REVIEW

Tennis injuries: occurrence, aetiology, and prevention

B M Pluim, J B Staal, G E Windler, N Jayanthi

Br J Sports Med 2006;**40**:415–423. doi: 10.1136/bjsm.2005.023184

A systematic search of published reports was carried out in three electronic databases from 1966 on to identify relevant articles relating to tennis injuries. There were 39 case reports, 49 laboratory studies, 28 descriptive epidemiological studies, and three analytical epidemiological studies. The principal findings of the review were: first, there is a great variation in the reported incidence of tennis injuries; second, most injuries occur in the lower extremities, followed by the upper extremities and then the trunk; third, there have been very few longitudinal cohort studies that investigated the association between risk factors and the occurrence of tennis injuries (odds ratios, risk ratios, hazard ratios); and fourth, there were no randomised controlled trials investigating injury prevention measures in tennis. More methodologically sound studies are needed for a better understanding of risk factors, in order to design useful strategies to prevent tennis injuries.

See end of article for authors' affiliations

Correspondence to: Dr Babette M Pluim, Royal Netherlands Lawn Tennis Association, PO Box 1617, 3800 BP Amersfoort, Netherlands; bpluim@euronet.nl

Accepted 22 January 2006

Tennis is a global sport, with participation in more than 200 countries affiliated with the International Tennis Federation.[1] It is also a professional sport in which millions of dollars in prize money are at stake for both men and women players. In the Netherlands, it is the second most popular sport, with more than one million participants from a population of 16 million.[2] Among Dutch women it is actually the most popular sport.[3] In other European countries tennis also ranks high on the list of popular sports.[3]

Like many other sports, playing tennis—at either a recreational, collegiate, or professional level—places participants at risk of injury. Though many injuries that occur in tennis are common to other sports, tennis does have a unique profile of injuries.[4] Differences in equipment, biomechanics, and physical demands result in an injury profile that differs from other racquets and throwing sports.[4] Sports injuries, including tennis injuries, are a common cause of disability and, in some cases, absence from work.[5–7] This can have substantial socioeconomic consequences, both on a personal and a societal level.[8] For these reasons it is important to develop effective measures for the prevention of tennis injuries.

To develop prevention strategies, both the incidence and severity of tennis injuries must be determined. The severity of an injury can be described on the basis of the nature of the injury, the duration and nature of treatment, time lost from sports participation or work, permanent disability, and cost.[9] Another important step is to determine risk factors and other mechanisms that are associated with these injuries.[9 10] This aetiological research entails understanding the causes of injury, with the goal that modification or removal of these causes can prevent the occurrence of the injuries.[10] The next step consists of the formulation of preventive measures.[10] These measures must be evaluated with regard to their effectiveness before implementation. Ideally, evaluation should include randomised controlled trials.[10–12]

Our aim in this review of published reports was to provide an overview of the available scientific knowledge on the occurrence, aetiology, and possibilities for prevention of tennis injuries. We asked the following three questions. First, what are the most common tennis injuries, based upon the reported prevalence and incidence figures? Second, what associated risk factors and mechanisms are described with regard to the aetiology of tennis injuries? And third, what is known about the efficacy of prevention efforts designed to reduce the occurrence of tennis injuries?

Another purpose of this review was to identify gaps in knowledge with respect to the occurrence, aetiology, and prevention of tennis injuries and to encourage further methodologically sound epidemiological research in this field.

METHODS

We undertook a literature search to retrieve potentially relevant articles published since 1966. The following electronic databases were explored: Pubmed (from 1966 to October 2005), Embase (from 1989 to October 2005), and Cumulative Index to Nursing and Allied Health Literature (CINAHL) (from 1982 to October 2005). A priori defined search terms (Medical subject heading (Mesh) and text words) that were used in this search were: ''injury'', ''injuries'', ''prevalence'', ''incidence'', ''incidence density'', ''proportion'', ''distribution'', ''population'', ''aetiology'', ''etiology'', ''mechanism'', ''risk factor'', ''risk factors'', ''prevention'' and ''intervention''. These terms were combined with ''tennis''. Reading titles and abstracts identified potentially relevant articles. Citation tracking of the articles retrieved was also performed to identify additional relevant articles.

To be included in this review studies had to meet the following inclusion criteria: they must contain data on tennis injuries; they must investigate the frequency of tennis injuries, the aetiology (for example, risk factors) of tennis injuries, the efficacy of prevention strategies, or a

combination of these purposes; and they must have been published in English, German, or Dutch. Studies focusing on treatment for tennis injuries and literature reviews were excluded. For the purpose of this review we defined a tennis injury as a musculoskeletal problem requiring reduction or interruption of tennis activity for any length of time, with or without evaluation or treatment by a health care provider.[13]

We did not expect to find many cohort or randomised controlled studies in this field. Furthermore, with the expected heterogeneity in study designs and methods, we elected not to follow a formal meta-analytic approach. The studies retrieved were classified as case reports, laboratory studies, descriptive epidemiological studies, analytic epidemiological studies, or intervention/prevention trials. A similar approach was conducted earlier by Pollack *et al*[14 15] with regard to the available evidence for the prevention of softball injuries. For reasons of clarity we defined descriptive epidemiological studies a priori as cohort studies (either cross sectional or longitudinal), describing the frequency (that is, prevalence or incidence or both) of tennis injuries in a cohort or subcohort. Analytic epidemiological studies were defined as cohort studies (either cross sectional or longitudinal) which aimed to estimate a measure of association (that is, odds ratio, risk ratio, hazard ratio) between risk factors and the occurrence of tennis injuries. The results of the selected studies will be described and summarised to formulate answers to the research questions posed above. The emphasis lies on the results of descriptive and analytic epidemiological studies, and intervention/prevention studies rather than laboratory studies or case series and reports.

RESULTS

Our search in the Pubmed, Embase, and Cinahl databases resulted in, respectively, 1368, 1617, and 2460 potentially relevant hits. To identify appropriate papers for the present review, the titles and abstracts were read and, if considered relevant, selected by two persons (BMP and JBS). In cases of disagreement further discussion was undertaken to achieve consensus. We found 39 case reports, 49 laboratory studies, 28 descriptive epidemiological studies, three analytic epidemiological studies, and no intervention study which met the inclusion criteria of the present review. Table 1 provides an overview of the distribution of study type and body region within the relevant articles.

Case reports

Of the 39 case reports, 29 dealt with injuries of the upper extremity,[16–44] eight with injuries of the lower extremity,[45–52] and two with the trunk.[53 54] Of the case reports, the most common condition in the upper extremity injury section was stress fractures (14 case reports).[16–29] Stress fractures in the upper extremity included the metacarpals, hamate bone, radius, ulna, and humerus. The suggested causal mechanism involved repeated loading on the upper extremity during the tennis stroke,[27 28] and included the impact of the racket butt against the palm of the hand,[16–18] and high torsional stresses.[25 27 28]

Vascular injury in the upper extremity was mentioned four times.[32–35] Though an uncommon injury, it has also been reported in overhead batting and racquet sports. Vascular injury may result from compression of the large vessels in the axilla during the service motion, resulting in aneurysm formation.[35] Distal embolisation may occur.[34] Endothelial injury caused by repeated microtrauma to the hand by the racket was also reported.[32 33]

Regarding the lower extremity, injuries were more equally distributed and included case reports on tendon injuries,[46 48] plantar fascia tears,[49 52] muscles tears,[45] stress fractures,[47 50] and intra-articular knee injury.[51]

Laboratory studies

Forty nine laboratory studies were identified: 36 involved the upper extremity,[55–90] six the lower extremity,[91–96] three the trunk,[97–99] and four the whole body.[100–103] In the upper extremity articles, the following topics were discussed most often: range of motion (seven studies)[55 58 61–65] and strength (nine studies)[55–60 62 65 66] of the shoulder, and biomechanical analysis of the stroke (six studies).[69–71 74 75 77]

In the studies examining range of motion of the shoulder, internal and external rotation was measured using a goniometer. In six[58 61–65] of seven studies[55 58 61–65], a significant decrease of internal rotation and total range of motion was demonstrated in the dominant arm. Kibler *et al*[64] showed that the loss of total range of motion was progressive with age and years of tournament play.

Muscular strength of the shoulder was determined by isokinetic testing. Five[58–60 62 65] of seven studies[55 56 58–60 62 65] showed an imbalance of muscle strength, with significantly greater isokinetic strength in the dominant arm than in the non-dominant arm for internal rotation, leading to a reduced external/internal rotation ratio. Both the loss of internal rotation motion and the muscle strength imbalance were hypothesised to increase the risk of shoulder injuries.

In three[91 95 96] of the six articles[91–96] focusing on the lower extremity, the interaction between shoe and court surface was examined. The main conclusion of these studies was that lateral stability of the shoe is important in the prevention of injuries.

Descriptive epidemiological studies

Twenty eight descriptive epidemiological studies were identified, including 19 on tennis injuries in general,[104–124] seven on injuries of the upper extremity,[125–132] one on the lower extremity,[133] and one on the trunk.[134]

Injury incidence

Injury incidence varied from 0.05[122–124] to 2.9[119] injuries per player per year (table 2). Per hour of play, the reported incidence varied from 0.04 injuries/1000 hours[108] to 3.0 injuries/1000 hours.[105] Incidence and prevalence rates for tennis elbow were quite high, with reported incidence varying from 9%[128] to 35%[130] and prevalence varying from 14%[128] to 41%.[131 132]

Table 1 Distribution of identified studies by type of study and body region

	Case studies	Laboratory	Descriptive epidemiological	Analytical epidemiological	Intervention and prevention
General	0	4	19	1	0
Upper extremity	29	36	7	0	0
Lower extremity	8	6	1	1	0
Trunk	2	3	1	1	0
Total	39	49	28	3	0

Table 2 Characteristics and results of included descriptive epidemiological studies

Study*	Study design	Study population	Injury definition	General incidence	Upper ext (%)	Lower ext (%)	Trunk/ head (%)	Type of injury reported	Severity
Vriend[104]	Cross sectional study: telephone interviews, with recall period of 3 m (2000–2004)	General population: in each of the 5 y, 10 000 people were interviewed, of whom ~50% were sports participants	All acute and chronic injuries or ailments that developed as a result of or during sports participation in the past 3 m	1.1/1000 h: O/D 0.9/1000 h; I/D 1.6/1000 h	29.1	53.6	10.2 (not defined 3.7)	NR	52% required medical treatment (O/D 49%, I/D 59%, NS)
Jayanthi[105]	Cross sectional, questionnaire; recall period 1 y	140 M, 388 F recreational league players (International Tennis Number 3 to 8); mean age 46.9 y	Any injury or pain the player had experienced in the past 12 m preventing play for ⩾7 d	3.0 inj/1000 h; prevalence 52.9 inj/100 players	41	49	3	Overuse injuries predominated, most in upper extremity	NR
Kühne[106]	Prospective study, follow up 6 months	60 competitive, 50 recreational players; C range 16–35 y, mean 25; R range 40–68 y, mean 53	The injuries and problems that the player experienced during the tennis season	1.5 inj/player/y	25	64	11	Cramps, strains, and sprains were most common	3.3% of acute and 2.2% of chronic injuries were eventually operated
Da Silva[107]	Prospective study with 1 y follow up; all medical treatments required during tournament	Elite junior players, participating in the national circuit in Brazil in the <12, <14, <16, and <18 age categories	Any consultation and/or treatment given to a player during a tournament on site	6.9 medical treatment/ 1000 games played	NR	NR	NR	Cramps (muscle contracture) were most common	NR
LIS 1999–2003[108]	Prospective study of injuries treated at the first aid department of 15 selected hospitals in Netherlands	General population; 7700 tennis players	Injuries requiring treatment at the first aid department of the hospital	0.04 inj/1000 h	28	59	13	Acute, more severe type of injuries; sprains most common (59%)	Costs per injury €830; 5% hospitalised for an average of 5 d
Schmikli[109]	Cross sectional study: telephone interviews; recall periods 1 month (1986–87), 1 month (1992–93), and 3 months (1997–98)	General population, 1982–83; 67 139 persons, of whom 31 688 played sports	Injuries or ailments newly developed as a result of or during sports participation in the past 4 wk (3 m); chronic injuries not recorded	1986–87: I/D 1.8/ 1000 h; O/D 1.2/ 1000 h; 1992–93: I/D 2.9/1000 h; O/D 1.2/1000 h; 1997–98: I/D 1.0/ 1000 h; O/D 0.5/ 1000 h	NR	NR	NR	NR	Medical treatment required: O/D, 27%, 34%, and 39% of injuries; I/D, 57%, 60%, and 66%
Sallis[110]	Retrospective cohort study of injury reports compiled by athletic trainers with a 15 y follow up period	College players; range 18–22 y; 3767 participants, divided over sports, including tennis	Medical problem as a result of sport participation requiring visit to training room	0.456 M; 0.425 F per player/y	23.1 M; 21.9 F	62.2 M; 70.7 F	14.6 M; 7.2 F	NR	No ACL injuries, otherwise NR
Steinbrück[111]	Prospective longitudinal study with 25 y follow up; visits to sports orthopaedic and trauma OPD	General population; 1257 M and 858 F tennis players	Not defined: any medical problem that required a visit to the sports medicine clinic was registered as an injury	NR	21	60	19	Knee 25%; ankle 23%	NR
Weijermans[112]	Prospective cohort study of 46 tennis clubs; follow up 6 months (O/D tennis season); injuries reported to contact person	179 club players	Tennis related problem resulting in loss of practice or match time, need for medical consultation, or negative social/ economic consequences (absence from school/work)	0.11/1000 h	NR	67	NR	Mostly acute injuries; tennis leg and sprained ankle most common	For the 5 most common injuries, 60% needed medical consultation, and 20% absence from school/work

Table 2 (*Continued*)

Study*	Study design	Study population	Injury definition	General incidence	Upper ext (%)	Lower ext (%)	Trunk/ head (%)	Type of injury reported	Severity
Hutchinson[113]	Prospective cohort study, with follow up of 6 y	1440 male participants at the USTA National Boys Championships 1986–1988; 1990–1992	Any medical problem requiring physical or medical assistance	21.5/1000 athletic exposures; 9.9/100 players	26	51	22	Sprains 58%	One athlete transported to hospital for heat exhaustion
Baxter-Jones[114]	Prospective cohort study	156 elite players in five 2-y age groups from 8–16 y	Any injury resulting in discontinuation of training and/or medical treatment	0.52 inj/player/y	NR	NR	NR	Osteochondrosis 26%	Acute injuries 13 d lay-off time; chronic injuries 20 d
Lanese[115]	Prospective cohort study	12 M, 11 F college players, 18–22 y	Traumatic medical problem due to sports participation resulting in time loss from practice or competition	1.6 inj/1000 h (M); 1.0 inj/1000 h (F), p=0.37	NR	NR	NR	NR	2.42 (0.57) disability d per 100 person h
Winge[116]	Prospective study, follow up 6 months (O/D tennis season)	Elite players: 61 M, mean age 28 y; 28 F, mean age 22 y	Every problem that appeared in connection with tennis, handicapped the player during play, and/or required special treatment	0.52 inj/player/season; 2.3 inj/1000 h (M 2.7, F 1.1)	45.7	39	11	Shoulder injuries 17%	Mean injury period 44.5 d; absence from work practically 0
Krause[117]	Cross sectional	78 M + 49 elite players, age range 15–46 y	NR	0.7 inj/player/y	36.4	44.3	19.3	Shoulder, back, and ankle 85%	NR
Chard[118]	Longitudinal study, 8 y follow up; visits to sports medicine clinic	78 M + 53 recreational players, age range 8–66 y	Medical problem related to tennis that required a visit to the sports injury clinic (self referral for acute injuries; referral by GP for chronic injuries)	NR	35	45	20	PF problems 44%; acute injuries 70%, chronic injuries 30%	NR
Reece[119]	Retrospective cohort study: injuries requiring attention of medical officer or physiotherapist	24 M + 21 F elite players at Australian Institute of Sport, aged 16–20 y, mean 17.6	Any injury that required attention from the medical officer or physiotherapist	2.5 inj player/y (M); 2.9 inj/player/y (F)	20	59	21	Ankle sprain most common, followed by calf and quadriceps strain	2 conditions required surgical intervention
Von Salis-Soglio[120]	Cross sectional study: interview and medical examination	15 elite M players, 1–15 in German National ranking; mean age 28 y; range 15–43	NR	NR	NR	NR	NR	Shoulder and elbow problems (tennis elbow) most common	Small risk for long term problems
Von Krämer[121]	Retrospective study, follow up 17.5 y	100 M and 26 F recreational players, mean age 43 y	Complaints and diseases which resulted from playing tennis	NR	47.5	31.1	16.6	Tennis elbow 39%; Achilles tendon 15%)	NR
Biener[122–124]	Cross sectional	203 M, 72 F high level competitive players; mean age 28 y	NR	0.05 inj/player/y	48.6	43.4%	2/6	Tennis elbow 36%; sprains 21%; strains 14%	NR

*First author and reference number.
ACL, anterior cruciate ligament; ; d, days; ext, extremity; F, female; I/D, indoor; inj, injury; h, hours; m, months; M, male; NR, not reported; O/D, outdoor; OPD, outpatient department; PF, patellofemoral joint; wk, weeks; y, years.

Table 3 Characteristics and results of included analytic epidemiological studies

Study*	Study design	Study population	Risk factors	Outcomes	Adjustment for confounders	Results
Llana[137]	Cross sectional study	A sample of 146 tennis players in Spain selected from a sample of 4000 who had completed a questionnaire on ''discomfort'' associated with tennis shoes	Perceived design errors	Discomfort	No	Significant correlation (p = 0.02) between incorrect arch support and plantar discomfort
Spector[135]	Retrospective cohort study	81 female ex-elite athletes (67 middle and long distance runners, and 14 tennis players), aged 40–65, recruited from original playing records, and 977 age matched female controls from London UK	Long term weight bearing sports activity	Pain OA as defined by radiological changes (joint space narrowing and osteophytes) in hip joints, PF joints, and TF joints	Yes	The ex-athletes had greater rates of radiological OA at all sites. This association was strongest for the presence of osteophytes at the TF joints (OR = 3.57 (95% CI, 1.89 to 6.71)), at the PF joints (OR = 3.50 (1.80 to 6.81)), narrowing at the PF joints (OR = 2.97 (1.15 to 7.67)), femoral osteophytes (OR = 2.52 (1.01 to 6.26)), and hip joint narrowing (OR = 1.60 (0.73 to 3.48)), and was weakest for narrowing at the TF joints (OR = 1.17 (0.71 to 1.94)). The tennis players tended to have more osteophytes at the TF joints and hip
Nigg[136]	Prospective cohort study (2 m follow up)	171 members of tennis clubs	Shoe, temperature, type and duration of match play, subjective assessment of shoe comfort, sole grip and lateral stability	Pain	No	Stiffness of shoe and subjective evaluation of frictional properties of the shoe were significantly associated with pain

Only statistically significant results are reported.
*First author and reference number.
CI, confidence interval; m, months; OA, osteoarthritis; OR, odds ratio; PF, patellofemoral; TF, tibiofemoral.

Injury localisation

Ten[104–106 108 110–113 117 119] of 13 studies[104–106 108 110–113 116 117 119 121–124] showed a preponderance of injuries of the lower extremity compared with the upper extremity.

Injury type

Four[108 112 113 118] of six studies[105 108 112 113 116 118] reported more acute than chronic injuries. Most acute injuries occurred in the lower extremities, whereas most chronic injuries were located in the upper extremities. Injuries to the trunk comprised 5% to 25% of all injuries.[104–106 108 110 111 113 116–119 121–124]

Injury severity

Injury severity was expressed in various ways in the different studies, including number of injuries requiring hospital admission[108 113] or operative treatment,[106] average medical costs per injury,[108] time loss,[114 115] or the percentage requiring medical treatment.[104 109 112] Injuries sustained while playing indoors tended to be more severe than outdoor injuries, with a higher percentage requiring medical treatment.[104 109] In the study by Kuhne *et al*, 3.3% of acute and 2.2% of chronic injuries required surgery.[106] Five per cent of the injuries in the Letsel Informatie Systeem (LIS) study required an average of five days of hospital admission.[108] In the studies on juniors, injury severity was significantly less, with only one player of 1440 being taken to hospital and two injuries of 176 requiring surgery.[113]

Sex

Injury rates between men and women were compared in a prospective cohort study of intercollegiate tennis.[115] In this study, 1.6 injuries per 1000 hours were recorded for male tennis players versus 1.0 injury per 1000 hours in female players. This was not a statistically significant difference ($p = 0.37$).

Sallis *et al*[110] studied injury patterns in 18–22 year old tennis players. This was a retrospective cohort study of injury reports compiled by certified athletic trainers. The incidence was 0.46 injuries per male player per year and 0.42 injuries per female player per year. The differences was not statistically significant.

Hutchinson *et al*[113] compared injury patterns in elite junior players (male and female) during a three year period (1996–1998) at the United States Tennis Association (USTA) tennis championships. There was no significant difference in the overall rate of injury (new and recurrent) between male and female players.

Winge *et al*[116] found a higher injury rate in men (2.7 injuries per 1000 hours) than in women (1.1 injuries per 1000 hours). This was a statistically significant difference ($p<0.05$).

Age

The Letsel Informatie Systeem[108] is a continuous registration of injuries treated in the emergency departments of a selection of 15 hospitals and medical centres in the Netherlands. These injuries are generally acute and more serious. In this study, injury risk in tennis has been shown to gradually increase with age, from 0.01 injuries per player per year in the 6–12 year age group to 0.5 injuries per player per year in those over 75 years of age. An increased incidence with age was consistently shown for tennis elbow.[127–132]

Level of play

In these general descriptive epidemiological studies, the study populations can be characterised as recreational/

general, elite, or junior competitive. The studies include a wide distribution of retrospective, cross sectional, prospective cohort, and prospective longitudinal study designs. There were nine studies[104–106 108 109 111 112 118 121] involving recreational players or the general population, seven studies[110 115–117 119 120 122–124] involving elite players, and three studies[107 113 114] relating to junior tournament players. Study designs of junior and elite players often involved recording of injuries as medical consultations at tournaments or training centres. This method of injury reporting may inflate injury rates, therefore making it difficult to make direct comparisons with studies involving recreational players that often involve self reporting of their injuries.

We were able to identify only two studies that compared injury rates between players of different ability. Baxter-Jones *et al*[114] studied elite young athletes. They found that performance success was significantly related to injury rate. Jayanthi *et al*[105] described the incidence and prevalence of injuries in recreational players of different skill levels, ranging from International Tennis Number 3 to 8. Despite trends, there were no statistical differences in overall injury incidence and prevalence rates across all skill levels.

Volume of play

Studies describing the risks associated with volume of play are scarce. Increased playing time was associated with increased incidence of new cases of tennis elbow in recreational players playing more than two hours a day versus those playing less than two hours a day.[128] However, total incidence and prevalence of all tennis related injuries was not different among recreational players who played less than four hours a week, four to six hours a week, or more than six hours a week.[105]

Analytic epidemiological, and intervention studies

Three studies were found that investigated risk factors for tennis injuries (table 3). Two of these[135 136] had a longitudinal study design and one[137] was cross sectional. Adjustments for confounding variables was made in one longitudinal cohort study.[135] The type of sports injury described in the investigated studies was variable and consisted of discomfort or pain from wearing tennis shoes, sport related injuries in general, low back pain, and osteoarthritis.

Llana *et al*[137] described in a cross sectional study a significant correlation ($p = 0.02$) between perceived incorrect arch support and plantar discomfort. Spector *et al*[135] found that long term weight bearing sports activity was associated with the development of osteoarthritis.

No intervention study was retrieved investigating the effects of prevention measures on tennis injuries.

DISCUSSION

The principal findings of our study are first, that there is a great variation in the reported incidence rate of tennis injuries; second, that most injuries occur in the lower extremities, followed by the upper extremities and then the trunk; third, that there are very few cohort studies available that estimate a measure of association between risk factors and occurrence of tennis injuries; and fourth, that there are no randomised controlled trials on preventative measures in tennis.

The variation in the reported incidence rates of tennis injuries most probably reflects variation in injury definition, study design, populations under study, methods of data collection, and the duration of follow up or recall period. The lowest incidence rate (0.04 injuries per 1000 players per year) was reported in the LIS study.[108] Injuries in this study included only those for which the player was treated at a hospital casualty department. This implies that predominantly more acute and serious injuries will be reported, as players with less serious and chronic injuries are more likely to visit their general practitioner, physiotherapist, or sports physician. The other study with a relatively low injury rate (0.11/1000 hours of play) was by Weijermans *et al*.[112] In that study, injuries sustained by tennis players at a club had to be reported to a contact person in order to be recorded. This may have resulted in underreporting of injuries. Biener *et al*[122–124] also reported a very low injury rate, which can be explained by their long recall period of 17.5 years.

The highest injury rates were found by Hutchinson *et al*[113] and Silva *et al*.[107] This is undoubtedly related to their rather inclusive injury definitions: ''any medical problem that required physical or medical assistance''[113] and ''any consultation and/or treatment given to a player during a tournament on site'',[107] respectively. Using these definitions, injuries which may not have had any effect on tennis play, time loss, or work were also included. Kuhne *et al* addressed this problem by making a separate category for ''Bagatellverletzungen'' (minor injuries), which included sunburns, abrasions, and blisters. We were not able to find any study that identified the relation of match volume within a tournament or through a season and the risk of injury. Prospective studies of independent risks associated with increased playing time in junior tournament players are lacking and necessary in order to counsel parents, coaches, and tournament directors with appropriate evidence based recommendations.

Despite the wide variation of reported injury rates and study designs, comparisons of injury rates in tennis can be made with the rates in other sports. In order to make optimal comparisons, similar study designs and injury definitions should be used. There were 377 injuries in 456 matches involving all team sports studied during the 2004 summer Olympic Games.[138] There was a total injury incidence of 0.8 injuries per match and 54 injuries per 1000 player matches, where injury was defined as any physical complaint incurred during the match that received medical attention regardless of consequence. Handball players (114/1000 player matches) and soccer players (108/1000 player matches) had the highest injury rates, while volleyball players (7.7/1000 player matches) had the lowest. With a similar definition of injury and comparable study design, Hutchinson *et al*[113] reported 21.5 injuries/1000 athletic exposures and Silva *et al*[107] reported 6.9 medical appointments/1000 games in prospective studies of junior national tournament tennis players.

It may be more appropriate to compare tennis with other individual non-contact sports rather than contact team sports. A retrospective cohort survey study in golfers reported 3.06 injuries/player injured in professional players of average age 36.5 years, and 2.07 injuries/player injured in amateur players of average age 47.2 years.[139] This study did not report the total prevalence of injuries/100 players but had a total of 637 injuries in 703 golfers surveyed. In a cross sectional survey of recreational tennis players with an average age of 46.9 years, there were 299 injuries in 528 players giving a prevalence of 52.9 injuries/100 players.[105] In a cross sectional survey study of recreational runners, 45.8% of 4358 male joggers sustained jogging injuries in the previous one year period.[140] A prospective study of recreational runners training for a 10 km race reported that 29.5% of runners experienced an injury that caused at least some pain after exercise.[141] Comparable prospective studies of recreational tennis players over a six month period reported injury rates of 0.11/1000 hours played[112] and 1.5 injuries/player/year.[106]

Despite some variation in study design and definition of injury, tennis appears to have lower injury rates than contact team sports and also in some comparisons with non-contact individual sports such as golf and running. However, no

known study has made direct comparisons between risks of injury or lifetime prevalence of injury between tennis and other sports.

Unfortunately, we were not able to identify any intervention studies on tennis injuries. An intervention study by Kibler *et al*,[142] in which 51 tennis players undertook a specific programme of stretching exercises showed that the exercises improved the range of motion. Although they did not record the rate of injury, the authors hypothesised that this stretching programme would reduce injury risk. There is currently no evidence that limited flexibility is associated with an increased risk for tennis injuries. In a systematic review of intervention studies on the effect of stretching, Herbert and Gabriel[143] showed that stretching before exercise did not result in a reduction of injury risk. However, they noted that generalisation of this conclusion required further testing. It therefore may be worthwhile to investigate the effects of the type of programme designed by Kibler *et al*[142] on the occurrence of tennis injuries.

The aim of the present literature review was to provide an overview of available knowledge on the occurrence, aetiology, and prevention of tennis injuries. For practical reasons we refrained from doing a formal methodological quality assessment of individual studies or a quantitative data synthesis. However, by presenting studies with different study designs, a picture emerges that represents the current base of knowledge in this field. It is clear from the results that further studies on injury rates, risk factors, and prevention of tennis injuries are needed. Researchers should, if possible, choose a prospective study design in order to decrease the risk of recall bias.

A comparison of injury rates across studies will be facilitated when similar definitions of injuries are used and are clearly stated in the studies. The injury definitions in the studies in this review can be categorised as ''time loss'', ''medical assistance'', and ''tissue injury'' definitions.[144 145] Each definition has advantages and disadvantages[145] and delivers its own scope at the problem of tennis injuries. A clear benefit of using a ''time loss'' definition is that it will generally result in the recording of injuries which substantially affect the player's health or performance, or both.[145]

Few studies have been carried out on the reliability of injury recording systems, and this should therefore also be priority for future research.[145–147] To improve the reliability of data collection it would be wise to use instruction manuals for observers. Another important epidemiological variable is exposure time. This is a measure of participation time in training and matches. It represents the amount of time the player is at risk of injury. The exposure time should, if possible, be recorded individually for each player. Individually recorded exposure times enable researchers to study risk factors in an advanced way by using a Cox proportional hazards regression model.[148] However, because of practical limitations in many cases—especially in large cohort studies—estimates of exposure time must be used.

Currently, based on this literature review, we were unable to identify measures proven to prevent tennis injuries. There are no randomised controlled trials available, and the limited results of the studies on risk factors for tennis injuries fail to provide a clear perspective. Clinical experience and also the results of prevention studies in other sports[114 115] suggest that physical training specifically targeting injury-prone movement patterns may lead to beneficial results. It would be very interesting to test the hypothesis put forward by Kibler associating loss of glenohumeral internal rotation (GIRD) and shoulder strength imbalance with an increased risk of shoulder injuries.[142]

Other possibilities for prevention include: education of players, parents, and coaches about tennis injuries, interval musculoskeletal screening of players to identify problem areas before injuries occur, and adjustment of equipment including shoes, racquets, strings, and balls as well as court surfaces. However, further research is needed to move from a stage of clinical expertise and speculation to real evidence based prevention of tennis injuries.

What is already known on this topic

There is a great variation in the reported incidence rate of tennis injuries. Most injuries occur in the lower extremities, followed by the upper extremities and the trunk. Most acute injuries occur in the lower extremities, whereas most chronic injuries are located in the upper extremities.

What this study adds

By presenting studies with different study designs, a picture emerges that represents the current base of knowledge in this field. It is clear from the results that further studies on injury rates, risk factors, and prevention of tennis injuries are needed. A possible standard protocol for future studies is presented.

Authors' affiliations

B M Pluim, KNLTB, Amersfoort, Netherlands
J B Staal, Department of Epidemiology, Maastricht University, Maastricht, Netherlands
G E Windler, ATP, Ponte Vedra Beach, Florida, USA
N Jayanthi, Loyola University Medical Center, Chicago, Illinois, USA

Competing interests: none declared

REFERENCES

1 **ITF**. http://www.itftennis.com/abouttheitf/nationalassociations/index.asp. Accessed 20 January 006.
2 **Breedveld K**, Van der Meulen R, Harms L, *et al*. *Rapportage Sport 2003*. The Hague: Sociaal en Cultureel Planbureau, 2003.
3 **Van Bottenburg M**, Rijnen B, Van Sterkenburg J. *Sports participation in the European Union. Trends and differences*. Nieuwegein: Arko Sports Media, 2005.
4 **Pluim BM**, Safran M. From breakpoint to advantage. Includes description, treatment, and prevention of all tennis injuries. Vista: USRSA, 2004.
5 **Dekker R**, Groothoff JW, van der Sluis CK, *et al*. Long-term disabilities and handicaps following sports injuries: outcome after outpatient treatment. *Disabil Rehabil* 2003;**25**:1153–7.
6 **Dekker R**, Kingma J, Groothoff JW, *et al*. Measurement of severity of sports injuries: an epidemiological study. *Clin Rehabil* 2000;**14**:651–6.
7 **Dekker R**, van der Sluis CK, Groothoff JW, *et al*. Long-term outcome of sports injuries: results after inpatient treatment. *Clin Rehabil* 2003;**17**:480–7.
8 **Stam P**. Sportief bewegen en gezondheidsaspecten: een verkennende studie naar kosten en baten. Amsterdam: SEO, 1996.
9 **van Mechelen W**, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med* 1992;**14**:82–99.
10 **Rivara FP**. Introduction: the scientific basis for injury control. *Epidemiol Rev* 2003;**25**:20–3.
11 **Olsen OE**, Myklebust G, Engebretsen L, *et al*. Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial. *BMJ* 2005;**330**:449.
12 **Verhagen E**, van der Beek A, Twisk J, *et al*. The effect of a proprioceptive balance board training program for the prevention of ankle sprains: a prospective controlled trial. *Am J Sports Med* 2004;**32**:1385–93.
13 **Maffulli N**, Baxter-Jones AD, Grieve A. Long term sport involvement and sport injury rate in elite young athletes. *Arch Dis Child* 2005;**90**:525–7.
14 **Pollack KM**, Canham-Chervak M, Gazal-Carvalho C, *et al*. Interventions to prevent softball related injuries: a review of the literature. *Inj Prev* 2005;**11**:277–81.
15 **Last J**, ed. *A dictionary of epidemiology*, 3rd edition. New York: Oxford University Press, 1995.
16 **Guha AR**, Marynissen H. Stress fracture of the hook of the hamate. *Br J Sports Med* 2002;**36**:224–5.
17 **Stark HH**, Jobe FW, Boyes JH, *et al*. Fracture of the hook of the hamate in athletes. *J Bone Joint Surg Am* 1977;**59**:575–82.

18 **Parker RD**, Berkowitz MS, Brahms MA, *et al*. Hook of the hamate fractures in athletes. *Am J Sports Med* 1986;**14**:517–23.
19 **Waninger KN**, Lombardo JA. Stress fracture of index metacarpal in an adolescent tennis player. *Clin J Sport Med* 1995;**5**:63–6.
20 **Murakami Y**. Stress fracture of the metacarpal in a adolescent tennis player. *Am J Sports Med* 1988;**16**:419–20.
21 **Bespalchuk A**, Okada K, Nishida J, *et al*. Stress fracture of the second metacarpal bone. *Skel Radiol* 2004;**33**:537–40.
22 **Loosli AR**, Leslie M. Stress fractures of the distal radius. A case report. *Am J Sports Med* 1991;**19**:523–4.
23 **Fragniere B**, Landry M, Siegrist O. Stress fracture of the ulna in a professional tennis player using a double-handed backhand stroke. *Knee Surg Sports Traumatol Arthrosc* 2001;**9**:239–41.
24 **Young CC**, Raasch WG, Geiser C. Ulnar stress fracture of the non-dominant arm in a tennis player using a two-handed backhand. *Clin J Sport Med* 1995;**5**:262–4.
25 **Bollen SR**, Robinson DG, Crichton KJ, *et al*. Stress fractures of the ulna in tennis players using a double-handed backhand stroke. *Am J Sports Med* 1993;**21**:751–2.
26 **Bell RH**, Hawkins RJ. Stress fracture of the distal ulna. A case report. *Clin Orthop Relat Res* 1986;**209**:169–71.
27 **Rettig AC**. Stress fracture of the ulna in an adolescent tournament tennis player. *Am J Sports Med* 1983;**11**:103–6.
28 **Rettig AC**, Beltz HF. Stress fracture in the humerus in an adolescent tennis tournament player. *Am J Sports Med* 1985;**13**:55–8.
29 **Sinha AK**, Kaeding CC, Wadley GM. Upper extremity stress fractures in athletes: clinical features of 44 cases. *Clin J Sport Med* 1999;**9**:199–202.
30 **Ishikawa H**, Ueba Y, Yonezawa T, *et al*. Osteochondritis dissecans of the shoulder in a tennis player. *Am J Sports Med* 1988;**16**:547–50.
31 **Retrum RK**, Wepfer JF, Olen DW, *et al*. Case report 355: Delayed closure of the right olecranon epiphysis in a right-handed, tournament-class tennis player (post-traumatic). *Skeletal Radiol* 1986;**15**:185–7.
32 **Nakamura T**, Kambayashi J, Kawasaki T, *et al*. Hypothenar hammer syndrome caused by playing tennis. *Eur J Vasc Endovasc Surg* 1996;**11**:240–2.
33 **Noel B**, Hayoz D. A tennis player with hand claudication. *VASA* 2000;**29**:151–3.
34 **Ikezawa T**, Iwatsuka Y, Asano M, *et al*. Upper extremity ischemia in athletes: embolism from the injured posterior circumflex humeral artery. *Int J Angiol* 2000;**9**:138–40.
35 **Caiati JM**, Masters CM, Todd EJ, *et al*. Symptomatic axillary artery dissection in a tennis player. Case report. *Am J Sports Med* 2000;**28**:411–12.
36 **Birnbaum DA**. Missed avulsion fracture of the lesser trochanter in a tennis professional. *Med Trial Tech Q* 1979;**26**:121–5.
37 **Koob E**, Steffens K. [True trigger wrist (a case report)]. *Handchir Mikrochir Plast Chir* 1988;**20**:188–290.
38 **Burkhart SS**. Os acromiale in a professional tennis player. *Am J Sports Med* 1992;**20**:483–4.
39 **Dawson WJ**. Sports-induced spontaneous rupture of the extensor pollicis longus tendon. *J Hand Surg Am* 1992;**17**:457–8.
40 **Tsur A**, Gillson S. Brachial biceps tendon injuries in young female high-level tennis players. *Croat Med J* 2000;**41**:184–5.
41 **Prochaska V**, Crosby LA, Murphy RP. High radial nerve palsy in a tennis player. *Orthop Rev* 1993;**22**:90–92.
42 **Xarchas KC**, Leviet D. Non rheumatoid closed rupture of extensor carpi ulnaris tendon. Report of a case in a professional athlete. *Acta Orthop Belg* 2002;**68**:399–402.
43 **Faraj A**, Rahman H, Norton R. Acute calcific tendinitis of abductor pollicis longus in a tennis player. *Sports Exerc Inj* 1998;**4**:138–9.
44 **Berlemann U**, al-Momani Z, Hertel R. Exercise-induced compartment syndrome in the flexor-pronator muscle group. A case report and pressure measurements in volunteers. *Am J Sports Med* 1998;**26**:439–41.
45 **Rinn T**, RCN. Medial gastrocnemius tear (''tennis leg''): a case report. *J Sports Chiropr Rehabil* 1996;**10**:37–40.
46 **Lowry AW**, McFarland EG, Cosgarea AJ, *et al*. Partial rupture of the quadriceps tendon in a tennis player. *Clin J Sport Med* 2001;**11**:277–9.
47 **Hyde T**, Kettner N, Epstein B. Concurrent stress fractures of the femoral shaft in a tennis player. *J Neuromusculoskeletal Syst* 1998;**6**:24–30.
48 **Trepman E**, Mizel MS, Newberg AH. Partial rupture of the flexor hallucis longus tendon in a tennis player: a case report. *Foot Ankle Int* 1995;**16**:227–31.
49 **McElgun TM**, Cavaliere RG. Sequential bilateral rupture of the plantar fascia in a tennis player. *J Am Podiatr Med Assoc* 1994;**84**:137–41.
50 **Motto SG**. Stress fracture of the lateral process of the talus – a case report. *Br J Sports Med* 1993;**27**:275–6.
51 **Powell JM**, Kavanagh TG, Kennedy DK, *et al*. Intra-articular knee injuries in racquet sports. A review of 128 arthroscopies. *Surg Endosc* 1988;**2**:39–43.
52 **Herrick R**, Herrick S. Rupture of the plantar fascia in a middle-aged tennis player. A case report. *Am J Sports Med* 1983;**11**:95.
53 **Hofmann A**, Weishaupt P. [High performance sports and backache: the value of functional analysis and progressive dynamic strength training of the trunk muscles. Case report of a 15-year-old high performance tennis player]. *Sportverletz Sportschaden* 1999;**13**:M7–9.
54 **Mithofer K**, Giza E. Pseudarthrosis of the first rib in the overhead athlete. *Br J Sports Med* 2004;**38**:221–2.
55 **Stanley A**, McGann R, Hall J, *et al*. Shoulder strength and range of motion in female amateur-league tennis players. *J Orthop Sports Phys Ther* 2004;**34**:402–9.
56 **Ng L**, Kramer J. Shoulder rotator torques in female tennis and nontennis players. *J Orthop Sports Phys Ther* 1991;**13**:40–6.
57 **Mont MA**, Cohen DB, Campbell KR, *et al*. Isokinetic concentric versus eccentric training of shoulder rotators with functional evaluation of performance enhancement in elite tennis players. *Am J Sports Med* 1994;**22**:513–17.
58 **Ellenbecker T**. Shoulder internal and external rotation strength and range of motion of highly skilled junior tennis players. *Isokinetics Exerc Sci* 1992;**2**:65–72.
59 **Ellenbecker T**. A total arm strength isokinetic profile of highly skilled tennis players. *Isokinetics Exerc Sci* 1991;**1**:9–21.
60 **Pensivy S**. In the game. Tennis shoulder: many tennis athletes have a shoulder syndrome that creates muscle strength imbalance. *Adv Dir Rehabil* 2002;**11**:29–30.
61 **Ellenbecker TS**, Roetert EP, Bailie DS, *et al*. Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers. *Med Sci Sports Exerc* 2002;**34**:2052–6.
62 **Ellenbecker TS**, Roetert EP. Effects of a 4-month season on glenohumeral joint rotational strength and range of motion in female collegiate tennis players. *J Strength Cond Res* 2002;**16**:92–6.
63 **Ellenbecker TS**, Roetert EP, Piorkowski PA, *et al*. Glenohumeral joint internal and external rotation range of motion in elite junior tennis players. *J Orthop Sports Phys Ther* 1996;**24**:336–41.
64 **Kibler WB**, Chandler TJ, Livingston BP, *et al*. Shoulder range of motion in elite tennis players. Effect of age and years of tournament play. *Am J Sports Med* 1996;**24**:279–85.
65 **Ellenbecker T**, Roetert EP. Age specific isokinetic glenohumeral internal and external rotation strength in elite junior tennis players. *J Sci Med Sport* 2003;**6**:63–70.
66 **Ellenbecker TS**, Roetert EP. Testing isokinetic muscular fatigue of shoulder internal and external rotation in elite junior tennis players. *J Orthop Sports Phys Ther* 1999;**29**:275–81.
67 **Ellenbecker TS**, Roetert EP. Isokinetic profile of elbow flexion and extension strength in elite junior tennis players. *J Orthop Sports Phys Ther* 2003;**33**:79–84.
68 **Bernhang AM**, Dehner W, Fogarty C. Tennis elbow: a biomechanical approach. *J Sports Med* 1974;**2**:235–60.
69 **Elliott BC**. Biomechanics of the serve in tennis. A biomedical perspective. *Sports Med* 1988;**6**:285–94.
70 **Kibler WB**. Biomechanical analysis of the shoulder during tennis activities. *Clin Sports Med* 1995;**14**:79–85.
71 **Blackwell JR**, Cole KJ. Wrist kinematics differ in expert and novice tennis players performing the backhand stroke: implications for tennis elbow. *J Biomech* 1994;**27**:509–16.
72 **Wu SK**, Gross MT, Prentice WE, *et al*. Comparison of ball-and-racquet impact force between two tennis backhand stroke techniqes. *J Orthop Sports Phys Ther* 2001;**31**:247–54.
73 **Riek S**, Chapman AE, Milner T. A simulation of muscle force and internal kinematics of extensor carpi radialis brevis during backhand tennis stroke: implications for injury. *Clin Biomech (Bristol)* 1999;**14**:477–83.
74 **Bahamonde RE**, Knudson D. Kinetics of the upper extremity in the open and square stance tennis forehand. *J Sci Med Sport* 2003;**6**:88–101.
75 **Knudson D**, Blackwell J. Upper extremity angular kinematics of the one-handed backhand drive in tennis players with and without tennis elbow. *Int J Sports Med* 1997;**18**:79–82.
76 **Kleinöder H**, Mester J. [Stress for the hitting arm by wrist and forearm actions in tennis]. *Dtsch Z Sportmed* 1998;**49**:217–20.
77 **Marshall RN**, Elliott BC. Long-axis rotation: the missing link in proximal-to-distal segmental sequencing. *J Sports Sci* 2000;**18**:247–54.
78 **Knudson DV**. Factors affecting force loading on the hand in the tennis forehand. *J Sports Med Phys Fitness* 1991;**31**:527–31.
79 **Kelley JD**, Lombardo SJ, Pink M, *et al*. Electromyographic and cinematographic analysis of elbow function in tennis players with lateral epicondylitis. *Am J Sports Med* 1994;**22**:359–63.
80 **Ryu RK**, McCormick J, Jobe FW, *et al*. An electromyographic analysis of shoulder function in tennis players. *Am J Sports Med* 1988;**16**:481–5.
81 **Morris M**, Jobe FW, Perry J, *et al*. Electromyographic analysis of elbow function in tennis players. *Am J Sports Med* 1989;**17**:241–7.
82 **Giangarra CE**, Conroy B, Jobe FW, *et al*. Electromyographic and cinematographic analysis of elbow function in tennis players using single- and double-handed backhand strokes. *Am J Sports Med* 1993;**21**:394–9.
83 **Bauer JA**, Murray RD. Electromyographic patterns of individuals suffering from lateral tennis elbow. *J Electromyogr Kinesiol* 1999;**9**:245–52.
84 **Stroede CL**, Noble L, Walker HS. The effect of tennis racket string vibration dampers on racket handle vibrations and discomfort following impacts. *J Sports Sci* 1999;**17**:379–85.
85 **Hatze H**. The effectiveness of grip bands in reducing racquet vibration transfer and slipping. *Med Sci Sports Exerc* 1992;**24**:226–30.
86 **Hennig EM**, Rosenbaum D, Milani TL. Transfer of tennis racket vibrations onto the human forearm. *Med Sci Sports Exerc* 1992;**24**:1134–40.
87 **Strizak AM**, Gleim GW, Sapega A, *et al*. Hand and forearm strength and its relation to tennis. *Am J Sports Med* 1983;**11**:234–9.
88 **Colak T**, Bamac B, Ozbek A, *et al*. Nerve conduction studies of upper extremities in tennis players. *Br J Sports Med* 2004;**38**:632–5.
89 **Brasseur JL**, Lucidarme O, Tardieu M, *et al*. Ultrasonographic rotator-cuff changes in veteran tennis players: the effect of hand dominance and comparison with clinical findings. *Eur Radiol* 2004;**14**:857–64.
90 **Vad VB**, Gebeh A, Dines D, *et al*. Hip and shoulder internal rotation range of motion deficits in professional tennis players. *J Sci Med Sport* 2003;**6**:71–5.
91 **Stussi E**, Stacoff A. [Biomechanical and orthopedic problems of tennis and indoor sports shoe]. *Sportverletz Sportschaden* 1993;**7**:187–90.
92 **Krabbe B**, Farkas R, Baumann W. [Stress on the upper ankle joint in tennis-specific forms of movement]. *Sportverletz Sportschaden* 1992;**6**:50–7.

93 **Simpson KJ**, Shewokis PA, Alduwaisan S, *et al*. Factors influencing rearfoot kinematics during a rapid lateral braking movement. *Med Sci Sports Exerc* 1992;**24**:586–94.
94 **Nigg B**, Segesser B. The influence of playing surfaces on the load on the locomotor system and on football and tennis injuries. *Sports Med* 1988;**5**:375–85.
95 **Luethi S**, Frederick E, Hawes M, *et al*. Influence of shoe construction on lower extremity kinematics and load during lateral movements in tennis. *Int J Biomech* 1986;**2**:166–74.
96 **Reinschmidt C**, Nigg BM. Current issues in the design of running and court shoes. *Sportverletz Sportschaden* 2000;**14**:71–81.
97 **Knudson D**, Blackwell J. Trunk muscle activation in open stance and square stance tennis forehands. *Int J Sports Med* 2000;**21**:321–4.
98 **Roetert E**, McCormick T, Brown S, *et al*. Relationship between isokinetic and functional trunk strength in elite junior tennis players. *Isokinetics Exerc Sci* 1996;**6**:15–20.
99 **Dalichau S**, Scheele K. [Influence of sports mechanic demands in competitive tennis on the thoracolumbar spinal profile]. *Sportverletz Sportschaden* 2002;**16**:64–9.
100 **Chandler T**, Ellenbecker T, Roetert E. Sport-specific muscle strength imbalances in tennis. *Strength Condition* 1998;**20**:7–10.
101 **Goodman B**, Berke M, Schwartz L. The biomechanics of tennis injuries. *Phys Med Rehabil State Art Rev* 1997;**11**:675–95.
102 **Chandler TJ**, Kibler WB, Uhl TL, *et al*. Flexibility comparisons of junior elite tennis players to other athletes. *Am J Sports Med* 1990;**18**:134–6.
103 **Kraemer W**, Triplett N, Fry A, *et al*. An in-depth sports medicine profile of women college tennis players. *J Sport Rehabil* 1995;**4**:79–98.
104 **Vriend I**, Van Kampen B, Schmikli S, *et al*. Ongevallen en Bewegen in Nederland 2000–2003. *Ongevalsletsels en sportblessures in kaart gebracht*. Amsterdam: Consument en Veiligheid, 2005.
105 **Jayanthi N**, Sallay P, Hunker P, *et al*. Skill-level related injuries in recreational competition tennis players. *Med Sci Tennis* 2005;**10**:12–15.
106 **Kuhne C**, Zettl R, Nast-Kolb D. [Injuries- and frequency of complaints in competitive tennis- and leisure sports]. *Sportverletz Sportschaden* 2004;**18**:85–9.
107 **Silva RT**, Takahashi R, Berra B, *et al*. Medical assistance at the Brazilian juniors tennis circuit–a one-year prospective study. *J Sci Med Sport* 2003;**6**:14–18.
108 Letsel Informatie Systeem 1999–2003. Amsterdam: Consument en Veiligheid, 2004.
109 **Schmikli S**, De Wit M, Backx F. Sportblessures driemaal geteld. Kerncijfers en trends uit landelijk onderzoek naar sportblessures in Nederland. Arnhem: NOC*NSF, 2001.
110 **Sallis RE**, Jones K, Sunshine S, *et al*. Comparing sports injuries in men and women. *Int J Sports Med* 2001;**22**:420–3.
111 **Steinbruck K**. [Epidemiology of sports injuries–25-year-analysis of sports orthopedic-traumatologic ambulatory care]. *Sportverletz Sportschaden* 1999;**13**:38–52.
112 **Weijermans N**, Backx F, Van Mechelen W. Blessures bij outdoor-tennis. *Geneesk Sport* 1998;**3**:95–9.
113 **Hutchinson MR**, Laprade RF, Burnett QM, *et al*. Injury surveillance at the USTA Boys' Tennis Championships: a 6-yr study. *Med Sci Sports Exerc* 1995;**27**:826–30.
114 **Baxter-Jones AD**, Maffulli N, Helms P. Low injury rates in elite athletes. *Arch Dis Child* 1993;**68**:130–2.
115 **Lanese RR**, Strauss RH, Leizman DJ, *et al*. Injury and disability in matched men's and women's intercollegiate sports. *Am J Public Health* 1990;**80**:1459–62.
116 **Winge S**, Jorgensen U, Lassen Nielsen A. Epidemiology of injuries in Danish championship tennis. *Int J Sports Med* 1989;**10**:368–71.
117 **Krause R**, Pöttinger P. Tennisverletzungen von Leistungsspielern. *Prakt Sport-Traumatol Sportmed* 1988;**1**:47–9.
118 **Chard MD**, Lachmann SM. Racquet sports–patterns of injury presenting to a sports injury clinic. *Br J Sports Med* 1987;**21**:150–3.
119 **Reece L**, Fricker P, Maguire K. Injuries to elite young tennis players at the Australian Institute of Sports. *Aust J Sci Med Sport* 1986;**18**:11–15.
120 **Von Salis-Soglio G**. Sportverletzungen und Sportschäden beim Tennis. *Dtsch Z Sportmed* 1979;**29**:244–8.
121 **von Krämer J**, Schmitz-Beuting J. Überlastungsschäden am Bewegungsapparat bei Tennisspielern. *Dtsch Z Sportmed* 1979;**2**:44–6.
122 **Biener K**, Caluori P. Sportmedizinischer Profil des Tennisspielers. *Sportarzt Sportmed* 1976;**8**:198–202.
123 **Biener K**, Caluori P. Sportmedizinischer Profil des Tennisspielers. *Sportarzt Sportmed* 1976;**9**:227–9.
124 **Biener K**, Caluori P. Sportmedizinischer Profil des Tennisspielers. *Sportarzt Sportmed* 1976;**10**:254–5.
125 **Hang YS**, Peng SM. An epidemiologic study of upper extremity injury in tennis players with a particular reference to tennis elbow. *Taiwan Yi Xue Hui Za Zhi* 1984;**83**:307–16.
126 **Lo YP**, Hsu YC, Chan KM. Epidemiology of shoulder impingement in upper arm sports events. *Br J Sports Med* 1990;**24**:173–7.
127 **Kamien M**. Tennis elbow in long-time tennis players. *Aust J Sci Med Sport* 1988;**20**:19–27.
128 **Gruchow HW**, Pelletier D. An epidemiologic study of tennis elbow. Incidence, recurrence, and effectiveness of prevention strategies. *Am J Sports Med* 1979;**7**:234–8.
129 **Kitai E**, Itay S, Ruder A, *et al*. An epidemiological study of lateral epicondylitis (tennis elbow) in amateur male players. *Ann Chir Main* 1986;**5**:113–21.
130 **Carroll R**. Tennis elbow: incidence in local league players. *Br J Sports Med* 1981;**15**:250–6.
131 **Priest J**, Braden V, Goodwin Gerberich S. The elbow and tennis, Part 1. An analysis of players with and without pain. *Physician Sportsmed* 1980;**8**:81–91.
132 **Priest J**, Braden V, Goodwin Gerberich S. The elbow and tennis, Part 2. Study of players with pain. *Physician Sportsmed* 1980;**8**:77–85.
133 **Feit EM**, Berenter R. Lower extremity tennis injuries. Prevalence, etiology, and mechanism. *J Am Podiatr Med Assoc* 1993;**83**:509–14.
134 **Saraux A**, Guillodo Y, Devauchelle V, *et al*. Are tennis players at increased risk for low back pain and sciatica? *Rev Rhum Engl Ed* 1999;**66**:143–5.
135 **Spector TD**, Harris PA, Hart DJ, *et al*. Risk of osteoarthritis associated with long-term weight-bearing sports: a radiologic survey of the hips and knees in female ex-athletes and population controls. *Arthritis Rheum* 1996;**39**:988–95.
136 **Nigg B**, Frederick E, Hawes M, *et al*. Factors influencing short-term pain and injuries in tennis. *Int J Sport Biomech* 1986;**2**:156–65.
137 **Llana S**, Brizuela G, Dura JV, *et al*. A study of the discomfort associated with tennis shoes. *J Sports Sci* 2002;**20**:671–9.
138 **Junge A**, Langevoort G, Pipe A, *et al*. Injuries in team sport tournament during the 2004 Olympic Games. *Am J Sports Med* 2005;**34**:1–12.
139 **Gosheger G**, Liem D, Ludwig K, *et al*. Injuries and overuse syndromes in golf. *Am J Sports Med* 2003;**31**:438–43.
140 **Marti B**, Minder C, Abelin T. On the epidemiology of running injuries. The 1984 Bern Grand Prix study. *Am J Sports Med* 1988;**16**:285–94.
141 **Taunton J**, Ryan M, Clement D, *et al*. A prospective study of running injuries: the Vancouver Sun Run ''In Training'' clinics. *Br J Sports Med* 2003;**37**:239–44.
142 **Kibler WB**, Chandler TJ. Range of motion in junior tennis players participating in an injury risk modification program. *J Sci Med Sport* 2003;**6**:51–62.
143 **Herbert R**, Gabriel M. Effects of stretching before and after exercising on muscle soreness and risk of injury: systematic review. *BMJ* 2002;**325**:468.
144 **Orchard J**, Seward H. Epidemiology of injuries in the Australian Football League, seasons 1997–2000. *Br J Sports Med* 2002;**36**:39–44.
145 **Hagglund M**, Walden M, Bahr R, *et al*. Methods for epidemiological study of injuries to professional football players: developing the UEFA model. *Br J Sports Med* 2005;**39**:340–6.
146 **McManus A**. Validation of an instrument for injury data collection in rugby union. *Br J Sports Med* 2000;**34**:342–7.
147 **Meeuwisse W**, Love E. Development, implementation, and validation of the Canadian Intercollegiate Sport Injury Registry. *Clin J Sport Med* 1998;**8**:164–77.
148 **Van Mechelen W**, Twisk J, Molendijk A, *et al*. Subject-related risk factors for sports injuries: a 1-yr prospective study in young adults. *Med Sci Sports Exerc* 1996;**28**:1171–9.