Incidence, Severity, Aetiology and Prevention of Sports Injuries
A Review of Concepts

Willem van Mechelen, Hynek Hlobil and Han C.G. Kemper
Department of Health Science, Faculty of Human Movement Sciences, Vrije Universiteit en University of Amsterdam, Amsterdam, The Netherlands

Contents

Summary
82
1. Sports Injury Incidence: Theoretical Considerations
   1.1 The Definition of Sports Injury
   1.2 Sports Injury Incidence
   1.3 Research Design
2. Sports Injury Data
   2.1 Sports Injury Incidence: The Netherlands as an Example
   2.2 Other Comparisons
3. Severity of Sports Injuries
   3.1 Nature of Sports Injuries
   3.2 Duration and Nature of Treatment
   3.3 Sports Time Lost
   3.4 Working Time Lost
   3.5 Permanent Damage
   3.6 Costs of Sports Injuries
4. Aetiology and Prevention of Sports Injuries
   4.1 Sport-Specificity of Sports Injuries
5. Conclusions

Summary

Notwithstanding the healthy influence of sporting activities on risk factors, in particular those of cardiovascular disease, it is becoming increasingly apparent that sports can present a danger to health in the form of sports injuries. The extent of the sports injury problem calls for preventative action based on the results of epidemiological research. For the interpretation of these facts uniform definitions are needed and limitations of research designs should be known. Measures to prevent sports injuries form part of what is called the 'sequence of prevention'. Firstly the extent of the sports injury problem must be identified and described. Secondly the factors and mechanisms which play a part in the occurrence of sports injuries have to be identified. The third step is to introduce measures that are likely to reduce the future risk and/or severity of sports injuries. This measure should be based on the aetiological factors and the mechanism as identified in the second step. Finally the effect of the measures must be evaluated by repeating the first step.
In this review some aspects of the first and second step of the sequence of prevention are discussed.

The extent of the sports injury problem is often described by injury incidence and by indicators of the severity of sports injuries. Sports injury incidence should preferably be expressed as the number of sports injuries per exposure time (e.g. per 1000 hours of sports participation) in order to facilitate the comparability of research results. However, one should realise that the outcome of research applying this definition of sports injury incidence is highly dependent on the definitions of ‘sports injury’ and ‘sports participation’.

The outcome of such research also depends on the applied research design and research methodology. The incidence of sports injuries depends on: the method used to count injuries (e.g. prospective vs retrospective); the method used to establish the population at risk; and on the representativeness of the sample.

Severity of sports injuries can be described on the basis of 6 criteria: the nature of the sports injury; the duration and nature of treatment; sporting time lost; working time lost; permanent damage; and cost. Here also uniform definitions are important and necessary in order to enhance the comparability of research data. In the second step of the ‘sequence of prevention’ the aetiological factors that play a role in the occurrence of a sports injury have to be identified by epidemiological studies. Epidemiological research on the aetiology of sports injuries requires a conceptual model. The most commonly applied model is a stress/capacity model in which internal (personal) and external (environmental) aetiological factors are identified. In this model stress and capacity must be in balance and preventative measures must be designed to achieve or maintain this balance. However, merely to establish the aetiological factors is not enough; the mechanism by which sports injuries occur must also be identified. Athletes are in constant interaction with their environment and aetiological factors must be approached from this point of view. In a second, more dynamic, conceptual model on the aetiology of sports injuries, the importance of the determinants of sports behaviour, as well as the interaction between the various aetiological factors, is discussed. Whether or not a sports injury results from sports behaviour largely depends on the extent to which ‘prevention’ is incorporated in the determinants of sports behaviour. The drawback of both conceptual models is the fact that neither of them incorporate a time perspective. They can therefore not be applied to research on the aetiology of overuse injuries. In this perspective the application of a stress/strain/capacity model can be useful. This is a more dynamic and time-based 3-phase sequential model in which behaviour, amongst other aetiological factors, plays an important role. In this model an athlete is seen as an active manipulator of stress by whom the amount of strain evoked by sports participation can be altered, thereby influencing the capacity to perform in a certain sports situation, but also influencing the risk to sustain a sports injury, either acute or long term.

Finally, despite the importance of the model of choice in studying the aetiology of sports injuries one should realise that again the choice of research design influences the outcome of such research. Case series usually give no information on the underlying population at risk, so they are of no value in drawing valid conclusions on the risk factors of injuries. Only by relating the injuries to corresponding population denominators can one estimate injury rates and identify important risk factors and high risk sportspeople. As in research on sports injury incidence; research on risk factors should be undertaken on groups that are homogeneous with regard to age, sex, level of competition and type of sport.

During recent decades both the government and sports organisations in the Netherlands have encouraged sporting activities, as exemplified by the ‘Trim U Fit’ (1968), ‘Sportreal’ (1976), ‘Nederland Oké’ (1980) and ‘Sport, zelfs ik doe het’ (1986) campaigns. The Netherlands was not alone in this: witness the ‘Sport for All’ campaign of the British Sports Council and, again in Britain, the ‘Exercise for Health’ campaign (Hutson 1983), as well as Fitness Canada (Shephard 1985). Underlying these ef-
forts was the supposedly healthy influence of sporting activities on risk factors, in particular those of cardiovascular diseases.

Reasons for participating in sport are many and varied but 2 relatively common ones are health/fitness and pleasure/relaxation (Manders & Kropman 1979).

It is becoming increasingly apparent that as well as having a health-giving aspect, sport can present a danger to health in the form of accidents and injuries. An individual who has to give up or cut down his or her sporting activities as a result of injury is unable to pursue some or all of his or her goals. If the injury is serious enough the athletes will also have recourse to the medical services to have it treated. Injuries can also result in absence from school or work.

Given these unwanted side effects of sports participation it was recognised in Europe and elsewhere that a preventative approach towards the reduction of sports injuries should have high priority. It was for that reason that, within the 'health for all by the year 2000' policy of the World Health Organization, the Council of Europe launched a European coordinated research project 'Sport For All: Sports Injuries and Their Prevention' in order to improve the understanding of sports injuries and to develop a scientifically based prevention strategy. Measures to prevent sports injuries do not stand by themselves. They form part of what might be called a 'sequence of prevention' (fig. 1; van Mechelen et al. 1987).

First, the problem must be identified and described in terms of incidence and severity of sports injuries. Then the factors and mechanisms which play a part in the occurrence of sports injuries have to be identified. The third step is to introduce measures that are likely to reduce the future risk and/or severity of sports injuries. This measure should be based on the actiological factors and the mechanisms as identified in the second step. Finally the effect of the measures must be evaluated by repeating the first step. In this review some aspects of the first and the second step of the sequence of prevention will be discussed.

1. Sports Injury Incidence: Theoretical Considerations

1.1 The Definition of Sports Injury

In general 'sports injury' is a collective name for all types of damage that can occur in relation to sporting activities. Various studies of incidence define the term sports injury in different ways (Boersma-Slütter et al. 1979; Franke & Franke 1980; Groh & Groh 1975; Hunter & Torgan 1983; LaCava 1978; Lysens & Ostlyn 1984; McLatchie 1979; Mueller & Blyth 1974). In some studies a sports injury is defined as one sustained during sporting activities for which an insurance claim is submitted (Brandt Corstius 1983). In other studies the definition is confined to injuries treated at a hospital casualty or other medical department (Boersma-Slütter et al. 1979; Clement & Taunton 1981; Edixhoven et al. 1980; Hitchcock & Karmi 1982; Jaffin 1981; Janka & Daxecker 1984; Jost et al. 1981; Kvidera & Frankel 1983; Maehlum & Daljord 1984; Maehlum 1984; Oh & Schmid 1982; Schürmeyer et al. 1983; Sedlin et al. 1984; Steinbrück & Rieden 1984; Steinbrück & Cotta 1983). The different definitions partly explain the differing incidences found. The results of these various surveys are therefore not comparable (Kranenburg 1982). If sports injuries are recorded through the medical channels, a fairly large percentage of serious, predominantly acute injuries will be observed and less serious and/or overuse injuries will not be recorded. If such a limited definition is used,
only part of the total sports injury problem is revealed: this ‘tip-of-the-iceberg’ phenomenon is commonly described in epidemiological research (Walter et al. 1985). This can be illustrated by the results of van Galen and Diederiks (1990); using a broad definition of sports injuries (any self-reported sports injury) in a national survey on sports injuries, 43% of all injuries were found to be medically treated.

To make sports injury surveys comparable and to avoid the ‘tip-of-the-iceberg’ phenomenon as far as possible, an unambiguous, universally applicable definition of ‘sports injury’ is the first prerequisite. This definition should be based on a concept of health other than that customary in standard medicine. In everyday life individuals are regarded as healthy if they are able to do their daily work. Athletes, on the other hand, are not fully recovered unless they can take part in their sport (training session or match). One of the definitions based on this premise is that used by the National Athletic Injury Registration System (NAIRS) in the US.

“The reportable injury is one that limits athletic participation for at least the day after the day of onset” (Vinger 1981). NAIRS classifies injuries, according to the length of incapacitation, into ‘minor’ (1 to 7 days), ‘moderately serious’ (8 to 21 days) and ‘serious’ (over 21 days or permanent damage). An example of an even more extensive definition that takes these considerations into account is the one proposed by the Council of Europe, in which a sports injury is defined as any injury as a result of participation in sport with one or more of the following consequences: (a) a reduction in the amount or level of sports activity; (b) a need for (medical) advice or treatment; and (c) adverse social or economic effects (van Vulpen 1989).

Even if one uniform definition of ‘sports injury’ is applied, the need remains for uniform agreement on other issues such as the way in which sports injury incidence is expressed, the ways in which reliable estimates are made of both the number of people engaging in sports and the number of injured sportspersons, etc.

1.2 Sports Injury Incidence

A common indication of disease in the population or a section of the population is incidence. If we substitute ‘sports injury or sports accident’ for ‘disease’, incidence can be defined as the number of new sports injuries or accidents during a particular period divided by the total number of sportspersons at the start of the period (= population at risk). Incidence also gives an estimate of risk. If we multiply the figure obtained by 100 we have the percentage rate (Sturmans 1984). Expressed in this way sports injury incidence provides a yardstick for the extent of the sports injury problem.

Incidence rate of sports injuries is usually defined as a number of new sports injuries during a particular period (e.g. 1 year) divided by the total number of sportspersons at the start of the period (population at risk). Here again, it should be realised that it is important when interpreting and comparing the various incidence rates to know which definition of ‘sports injury’ was used and how comparable were the samples.

Another problem lies in the way incidence rates are expressed. In some cases the number of injuries in a particular category of sportspersons per season or per year is taken, or the number of injuries per player per match. In both cases no allowance is made for any differences in exposure (the number of hours during which the person actually runs the risk of being injured), despite the fact that this factor certainly influences the risk of injury. Incidence figures that take no account of exposure are therefore, according to Kranenborg (1982), not a good indication of the true extent of the problem, nor can incidence rates for different sports be properly compared. It would be better to calculate the incidence of sports injuries in relation to exposure in days, hours or sports event. This would enable different sports and different sportspersons to be compared more fairly in this respect (Eriksson 1983; Kennedy et al. 1977; Wallace 1988; Zemper 1984).

For this purpose injury incidence is expressed by many researchers as the number of injuries per 1000 hours of sports participation (e.g. Backx et al. 1990; Ekstrand 1982; Lysholm & Wiklander 1987; van
Mechelen 1991). The equation of Chambers (1979) recently adapted by de Loës and Goldie (1988) can be used to calculate injury incidence taking exposure into account.

\[
\text{Injury incidence} = \frac{(\text{No. of sports injuries/year}) \times 10^4}{(\text{No. of participants}) \times (\text{hours of sports participation/week}) \times (\text{weeks of season/year})}
\]

De Loës and Goldie (1988) demonstrated very clearly that a league table of ‘injury sports’ based on the calculation of incidence without taking exposure into consideration differs from one that does correct incidence for exposure time. The importance of calculating incidence taking exposure time into account was also clearly demonstrated by van Galen and Diederiks (1990), who identified major differences in incidence per 1000 hours of sports participation depending on age, gender and sports. Lindenfeld et al. (1988) proposed that the definition of incidence of sports injuries should be further sharpened by using actual exposure time at risk, rather than overall time spent on sports participation. For reasons of practicality actual exposure time at risk is not very often used in research.

As can be seen from the above-mentioned injury incidence equation, not only the definition of sports injury will affect the outcome of the equation but also the definition of sports participation. One should be aware of differences between recreational and competitive sports, organised and nonorganised sports (van Galen & Diederiks 1990) and training and competition (van Mechelen et al. 1987), and one should decide whether to include or exclude some of these categories in the definition of sports participation.

1.3 Research Design

The extent to which sports injury incidence can be assessed depends on: the definition of sports injury; the way in which incidence is expressed; the method used to count injuries; the method to establish the population at risk; and the representativeness of the sample (Kranengborg 1982). Injuries can be counted retrospectively or prospectively, using questionnaires or person-to-person interviews. Prospective studies can, by quantifying exposure time, accurately estimate the risk and incidence of injury according to the level and type of exposure of an athlete, while retrospective studies can also identify some risk factors depending on choice of research design, e.g. case-control studies (Walter et al. 1985). Depending on the methods used the researcher will be confronted to a greater or lesser extent with phenomena such as recall bias, overestimation of the hours of sports participation (Klesges et al. 1990), incomplete response, nonresponse, invalid injury description, and problems related to the duration and cost of research. These aspects are not further discussed here in depth.

Despite these problems special attention has to be paid to the method of assessing the population at risk and to the representativeness of the sample. If the population at risk is not clearly identified it is not possible to calculate reliable incidence data. With regard to the representativeness of the sample it has to be taken into consideration that the performance of sports, and therefore the incidence of sports injuries, is highly determined by selection. Bol et al. (1991) recognised 4 kinds of selection (a) self-selection (personal preferences) and/or selection by social environment (parents, friends, school, etc.); (b) selection by sports environment (trainer, coach, etc.); (c) selection by sports organisations (organisation of competition by age and gender, the setting of participation standards, etc.); and (d) selection by social, medical and biological factors (socioeconomic background, mortality, age, aging, gender, etc.). For examples: within a certain sport competing at a high level increases sports injury incidence (Caine et al. 1989; Jørgensen 1988; Pettrone & Ricardelli 1987); in contrast to individual sports and team sports more injuries are sustained during matches than during training (Ekstrand & Nigg 1989; Fintelman et al. 1989); in contact sports more injuries are sustained than in noncontact sports (Chambers 1979; de Loës & Goldie 1988); during and shortly after the growth spurt boys sustain more injuries (Backous et al. 1988; Caine et al. 1989; Stanitski 1989).

Differences in injury incidence between various
specific types of sports are discussed below (see section 2.2).

The outcome of research on the extent of the sports injury problem is highly dependent on definitions of 'sports injury', 'sports injury incidence' and 'sports participation', and that allowance should be made for exposure time when calculating incidence. It should be borne in mind that the outcome of such research also depends on the applied research design and research methodology, as well as on the representativeness of the sample.

2. Sports Injury Data

2.1 Sports Injury Incidence: The Netherlands as an Example

Boersma-Sliitter et al. (1979) and Kranenborg (1980), using different methods, reach annual totals of 560,000 (medically treated) and 1.2 million (medically and nonmedically treated) injuries, respectively, corresponding to yearly rates of 20 and 46.5%. These figures are not directly comparable, since the 2 surveys differed, in particular with regard to sample, research method and definition of 'sports injury'. Obviously this affects the interpretation of the figures.

Rogmans and Weerman (1982) calculated in a survey of home and leisure time accidents that 21% of all accidents took place at sports and recreational locations; Verbeek et al. (1984) in a survey of the frequency of and background to sports injuries among schoolchildren, arrived at a rate of 10% a month; Inkaar (1985), using data from an ongoing survey of morbidity in the Netherlands, calculated an average rate of 2.4% over a period of 4 years.

Recently a representative nationwide telephone survey in the Netherlands revealed, in a total population of some 15 million, an overall sports injury incidence of 3.3 (95% confidence limits: 3.1 to 3.5) injuries per 1000 hours spent on sports; 1.4 injuries per 1000 hours spent on sports were medically treated (van Galen & Diederiks 1990). In this study an absolute number of 2.7 million sports injuries was calculated of which 1.7 million were medically treated. Major sports injury incidence differences per 1000 hours spent on sports were discerned with regard to age, sex, specific sport, recreational vs competitive sport and number of weekly hours spent on sports.

2.2 Other Comparisons

One way of indicating the relative extent of the sports injury problem is to compare the number of sports injuries with, for instance, the number of road accidents or accidents at work.

Through the Home Accidents Surveillance System (PORS), for instance, a total of 32,276 accidents were recorded by the casualty departments of the hospitals participating in the scheme during the second 6 months of 1983. Of these, 28.6% related to sport, 14.9% to leisure-time games, 0.7% to occupational activities and 9.1% to road accidents (Stichting Consument en Veiligheid 1985). Clearly, sport and games account for the majority.

Davies (1981) noted that more consultations took place at the casualty departments of Glasgow hospitals in 1979 for sports accidents than for road accidents. Williams (1975) estimated, without indicating how, that 5% of injuries treated at casualty departments in Great Britain related to sports accidents. Guyer and Ellers (1990) calculated the number of treatments of all unintentional childhood injuries (ages 0 to 19 years) in emergency wards of hospitals in 1985 in the US. Reasons for treatment were: 48.5% not specified, 23.0% falls, 16.3% sports and 7.1% traffic-related injuries.

In West Germany, Steinbrück and Cotta (1983) estimated that sports accidents made up 10 to 15% of total accidents and Von Schürmeyer et al. (1983), on the basis of data from other sources, gives the proportion of sports accidents among total inpatient and outpatient cases as 5 to 10%.

In a 1-year prospective study on acute sports injuries in a total population of a Swedish municipality with 31,620 inhabitants de Loës (1990) registered all emergency visits to the Public Health Care. 571 sports injuries were registered; they made up 17% of all acute injury visits, whereas acute home injuries, acute work injuries and acute traffic injuries made up 26, 19 and 7%, respectively (31%
not defined). In a similar study, Sandelin et al. (1987) estimated that in the adult population in Finland about 1.5 million acute medically treated injuries occurred in 1980. Work-related injuries made up 17%, sports injuries 14% and traffic injuries 12%.

However, these studies record only relatively serious accidents requiring medical attention and ignore chronic injuries and less serious accidents. In addition, reliable incidence rates can not be calculated from data of this kind, since there are no precise data on the population from which the injured are taken. Information on exposure time is also lacking and in many cases the sample is not representative (Walter et al. 1985).

A report by the Dutch Ministry of Health, Welfare and Cultural Affairs (WVC 1985) gives a ‘league table’ based on inpatient and outpatient treatment records. This expresses the risk of sports injuries in terms of the number of injuries per 100 practitioners of each sport. The highest risk is found in soccer (4.2%), the lowest in skating and table tennis (0.1%). Unfortunately no allowance is made for the fact that the amount of time spent on the various sports can differ, which in itself can affect the risk of receiving an injury. The orthopaedic clinic of the University of Heidelberg treated 8974 injuries to 8204 sportspersons from 1972 to 1981. Steinbrück and Cotta (1983) analysed these injuries, calculating a risk factor for each sport from the number of recorded injuries and the total number of organised sportspersons in the region concerned. Each sport had a different risk factor, but again no allowance was made for the different lengths of time spent on each sport. Van Galen and Diederiks (1990) made a similar ‘league table’ taking into account time spent on each sport, indoor soccer was ranked number 1 with 8.7 injuries per 1000 hours, basketball number 10 with 4.4 injuries per 1000 hours and swimming number 20 with 1.2 injuries per 1000 hours.

3. Severity of Sports Injuries

Severity can be described on the basis of 6 criteria:
- Nature of sports injury
- Duration and nature of treatment
- Sporting time lost
- Working time lost
- Permanent damage
- Cost

3.1 Nature of Sports Injuries

Lysens and Ostyn (1984) give the following categories of medical diagnosis: sprain (of joint capsule and ligaments), strain (of muscle or tendon), contusion (bruising), dislocation or subluxation, fracture (of bone), abrasion (graze), laceration (open wound), infection or inflammation, and concussion.

In order to scale the severity of sports injuries by medical diagnosis in some studies the AIS (Abbreviated Injury Scale) is used in which injuries are graded 1 to 6, where 6 is the code for the most severe, virtually unsurvivable, injury (de Loës & Goldie 1988).

It is the nature of the injury that determines whether assistance (medical or otherwise) is sought. It is known, for instance (Kranenborg 1981), that approximately 50% of injured korfball players seek medical assistance by consulting their GP, taking physiotherapy or attending a hospital casualty department. It is understandable that the other half does not consider medical treatment necessary since the most common injuries in indoor korfball are abrasions and other injuries not requiring medical treatment (van Geffen et al. 1990).


This is not true in every sport: fractures are the most common type of injury in horse-riding (Edixhoven et al. 1980; von Steinbrück 1980), hang-gliding (Penschuck 1980), parachute jumping (Stein-
berg 1988), roller skating (Horner & McCabe 1984; Jost et al. 1981; Kvidera & Frankel 1983) and skiing (Menke & Muller 1982). When assessing literature which takes diagnosis as the yardstick for the severity of injuries one needs to know where and by whom the injuries are examined. In the case of injuries treated at casualty departments there has already been a kind of preselection: these injuries are of a more serious kind. This could give the impression that sport produces only relatively serious, acute injuries. Overuse injuries (Kowal 1980; Orava et al. 1985) which have become much more common recently with the increasing popularity of recreational sports such as running and fitness training, are not included in casualty department records.

Recording of the nature of sports injuries enables the sports with relatively serious injuries to be identified. The need to prevent serious injuries in a particular sport need not coincide with a high overall incidence of injuries in that sport.

3.2 Duration and Nature of Treatment

Data on the duration and nature of treatment can be used to determine the severity of an injury more precisely, especially if it is a question of what medical bodies are involved in the treatment and what therapies used. The cost of medical treatment can be estimated (Tolpin et al. 1981), and the effectiveness of different therapies for similar injuries can be compared.

For example, in the municipality study of de Loës (1990) during 1 year, 571 acute injuries treated in Public Health Care Clinics were registered. Those 571 injuries led to a total of 989 visits to the Public Health Clinics, being 4% of all visits (including sports injury and nonsports injury visits). The average number of visits per sports injury was 1.9; fractures required 3.3 visits per injury, while wounds required only 1.1 visits per injury. Eight percent of the acutely injured sportspersons were hospitalised, with an average stay of 3.7 days per patient: 4.8 days per patient for fractures and 2.0 days per patient for contusions. In this study it was clear that the nature of a sports injury and the duration and nature of treatment are strongly related.

In a survey of 66,804 persons, any sports injury noted as such by the interviewed persons was taken down by van Galen and Diederiks (1990): 945 injuries were registered retrospectively over a 4-week recall period. With regard to these injuries first treatment following injury, subsequent emergency treatment and follow-up treatment were registered (table 1).

Average number of subsequent treatments per injury was also calculated: 4.9 for physiotherapy, 3.9 for sports first-aid attendant, 2.6 for medical specialist, 2.3 for first-aid ward and 1.8 for GP.

3.3 Sports Time Lost

It is important for a sportsperson to be able to take up his or her sport again as soon as possible after an injury. Sport and exercise play an essential part in people's free time and thus influence their mental well-being. The loss of sporting time is an important psychosocial factor (Tsongas 1981). The length of sporting time lost gives the most precise indication of the consequences of an injury to an individual.

Schlattmann et al. (1986) classify the seriousness of injuries in accordance with NAIRS, into 'minor' (1 to 7 days lost), 'moderately serious' (8 to 21 days) and 'serious' (over 21 days or permanent damage).

Sandelin et al. (1987) classified 71% of injuries as minor (absence from sport < 1 week), 20% as moderate (absence from sport 1 to 3 weeks) and 9% as severe, while de Loës and Goldie (1988) classified 20% as minor (absence from sport < 1 week), 50% as moderate (absence from sport 1 to 4 weeks) and 30% as severe.

Van Galen and Diederiks (1990) did not adopt the NAIRS classification of seriousness. They used the cessation or reduction of training as an indication of seriousness. In this study 56% of all medically treated injuries led to the cessation or reduction of training as did 40% of all nonmedically treated injuries. There appeared to be a strong relationship between sporting time lost and: (a) the
and Diederiks (1990) found that of 945 injured
was taken for 162 (29%) of those injuries, with an
average length of sick-leave of 21.5 days. Van Galen
recorded that compensated work-related sick leave
is not to exceed 1 week.

Injuries; 29% resulted in sick leave, of which 50% did
study, registered medically treated acute sports in­
 scheme. Sandelin et al. (1987), in a municipality
of sports injuries covered by a separate insurance
scheme. Many people, including students, old age pensioners, the disabled, the un­
employed, the self-employed, housewives and civil
servants, are excluded (Vermeer 1982). Data of this
kind can be used to compare the cost to society of
sports injuries with that of other situations involv­
ing risks, such as work and traffic (Kranenborg
1982). The comparison is of particular importance
to official bodies wanting to have the consequences
of sports injuries covered by a separate insurance
scheme. Sandelin et al. (1987), in a municipality
study, registered medically treated acute sports in­
juries; 29% resulted in sick leave, of which 50% did
not exceed 1 week.

In a 1-year municipality study de Loes (1990)
recorded that compensated work-related sick leave
was taken for 162 (29%) of those injuries, with an
average length of sick-leave of 21.5 days. Van Galen
and Diederiks (1990) found that of 945 injured
number of treatments; (b) injury site; and (c) medi­
cal diagnosis.

From these 3 population studies it can be con­
cluded that 50 to 60% of all sports injuries do not
lead to a substantial loss of sporting time.

3.4 Working Time Lost

Like the cost of medical treatment, the length
of working time lost gives an indication of the fi­
nancial consequences of sports injuries to society. If official statistics are used, e.g. data from the In­
dustrial Insurance Administration Office and In­
dustrial Insurance Boards, many people, including
students, old age pensioners, the disabled, the un­
employed, the self-employed, housewives and civil
servants, are excluded (Vermeer 1982). Data of this
kind can be used to compare the cost to society of
sports injuries with that of other situations involv­
ing risks, such as work and traffic (Kranenborg
1982). The comparison is of particular importance
to official bodies wanting to have the consequences
of sports injuries covered by a separate insurance
scheme. Sandelin et al. (1987), in a municipality
study, registered medically treated acute sports in­
juries; 29% resulted in sick leave, of which 50% did
not exceed 1 week.

In a 1-year municipality study de Loes (1990)
recorded that compensated work-related sick leave
was taken for 162 (29%) of those injuries, with an
average length of sick-leave of 21.5 days. Van Galen
and Diederiks (1990) found that of 945 injured
sportspersons 11% lost work time (average dura­
tion 8.8 days), 7% lost study time (average dura­
tion 5.6 days) and 3% lost other daily activity time
average duration 5.9 days).

However, sporting activities may reduce the
amount of sick leave taken by improving employ­
ees’ general physical and mental condition. A cost­
benefit analysis of the positive and negative effects
of sporting activities on loss of working time is
needed (Shephard 1985). According to Sörensen and
Sonne-Holm (1980), the adverse socioeconomic ef­
effects of sports injuries are negligible in comparison
with the positive effect of sporting activities. An
economic analysis of the effect of sports partici­
pation on working time (van Puffelen et al. 1989)
revealed a loss of working time as a result of sports
participation in the age groups 18 to 34 and 55+
years rather than a gain. Only in the 35- to 54-year­
old age group could a positive effect on working
time be found. Even in this study, however, the
overall effect on working time lost was calculated
to be negative.

3.5 Permanent Damage

The vast majority of sports injuries heal with­
out permanent disability. Serious injuries (accord­
ing to the NAIRS classification) such as fractures,
ligament, tendon and intra-articular injuries (Kent
1982), spinal injuries (Torg et al. 1979) and eye
injuries (Vinger 1981) can leave permanent dam­
age (residual symptoms). Excessive delay between

Table I. Percentage of patients receiving various forms of treatment for sports injuries (van Galen & Diederiks 1990)

<table>
<thead>
<tr>
<th>Treatment given by</th>
<th>First treatment following injury (n = 692)</th>
<th>Subsequent emergency treatment (n = 119)</th>
<th>Follow-up treatment (n = 263)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-treated</td>
<td>30</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>Sports first-aid attendant</td>
<td>24</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>General practitioner</td>
<td>29</td>
<td>26</td>
<td>12</td>
</tr>
<tr>
<td>Hospital first-aid ward</td>
<td>9</td>
<td>31</td>
<td>28</td>
</tr>
<tr>
<td>Physiotherapist</td>
<td>7</td>
<td>na</td>
<td>2</td>
</tr>
<tr>
<td>Medical specialist</td>
<td>0.4</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Sports masseur</td>
<td>15</td>
<td>6</td>
<td>12</td>
</tr>
</tbody>
</table>

Abbreviation: na = not applicable.
the occurrence of an injury and the medical assistance can aggravate the injury (Kent 1982). If the residual symptoms are slight, they may cause the individual to modify his or her level of sporting activity. In some cases, however, he or she may have to choose another sport or give up sport altogether. Serious physical damage can cause permanent disability or death (Dolmans 1985; Koplan 1970), thus reducing or eliminating the individual's capacity for work. When taking precautions, then, priority should be given to measures in sports where such injuries are common, even though the particular sport itself is characterised by a low incidence of sports injuries and/or a low absolute number of participants. The government could play a major part here (Ts ongas 1981). In a study by Sandelin et al. (1987) 11% of the patients complained of some late sequelae from their initial trauma 2 years after injury. In the majority of cases the initial trauma was a sprain type.

3.6 Costs of Sports Injuries

The calculation of the costs of sports injuries essentially involves the expression of the above-mentioned 5 categories of seriousness of sports injuries in economic terms. A general classification of the economic costs of sports injuries is set out by Tolpin et al. (1981). The economic costs are divided into:

1. Direct costs, i.e. the cost of medical treatment (diagnostic expenses such as x-rays, doctor's fee, cost of medicines, admission costs, etc.)
2. Indirect costs, i.e. expenditure incurred in connection with the loss of productivity due to increased morbidity and mortality levels (loss of working time and expertise due to death or handicap).

Social costs can be classified as quantifiable and unquantifiable. Quantifiable costs include insurance and legal expenses. Unquantifiable costs are the harmful effects of a sports injury on the psychosocial life of the individual or his family, e.g. owing to economic dependence, loss of social status or position or social isolation. These costs are quantifiable only to the extent that the quality of life is quantifiable (Miles 1979).

In the view of Tolpin et al. (1981) an adequate injury registration system is essential to any assessment of the total cost associated with sports injuries. The system must be reliable and continuous. Any cost analysis must identify the sports which are most 'expensive' for the community (Sørensen & Sonne-Holm 1980), so that the first interventions can be taken there.

The social consequences can to some extent be expressed in figures, and would seem to be of no small extent. Vermeer (1982), for instance, calculated that compulsorily insured persons alone lost 1073,000 working days as a result of sports injuries in 1979. This corresponds to sickness benefit paid out under the compulsory insurance scheme of over $US50 million. Vermeer explicitly notes that school children, students, civil servants, members of the armed forces, old age pensioners, widows and self-employed persons were not included in this calculation.

The direct and indirect costs in the Netherlands associated with medically treated sports injuries have been estimated to run up to $US225 million (Den Toom & Schuurman 1988).

Steinbriick and Cotta (1983) estimated the annual cost of sports injuries in West Germany at over $US2500 million. Matter et al. (1982) used insurance company data to estimate the direct and indirect cost of skiing accidents in Switzerland from 1978 to 1980 at $US12,900,000. Tolpin et al. (1981) calculated that some $US6 million were spent on medical treatment of eye injuries received in the course of sporting activities in the US in 1980. The total cost of roller skating accidents in the US has been estimated at $US100 million per annum (Kvidera & Frankel 1983). In the US many baseball and softball injuries are incurred in base sliding. The average medical cost per base sliding injury was estimated to be $US1223, and it was calculated that the installation of break-away bases across the US would save $US2 billion in medical costs per year (Janda et al. 1990). Guyer and Ellers (1990) estimated the total cost of hospital inpatient and emergency department treatment of children
(0 to 19 years) in the US in 1982 as a result of sports injuries was $US80.8 million of a total of $US7544.9 million, ranking third after traffic-related injuries $US2785.2 million and injuries as a result of a fall $US809.6 million. Davison and Ryan (1988) estimate the total cost of treatment by an outpatient sports injury clinic in the UK to be £89.25 per injury. De Loes (1990) calculated an overall mean of direct and indirect cost of $US335 per acute medically treated sports injury, identifying motorcycling, downhill skiing and equine sports as the most expensive sports, respectively $US618, $US400 and $US393.

It should be noted, however, that due to differences in healthcare systems and wage compensation systems international comparisons may be hampered. Even at a national level similar injuries may produce different costs in different states, as demonstrated by Pritchett (1980) with regard to the cost of high school football injuries in the 6 western states of the US.

Van Puffelen et al. (1989) calculated that sports participation resulted in an overall positive balance of 155 million Dutch guilders per annum for The Netherlands. However, a closer look at the 4 subcategories of costs analysed presented a diverse picture; there was a 23.3 million guilders positive balance with regard to GP consultation, a 22.1 million guilders negative balance as a result of the consultation of medical specialists, a 286.1 million guilders positive balance for inpatient treatment and a 130.2 million guilders negative balance due to working time lost.

In a review on ‘the economics of fitness and sport with particular reference to worksite programmes’ which was not specifically aimed at the description of the costs of sports injuries but at an overall cost-benefit analysis of fitness and sports Shephard (1989) concluded that, worksite exercise and fitness programmes ‘appear to be both cost effective and cost beneficial’ and that ‘a return in the range of $US2 to $US5 for every dollar invested with a total package of health promotion is achievable’. It should be noted, however, that competitive sports, in which most injuries are sustained, are different from health promotional exercise and fitness programmes.

4. Aetiology and Prevention of Sports Injuries

Risk factors can be divided into 2 main categories (Backx et al. 1990; Medved et al. 1973; Miles 1979; Rozendal et al. 1979; Schlatmann et al. 1986; Segesser 1983; van Enst 1982; van Vulpen 1989).

The first category comprises the internal personal factors, the second the external, environmental factors. Data from the literature (van Mechelen et al. 1987) enable the factors to be classified into these 2 types, internal and external (table II).

This division is based on partly proven, partly supposed causal relationships between the risk factors and the injury. However, it may well be that

<table>
<thead>
<tr>
<th>Internal factors</th>
<th>External factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical defect</td>
<td>Sports-related factors</td>
</tr>
<tr>
<td>Physical fitness</td>
<td>type of sport</td>
</tr>
<tr>
<td>aerobic endurance</td>
<td>exposure</td>
</tr>
<tr>
<td>strength</td>
<td>nature of event</td>
</tr>
<tr>
<td>speed</td>
<td>role of opponents</td>
</tr>
<tr>
<td>sporting skill/</td>
<td>and team mates</td>
</tr>
<tr>
<td>coordination</td>
<td></td>
</tr>
<tr>
<td>flexibility of muscles</td>
<td>state of floor or ground</td>
</tr>
<tr>
<td>Previous injury</td>
<td>lighting</td>
</tr>
<tr>
<td>Psychological factors</td>
<td>safety measures</td>
</tr>
<tr>
<td>self-concept</td>
<td>Equipment</td>
</tr>
<tr>
<td>risk acceptance</td>
<td>tools, e.g. stick or racket</td>
</tr>
<tr>
<td>type A and type C</td>
<td>risk acceptance</td>
</tr>
<tr>
<td>personality</td>
<td>protective equipment</td>
</tr>
<tr>
<td>locus of control</td>
<td>other equipment (shoes, clothing etc.)</td>
</tr>
<tr>
<td>Physical build</td>
<td>Weather conditions</td>
</tr>
<tr>
<td>height</td>
<td>temperature</td>
</tr>
<tr>
<td>weight</td>
<td>relative humidity</td>
</tr>
<tr>
<td>joint stability</td>
<td>wind</td>
</tr>
<tr>
<td>body fat</td>
<td>Trainer</td>
</tr>
<tr>
<td>Age</td>
<td>conduct of match rules</td>
</tr>
<tr>
<td>Sex</td>
<td>referee’s application of rules</td>
</tr>
</tbody>
</table>
both risk factor and injury are dependent on the same third factor in different ways (fig. 2; Last 1988). Thus, lowering the factor 'F' reduces the risk of injury in figure 2a but not in figure 2b.

The classification into internal and external factors can be approached on the basis of the stress/capacity model, which was used in its classical form in The Netherlands in the field of social and preventative medicine to describe the interaction between humans and their environment (Ettema 1973). It can also be applied in sports medicine, especially to the prevention of injuries. In this model the stress is determined by the sportsperson's environment, i.e. external factors. His or her capacity is determined by the state of the internal, personal factors. Stress and capacity must be in balance (Segesser 1983); preventative measures must therefore be designed to achieve or maintain this balance, either by raising the capacity or reducing the stress or both. As the sportsman's capacity increases, proneness to injuries decreases. In practice this was seen mainly as a question of improving physical fitness. It is known that fatigue reduces movement coordination, thus increasing the risk of injury. The incidence of injuries is higher than 'average' in the preseason (Ekstrand 1982) and during lengthy tournaments (Kersey & Rowan 1983), perhaps owing to insufficient aerobic endurance resulting in fatigue setting in sooner. Poor technique and lack of experience can also influence capacity. Inexperienced squash players, for instance, cause more injuries than experienced ones both to themselves and to others (Pflöringer & Keyl 1978).

According to the stress/capacity model, stress can be reduced by changing the external, environmental factors. For instance, the introduction of eye guards in squash reduced eye injury (Easterbrook 1982), the use of high top basketball shoes in combination with taping reduced the incidence of ankle sprains in basketball (Garrick & Requa 1973) and the introduction of mouthguards in field-hockey reduced dental injuries (Bolhuis 1987).

Merely to establish the causes of sports injuries, i.e. the internal and external factors, is not enough; the mechanism by which they occur must also be identified. Athletes are in constant interaction with their environment, and the risk factors must be approached from this angle. Miles (1977) formulated a 'sports injury equation', according to which the occurrence of sports injuries is determined by 'luck, environment, attitude to risks, individual susceptibility to injuries, training factors, safety precautions, personal factors, etc.'.

It is now becoming clear that sports injuries result from a complex interaction of identifiable risk factors, of which only a fraction seem to be identified (Lysens et al. 1984). The knowledge of risk factors relevant for all sports or groups of sports seems to be limited.

It should be stressed that the area of intrinsic risk factors is highly conjectural and that many plausible hypotheses lack substantiating evidence at the present (Lorentzen 1988). In a report by the Council of Europe (van Vulpen 1989) it was concluded that most of the epidemiological studies have concentrated on internal and external risk factors from a medical, rather monocausal, point of view and that little is known about the psychological and behavioural aspects of the occurrence of sports injuries. Taerck's (1977) statement that 'the multifaceted problem of what causes athletic injuries has only rarely been studied from a psycho-social point of view' still holds in 1991. Crossman (1985) remarked that 'further in depth research investigating the psycho-social factors influencing the incidence of injury is needed . . . .'

One of the few studies on psychosocial risk factors was performed by Lysens et al. (1986), who found a relationship between psychosocial factors,
such as high level of life change and stress coping, and the occurrence of sports injuries. In a review by Kelley (1990) of psychological risk factors and sports injuries 11 psychological risk factors are mentioned including high levels of positive or negative life change; high levels of type A behaviour (people who are often seen as aggressive, hard-driving, ruled by the clock and obsessed with accomplishing more than time will allow) and type C behaviour (people who are classified as dependent, sweet, passive, gentle and nice, but also resentful, unforgiving, worried, anxious, bored, frustrated and apathetic); high levels of trait anxiety, poor reaction and movement times due to poor attentional focus; high or low tolerance of pain; high levels of extraverted or introverted behaviour; behaviour associated with insecurity, overprotection and dependency; behaviour which reflects that the athlete feels little control over the athletic situation; behaviour which reflects poor self-concept and poor self-esteem; experience of conflict between passivity and aggression; and high levels of depression. The research of Lysens et al. (1986) and the above-mentioned shift in approach towards the psychosocial aspects of the occurrence of sports injuries draws attention to the fact that the injury risk is primarily dependent on the interaction between athletes and their personal characteristics, either physical or psychological, and the sports environment. This requires a more dynamic model (modified after Backx et al. 1990; Bol et al. 1991; Kok & Bouter 1990), as presented in figure 3, on the interrelation between the various risk factors and the occurrence of a sports injury and subsequent preventative measures, rather than the scale-balance approach of the classical stress/capacity model.

This model focuses on ‘sports behaviour’ which may lead to an injury. Risk factors, such as those relating to the athlete, the sports environment, personal equipment and load are seen as external variables, all (causally) involved in the activity and possibly leading to an injury. When such behaviour is identified with acceptable certainty the determinants of behaviour must be clarified (Kok & Bouter 1990).

Three factors are distinguished as determinants of behaviour: (a) attitude; (b) social influence; and (c) self-efficacy-cum-barriers. Kok and Bouter (1990) describe these determinants as follows:

1. ‘Attitude refers to the knowledge and beliefs of a person concerning the specific consequences of a certain form of behaviour. An attitude is the weighing of all consequences of the performance of the behaviour, as seen by the individual. Health is only seen as one of the considerations, and is often an unimportant one. When health is part of attitude one may suppose that healthy motivation is a combination of the perceived severity of the health risk, the perceived susceptibility to the health risk, and the effectiveness of the preventive behaviour.’

2. ‘Social influence is the influence by others; directly by what others expect, indirectly by what others do (modeling).’ ‘Social influence is often underestimated as a determinant of behaviour. It can lead to behaviour that conflicts with previous attitudes. Most sports situations are social situations.’

3. ‘Self-efficacy-cum-barriers stands for the determinant whether one is able to perform the (desired) behaviour. It involves an estimation of ability, taking into account possible internal (e.g. insufficient skill, knowledge, endurance) or external barriers (e.g. resistance from others, time and money not available, etc.). Self-efficacy is the people’s perception of their ability to perform the behaviour, and barriers are the real problems they face in actually performing the behaviour.’

Whether or not an injury results from sports behaviour largely depends on the extent to which ‘prevention’ is incorporated in the determinants of behaviour.

Regardless of whether the aetiology and prevention of sports injuries are approached from a balance-scale or behaviour-oriented, more complex perspective at least 1 problem remains. Neither approach adequately accounts for the aetiology of overuse injuries, which constitute about 10% of all sports injuries (van Galen & Diederiks 1990). Overuse injuries develop over long periods and are
difficult to diagnose and to treat (Peterson & Renström 1986). The abovementioned models do not incorporate a time perspective.

For this reason a third approach (fig. 4) based on a recent update of the stress/capacity model, as applied in the field of occupational medicine, will be discussed (van Dijk et al. 1990). This model takes into account the effects of training and overload over an extended period and behavioural aspects. It can therefore be useful in describing the aetiology of acute injuries, as well as overuse injuries.

The ‘stress-strain-capacity model’ is a time-based 3-phase sequential model. In this model stress and capacity are regarded as dynamic values in contrast to the classical stress/capacity balance scale model in which stress and capacity were seen as more or less static entities.

In the stress-strain-capacity model ‘stress’ is defined as external load, i.e. all external environmental factors affecting sports activity. ‘Strain’ is defined as all processes by which responses in the body are evoked as the result of stress and personal control. ‘Personal control’ is defined as the ability
of a sportsperson to actively influence the amount of stress which is imposed on him or her by this activity. Notable indicators of the acute effects and short term after-effects of strain are sweating, fatigue, diminished reaction speed and blood lactate accumulation. Short term after-effects can be arbitrarily defined as effects which do not persist to the beginning of the next occasion of stress (= the next period of activity). ‘Capacity’ is the sum of all intrinsic factors that allows an athlete to perform in sports at a certain moment. In this model capacity is determined by physical factors, skills and psychological/behavioural factors; knowledge, motivation and attitude. Capacity includes stable factors such as age, sex, etc., but also factors that can be influenced by the sports activity itself, e.g. fatigue at the end of a sports activity influencing coordination. Furthermore, capacity may be altered by a sportsperson by actively mastering the activity, Smith et al. (1990), in a literature review, discusses various psychological coping techniques as a mean of secondary injury prevention, i.e. for actively dealing with emotional distress experienced by injured athletes, thereby facilitating the process of rehabilitation.

Finally, long term and permanent after-effects are, again arbitrarily, defined as all nonacute after-effects, positive or negative, that are still present at the onset of the next occasion of stress (sports activity); ‘long term’ refers to the reversible effects and ‘permanent’ to irreversible effects. Examples of positive effects are improved level of performance, enhanced feeling of well-being and improved self-efficacy. Negative effects include muscle soreness, mood disturbance and lowered self-esteem. Incomplete recovery plays an important role at least with regard to the physical negative long term and permanent effects.

In contrast to the classical stress/capacity model, in the stress-strain-capacity model a sportsperson is no longer seen as the passive recipient of stress, but as the active manipulator of stress, by which the amount of strain can be altered by the sportsperson throughout the activity, thereby actively influencing the effects of that activity.

In this stress-strain-capacity model acute sports injuries can be regarded as an acute strain effect and overuse injuries as a long term nonacute strain effect. In both types of injury strain has gone beyond the limits of individual capacity in such a way that the sportsperson: (a) has to reduce the amount or level of sports activity; and/or (b) needs (medical) advice or treatment; and/or (c) experiences adverse social or economic effects. Acute injuries are marked by acute tissue damage, usually as a result of a single trauma. Overuse injuries are a result of repetitive, more or less identical, movements, predominantly restricted to the muscle, the tendon or the joint. A lack of complete tissue recovery plays an important role in the origin of overuse injuries.

In the stress-strain-capacity model a sports injury is the result of a complex interaction of various factors. When introducing specific preventative measures one should ask what specific factors (physical, psychological, behavioural) determine what specific injury in what specific sports activity over what course of time? Only if these questions

---

**Fig. 4. Stress/strain/capacity model (modified from van Dijk et al. 1990).**
are answered are all aetiological factors taken into consideration and effective prevention is possible.

Despite the importance of the model of choice in studying the risk factors of sports injuries, the choice of research design is also important. Case series usually give no information on the underlying population at risk, so they are of no value in drawing valid conclusions on the risk factors of injuries. Only by relating the injuries to corresponding population denominators one can estimate injury rates and identify important risk factors and high risk sportspersons (Walter et al. 1985). As in research on sports injury incidence, research on risk factors should be undertaken on groups homogeneous with regard to age, sex, level of competition and type of sport (Bol et al. 1991).

4.1 Sport-Specificity of Sports Injuries

Many sports injuries are highly sports specific which is in accordance with the various aetiological models. The locations and types of injuries found in the studies of particular sports clearly show that the type of sport determines both in many cases. Different injuries occur in wrestling (Snook 1980, 1982) than in soccer (Ekstrand 1982; Kristiansen 1983; Maehlum 1984; ), running (Jacobs et al. 1986; Kaplan et al. 1982; Macera et al. 1989; Marti et al. 1988; Walter et al. 1989), squash (Eastbrook 1982; Pförringer & Keyl 1978) or tennis (Kulund et al. 1979). Nomenclature such as ‘tennis elbow’, ‘golfer’s elbow’ and ‘jumper’s knee’ suggest that particular injuries are sport-specific (Travers 1980), and consequently that precautions against injuries should be sport-specific. On the other hand, sports where similar injuries occur could be grouped together, and similar measures could be taken for these groups.

5. Conclusions

Incidence and severity provide a yardstick for the first step of prevention of sports injuries. However, in order to get reliable and comparable data, uniform definitions and adequate research designs and methodology are needed. Various internal and external risk factors for sports injuries have to be identified. It should be kept in mind, however, that sports injuries may have several causes, including the behaviour of the sportsperson, and that many injuries evolve over time. Conceptual models of the aetiology of sports injuries should therefore take behaviour into account and should be time-based. The stress-strain-capacity model as presented is an example of such a model.

Acknowledgement

This study was partly supported with a research grant of the Dutch Ministry of Welfare, Health and Cultural Affairs as a contribution to the Council of Europe research project ‘Sport for All: Sports Injuries and Their Prevention’.

References

Bolhuis JHA, Tandletsel in de hockeysport. Thesis, University of Utrecht, 1987
Brandt Cortstius JJ. Het voorkomen van sportblessures – preventie is meer dan vaststellen van incidentie. Masters thesis, Inter Faculteit der Lichamelijke Opvoeding, Amsterdam, 1983
van Dijk FJH, van Dommelen M, Kompier MAJ, Meijman TF. Herwaardering model belasting-belastbaarheid 68: 3-10, 1990