The epidemiology of anterior cruciate ligament injury in football (soccer): a review of the literature from a gender-related perspective.

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THE EPIDEMIOLOGY OF ANTERIOR CRUCIATE LIGAMENT INJURY IN FOOTBALL (SOCCER): A REVIEW OF THE LITERATURE FROM A GENDER-RELATED PERSPECTIVE

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ABSTRACT

Football (soccer), the most popular sport worldwide, is associated with a high injury risk and the knee joint is often affected. Several studies have found female players to be more susceptible to knee injury, anterior cruciate ligament (ACL) injury in particular, compared to their male counterparts. There is, however, some controversy regarding the magnitude of this risk increase and a few studies have found no differences. The influence of age and activity type on gender-related differences in injury risk is only scarcely investigated. In this paper, the literature reporting gender-specific ACL injury risk in football is reviewed. A literature search yielded 33 relevant articles that were included for review. These show that female players have a 2-3 times higher ACL injury risk compared to their male counterparts. Females also tend to sustain their ACL injury at a younger age than males and a limiting factor in the existing literature is that age is not adjusted for in comparisons of ACL injury risk between genders. Furthermore, the risk increase in females is primarily evident during match play, but type of exposure is also rarely adjusted for. Finally, the studies included in this review share important methodological limitations that are discussed as a starting point for future research in the field.

Key words

ACL, epidemiology, female, risk, sex, injury

INTRODUCTION

The risk of suffering an injury to the anterior cruciate ligament (ACL) is quite low in the general population [19, 32, 34], but considerably higher in many popular team sports including football (soccer). Football is the most popular sport worldwide with more than 260 million active players, of whom 10% are females, according to the recent Big Count survey in 2006 (www.fifa.com). The knee injury risk in football is known to be high and the current knowledge of ACL injury in football was recently reviewed from a risk factor and prevention perspective [3-4]. There is growing evidence on how to prevent ACL injury in football [12, 24, 30], but most of the existing knowledge about risk factors for ACL injury is based on studies from other football codes such as American or Australian Rules football [3].

Nevertheless, the risk factor most commonly studied in football is probably the influence of gender on the ACL injury risk. Female football players have been shown to be more susceptible to ACL injury in several cohort studies of different settings [1, 5-6, 21-22, 25, 31, 35, 48]. Higher relative risks among female footballers have also been reported from insurance claims and surgery register data [11, 39]. However, there are also a few recent cohort studies reporting no significant gender-related difference in ACL injury risk [27, 33].

The objective of this review was to summarise the scientific literature reporting gender-specific ACL injury risk in football and to discuss the findings from a methodological perspective. It was not within the scope of this review to discuss the causes of any gender-related difference, since this has been done previously [3, 38, 41].

LTERATURE SEARCH

The PubMed MEDLINE database (www.ncbi.nlm.nih.gov) was accessed 29/12/2009 for a general literature search using the term "football OR soccer AND injuries". The abstracts of all papers of potential interest were skimmed for inclusion in this review. In addition, the reference lists from identified papers were checked for further relevant articles as well as the personal libraries of the authors.

The database search yielded 3837 articles and, based on the title and/or the abstract, 92 papers were screened for eligibility and 26 of them were included in this review [1-2, 5, 7-8, 10-11, 13-17, 21-22, 23, 27, 29, 31, 39-40, 42-45, 47, 49]. Only original papers with available abstracts were considered for inclusion and to be included they had to report specific ACL injury data and not only figures for knee injuries or knee sprains. In addition, two papers were identified from the reference lists of these articles [6, 25], and another five papers from the authors' personal collections [18, 33, 35, 37, 48]. In total, 33 papers were thus included for review.

EPIDEMIOLOGY OF ACL INJURY

ACL injury constitutes less than 5% of all time loss injuries in most cohort studies regardless of the playing level (Table 1). The annual prevalence of ACL injury is reported to be between 0.5 and 6.0% of all female players and between 0.6 and 8.5% of all male players, respectively (Table 1). In addition to the studies listed in Table 1, we identified another three studies describing descriptive ACL injury epidemiology in football. In two studies with long-term data from the National Collegiate Athletic Association Injury Surveillance System (NCAA-ISS) in the USA, ACL injury constituted 6% of all match injuries and 2% of all training injuries in females [13], but less than 1% of all injuries among males [2]. The third study was conducted on a French adolescent football academy during eight years where 119 female players participated for one or more seasons [29]. In this study, the number of players participating each season or the total number of player-seasons is unclear, but 11 players sustained 12 ACL injuries (1.9% of all injuries) over the study period.

Insert Table 1 near here

When reviewing cohort studies taking exposure into account (Table 2), there seems to be a tendency of a higher ACL injury incidence in females during match play, whereas no relevant gender-related difference seems to exist during training. Irrespective of gender, the studies have consistently found the ACL injury incidence to be much higher (range 7-65 times) during match play.

Insert Table 2 near here

There are several cohort studies reporting gender-related data on the relative risk of ACL injury by

taking exposure or another denominator into account (Table 3). The majority of these studies show a female-to-male-ratio (F/M-ratio) of between two and three [1, 5-6, 11, 21, 31, 35, 39, 48]. However, there are some exceptions. There is one study showing a 7-9 times higher rate in females compared to their male counterparts [25]. Another study found a threefold increase in risk on natural grass, but no gender-related difference on artificial turf [22]. In addition, there are two recent studies that did not show any risk increase among female players [27, 33].

Insert Table 3 near here

The studies included in this review have mostly involved adult players and the youngest players have been 13 years [42]. Although ACL injury is rare in pre-pubertal children, no difference has been found between girls and boys up to 12 years-of-age according to insurance claims data from the USA [40]. Only a few studies have reported the average age at injury, but all these studies have consistently shown that female players are younger when they sustain their ACL injury [11, 39, 48]. According to a questionnaire survey in Norway based on surgery records, ACL-injured female players were significantly younger (19 vs. 27 years) than their male counterparts [11]. In another study based on reported insurance claims in Sweden, female players were four years younger (19 vs. 23 years) when sustaining their injury than the male players [39]. Recently, we reported that female elite players were 4 years younger (21 vs. 25 years) than male elite players when tearing their ACL [48].

DISCUSSION

Female-to-male ratio

Female athletes participating in jumping, cutting and pivoting team sports such as football, basketball and volleyball are often claimed to have a 4-6 times higher ACL injury risk compared to their male counterparts [26]. The ACL injury incidence has even been reported to be up to eightfold higher among female athletes in other compilations [46]. There is, to our knowledge, no previous review summarising gender-related differences in ACL injury risk from a methodological perspective. According to this review, the magnitude of the previously reported risk increase for female athletes can be questioned. This is further supported by a recent meta-analysis [36], where the average F/M-ratio in football was found to be 2.67. In this meta-analysis, however, only five prospective cohort studies could be used in the calculation of the F/M-ratio. We included more studies in our literature review, but it was not possible to conduct a meta-analysis since some of the studies had no exposure data. Nevertheless, the majority of the studies found a two- to threefold increase in risk which is in line with the F/M-ratio identified in the aforementioned meta-analysis [36]. As seen in Table 3, we found only one study that reported more than a four-fold increased relative risk among female football players [25].

The NCAA-ISS was instituted already in 1982, originally reporting injuries only from American football, but subsequently other intercollegiate sports such as football were included. From the season of 1989-1990, knee injury data had to be specified making it possible to extract prospective ACL injury figures. In NCAA-ISS, the ACL injury risk has consistently been found to be between 2.4 and 2.8 times higher among female football players [1, 5-6, 31]. The obvious strength of the NCAA studies is the large number of ACL injuries reported over a varying number of consecutive seasons together with weekly submitted exposure. However, the main limitation is that no checks

of data accuracy were performed and the quality of data is therefore unknown. Furthermore, it is not clear how ACL injury was defined, although it seems that ACL injury did not have to be surgically verified [5]. In addition, we can assume that the collegiate players typically are 18-22 years old, but since no specific age data is reported it is unclear whether the age at injury differs between genders. We know from a few studies that age at injury tends to be lower in females [11, 39, 48], and insurance claims data from youth football in the USA suggests that the ACL injury risk may be highest for 16 year-old females [40]. Age can thus be a confounding factor in gender-related comparisons of injury risk and should be adjusted for. Another weakness is that injury incidence is reported as the number of injuries per athlete-exposure (AE). When calculating the injury rate, AE is less accurate than player-hours as the duration of the exposure is not always equal; reporting incidence based on AE is therefore not recommended in football injury surveillance [20]. To avoid the limitations with using AE, the exposure were converted to player-hours in two recent papers on the same collegiate cohort [21-22].

Using similar definitions and design as in the intercollegiate studies, one study on high school players in the USA found a more than threefold increased risk of ACL injury among females [35]. However, there are several limitations to this study as well. First, the number of ACL injuries included is limited (n=44) and only injuries requiring surgery were included in the statistics. Second, no exposure data was collected and instead the total number of players at risk was used as the denominator. Third, no age data is reported and it is therefore unclear also in this setting whether age at injury differs between the genders. Similarly, the studies from the US military and naval academies [25, 33], can in many ways be comparable to those described above from college and high school since the data is obtained from their participation in intercollegiate and intramural football. These studies are thus associated with essentially the same limitations as mentioned

previously, but both of these studies also report on very small materials (n=18 and n=22, respectively). More importantly, the two studies report conflicting results; the first study found the highest F/M-ratios (6.9-9.5) reported in the literature [25], while the second study found no gender difference or even lower risk among females (F/M-ratio 0.4-1.1) [33]. The underlying reasons for this discrepancy are unclear.

We have recently reported gender-related figures for ACL injuries sustained at the elite level [27, 48]. The major strength in these two studies is the monthly submitted individual playing times together with regular checks of data accuracy. Moreover, the injuries are carefully defined and all ACL injuries, irrespective of the severity or treatment, are included. The main limitations of the first study are the absence of age data and the small number of injuries (n=16) thereby reducing the statistical power [27]. In the second study, the study sample is considerably larger (n=78) since data was collected over several seasons and the differences in mean age between the cohorts are also taken into account [48]. Similar to the recent studies from NCAA [21-22], separate rates were reported for match play and training. This might be an important methodological issue, since several studies have shown that match play accounts for most of the risk increase in females, whereas training incidences are similar [8, 17-18, 21-23, 29, 45, 48]. Hence, activity type (i.e. match play or training) could, similarly to age, be a confounding factor that one should adjust for.

Finally, there are two questionnaire studies based on either surgery register files or insurance claims [11, 39]. The principal strength of such studies is the size of the samples (n=176 and n=338, respectively). Further advantages with insurance claims studies are that data for all ACL injuries regardless of treatment are collected as well as birth date and when the injury occurred. The major limitation of both study types is, of course, the retrospective data collection procedure and there

might be both insufficient cross-checking of data accuracy and recall bias when answering a questionnaire. Furthermore, even if severe injuries are less likely to be overlooked, there is always a "tip of the iceberg" phenomenon to some extent [28]. Although the number of players carrying insurance in the company is known, i.e. the population at risk, there is no exposure factor. The exposure factor is also lacking in studies based on surgery records and can only be more or less accurately estimated. In addition, the number of players at risk is unknown and ACL injuries not leading to surgery are excluded.

Methodological considerations and directions for future research

The search phrase used in the present review was deliberately broad, since our main intention was to include as many studies as possible. If the search terms had been more specified, some of the general injury surveillance studies would have been missed. On the other hand, our literature search identified a substantial number of articles that had to be excluded since other football codes or injuries other than ACL injury were studied. As mentioned previously, it was not possible to conduct a meta-analysis or use another systematic statistical approach due to lack of or inconsistency in reporting exposure data in many of the studies included. Furthermore, the annual frequency and prevalence of ACL injury was found to vary substantially between studies and it was therefore difficult to see if there are any gender-related differences in this aspect. In studies reporting on ACL injury incidence it seems, however, that there is an increased ACL injury risk in females during match play compared to males, but that the risk during training is more equal. In addition, the ACL injury risk is consistently shown to be much higher during match play, and gender-specific incidences should therefore always be reported for training and match play separately to be able to create activity-specific rate ratios.

In closing, we propose that studies investigating the influence of gender on ACL injury risk should preferably be sport-specific and not include a mix of athletes from different sports. It is also vital that studies include an adequate number of ACL injuries to get the desired statistical power, and a sample size calculation specific to the type of test that will be used is recommended [9]. Ideally, all ACL injuries should be included, not only complete tears, surgically proven injuries or first-time (index) injuries etc. to get a true picture of the injury burden. Reporting injury incidence should be based on athlete-hours and not athlete-exposures [20], submitted weekly or monthly to the research centre. Basic anthropometric data, as a minimum player age, should be reported for the different groups studied since female players are often younger than males. Potential confounding factors such as age and activity type should preferably be adjusted for in the statistical model. As shown recently by our group, the F/M-ratio was lowered more than 20% when adjusting for differences in age between Swedish female and male elite players [48].

Conclusions

In this review on gender-related differences on ACL injury epidemiology in football, we conclude that ACL injury is a rather unusual football injury rarely constituting more than 5% of all time loss injuries regardless of the playing level. The vast majority of the identified studies have shown that female players seem to have a 2-3 times higher ACL injury risk compared to male players. This risk increase is of the same magnitude as found in a recent meta-analysis on football involving fewer studies [36], but considerably lower than that suggested in some general reviews [26, 46]. Although much less studied, female players also tend to sustain their ACL injuries at a younger age than male players. Hence, age could be a confounding factor in gender-related comparisons of injury risk and it is therefore important to standardise for age or make other adjustments in the

analyses. Similarly, gender-related comparisons might also need to be adjusted for activity type, since the risk increase found in females seems to be match-related to a great extent.

Conflict of interest

The authors declare that they have no conflict of interest.

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Table 1. Cohort studies reporting annual prevalence and frequency of ACL injury using a time loss injury definition.

	Country	Setting	No. of players	No. of players with ACL injury (%)	No. of injuries	No. of ACL injuries (%)
Women						
Becker et al., 2006 [10]	Germany	12 division I teams 2000-2001	254	11 (4.3)	216	11 (5.1)
Engström et al., 1991 [16]	Sweden	2 division I-II teams 1988	41	2 (4.9)	78	2 (2.6)
Faude et al., 2005 [17]	Germany	9 division I teams 2003-2004	165	10 (6.0)	241	11 (4.6)
Hägglund et al., 2009 [27]	Sweden	12 division I teams 2005	228	8 (3.5)	299	8 (2.7)
Steffen et al., 2007 [42]	Norway	109 Under-17 teams 2005	2020	11 (0.5)	526	11 (2.1)
Söderman et al., 2001a [43]	Sweden	10 division I-V teams 1996	153	1 (0.7)	79	1 (1.3)
Söderman et al., 2001b [44]	Sweden	13 division II-III teams 1998	146	5 (3.4)	80*	5 (6.3)*
Tegnander et al., 2008 [45]	Norway	10 division I teams 2001	181	2 (1.1)	189	2 (1.1)
Waldén et al., 2010 [48]	Sweden	13 division I teams 2004-2009**	486**	15 (3.1)	637	15 (2.4)
Östenberg & Roos, 2000 [49]	Sweden	8 division I-V teams 1996	123	3 (2.4)	65	3 (4.6)
Men						
Árnason et al., 1996 [7]	Norway	5 division I teams 1991	84	1 (1.2)	85	1 (1.2)
Árnason et al., 2004 [8]	Norway	17 division I-II teams 1999	306	5 (1.6)	244	5 (2.0)
Ekstrand et al., 1983 [14]	Sweden	12 division IV teams 1980	180	1 (0.6)	256	1 (0.4)
Engström et al., 1990 [15]	Sweden	3 division I-II teams 1987	64	4 (6.3)	85	4 (4.7)
Faude et al., 2009 [18]	Germany	18 division I teams 2004-2005	471	12 (2.5)	1187	12 (1.0)
Hägglund et al., 2009 [27]	Sweden	11 division I teams 2005	239	8 (3.3)	548	8 (1.5)
Rahnama et al., 2009 [37]	Iran	16 division I teams 2005-2006	390	33 (8.5)	62**	33 (53.2)
Waldén et al., 2005 [47]	Sweden	12 division I teams 2001	310	4 (1.3)	715	4 (0.6)
Waldén et al., 2010 [48]	Sweden	16 division I teams 2001-2009***	1211**	19 (1.6)	2607	20 (0.8)
Waldén et al., 2010 [48]	Europe****	28 division I teams 2001-2009***	2962**	42 (1.4)	5791	43 (0.7)

*Only lower limb injuries

**Only knee injuries

***Teams participated in varying number of seasons during the study period and instead the number of player-seasons is listed

****Belgium, England, France, Germany, Italy, Portugal, Scotland, Spain, Switzerland, the Netherlands and Ukraine

Table 2. Prospective cohort studies reporting ACL injury incidence per 1000 hours.

	Country	Setting	No. of ACL injuries	ACL injury incidence
Women				
Faude et al., 2005 [17]	Germany	9 division I teams 2003-2004	11 - 11 match - 0 training	?* - 2.2 match - 0 training
Fuller et al., 2007a, b [21-22]	USA	64 college and university teams 2005 and 72 teams 2006	81 (grass) - 61 match** - 20 training** 10 (artificial turf) - 9 match** - 1 training**	? (grass)* - 1.64 match - 0.09 training ? (artificial turf)* - 1.29 match - 0.02 training
Giza et al., 2005 [23]	USA	8 division I teams 2001-2002	8 - 5 match - 3 training	0.09 - 0.9 match - 0.04 training
Hägglund et al., 2009 [27]	Sweden	12 division I teams 2005	8	0.15
Le Gall et al., 2008 [29]	France	Football academy 1998-2006	12 - 10 match - 2 training	0.12 - 1.1 match - 0.02 training
Steffen et al., 2007 [42]	Norway	109 Under-17 teams 2005	11	0.08
Tegnander et al., 2008 [45]	Norway	10 division I teams 2001	2 - 2 match - 0 training	?* - 0.6 match - 0 training
Waldén et al., 2010 [48]	Sweden	13 division I teams 2004-2009	15 - 11 match - 4 training	0.14 - 0.72 match - 0.04 training
Östenberg & Roos, 2000 [49]	Sweden	8 division I-V teams 1996	3	0.3
Men				
Árnason et al., 2004 [8]	Iceland	17 division I-II teams 1999	5 - 3*** - 2***	0.15 - 0.5 match - 0.07 training
Faude et al., 2009 [18]	Germany	18 division I teams 2004-2005	12 - 12 match - ? training*	?* - 1.0 match - ? training*
Fuller et al., 2007a, b [21-22]	USA	52 college and university teams 2005 and 54 teams 2006	19 (grass) - 13 match** - 6 training** 4 (artificial turf) - 3 match** - 1 training**	? (grass)* - 0.47 match - 0.03 training ? (artificial turf)* - 0.42 match - 0.02 training
Hägglund et al., 2009 [27]	Sweden	11 division I teams 2005	8	0.11
Waldén et al., 2010 [48]	Sweden	16 division I teams 2001-2009	20 - 12 match - 8 training	0.06 - 0.28 match - 0.03 training
Waldén et al., 2010 [48]	Europe****	28 division I teams 2001-2009	43 - 36 match - 7 training	0.06 - 0.31 match - 0.01 training

ACL: Anterior cruciate ligament
* Not reported or not possible to compute
** Personal communication with Colin Fuller, MD, PhD, 10/11/2009
*** Personal communication with Árni Árnason, PT, PhD, 04/01/2010
**** Belgium, England, France, Germany, Italy, Portugal, Scotland, Spain, Switzerland, the Netherlands and Ukraine

Table 3. Studies reporting gender-related differences in ACL injury risk.

	Country	Setting	No. of ACL injuries	Female-to-male-ratio
Insurance claims data				
Roos et al., 1995 [39]	Sweden	Records during 1 year (1986)	338 (106 F; 232 M)	1.88
Surgery register data				
Bjordal et al., 1997 [11]	Norway	Records during 10 years (1982-1991)	176 (43 F; 133 M)	1.75
Military academy data				
Gwinn et al., 2000 [25]	USA	Naval Academy during 6 years (1991-1997)	Intercollegiate 6 (5 F; 1 M) Intramural 12 (2 F; 10 M)	9.48 6.86
Mountcastle et al., 2007 [33]	USA	Military Academy during 10 years (1994-2003)	Intercollegiate 9 (4 F; 5 M) Intramural 13 (1 F; 12 M)	1.19 0.43
High school data				
Powell & Barber-Foss, 2000 [35]	USA	NATA during 3 years (1995-1998)	44 (33 F; 11 M)	3.41
College data				
Agel et al., 2005 [1]	USA	NCAA during 13 years (1990-2002)	586 (394 F; 192 M)	2.81
Arendt & Dick, 1995 [5]	USA	NCAA during 5 years (1989-1993)	178 (97 F; 81 M)	2.38
Arendt et al., 1999 [6]	USA	NCAA during 5 years (1994-1998)	235 (158 F; 77 M)	2.75
Fuller et al., 2007a [21]	USA	NCAA during 2 years (2005-2006)	Grass 74 (61 F; 13 M)* Artificial turf 12 (9 F; 3 M)*	3.49 3.07
Fuller et al., 2007b [22]	USA	NCAA during 2 years (2005-2006)	Grass 26 (20 F; 6 M)* Artificial turf 2 (1 F; 1 M)*	3.00 1.00
Mihata et al., 2006 [31]	USA	NCAA during 15 years (1989-2004)**	669 (457 F; 212 M)	2.67
Elite data				
Hägglund et al., 2009 [27]	Sweden	23 teams during 1 year (2005)	16 (8 F; 8 M)	1.31
Waldén et al., 2010 [48]	Sweden	29 teams during 9 years (2001-2009)***	35 (15F; 20 M)	2.62

ACL: Anterior cruciate ligament; F: Female; M: Male; NATA: National Athletic Trainers' Association; NCAA: National Collegiate Athletic Association

The female-to-male-ratio is expressed as a risk or rate ratio with the total number of players at risk or risk exposure as the denominator

*Personal communication with Colin Fuller, MD, PhD, 10/11/2009

** The 1996-1997 season was not included

*** Teams participated in varying number of seasons during the study period