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Research article

Prospective epidemiological study of basketball injuries during one competitive season: Ankle sprains and overuse knee injuries

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Abstract
This prospective cohort study aims to assess the overall incidence of acute and overuse basketball injuries and identifies risk factors associated with ankle sprains and knee overuse injuries. In total, 164 senior players (23.7 years ± 7.0) of all levels of play, and including both men and women, participated voluntarily during one season. A total of 139 acute and 87 overuse injuries were reported, resulting in an overall injury incidence of 9.8 (8.5 to 11.1) per 1,000 hours. The incidence of acute injuries was 6.0/1,000 hours. Ankle sprains (n = 34) accounted for most acute injuries, and 52.9% of all players with ankle sprains reported a previous ankle sprain. Relative Risks (RR) and Odds Ratio (OR) with their 95% Confidence Intervals (CI) were calculated to determine significant differences. Landing on an opponent's foot was the major inciting event, significantly more so than non contact mechanisms (RR=2.1 [95% CI: 1.0-4.2]). Acute knee injuries resulted in the highest playing absence (7 weeks 2 days ± 9 weeks 1 day). Overuse injury incidence was 3.8/1,000 hours. The knee (1.5/1,000 hours) was the most common site. Forward players sustained less knee overuse injuries than players of all other playing positions, and significantly less than center players (OR=0.5 [95% CI: 0.2-0.9]). This study showed that ankle sprains and overuse knee injuries are the most common injuries in basketball, both accounting for 14.8%. Injury prevention programmes however should not concentrate on those injuries only, but might one to consider that acute knee injuries, in spite of the fact that they occur less frequently, also merit further research.

Key words: Aetiology, ankle sprain, injury cause, injury mechanism, overuse knee injury.

Introduction

Basketball continues to increase in popularity at all levels of play, from recreational to professional (Zvijac and Thompson, 1996) and remains immensely popular, not just in the United States, but throughout the world (Cantwell, 2004). This tendency is also present in Belgium, with a 173% increase in the number of participants over the last 30 years (Van der Aerschot et al., 2004). This growing participation level in basketball is mainly the result of the attention paid by the media to the NBA competition in the US (Zvijac and Thompson, 1996) and of the inception of the WNBA in 1997 (Deitch et al., 2006). A sport such as basketball, which is traditionally perceived to be safer and is considered to be a non contact sport, (Gomez et al., 1996) has so far not been the focus of much research. More attention has gone to more popular sports like football and to sports which are physically more demanding and carry a higher risk of very serious injuries at all levels of participation (Gomez et al., 1996). Nevertheless, basketball has gained more attention these last 10 years in the scientific literature of injury surveillance (Deitch et al., 2006; Hickey et al., 1997; McKay et al., 2001a; b; Meeuwisse et al., 2003; Messina et al., 1999; Starkey, 2000). Basketball appears to have the highest frequency of injuries among non contact sports; it is even referred to as being more dangerous, with a higher injury risk, than contact sports (Conn et al., 2003; Finch et al., 1998; Finch and Mitchell, 2002; Luidinga and Rogmans, 1985; Rogmans and van Weperen, 1986; Ytterstad, 1996). Consequently, the intensity and aggressiveness of the game should not be underestimated (Meeuwisse et al., 2003), because the contemporary game of basketball puts full emphasises on the speed and power of competitors (Starkey, 2000). Strength and quickness are necessary to control an opponent's position, "muscle" a rebound, or "power" a shot, all of these are prerequisites for a successful basketball career (Starkey, 2000). As the sport grows, in terms of numbers of participants and intensity, so does the number of injuries (van Mechelen et al., 1992). So far, there is not a great deal of data to be found on the injury susceptibility of basketball players in European countries (Benazzo et al., 2001; Colliander et al., 1986; Huguet and Begué, 1998). Furthermore, the data are collected through retrospective investigations and concern either male professional players in France (Huguet and Begué, 1998), young players in Italy (Benazzo et al., 2001) or Swedish elite players (Colliander et al., 1986). Studies concerning the epidemiology of basketball injuries have been very popular in the US (Anderson et al., 2003; Arendt and Dick, 1995; Deitch et al., 2006; Gomez et al., 1996; Henry et al., 1982; Messina et al., 1999; Prebble et al., 1999; Starkey, 2000; Zelisko et al., 1982) and research has focused mainly on professional levels (Deitch et al., 2006; Henry et al., 1982; Hickey et al., 1997; Starkey, 2000; Zelisko et al., 1982) or high school players (Gomez et al., 1996; Messina et al., 1999). We can conclude that the level of evidence in Europe concerning the epidemiology of basketball is very low. Before translating injury data resulting from epidemiological studies performed in the US to European players, we have to bear in mind that the game of basketball as played in the US is different from its European counterpart, which is partly caused by the different rules maintained by the NBA and FIBA (Fédération Internationale du Basketball Association), although we have yet to prove

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that the difference in rules between both leagues does indeed lead to changes in the injury risk or pattern.

An important purpose of sports injury epidemiology however, is to supply knowledge on injuries that occur frequently and which have serious consequences, and to describe their aetiology in order to provide a basis for preventive measures (van Mechelen et al., 1992). Studies on basketball injury incidence in Europe have been retrospective and reliable information from season-long studies is scarce (Colliander et al., 1986; Benazzo et al., 2001; Huguet and Begué, 1998).

The purpose of this study was to examine the overall incidence of basketball injuries, both acute and overuse, at all levels of play, and to describe the factors associated with ankle sprains and overuse knee injuries. For this purpose a season-long prospective cohort study in a population of competitive basketball players was conducted.

Methods

Team recruitment

The goal was to perform research in Flanders on both men and women in senior competitive teams on all levels of play. A total of 12 teams, 2 on each level, were randomly contacted by phone. The teams were invited to participate voluntarily. Two additional teams (regional level men) were informed about the project by the already participating teams, and volunteered to take part.

Subjects

In total, 14 teams of different senior competitive levels professional (only 2 men's teams), national (8) and regional (4) agreed to prospectively register information about both acute and overuse injuries during one basketball season. The total sample consisted of 164 players, 81 men and 83 women, and represented 2.5% of the 'total basketball population in Flanders'. In order for subjects to be included in the study the following criteria applied: the subjects had to play for the senior team and this team had to be the player's original team. Any youth and other players which only joined in occasionally, were excluded.

Organizational aspects

The study was conducted in accordance with the institutional rules for human research and the Declaration of Helsinki for Medical Research involving human subjects. Written informed consent was obtained from each player. During the previous season, a supervisor randomly contacted 14 teams by phone to introduce the project to them. If the team agreed to participate, one team designate (TD), who was either a physician, a physical therapist or a trainer/coach, was appointed within the team. Meetings with these TDs were established in the pre-season to provide the necessary information. During the season preparation period, the TDs organized meetings with all the players to inform them about the practical issues. The TDs were constantly observed and motivated through monthly visits by the supervisor. The TDs completed the injury forms in accordance with the applied injury definitions every time a basketball player sustained an injury.

Injury definitions

An acute injury was defined as being a basketball accident with a sudden, direct cause/onset, which required at least minimum (medical) care including, e.g. ice, tape, etc. and which caused the injured player to miss out on at least 1 training or game session (Verhagen et al., 2004b). Muscle cramps and mild bruises were excluded from the definition. An athlete sustained an overuse injury when he/she suffered a physical discomfort with an insidious onset, which caused pain and/or stiffness of the musculoskeletal system, and which was present during and/or after the basketball activity. Such an injury was only reported if it persisted for at least 3 basketball active days. Malaise and illness were excluded.

Data collection

All information was collected through questionnaires. A standard questionnaire, used to collect the demographic information at baseline (e.g. playing position, years of basketball experience, etc.), was completed by each player. The information about acute and overuse injuries was gathered through an injury registration form, with different questions for acute and overuse injuries because of their intrinsic differences. Each form consisted of 3 parts: part 1 concerned the circumstances involved and was filled out by the injured players themselves, part 2 collected the medical diagnosis in cases where a doctor was consulted and part 3 contained questions on time loss and was completed by the injured players. At the end of the season, a checklist was handed out to check whether all injury forms were accounted for and to determine whether follow-up was necessary when the athlete had not yet gained full recovery at the end of the season.

Exposure time

Exposure time was determined for each team separately, not for each player. To measure the exposure hours, attendance lists for games and training sessions were developed. The attendance lists for training sessions included the dates on which they took place, their duration as well as the number of participating players. Trainers were asked to report whether or not the player was present, or if he did not play for the whole time of the training session. The total number of games played by every team was collected. Exposure time was calculated as follows: each game lasts 40 minutes of actual play and there are always 5 players on the court. Also, the duration of the warming-up for each separate game played was reported.

Injury incidence

The incidence of injury was expressed per 1,000 basketball exposure hours. An injured athlete was reintroduced into the study after recovery from an injury. Consequently, a player could sustain one or more different injuries.

Injury severity

To express the severity of acute injuries, the days of basketball inactivity were calculated and presented in weeks (w) and days (d). The days of basketball inactivity were defined as the number of days for which the player was not able to play or train because of the injury sustained.

Table 1. Subject characteristics. Values are given as mean (standard deviation).

Level of play		n	Age (yrs)	Weight (kg)	Height (m)	Basketball Experience (yrs)
Professional	Men	16	26.8 (5.6)	92.2 (12.6)	1.97 (.08)	17.4 (5.2)
National	Men	19	24.6 (4.5)	85.9 (9.9)	1.93 (.08)	13.6 (4.9)
	Women	52	21.6 (6.5)	64.1 (8.1)	1.73 (.06)	9.5 (4.9)
Regional	Men	46	28.8 (7.7)	81.2 (10.7)	1.87 (.08)	14.8 (7.5)
	Women	31	23.0 (5.8)	65.6 (10.4)	1.74 (.06)	9.5 (5.5)

The NAIRS (van Mechelen et al., 1992) was used to define minor, moderate and severe injuries. To determine the severity of overuse injuries, the 4-point scale of Puffer and Zachazewski (1988) was applied. A fifth point was added to the scale for overuse injuries not corresponding to one of the other 4 categories.

Statistical analysis

Relative Risks (RR) [95% CI] were calculated to analyse differences between acute and overuse injuries, men and women, game versus training, offense versus defense and risky movements. To compare the different player positions Odds Ratio (OR) [95% CI] were achieved. RR were determined where exposure time was available and OR were calculated in cases where exposure time could not be estimated.

Results

Subjects

All participating players of the 14 teams completed the study. The sample characteristics are shown in Table 1.

Given the study design, only 32.3% of the players remained injury-free throughout the season, and 37.2% sustained more than 1 injury.

Injury incidences

A total exposure of 16,002h for men and 7,034h for women was reported throughout the 32 week season, during which a total of 226 injuries occurred (Table 2). The players sustained significantly more acute than overuse injuries (RR=3.8 [95% CI: 1.2-2.1]). Relative risks show a significant higher risk for acute than overuse injuries in men (RR=2.9 [95% CI: 1.2-2.5]), but not in women (RR=5.7 [95% CI: 1.0-2.2]). A significant difference is found for the injury incidence between men and women for the total number of injuries (RR=8.0 [95% CI: 1.3-2.3]), acute injuries (RR=5.1 [95% CI: 1.2-2.3]) and overuse injuries (RR=2.9 [95% CI: 1.3-2.9] with women at higher risk.

Comparing the competitive levels, the relative risks reveal that the national level shows significantly lower risks than the regional level, for the total number of injuries (RR=0.7 [95% CI: 0.5-0.9]) as well as for acute injuries (RR=0.6 [95% CI: 0.4-0.8]). In men, players of the professional level sustained fewest injuries (0.6/1,000 hours) and the national level showed significantly less injuries compared to the regional level (RR=0.5 [95% CI: 0.4-0.8]). In women, a significantly lower risk for acute injuries was found in the national level compared to the regional level (RR=0.5 [95% CI: 0.3-0.8]).

Acute injuries

With a total of 139 acute injuries, the acute injury incidence was 6.0/1,000 hours (95% CI: 5.0 – 7.0) (Table **3**). The mean absence from basketball activity after an acute injury was 2w 5d (± 5w 1d), with the longest inactivity period for acute knee injuries (7w 2d ± 9w 1d). With a relative risk of 23.7 (95% CI: 18.6 – 30.1) the risk of acute injuries was higher for game play than for training (Table 2).

In terms of acute injuries, the lower extremity was the most commonly injured body region, with 71 injuries (i.e. 51.1% of all acute injuries) (Table **3**). Ankle injuries (n = 34), all sprains, accounted for most of these. The risk of ankle sprains differed significantly between game and training (RR=27.2 [95% CI: 16.7-44.2]) and between women and men (RR=3.7 [95% CI: 1.9-7.0]), the risk being higher during game and in women.

Overuse injuries

During the season, 87 overuse injuries were reported (Table 3). The overall incidence of overuse injuries was 3.8/1,000 hours (95% CI: 3.0 - 4.6). Knee (39.1%) and back (16.1%) were the main overuse injury localisations. Analysis reveals that 88.2% of the knee overuse injuries can be defined as 'anterior knee pain' (AKP), according to the definition of Thomee et al. (1999). With 17% of the players seeking medical care, 80% were diagnosed as suffering from the so called 'Jumper's knee', and 20% as having a cartilage lesion. The risk of AKP was significantly higher in female than male players (RR=2.3 [95% CI: 1.1-4.7]).

Ankle sprains and overuse knee injuries

With an equal absolute number of 34 injuries and an incidence of 1.5/1,000 hours (95% CI: 1.0-2.0), ankle sprains and overuse knee injuries were the most common injury types. The incidence differed significantly when compared to almost all other injuries, except for back

Table 2. Basketball exposure, the number of injuries and injury incidence (95% CI), during the basketball season.

	TOTAL [1]			TRAINING [2]			GAME [2]		
	Exposure (hrs)	Injuries (n)	Incidence (n/1,000 hrs)	Exposure (hrs)	Injuries (n)	Incidence (n/1,000 hrs)	Exposure (hrs)	Injuries (n)	Incidence (n/1,000 hrs)
Men	16,002	128	8.0 (6.6- 9.4)†	14,912	30	2.0 (1.3-2.7)*	1,090	51	46.8 (33.9-59.6)*
Women	7,034	98	13.9 (11.2-16.7)†	6,256	15	2.4 (1.3-2.7) ‡	778	43	55.3 (38.7-71.8) ‡
Total	23,036	226	9.8 (8.5-11.1)	21,168	45	2.1 (1.5-2.7) #	1,868	94	50.3 (40.1-60.5) #

[1] Both acute and overuse injuries, [2] Only acute injuries.
†, ‡, # and * denote significant difference (95% CI).

Table 3. Number of injuries, injury incidence (95% CI), given by injury localisation. Absence (mean number of weeks and days with standard deviations) was only registered for acute injuries.

	Overall		Acute			Overuse	
Anatomic localisation	Injuries (n)	Injury incidence (n/1,000h)	Injuries (n)	Injury incidence (n/1,000h)	Absence (weeks &days)	Injuries (n)	Injury incidence (n/1,000h)
Ankle	34	1.5 (1.0 – 2.0)	34	1.5 (1.0 – 2.0)	2w 5d (3w 0d)	-	-
Knee	52	2.3 (1.6 – 3.9)	18	0.8 (0.4 – 1.1)	7w 2d (9w 1d)	34	1.5 (1.0 – 2.0)
Other LE [1]	42	1.8 (1.3 - 2.4)	19	0.8 (0.4 – 1.2)	3w 4d (7w 2d)	23	1.0 (0.6 – 1.4)
Fingers	22	0.9 (0.6 – 1.4)	22	0.9 (0.6 – 1.4)	0w 6d (1w 3d)	-	-
Other UE [2]	15	0.7 (0.3 – 1.0)	11	0.5 (0.2 – 0.8)	2w 1d (2w 5d)	4	0.1 (0.0 – 0.3)
Head & Face	18	0.8 (0.4 – 1.1)	18	0.8 (0.4 – 1.1)	0w 5d (0w 6d)	-	-
Back	28	1.3 (0.8 – 1.7)	14	0.6 (0.3 – 0.9)	1w 6d (1w 0d)	14	0.6 (0.3 – 0.9)
Other/unknown	15	0.7 (0.3 – 1.0)	3	0.1 (-0.0 – 0.3)	0w 4d (0w 0d)	12	0.5 (0.2 - 0.8)
Total	226	9.8 (8.5 – 11.1)	139	6.0 (5.0 – 7.0)	2w 5d (5w 1d)	87	3.8 (3.0 – 4.6)

Abbreviations: LE = lower extremity, UE = upper extremity, w = weeks, d = days.

injuries (acute and overuse) (RR=0.8 [95% CI: 0.5-1.4]) and finger sprains (RR=0.6 [95% CI: 0.4-1.1]).

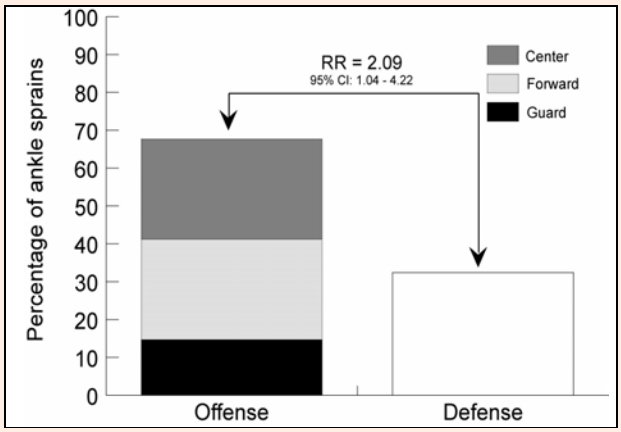

Figure 1. Percentages of injuries concerning ankle sprains occurring during offense and defense (game only) by player function. Significant differences between offense and defense are presented as RR (relative risks) with their confidence intervals (CI) at 95%.

Ankle sprains

For ankle sprains, re-injuries accounted for 52.9% and new injuries for 47.1%. Most of the re-injuries occurred after 1 year or more (50%). The categories 'more than 1w' (RR=0.1 [95% CI: 0.02-0.6]) and '6 months or more' (RR=0.2 [95% CI: 0.05-0.9]) were significantly less frequently seen. During games, the relative risk for ankle sprains was significantly higher in offense than in defense and was 2.1 (95% CI: 1.0-4.2) (Figure 1). There are no significant differences measured between the risk of ankle sprains and the playing position in offense. Landing on an opponent's foot was responsible for the occurrence of most of the ankle sprains, and significantly more so than non contact mechanisms (RR=2.1 [95% CI: 1.0-4.2]) (Table 4). Jumping tasks carry a significantly higher risk for sustaining ankle sprains compared to sudden changes of direction, running to score (both RR=4.5 [95% CI: 1.7-12.1]), and passing & receiving (RR=9.0 [95% CI: 2.7-30.0]). Not only do contact mechanisms account for the highest injury incidence of ankle sprains, but the cause of all other acute injuries is also significantly higher for contact mechanisms than for non contact mechanisms (RR=2.3 [95% CI: 1.6-3.4]). Relative risks showed that contact with an opponent was significantly more common than all other injury causes considered separately (e.g. contact ball, non contact, etc.) (data not shown).

Overuse knee injuries

The self-reported causes for AKP were: exercise loads being too high (56.7%), monotony of exercise (10.0%) and previous trauma (3.3%). AKP was seen in players of all playing positions (Figure 2). The prevalence of AKP divided by player position showed that forward players had the lowest prevalence (12%), followed by guard players (20%), and center players (26%). A significant difference between the prevalence of AKP was only found between forward and center players (OR=0.5 [95% CI: 0.2-0.9]), with forward players at lower risk. The severity of AKP showed that almost 40% of the players with AKP complained of symptoms that met stage 3 and 4, 20% had symptoms according to stage 2, and only 6.7% showed signs corresponding to stage 1 at the moment of injury reporting (Puffer and Zachazewski, 1988).

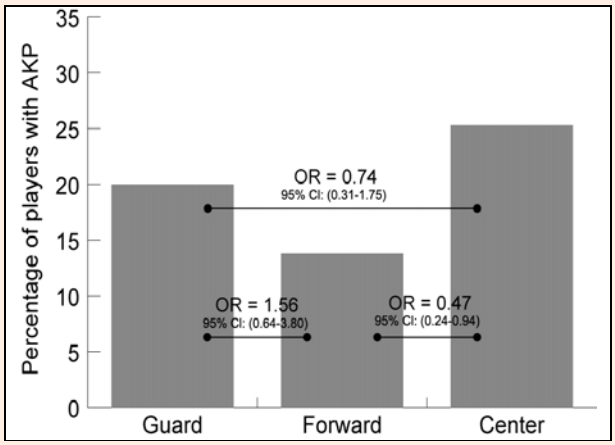

Figure 2. Percentages of players with anterior knee pain (AKP) by player function. Odds ratio (OR) with 95% confidence intervals (CI) are measured to determine significant differences between player functions.

Discussion

This one season prospective cohort study showed an overall basketball injury incidence of 9.8/1,000 hours. A review of the literature on sports epidemiology reveals

Table 4. Movements involved in the occurrence of ankle sprains.

Ankle sprains	Contact	Non-contact	Total
Jumping tasks [1]	44.1 %	8.8 %	52.9 % *†‡
Cutting	5.9 %	5.9 %	11.8 % *
Running to score [1]	11.8 %	0.0 %	11.8 % †
Passing & Receiving	2.9 %	2.9 %	5.9 % §
Unknown	2.9 %	14.7 %	17.6 %
Total	67.6 % #	32.4 % #	100%
Other acute injuries	69.7% §	30.3% §	100%

[1] Rebounding, jump shots, block shots are defined as jumping tasks, lay-ups in all its variations is defined as running to score.
*, †, ‡, # and § denote significant difference according to RR with 95% CI.

inconsistencies in data collection methods between different studies and few prospective epidemiological studies in basketball have been performed so far (Gomez et al., 1996; McKay et al., 2001b; Meeuwisse et al., 2003; Messina et al., 1999) but none of these within European countries. Also, there is significant variability in the definitions used (Messina et al., 1999). Because of the strict definitions applied here, we found a higher injury rate than Yde and Nielsen (1990) at club level; however, McKay et al. (2001b) showed a higher injury incidence of 24.7/1,000 hours at national/elite level compared to our results. Incidence observed in our study was also considerably higher compared to other prospective investigations (Meeuwisse et al. 2003, Messina et al., 1999). The injury incidence found at the professional level in our study, is more than twice as high as the injury incidence found by Deitch et al. (2006), Huguet and Begué, (1998) and Starkey (2000), but is more or less in line with the results of Henry et al. (1982), although our outcome is slightly higher.

Not all participating players were injured, but as seen in our study (67.7%), 44.7% (Meeuwisse et al., 2003) to 69% (Henry et al., 1982) of all players are affected by injuries.

The lower the level of play, the higher the risk of sustaining injuries, as is shown by the relative risks. This difference can be caused by many things, such as e.g. skill level and age, to name a few. The true reason for this difference however, cannot be deduced from this study.

With an incidence of 1.5/1,000 hours in the present study, ankle sprains, along with overuse knee injuries, were by far the most common type of injuries. The high prevalence of ankle injuries is supported by findings from previous epidemiological studies, which have also shown that these injuries are common (Colliander et al., 1986; Deitch et al., 2006; Gomez et al., 1996; Henry et al., 1982; Hickey et al., 1997; Huguet and Begué, 1998) and that sprains of the lateral ligaments make up the majority of these injuries (Apple et al., 1982; Deitch et al., 2006; Henry et al., 1982; Hickey et al., 1997). Knee injuries have also been recognized as being common in basketball (Colliander et al., 1986; Deitch et al., 2006; Henry et al., 1982; Hickey et al., 1997; Huguet and Begué, 1998) and patellar tendonitis or Jumper's knee has long been known to be particularly prevalent in high level basketball players (Henry et al., 1982; Hickey et al., 1997; Lian et al., 2005; Starkey, 2000; Zelisko et al., 1982). In our study, the injury incidence for ankle sprains was similar compared to overuse knee injuries. This is why further analysis in this paper has focused on the general and sports specific circumstances involved in these two kinds of injuries.

In our study we were not able to compare the risk for new or recurrent ankle sprains, since we had no information on previous ankle sprains of the uninjured sample. The injury rate of re- (47.1%) and new injuries (52.9%) was comparable. McKay et al. (2001a) found that a history of ankle injuries was the best predictor for the occurrence of ankle injuries. Meeuwisse et al. (2003), however, could not confirm a significant difference between the risk for re- or new injury.

Significantly more ankle sprains were sustained during games. Meeuwisse et al. (2003) also found games to be more dangerous for the occurrence of ankle sprains, but only for ankle sprains resulting in 7 or more session losses. Ferretti et al. (1992) suggested that the increased frequency of injuries in games is caused by of the high-intensity level of competition and because of the maximum effort that is expended during games. The athlete is at maximum risk, which might make athletes more vulnerable to injury.

Our results showed that ankle sprains were particularly seen in offense, but no significant difference could be found between the different playing positions. The study by Meeuwisse et al. (2003) revealed lowest risk for forwards and highest for center players, but could not prove a statistically significant difference.

Landing on an opponent's foot in this study has been identified as the first major inciting event causing ankle sprains, which is mainly the result of jumping tasks. In second place, ankle sprains were brought on by sudden changes of direction. An earlier study performed by McKay et al. (2001a), also showed that the two main risk factors for ankle sprains in basketball are landing or jumping on someone else's foot or making a sharp cutting manoeuvre.

Not only in ankle sprains, but also in all other acute injuries, contact mechanisms were reported significantly more as a cause of injury, and contact with an opponent was seen significantly more than non contact mechanisms. Also Meeuwisse et al. (2003) registered more injuries resulting from contact than from non contact, and Zelisko et al. (1982) found a high prevalence of injuries caused by contact with another player.

Our study shows a high incidence of AKP, and Jumper's knee was the most common diagnosis. The main reported causes for AKP were high training loads or monotony of exercise. Anderson et al. (2003) demonstrated

the existence of a temporal relationship between training load and injury, which suggested a causative link. An increase in injuries occurred during times of increased training loads. Center players seem to have a significantly higher prevalence of AKP than forward players.

This was the first prospective cohort study on the epidemiology of basketball injuries performed in a European country. As in all epidemiological studies, there were pitfalls we tried to avoid. We had to rely on the motivation and honesty of the players and TDs for filling out every injury sustained and answering the injury definitions. It appears that our injury incidences were quite high compared to those found in the existing literature; this, we think, sheds a positive light on our research. The high injury rate found is also a result of the injury definitions used in this study. The importance of carefully defining injury, meticulously collecting data, characterizing exposure and calculating risks and rates has previously been well described (Gomez et al., 1996). Since we consider injury definitions as the gateway for injury reporting, injury definitions used here were very strict and included minor, moderate as well as serious injuries. This could also explain the high injury incidence found in the present study. The investigated sample can be considered rather small. In research however, one has to decide which methodological issues will be applied, and whether they appropriately answer the questions and purposes put forward at the beginning of the study. The small sample size allows for a close follow-up, resulting in a zero drop-out rate and an injury reporting which covers minor and severe injuries as well as acute and overuse injuries. Although a longer data collection time span would have provided more injury data, the period of investigation as determined at the start of the study was set up to ensure close follow-up of this kind of population. Exposure measurement for each individual should be taken into account in the future to calculate the differences between the playing positions using RR instead of OR. Also the reporting of previous ankle sprains is a valuable tool which should be considered in the future.

Conclusion

Given the high injury incidence of 9.8/1,000 hours and given the fact that contact mechanisms are the major cause of acute injuries (69.2%), we believe that basketball can no longer be perceived to be a safe, non contact sport, and we concur with the statement of Backx et al. (1991) that high-risk sports involve contact, a high jump rate and include indoor activities. Basketball fits this description of proneness to injuries, and it has one of the highest overall injury rates among non contact sports (Conn et al., 2003; Meeuwisse et al., 2003; Yde and Nielsen, 1990). Also Starkey (2000) quoted that the nature of the game of basketball has changed dramatically over the years, evolving from a game of finesse to a collision sport and finally to its current designation as a high-risk sport.

This prospective epidemiological cohort study was the first one performed in Europe and one of the few studies taking into account exposure time. The acute injury incidence in basketball was 6.0/1,000 hours, the overuse injury incidence was 3.8/1,000 hours. As seen in previous studies, ankle sprains (Apple et al., 1982; Colliander et al., 1986; Deitch et al., 2006; Gomez et al., 1996; Henry et al., 1982; Hickey et al., 1997; Huguet and Begué, 1998) and overuse knee injuries (Henry et al., 1982; Hickey et al., 1997; Lian et al., 2005; Starkey, 2000; Zelisko et al., 1982) are clearly the most common injuries in basketball and in this study both accounted for 14.8% of all basketball-related injuries. It has never been reported before that the risk of injury rises as the level of competition gets lower. Concerning ankle sprains, this study is the first one to report that ankle sprains occur significantly more during games than during training and are significantly more often sustained in offense than defense. The self-reported causes of AKP and their severity have never been studied before and the risk of AKP is highest in center players. This study could not prove a difference in injury pattern between European basketball players and NBA players, which was to be expected. Although a wide range of injury types has been reported, ankle sprains and overuse knee injuries should be of particular interest in studies on prevention strategies in basketball. A high number of ankle sprains are recurrent, and if the possibility exists to prevent an initial ankle sprain, a very important risk factor will have been eliminated. Prevention strategies such as ankle taping and bracing (Verhagen et al., 2000) and balance training (Verhagen et al., 2004a) have already been shown to be effective as prophylactic measures for ankle sprains in basketball as well as in other sports (McGuine and Keene, 2006). Attention should also be paid to the prevention of jumper's knee, which constitutes a high prevalent injury of the basketball player. Furthermore, prevention should also focus on the lower competitive levels, where players are at a higher risk compared to other levels. Even though they occur less frequently, research should also focus on severe acute injuries, where prevention should also play an important role.

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References

Anderson, L., Triplett-McBride, T., Foster, C., Doberstein, S. and Brice, G. (2003) Impact of training patterns on incidence of illness and injury during a women's collegiate basketball season. *Journal of Strength and Conditioning Research* **17**, 734-738.

Apple, D.F., O'Toole, J. and Annis, C. (1982) Professional basketball injuries. *The Physician and Sportsmedicine* **10**, 81-86.

Arendt, E. and Dick, R. (1995) Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature. *American Journal of Sports Medicine* **23**, 694-701.

Backx, F.J., Beijer, H.J., Bol, E. and Erich, W.B. (1991) Injuries in high-risk persons and high-risk sports: a longitudinal study of 1818 school children. *American Journal of Sports Medicine* **19**,124-130.

Benazzo, F., Zanon, G., Hidalgo, J.M.M., Rivolta, F. and Bonzanini, G. (2001) Epidemiological aspects of basketball injuries in young

players. *European Journal of Sports Traumatology and Related Research* **23**, 170-172.
Cantwell, J.D. (2004) The Physician Who Invented Basketball. *American Journal of Cardiology* **93**, 1075-1077.
Colliander, E., Eriksson, E., Herkel, M. and Skold, P. (1986) Injuries in Swedish elite basketball. *Orthopedics* **9**, 225-227.
Conn, J.M., Annest, J.L. and Gilchrist, J. (2003) Sports and recreation related injury episodes in the US population, 1997-99. *Injury Prevention* **9**,117-123.
Deitch, J.R., Starkey, C., Walter, S.L. and Moseley, J.B. (2006) Injury risk in professional basketball players. A comparison of Women's National Basketball Association and National Basketball Association Athletes. *American Journal of Sports Medicine* **34**, 1077-1083.
Ferretti, A., Papandrea, P., Conteduca, F. and Mariani, P.P. (1992) Knee ligament injuries in volleyball players. *American Journal of Sports Medicine* **20**, 203-207.
Finch, C.F., Valuri, G. and Ozanne-Smith, J. (1998) Sport and active recreation injuries in Australia: evidence from emergency department presentations. *British Journal of Sports Medicine* **32**, 220-225.
Finch, C.F. and Mitchell, D.J. (2002) A comparison of two injury surveillance systems within sports medicine clinics. *Journal of Science and Medicine in Sport* **5**, 321-335.
Gomez, E., Delee, J.C. and Farney, W.C. (1996) Incidence of injury in Texas girls' high school basketball. *American Journal of Sports Medicine* **24**, 684-687.
Henry, J.H., Lareau, B. and Neigut, D. (1982) The injury rate in professional basketball. *American Journal of Sports Medicine* **10**, 16-18.
Hickey, G.J., Fricker, P.A. and McDonald, W.A. (1997) Injuries in young elite female basketball players over a six-year period. *Clinical Journal of Sport Medicine* **7**, 252-256.
Huguet, J. and Begué, J. (1998) The pathology of basketball. *Sports & Medicine Today* **1**, 72-76.
Luidinga, R. and Rogmans, W.H. (1985) Epidemiologie van acute sportletsels. *Nederlands Tijdschrift voor Geneeskunde* **129**, 1051-1054. (In Dutch).
McGuine, T.A. and Keene, J.S. (2006) The effect of a balance training program on the risk of ankle sprains in high school athletes. *American Journal of Sports Medicine* **34**, 1103-1111.
McKay, G.D., Goldie, P.A., Payne, W.R. and Oakes, B.W. (2001a) Ankle injuries in basketball: injury rate and risk factors. *British Journal of Sports Medicine* **35**,103-108.
McKay, G.D., Goldie, P.A., Payne, W.R., Oakes, B.W. and Watson, L.F. (2001b) A prospective study of injuries in basketball: a total profile and comparison by gender and standard of competition. *Journal of Science and Medicine in Sport* **4**, 196-211.
Meeuwisse W.H., Sellmer, R. and Hagel, B.E. (2003) Rates and risks of injury during intercollegiate basketball. *American Journal of Sports Medicine* **31**, 379-385.
Messina, D.F., Farney, W.C. and DeLee, J.C. (1999) The incidence of injury in Texas high school basketball. A prospective study among male and female athletes. *American Journal of Sports Medicine* **27**, 294-299.
Lian, O.B., Engebretsen, L. and Bahr, R. (2005) Prevalence of jumper's knee among elite athletes from different sports: a cross-sectional study. *American Journal of Sports Medicine* **33**, 561-567.
Prebble, T.B., Chyou, P.H., Wittman, L., McCormich, J., Collins, K. and Zoch, T. (1999) Basketball injuries in a rural area. *Wisconsin Medical Journal* **98**, 22-24.
Puffer, J.C. and Zachazewski, J.E. (1988) Management of overuse injuries. *American Family Physician* **38**, 225-232.
Starkey, C. (2000) Injuries and illnesses in the National Basketball Association: A 10-year perspective. *Journal of Athletic Training* **35**,161-167.
Rogmans, W.H. and van Weperen, W. (1986) De invloed van sportmateriaal op het letselrisico. *Geneeskunde en Sport* **19**, 53-58. (In Dutch).
Thomee, R., Augustsson, J. and Karlsson, J. (1999) Patellofemoral pain syndrome: a review of current issues. *Sports Medicine* **28**, 245-262.
Van der Aerschot, H., Massez, C., Brusselle, S. and Van Lierde, A. (2004) Vlaamse Sportfederaties: Evolutie van het aantal leden van de Vlaamse Sportfederaties (1996-2003). 4-21. (In Dutch).
van Mechelen, W., Hlobil, H. and Kemper, H.C. (1992) Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Medicine* **14**, 82-99.
Verhagen, E.A., van Mechelen, W. and de Vente, W. (2000) The effect of preventive measures on the incidence of ankle sprains. *Clinical Journal Sport Medicine* **10**, 291-296.
Verhagen, E.A., van der Beek, A.J., Twisk, J., Bouter, L.M., Bahr, R.M. and van Mechelen, W. (2004a) The effect of a proprioceptive balance board training program for the prevention of ankle sprains. A prospective controlled trial. *American Journal of Sports Medicine* **32**, 1385-1393.
Verhagen, E.A., van der Beek, A.J., Bouter, L.M., Bahr R.M. and van Mechelen W. (2004b) A one season prospective cohort study of volleyball injuries. *British Journal of Sports Med* **38**, 477-481.
Yde, J. and Nielsen, A.B. (1990) Sports injuries in adolescents' ball games: soccer, handball, basketball. *Br J Sports Med* **24**, 51-54.
Ytterstad, B. (1996) The Harstad injury prevention study: the epidemiology of sports injuries. An 8 year study. *British Journal of Sports Medicine* **30**, 64-68.
Zelisko, J.A., Noble, H.B. and Porter, M. (1982) A comparison of men's and women's professional basketball injuries. *American Journal of Sports Medicine* **10**, 297-299.
Zvijac J. and Thompson, W. (1996) Basketball. In: *Epidemiology of sports injuries*. Ed: Caine, D.J., Caine C.G. and Lidner, K.J. 10th edition. Champaign USA: Human Kinetics. 86-95.

Key points

- Ankle sprains are the most common acute injuries in basketball with the inciting event being landing on an opponent's foot or changing direction.
- Anterior knee pain is the most common overuse injury. Etiologic factors are well described in literature, but prevention strategies are lacking.
- Acute knee injuries account for the highest inactivity and should therefore also be prevented.
- Most of the injuries are due to contact mechanisms and therefore the definition of basketball as a non contact sport is questionable.
- Highest injury risks are found in women and in the lower levels.

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