Video, Wigan), and permission to use the material was granted through the Rugby Football League. The categorisation of physical collisions was carried out as outlined previously.[12]

Following the analysis of physical collision categories, it was possible to calculate the following; 1) each player's total defensive involvement (the sum of tackles and incomplete tackles), 2) total attacking involvement (the sum of "tackled in possession", "broken tackle" and passes out of the tackle), 3) total physical involvement (defensive plus attack) in each game analysed, and 4) the differences in physical collisions incurred by backs and forwards.

Statistical analyses consisted of the calculation of injury rate per 10,000 physical collisions as a standardised rates of exposure, and descriptive statistics for physical collisions (mean and 95% CI). In order to compare differences between the proportions of physical collisions a single proportion test was used,[13] while a test for differences between injury rates used the method of Clarke,[14] and the relative risk (RR and 95% CI) was computed. In order to analyse the differences between forwards and backs in the number of games missed by injured players, the Mann Whitney U and Kruskal Wallis tests were employed since the data were not normally distributed.

RESULTS

The descriptive statistics of the number of physical collisions incurred by forwards and backs are shown in table 1, which indicates that forwards were involved in significantly more physical collisions during defensive tackling than backs ($z = 2.73$, $P = 0.0032$). Furthermore, forwards were involved in a significantly greater total number of physical collisions ($z = 2.97$ $P=0.0015$). This was largely as a result of the increased defensive tackling demands by forwards, since there was no significant difference in the number of attacking collisions incurred by forwards and backs.

Table 1. Mean number of physical collisions incurred per game by forwards and backs.

Position	Tackling Mean	(Defence) 95% CI	Tackled Mean	(Attack) 95% CI	Total Physical Collisons Mean	Total Physical Collisons 95%CI
Backs	16	15 - 18	13	12 - 14	29	28 - 31
Forwards	39*	37 - 41	16	15 - 17	55**	52 - 58
All Players	27	25 - 29	14	13 - 15	41	39 - 43

* Significantly different from attacks

** Significantly different from backs

The number of injuries received, sub-divided by activity at the time of injury and the standardised injury rates per 10,000 physical collisions among forwards and backs are shown in table 2. There were no significant differences between forwards and backs in the total number of injuries received (7 vs. 13, z = 1.12, P = 0.26). However, examination of the standardised injury rates revealed that backs had a higher total standardised injury rate than forwards (z = 2.21, P = 0.027). When injuries that were received in the tackle (either to the tackler or the player being tackled) were examined, there was no significant difference in injury rate between forwards and backs. The forward playing unit demonstrated higher injury rates for physical collisions when attacking (RR = 3.68 [95%CI 0.62 – 22.1]), compared with the back playing unit (RR 1.01 [0.27 – 3.77]). It was also noted that backs had higher injury rates than forwards in both attack and defence, but these differences were not significant. Overall, the tackle situation accounted for a majority (14/20) of all injuries observed.

Table 2. Injury rates per 10,000 physical collisions for forwards and backs

	Collisions			Injuries				Injury rate per 10,000 Collisions		
	Attack	Defence	Total	Tackled	Tackling	Other	Total	Attack	Defence	Total
Backs	1892	2394	4286	4	5	4	13*	21.14	20.88	16.33
Forwards	2016	4952	6968	3	2	2	7	14.88	4.04	7.17
Teams	3908	7346	11254	7	7	6	20	17.91	9.53	12.44

*Significantly difference to forwards

In the act of tackling an opponent, the upper body incurred the greatest proportion of injuries (5/7, z= 0.76, P= 0.44), in which there were two arm injuries (both forwards) and three shoulder injuries (all to backs). The only other two injuries observed were to the foot and both were incurred by backs. In contrast, when being tackled the lower body received the greatest proportion of all injuries (5/7), with the only two upper body injuries being incurred one to the head (concussion) and the other to the rib area.

Injuries that were received by players and categorised as 'other' which did not occur in the tackle included three joint sprains to backs, that were received whilst running and changing direction quickly i.e. not resulting from physical collisions, as well as two incidences of foul play which were also included in this category.

Overall backs missed more games in total as a result of injury incurred than forwards (45 vs. 23). However, forwards had higher median scores for games missed when their injuries were incurred in tackling (5 games vs. 2 games [Median scores]), and in being tackled (4 games vs. 2 games), although neither of these differences were significant (P>0.05).

DISCUSSION

The present study revealed a similar findings to other work,[7,8] in that the majority (14/20) of injuries occurred in the tackle. Half of these (7/14) were to the person being tackled, which is lower than reported previously.[9] However, while previous investigations have suggested that injury was probably related to the number of physical collisions that players were involved in during a game,[6,7] the unique finding of the present study was that when the injury rate was standardised, backs had a significantly higher overall injury rate per 10,000 collisions than forwards, suggesting that positional play has an influence on injury rate. However, when the injuries received in the tackle were examined separately, the difference in injury rates between forwards and backs was removed. Nevertheless, in the present study backs experienced higher rates of injury than forwards (per 10,000 physical collisions), whilst being involved in significantly less physical collisions. This suggests that backs are more likely to be injured outside of the tackle situation.

The collision in rugby league is considered to be a major risk factor.[6,7] It has been argued that extrinsic risk factors are independent of the injured person, and are related to the types of activity during the incident of injury,[16] and the manner in which sport is practised.[17] These observations may be true of the physical collisions experienced in rugby league, especially when there is usually more than one person involved in the physical collision such as the tackle.[18] Therefore, self protection and safety of both the tackler and the person being tackled are important techniques that coaches teach to players.[5,19]

Since the tackle is the activity in rugby league in which so many injuries take place, some authors have suggested that injury prevention strategies directly aimed at making the tackle safer, should be considered.[9] Recent developments have seen certain types of physical contact outlawed (e.g. the spear tackle) and the banning of contact with a player who has jumped to catch a high ball.[23] However due to the markedly different number of physical collisions in which players are involved, it may be necessary to develop specific injury prevention programmes for the different positional playing units.[9]

It is also necessary to consider some intrinsic risk factors which may influence injury rates in rugby league players. Several authors have reported that forward players have a greater body mass, with larger overall fat-free mass but possess more body fat than backs.[20,21,22] While it has been suggested that increased body fat may have a protective effect in the collision,[20] the larger fat-free mass of forwards would result in these players being relatively stronger, more difficult to tackle and thus halt progress. Furthermore both upper and lower body strength has been reported to be significantly higher in forwards than backs; upper body strength is important for making tackles, while leg strength is important for breaking them.[21] However, increased body fat could also be a disadvantage in terms of energy expenditure and work load,[20,21] especially with the game now being played in higher temperatures. Since backs possess lower levels of upper and lower body strength than forwards, this could make them more susceptible to injury in the physical collision. Furthermore backs may also be more predisposed to non-collision injury as a result of their style of play which involves more turning and changing direction during running than forward play.

Not withstanding the injury associated with physical contact, almost one third (6/20) of injuries in the present study did not take place during physical contact. Four of these injuries were to backs (three ligament sprains and a muscle strain) and two to forwards (one joint sprain and one dislocation). Nevertheless such injuries will undoubtedly have specific causes, for example backs may be more susceptible to ligament sprains and muscle strains because they are involved in more changes of direction during running.. In some instances video evidence suggested a likely possible cause, for example a back player who injured a hamstring whilst sprinting with the ball.

Recently, concern has been expressed about the ferocity of tackles and the role this might play in the incidence of injury.[24] It has already been stated that the defending team usually has more than one player tackling the ball carrier,[18] and the implications of this need to be investigated in future research. The present study demonstrated that backs have slightly higher standardised injury rates than forwards, in spite of being involved in fewer physical collisions. The difficulty appears to be deciding why a player gets injured in a particular collision situation.[25] If it takes more tacklers to halt the progress of a particular player, is that player at greater risk of being injured? Or, could it be the specific types of tackle that backs receive that results in them receiving more injuries per 10,000 physical collisions? Alternatively, the intrinsic injury risk factors such as strength, body composition and flexibility which influence injury incidence need to be considered. Another important consideration is the momentum of the players at the point of contact. Momentum results from a combination of strength, speed, body mass and distance covered which can serve to increase the force of a given collision and thereby increase the risk of injury. In rugby union it has been suggested that the momentum of the players is an important factor in determining whether a player is injured in a tackle, with most injuries occuring at running or sprinting speeds.[26]

CONCLUSION

The present study found that there was no relationship between the number of individual physical collisions which players incurred and the incidence of injury. It is possible that the lack of an observed relationship may be due to the small number of injuries in the present study, or because of the confounding effect of an increased number of non collision injuries in backs. Future research into injury in rugby league football needs to continue to monitor injury incidence and prevalence. The game has undergone a number of changes in recent years, such as modifications in the laws of the game and movement of the playing calendar, which have undoubtedly influenced injury patterns.[5] Therefore, any further changes might have a similar influence and need to be monitored. Future investigations also need to examine the evidence with regards to intrinsic injury risk factors exhibited by players. If injury prevention programmes are to be put in place, they need to be based on the knowledge of both intrinsic and extrinsic aetiological risk factors that contribute to increased injury risk.[15]

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An operational model to investigate contact sports injuries

CONOR GISSANE, JOHN WHITE, KATHLEEN KERR, and DEANNA JENNINGS

Department of Health Studies, Brunel University, Osterley Campus, Isleworth, Middlesex, TW5 7DU, UNITED KINGDOM; Division of Public Health Sciences, Queen's Medical Centre, University Hospital, Nottingham, NG7 2UH, UNITED KINGDOM; Division of Physiotherapy Education, Clinical Sciences Building, University of Nottingham, Nottingham, NG5 1PB, UNITED KINGDOM; and Wall House Surgery, Yorke Road, Reigate, Surrey, RH2 9HG, UNITED KINGDOM

ABSTRACT

GISSANE, C., J. WHITE, K. KERR, and D. JENNINGS. An operational model to investigate contact sports injuries. *Med. Sci. Sports Exerc.*, Vol. 33, No. 12, 2001, pp. 1999–2003. **Purpose:** A cyclical operational model is proposed to examine the interrelationship of a number of factors that are involved in sports injury epidemiology. In sports injury research, investigations often attempt to identify a unique risk factor that distinguishes an injured player. However, a wide variety of factors can contribute to a sports injury occurring, and an understanding of the cause of injury is important to advance knowledge. **Methods:** The proposed model identifies a healthy/fit player initially, although the player may exhibit a number of intrinsic risk factors for sports injury. Before exposure to extrinsic risk factors, there is the opportunity for implementation of prevention strategies by coaching personnel and the sports medicine team. These strategies might include, among others, appropriate warm-up, adequate hydration, wearing protective equipment, and prophylactic taping. Additionally, preventative screening could take place to assess the various intrinsic and extrinsic risk factors that could lead to sports injury. **Discussion:** Two examples of how the operational model relates to contact sports injury cases are presented. Participating in sport inevitably exposes the player to external risk factors that predispose toward injury. The treatment of the injured player aims to restore the player to preinjury playing status and to prevent the injury from becoming chronic. **Conclusions:** It is suggested that the application of this proposed cyclical model may lead to greater success in understanding the multifaceted nature of sports injuries and furthermore help minimize injury risk and support the rehabilitation of injured contact sports participants. **Key Words:** EPIDEMIOLOGY, INJURY, INCIDENCE, PREVALENCE, RISK FACTORS, PREDISPOSITION

In sports injury research, the aim of inquiries has often been to find a unique marker or risk factor that will identify injured players (24). Usually the frequency of injury is examined in relation to the presence or absence of a specific risk factor (28). However, most sports injuries are rarely attributed to a single risk factor. Although injuries may sometimes appear to be random accidents, many factors play a role before the actual occurrence of an injury event (24). An understanding of the etiology of injury is also important for the advancement of knowledge (23).

Although sports participation is acknowledged as having a health-promoting benefit, it can also have deleterious effects on health in the form of injuries and accidents (37). Action to prevent sports injuries should be based on the knowledge of etiological factors that contribute to increased injury risk (38). Various authors have described many risk factors, which are usually grouped into intrinsic (subject related) factors and extrinsic (externally related) factors (2,19,20).

Intrinsic factors have been defined as individual biological, biomechanical, and psychosocial characteristics predisposing a person to the outcome of injury (2). Extrinsic risk factors are independent of the injured person and are related to the types of activity during the incident of injury (35) and the manner in which sport is practiced (20). A summary of both intrinsic and extrinsic risk factors documented in the sports injury literature is presented in Table 1. However, even the classification of risk factors into intrinsic and extrinsic could be criticized as being artificial (19), because injuries that result from participation are multi-risk phenomena, with a variety of risk factors interacting at a given time (20).

Because sports injuries do not occur independently, previous research has suggested strategies for the investigation of sports injuries (37,40) by using a sequence of events with four stages (37);

1. The initial stage involves the identification of the problem and the description of injury in terms of injury incidence and the severity of injury.

2. The next stage identifies the risk factors and mechanisms that play a part in sports injury episodes.

3. Once these have been identified, measures that will have the likely effect of reducing sports injuries can be introduced. These measures are based on the injury mechanisms and risk factors that have been identified in stage 2.

4. The final stage of the sequence is to repeat the initial stage with the preventive measures in place, in order to determine the extent to which such measures are effective.

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TABLE 1. Intrinsic and extrinsic risk factors reported in the literature.

Intrinsic Risk Factors	Extrinsic Risk Factors
Physical characteristics	Exposure (20)
Age (20,40)	Type of sports (20)
Sex (20,40)	Playing time (20)
Somatotype (20)	Position in the team (20)
Body size (40)	Level of competition (20)
Previous injury (20,40)	Warm-up (40)
Physical fitness (20)	Personal equipment (40)
Joint mobility (20,40)	Training (20)
Muscle tightness (20,40)	Coaching (40)
Ligamentous laxity (20)	Refereeing (40)
Malalignment of lower extremities (20,40)	Control of game (40)
	Opponents
Dynamic strength (40)	Foul play (40)
Static strength (40)	Opponent's physique (40)
Skill level (40)	Environment (20)
Psychological characteristics (20)	Type and condition of playing surface (20,40)
Psychosocial characteristics (20)	Weather conditions (20,40)
Skill level (40)	Time of day (20)
Willingness to take risks (40)	Time of season (20)
Interaction with other players (40)	Equipment
Experience of sport (40)	Protective equipment (20)
	Footwear (20)
	Orthotics (40)

Later work proposed a multifactorial model for the investigation of sports injuries (23), in which an indefinite number of intrinsic risk factors may predispose an individual to injury (Fig. 1). If an athlete is predisposed to injury, extrinsic factors could exert their influence, i.e., extrinsic risk superimposed upon intrinsic factors.

However, an injury may require a further "initiating event," such as a collision or sudden change of direction. These "initiating events" may be focused upon by the sports medicine practitioner, with little attention being paid to those factors that were more distant from the event, e.g., how does an athlete become susceptible to injury?

Both the strategy for injury prevention (37) and the multifactorial model of etiology (23) have valid and important contributions to make for the investigation of sports injuries. However, a linear model with a beginning and an endpoint may be too simplistic because it is logical to assume that these

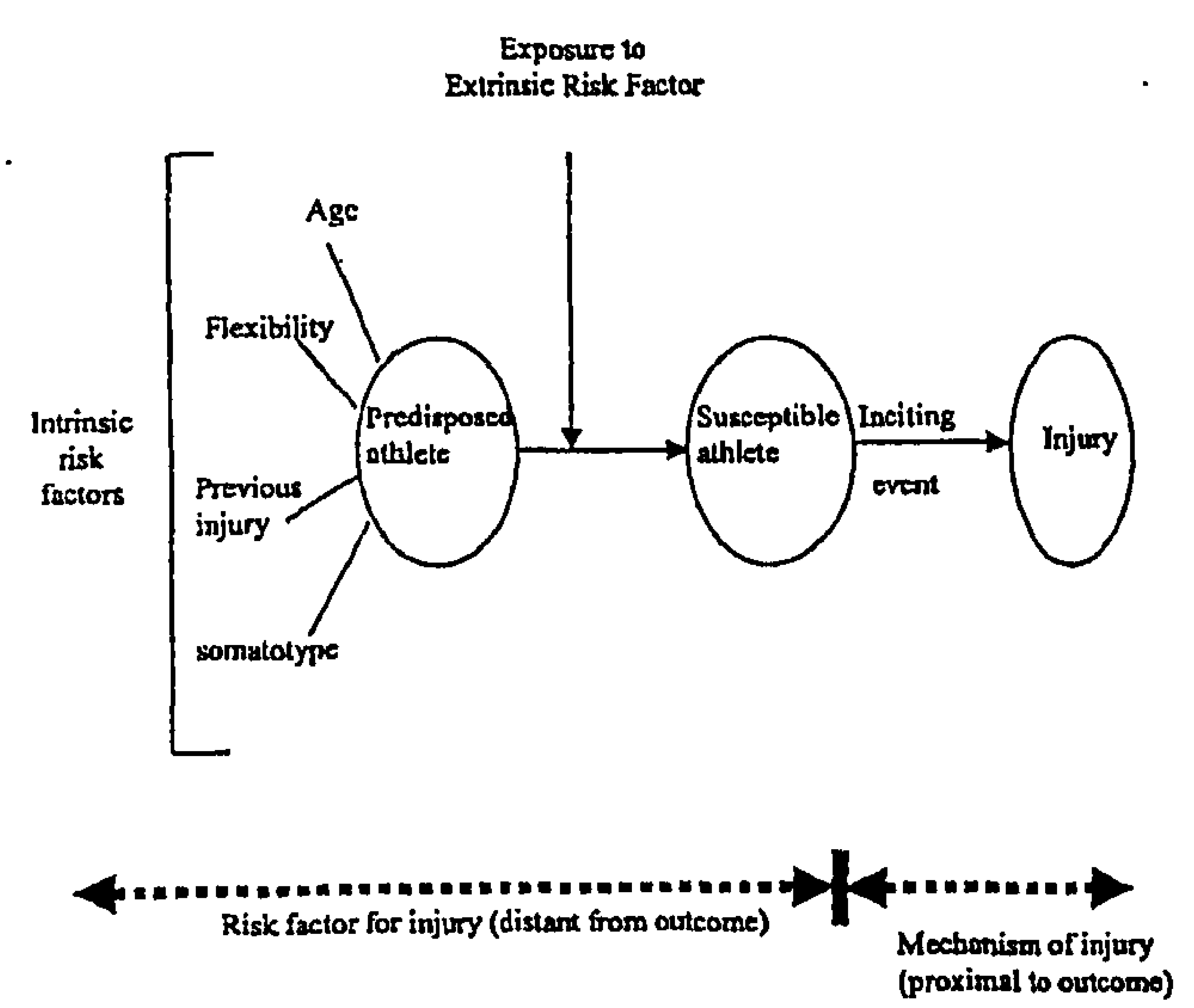

FIGURE 1—A new multifactorial model of athletic injury etiology (from ref. 23).

intrinsic risk factors are not fixed and that they can vary over time. Furthermore, Figure 1 is a linear model that does not account for what happens after injury, how the athlete may return to sport, and how the susceptibility to injury changes.

MATERIALS AND METHODS

A proposed cyclical operational model for the investigation of contact sports injuries. Traditional approaches to the epidemiological investigation of sports injuries have tended to focus on the incidence and prevalence of injury, applied both to individual sports, and to overall national statistics. The model developed here aims to expand this traditional approach to take into consideration the multitude of factors that may predispose to injury and that may determine the ultimate outcome of the injury for the contact sport athlete.

The cyclical model consists of five linked stages. First, the ostensibly healthy/fit athlete may be at risk of injury from a number of predisposing factors. These may with or without the additional exposure to external risk factors in the presence of a potential injury event result in injury incidence. The duration of time that the injury persists, during treatment and rehabilitation, contributes to the prevalence of the injury, and the ultimate outcome may be a return to sport at the original level, thus completing the cycle, or a return at a different level or even premature retirement (Fig. 2). Each of the elements of the model is now described in greater detail.

The healthy/fit player. Inherent within the ostensibly healthy/fit player exist a myriad of intrinsic risk factors that have been suggested by the literature (23). For example, it has been reported that field hockey, soccer, and lacrosse players exhibited an increased risk for ankle sprain when they displayed an increased eversion:inversion strength ratio (1).

At this stage in the cycle, the strategies for intervention may be termed "primary prevention" (20), with the aim of preventing injuries from occurring in the first instance (6). Knowledge of the individual's risk factors may be of benefit in primary prevention. These strategies, among others, might include such measures as appropriate warm-up, adequate hydration, and prophylactic taping. They might also include wearing protective equipment such as gum shields in rugby (14), hurling (4), and ice hockey (29) or head guards in hurling (4) and ice hockey (16,29). Such strategies would also include coaching proper technique in contact sports when either making or receiving a tackle (3) and teaching correct falling technique in judo (16). Coaches and sports medicine practitioners seek to prevent injury, and it is the most logical and least costly method of health care (24). Additionally, prevention screening could take place to assess intrinsic risk factors that could lead to sports injury problems (22). For example, it has been shown that postural and mechanical factors can predispose female basketball players (7), rugby, and soccer (39) players to injury, whereas screening has been advocated for groin injury prevention in rugby league football (27).

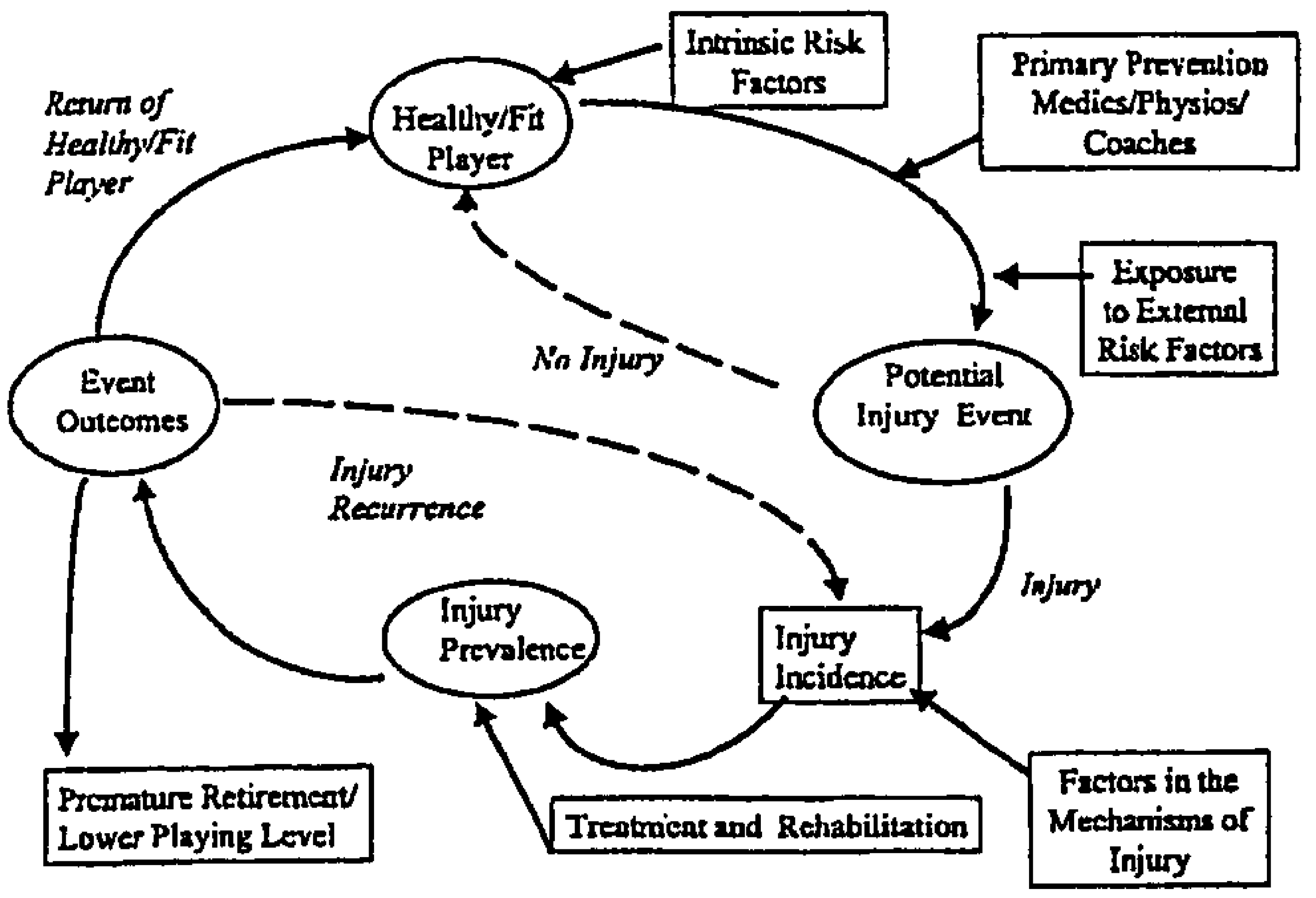

FIGURE 2—A cyclical operational model for the investigation of contact sports injuries.

Potential injury event. In addition to the intrinsic factors, extrinsic factors will play an important part in the potential for injury. The exposure to extrinsic risk factors will undoubtedly vary across sports and may vary within positions in certain sports, as well as the conditions under which sport is played. For example, both field hockey (13) and American football (33) have reported increased injury rates when games are played on Astroturf. In American football, both the risk of knee (RR = 1.18) and ankle (RR = 1.39) injuries are increased when the game is played on artificial compared with real grass (28).

The event that initiates an injury is one of the most identifiable parts of the injury process and has been the focus of much research (23). In contact team sports, these events are likely to be highly game specific, and indeed position specific. It has been suggested that there are a high number of thigh injuries in professional soccer (12) that commonly result from physical contact with an opponent (5). It has also been suggested that with the exception of goalkeepers, there are few upper body injuries that prevent soccer players from playing (22).

At this stage in the cycle, a player who is not injured can continue to play while still exhibiting the same intrinsic risk factors, whereas if he/she becomes injured the player progresses to the next stage of the model.

Injury incidence. In descriptive sports medicine, epidemiological terminology, incidence has been defined by the number of new events or cases of injury that develop in a population of individuals at risk during a specified time interval (8). The incidence of injury in specific sports is an area that has received much attention (7,9,16). However, the comparison across studies is often difficult due to the varying definitions of injury that have been employed (38). Nevertheless, where comparisons can be made, there is a range of injury incidence rates among contact sports as demonstrated in Table 2.

Injury prevalence. In descriptive sports epidemiology, injury prevalence has been quantified by the proportion of individuals in a population who have an injury at a specific instant. It provides an estimate of the probability or risk that an individual will be injured at some point in time (8). Injury prevalence depends upon both the incidence rate of an injury and the period of time between the initiating event to the return to full fitness. In sporting terms, the prevalence of an injury is an important consideration, because the treatment and rehabilitation of injuries takes time and this is often a major factor in injury prevalence. It has been suggested that because professional sport is a business, it is often desirable on the part of both the team and the player to keep time lost from playing to a minimum (18). Prevalence can also be influenced by game regulations, for example, in rugby union football a player who is concussed is required not to either play or train for a period of 21 d (International Rugby Football Board resolution 5.7), whereas in rugby league football there is a sliding scale of required abstinence for the severity of injury based on the symptom severity of concussion. Therefore, concussions that are considered relatively minor in rugby league football would have a far higher prevalence in rugby union football, which could contribute to a distortion in specific injury prevalence among similar sports.

TABLE 2. Injury incidence rates among contact team sports.

Sport	Injuries per 1000 Player Hours	Reference
Rugby League Football	34*	Stephenson et al., 1996 (34)
Rugby Union Football	20*	Hughes and Fricker, 1994 (10)
Australian Rules Football	35*	Seward et al., 1993 (32)
Soccer	22.6	Inklaar et al., 1996 (11)

* Injuries requiring a player to be unable to play for more than 1 wk.

The type and duration of treatment of the athlete is dependent upon each specific injury that the player has sustained. For example, it has been reported that 44% of rugby injuries only require treatment with RICE (rest, ice, compression, and elevation) (10), whereas others may require surgical intervention (36).

During the rehabilitation process, both secondary and tertiary prevention can take place. The aim of secondary prevention is to restore health when it is impaired (17). In sports medicine, it is defined as the process of preventing or delaying the development of irreversible structural damage by therapeutic intervention (20). These measures can influence the prevalence of injury by reducing the amount of time that a person remains injured, but not the incidence. Appropriate and early management of soft tissue injury, in particular, has been shown to promote early recovery (21).

Therapy that seeks to limit the injury process from becoming either chronic or persistent has been termed tertiary prevention (20). The aim of tertiary prevention is to reduce both the incidence and prevalence of long-term disability (20). Sound treatment and rehabilitation have been suggested to be one of the most adequate preventive measures for secondary and tertiary prevention (19).

Event outcomes. In the proposed cyclical operational model for the investigation of sports injuries (Fig. 2), an injury has three possible event outcomes. A player can return to a healthy/fit state, the injury can recur, and either the player can retire from competition at that level or continue participating at a lower level. The obvious ideal is to return to playing at the preinjury level of performance. For athletes to be regarded as healthy, they must be able to take part fully in both training and playing (20). However, professional athletes are unlike a number of other occupational groups in that they are often quite willing to train and play in spite of injury, compared with others, who normally return to work only when they are completely recovered (30).

Recurrent injuries are also a major problem in sport and have been reported to account for 16.5% of all injuries in rugby union football (7). Recurrent injuries increase the incidence rate and the amount of time lost for an injured player, thus also increasing the prevalence rate of injury. Furthermore, one of the greatest risk factors for injury is the history of previous injury (40).

In extreme circumstances, professional sport players are sometimes forced into premature retirement because of injury. In such cases, it has been reported that rugby league football players who suffered long-term consequences of injury after their playing careers experienced difficulties, which included job limitations, reduced income-earning potential, and increased personal medical costs (26).

In certain situations, players will be unable to return to playing, and the management of such an injury may seek to maximize the quality of life rather than fully remediate the injury (19). Previous work has described cervical spine injuries of two rugby union football players who could no longer return to play (31). These players are now members of the Rugby Amistat Foundation, which is dedicated to the well-being of players who have suffered physical and mental trauma after disabling injury (31).

The overall design of the proposed operational model is cyclical because even if a player returns to health/fitness, the sports injury itself may constitute an intrinsic risk factor for the predisposition of future injury. Even if a player is fortunate enough to avoid an injury, the individual's intrinsic risk factors are unlikely to remain the same over time. For example, at the beginning of every season, a player has another year of experience and is another year older, both of which have been described as potential sports injury risk factors (20,40). This will serve to alter the nature of intrinsic risk factors present. In addition to this, coaches in contact sports often emphasize increasing muscle bulk during the closed season (25), which may also serve to alter an individual's intrinsic risk factors.

DISCUSSION

The advantage of the cyclical model over the previous linear model (23) is that knowledge and awareness of the factors involved at each stage of the model allows for the development of appropriate strategies for the prevention of injury at the primary, secondary, and tertiary levels. Therefore, the practical application of this model may help the sports medicine practitioner deal more effectively with the injury problems of athletes in contact sports.

This paper proposes to provide an example of the application of this model to two specific sports situations in the contact sport of rugby union football.

Case 1: first rib synchondrosis. An injury to the first rib synchondrosis in a rugby football player is an example of an acute injury caused primarily as a consequence of extrinsic factors (15). However, the muscle bulk in the shoulder area and the strength of the muscles represent the player's internal (intrinsic) risk factors. The external exposure to a (extrinsic) risk factor would be the contact with the opposing player and the opposing player's physique.

In this example, the specific injury incidence was a first rib synchondrosis. The injury contributed to the incidence as an injury event, and the treatment, which was described as conservative and lasting for 12 wk, contributed to the prevalence throughout the recovery period. At the end of the treatment, the event outcome was that the player was pain free and a repeated CT scan showed that the injury had healed. The player was then allowed to resume contact sport at the same level, which would return him to the start of the cycle, where this injury may or may not represent an intrinsic risk factor to future injury.

Case 2: incarcerated hernia. An incarcerated hernia during a lineout (36) might fit into the model as follows; this is an acute injury superimposed upon an intrinsic weakness. For this injury, the intrinsic risk factors would include the preexisting hernia and the player's position, somatotype, and gender, whereas the predisposing external risk factors would include the fact that it took place in a lineout. This is an area of the game that has recently been the subject of some rule changes, which has resulted in lineout jumpers being supported and lifted by adjacent players. This is a technique that is coached and rehearsed during practice sessions. The act of being supported in an unstable mid-air position could be considered to be an external risk factor. The exertion of jumping may have increased the intra-abdominal pressure, thus increasing the size of the hernia. This would be compounded by the increased external pressure to the groin area, transmitted through the shorts, by the action of two other players lifting and holding the lineout jumper.

The particular injury was the hernia, which required treatment with surgery. The prevalence of the injury was for a period of 5 wk in total, after which the event outcome was the player being able to return to play, again completing the cycle.

CONCLUSIONS

The model that has been proposed seeks to acknowledge the multifactorial nature of sports injury. It further recognizes that the sports injury is not an endpoint (23), because rehabilitation and recovery are part of the continuing process. In so doing, it attempts to bridge the gap between descriptive and analytical sports injury epidemiology. Sports participants almost always seek to return to play, but on their return their intrinsic risk factors and the external risk factors will undoubtedly be different. Although the model has been applied to rugby football and the myriad of factors that can influence injury, the situation will undoubtedly be different in other sports and needs to be investigated further.

The previously published work underpinning the development of the proposed cyclical model (Fig. 2) has been presented to illustrate the application to sports injury research and demonstrate the advantages over the previously proposed linear model (Fig. 1). Furthermore, it is envisaged that the new model may be used to further develop current descriptive and future analytical epidemiological approaches to sports injury research.

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Address for correspondence: Conor Gissane, Department of Health Studies, Brunel University, Osterley Campus, Isleworth, Middlesex, TW7 5DU, England, United Kingdom; E-mail: conor.gissane@brunel.ac.uk.

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A Pooled Data Analysis of Injury Incidence in Rugby League Football

Conor Gissane,[1] *De Jennings*,[2] *Kathleen Kerr*[3] and *John A. White*[4]

1 Department of Health Studies, Brunel University, Osterley Campus, Isleworth, Middlesex, UK
2 Wall House Surgery, Reigate, Surrey, UK
3 Division of Physiotherapy Education, Nottingham University, Nottingham, UK
4 Centre for Sports Medicine, Queen's Medical Centre, University of Nottingham, Nottingham, UK

Abstract

Objective: The aim of this study was to summarise the injury rates in professional rugby league football.
Methods: Previously published studies were identified from database searches of the literature from Medline, Sports Discus and Web of Science. A total of 18 articles, which reported the prospective injury data collection for at least one playing season in professional rugby league worldwide, were included. The definition of injury adopted required an injured player to miss the subsequent game through injury. Ten studies satisfied the injury definition criteria for inclusion. A review of articles and extraction of relevant data were carried out independently by two authors.
Results: A total of 517 injuries were reported during 12 819 hours of exposure (753 games), which resulted in an overall injury rate of 40.3 injuries per 1000 hours [95% confidence interval (CI) 36.9 to 43.8]. Most injuries were to the lower half of the body (20.7 per 1000 hours, 95% CI 17.7 to 24), with the trunk receiving the least (6.7 per 1000 hours, 95% CI 5 to 8.6).
Conclusions: Injury rates in professional rugby league are higher than in some other contact sports, probably because of the large number of physical collisions that take place. This pooled data analysis provides more accurate estimates of injury incidence in the game of professional rugby league football.

Rugby League football has been described as a fast moving contact sport,[1] and as a collision sport.[2] It is an invasion game, whereby one team attempts to invade the territory of the other team with the object of scoring points, while the opposition uses physical force, within the laws of the game, to try and stop them. To do this, the internal structure of the game demands that the side that is not in possession tackles their opponents who are in possession of the ball. Tackling can be described as the act of preventing a ball carrier running with the ball, or passing or kicking the ball to another member of the attacking team. The ball carrier can be tackled by any number of the opposing team's players.[3]

A rugby league team consists of 13 players (six forwards and seven backs) who have six possessions to advance the ball down field. The ball must be passed backwards, but can be carried or kicked down field. Unlike American football, there are no special teams or sub-units within a team (other than forwards and backs), so each player has a role to play in both attack and defence.

Research into the incidence of injury in rugby league has shown that injury incidence is high compared with other sports, for example rugby union.[4,5] However, one shortcoming of many of these studies is that they deal with a relatively small number of players and often only one club, thus reducing their generalisability.

One strategy to enhance the information provided from epidemiological studies is to combine the information from multiple studies into a single estimate.[6] For this technique to be successful it is important that the studies that are included have compatible structure with respect to inclusion criteria, follow-up, and exposure history. The combined data from these individual studies can then be statistically reanalysed to provide more precise injury data.[7]

The purpose of the present study was to provide pooled estimates of injury incidence in rugby league football from published studies; more specifically, this included estimates of injury incidence, injury severity, site of injury and the comparison of injury rates between forward players and back players.

Methods

The methodology included the development of a search strategy to locate articles investigating injury in rugby league. Inclusion/exclusion criteria were developed to ensure compatibility, and finally, combined analysis was performed.

Search Strategy for Identification of Databases

The search strategy involved searching Medline, Sports Discus and Web of Science databases, covering the period from 1985 to 2000. A total of 18 studies were identified. The following terms were used: rugby *with* league *and* injury.

Inclusion Criteria

In the present analysis the authors collated published studies that reported the incidence of injury in rugby league football. The inclusion criteria were:

- Studies published later than 1990
- Data collection carried out prospectively on professional players
- A definition of a recordable injury being one that required an injured player to miss the subsequent game
- A count of the number of games studied to allow the calculation of player time injury rates.

Procedures

A total of 18 articles were identified that reported prospective data collection of rugby league injury, and details of these studies are shown in table I. Of these, only ten satisfied the inclusion criteria,[4,5,8-13] but two of these studies had to be excluded[14,15] for re-reporting the same source data in a previous article.[12]

Upon further examination, it was also apparent that in some of the remaining eight studies that satisfied the inclusion criteria, authors had used the same common baseline data sets to highlight further trends in their data. For example, the data reported by Gissane et al.[4] were contained within data reported in a later article.[13] While Stephenson et al.[13] and Gissane et al.[10] used the same baseline data, one group of investigators reported the overall incidence of injury in rugby league,[13] while the other sought to highlight the differences in injury rates between forwards and backs.[10] This resulted in a total of six studies being included in the final pooled analysis, which are highlighted in table I, three of which reported both first team and reserve grade information.[8,9,13]

Since many studies did not include all areas of interest for analysis, it was necessary to extract specific information from individual studies at different stages of the analytical process.

Statistical Analysis

The data from individual studies were combined using the method described by Breslow and Day.[23] Person-time incidence rates and 95% confidence intervals (CI) were calculated using confidence interval analysis software.[24] To test for significant differences, proportion tests (z), and chi-squared

Table I. Summary of rugby league injury studies that reported prospective data collection[a]

Study	Study design	Sampling time (no. of seasons)	Grade/level	Participating clubs
Alexander et al.[16]	Prospective	1	1st, reserve, U21	1
Alexander et al.[1]	Prospective	2	1st, reserve, U21	1
Estell et al.[8]	Prospective	1	1st, reserve, U21, U19, U17, U15	1
Gabbett[17]	Prospective	3	Amateur	3
Gibbs[18]	Prospective	3+2	1st, reserve, U21	1
Gibbs[9]	Prospective	3	1st, reserve, U21	1
Gissane et al.[11]	Prospective	5	1st	1
Gissane et al.[10]	Prospective	4	1st, reserve	1
Gissane et al.[4]	Prospective	1	1st, reserve	1
Gissane et al.[19]	Prospective	1	1st	2
Hodgson-Phillips[15]	Prospective	4	1st	1
Hodgson-Phillips et al.[12]	Prospective	4	1st	1
Hodgson-Phillips et al.[14]	Prospective	4	1st	1
Lythe and Norton[20]	Mixed	1	Not stated	Not stated
Norton and Wilson[21]	Prospective	1	1st, reserve, senior B, open-age amateur	24
Seward et al.[5]	Prospective	1	1st, reserve, U21	9
Stephenson et al.[13]	Prospective	4	1st, reserve	1
Walker[22]	Prospective	5	Not stated	1

a Studies in bold include overall analysis.

U15 = under 15s; U17 = under 17s; U19 = under 19s; U21 = under 21s.

(χ^2) goodness-of-fit tests were used, along with relative risk (RR) where appropriate.

Results

The included studies reported injury data from a total of 753 games, 548 first team and 205 at reserve grade. The total number of hours of observation for injury exposure was calculated as 13 players × length of the game × number of games played (two teams of 13 playing for 1 hour constitutes 26 player hours). Games are usually 80 minutes in length, but in two studies,[8,25] reserve grade games were 70 minutes long. There were a total of 12 819 player-hours across the six studies, 9474 player-hours at first team and 3344 player-hours at reserve grade.

The injury incidence figures are shown in table II. There was an overall injury rate of 40.3 injuries per 1000 player-hours. First team players experienced a slightly higher injury rate than reserve grade players did, although the difference was not significant ($z = 0.49$, $p = 0.62$).

It was possible to pool data on the site of injury from four studies, which totalled 8365 exposure hours[5,11,13,25] and figure 1 displays the injury rates for the different sites of the body from these studies. There were significant differences between these injury rates ($\chi^2 = 12.34$, df = 3, $p < 0.01$) with injuries to the lower limb accounting for 46.4% of the total, followed by the upper limb (20%), head and neck (18.7%) and trunk (14.7%).

Only two studies[10,25] have reported a comparison between forward and back players for injury rates, which totalled 3673 player-hours of exposure (forwards = 1811.39 player-hours, backs = 1861.9 player-hours). This gave rise to injury rates of 66 per 1000 hours (95% CI 55 to 79) and 61 per 1000 hours (50 to 73) for forwards and backs, respectively. The RR of 1.09 demonstrated that playing as a forward increased the risk of injury by only 9%, although the 95% CI for the RR (0.85 to 1.40) indicated that the increased risk was not significant.

Injury severity was graded according to the criteria used by Gibbs.[25] An injury was classified as

Table II. Pooled injury incidence data of included studies

Study	Grade/ level	No. of seasons reported	Injuries (no.)	Games played (no.)	Exposure time (h)	Injury rate per 1000h	95% CI
Hodgson-Phillips et al.[12]	1st	4	77	115	1988.4	38.7	30.1-47.4
Seward et al.[5]	1st	1	151	178	3077.6	49.1	41.2-56.9
Gissane et al.[11]	1st	1	20	23	397.7	50.3	28.3-72.3
Stephenson et al.[13]	1st	4	72	138	2386.0	30.2	23.2-37.1
Estell et al.[8]	1st	1	20	28	484.1	41.3	23.2-59.4
Gibbs[9]	1st	3	47	66	1141.1	41.2	29.4-53.0
Combined	**1st**		**387**	**548**	**9474.9**	**40.8**	**36.8-44.8**
Gibbs[9]	Reserve	3	41	66	1001.0	41.0	29.4-55.6
Stephenson et al.[13]	Reserve	4	75	111	1919.2	39.1	30.7-49.0
Estell et al.[8]	Reserve	1	14	28	424.7	33.0	15.7-50.2
Combined	**Reserve**		**130**	**205**	**3344.9**	**38.9**	**32.2-45.6**
Overall			**517**	**753**	**12819.8**	**40.3**	**36.9-43.8**

CI = confidence interval.

minor (one game missed), moderate (two to four games missed), or major (five or more games missed). It was possible to pool the results from three studies[12,13,25] that covered a total of 9437 hours of exposure, and the injury rates are shown in table III. Overall, minor injuries accounted for 43% of the total, with moderate and severe injuries accounting for 32.9 and 25%, respectively. However, the differences between the injury categories were not significant ($\chi^2 = 5.37$, df = 2, $p > 0.05$).

Discussion

The major findings of the current analysis were: (i) that there was no difference between the injury rates of first and reserve grade players; (ii) there were significant differences between the injury rates for different sites of the body, with the lower limb having the highest injury rate; (iii) there was a small but not significant increased risk of injury when playing as a forward compared with playing as a back; and (iv) there was no significant difference between the degree of severity of injuries sustained by players.

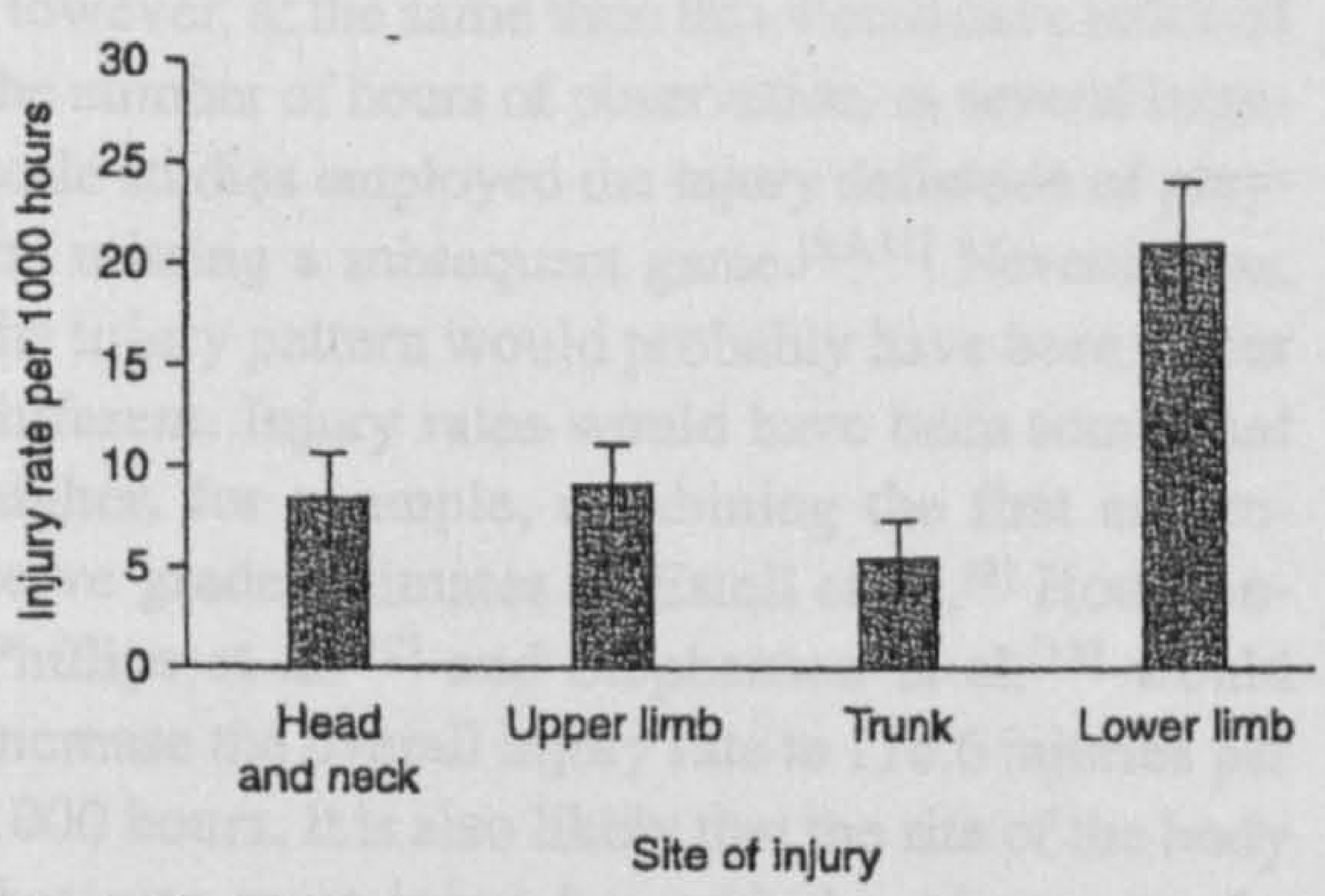

Fig. 1. Pooled data for site of injury (rates per 1000 hours with 95% confidence interval).

Pooling data from a number of studies of similar design is a technique that can produce an overall estimate which incorporates the information provided by those studies.[26] Therefore, the major strength of the present pooled analysis is the fact that it provides more accurate estimates of injury rates than the individual studies which provided the initial raw data. Therefore, injury rates from the present study can be compared with injury rates from previous studies.

The combined data demonstrated no significant differences between the injury rates for first and reserve teams. Individual studies have also all reported nonsignificant differences between grades.[8,13,25] Furthermore, this finding was evident irrespective of the definition of injury that was adopted. For example, one study[25] only reported injuries that required a player to miss more than one game, while the two other studies[8,13] originally reported all injuries that received treatment.

The combined injury estimate of 46.4% of the total for lower body injuries is very similar to the 41[5] and 45%[11] reported in individual studies. One major feature of rugby league is the amount of tackling that takes place. The thigh area is where most coaches will instruct players to aim tackles,[2,27] which would tend to make it an area of the body more susceptible to injury. However, there is no real evidence to indicate which area of the body is contacted first, or with how much force, in the tackle. Furthermore, when tackles are aimed at the upper part of the body, arms and shoulders can be used to protect such areas as the trunk and head, whereas the lower limb will remain somewhat exposed to contact.

The finding that almost half of the injuries in the pooled data analysis were to the lower limb is in contrast to an earlier report that the head and neck were the most frequently injured sites.[4]This discrepancy may also be caused by differences in injury definition. If all injuries that required treatment were included, then lacerations that required suturing would be counted, even though these would not require a player to miss a subsequent game. Indeed, it has been suggested that including such injuries, in addition to those requiring a player to miss a subsequent game, would increase the injury count by as much as 43%.[25]

If this study had adopted an injury definition for all injuries that received treatment, it would have increased the number of studies that could be utilised. However, at the same time this would have reduced the number of hours of observation, as several large-scale studies employed the injury definition of players missing a subsequent game.[5,9,11] Nevertheless, the injury pattern would probably have been rather different. Injury rates would have been somewhat higher, for example, combining the first and reserve grade estimates of Estell et al.,[8] Hodgson-Phillips et al.[12] and Stephenson et al.[13] would increase the overall injury rate to 116.6 injuries per 1000 hours. It is also likely that the site of the body that was most injured would also change to the head and neck.[4,13] This definition would then include all minor concussions and sutures that would not prevent a player from playing in the next match.

One recognised limitation when compiling the present analysis was that it was not possible to provide an accurate estimate of the phase of play in which injury took place. Although two previous studies[10,13] have suggested that most injuries are received by the ball carrier whilst being tackled, both reported the same baseline data, so it is essentially a single study. Furthermore, no other investigators have reported injury occurrence in relation to the phase of play.

The aggregation of two data sets[10,25] revealed that there was no increased risk of injury when playing as a forward compared with playing as a back. Recent work[28] has shown that forwards are involved in many more physical collisions than backs during the course of a game (55 *vs* 29). This situation is similar in forwards compared in both attack (16 *vs* 13) and defence (39 *vs* 16). These increased numbers of physical collisions experienced by forwards do not appear to predispose them to injury.

The pooled data analysis of three studies[12,13,25] indicated that there were no significant differences between categories of severity of injury. Nevertheless, although 43% of injuries required players to miss only one game, it was disturbing to note that one in every four injuries required a player to miss five or more games. Since recent changes in playing calendars and league structures, five games now represent almost 20% of a season, which will require increased numbers of players to cover for the playing time lost as a result of injury.

Conclusion

Within the limits of the definition of injury used in the present study (an injury requiring a player to miss a subsequent game), the pooled analysis has

Table III. Injury rates for grades of severity

Severity	Rate per 1000h	95% CI
Minor	16.64	14.1-19.5
Moderate	12.7	10.5-15.2
Major	9.32	7.5-11.5

CI = confidence interval.

allowed the calculation of more accurate estimations of injury rates in professional rugby league and has attempted to make the results more generalisable. The resulting combined analysis reduces the variability associated with imprecise estimates and potential biases associated with individual studies. It also removes the influence of individual sub-cohort characteristics, such as playing style.[6]

To date, rugby league is a sport that has not undergone a comprehensive scientific investigation. However, it may be possible in future to add subsequent studies to the present pooled analysis with a view to improving the understanding of factors surrounding injury incidence in rugby league football.

To provide more comprehensive data on injury incidence in rugby league football further prospective studies are required. Furthermore, these studies should include the common definitions of injury, the phases of play in which injury occurs, and the precise mechanism of injury. Such approaches would be best facilitated by the adoption of a standardised injury surveillance system that would allow further in-depth analysis to be performed.

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Correspondence and offprints: *Conor Gissane*, Department of Health Studies, Brunel University, Osterley Campus, Isleworth, Middlesex, TW7 5DU, UK.
E-mail: conor.gissane@brunel.ac.uk