ARTHRITIS & RHEUMATISM
Vol. 50, No. 10, October 2004, pp 3145–3152
DOI 10.1002/art.20589

High Prevalence of Knee Osteoarthritis, Pain, and Functional Limitations in Female Soccer Players Twelve Years After Anterior Cruciate Ligament Injury

L. S. Lohmander, A. Östenberg, M. Englund, and H. Roos

Objective. **To determine the prevalence of radiographic knee osteoarthritis (OA) as well as knee-related symptoms and functional limitations in female soccer players 12 years after an anterior cruciate ligament (ACL) injury.**

Methods. **Female soccer players who sustained an ACL injury 12 years earlier were examined with standardized weight-bearing knee radiography and 2 self-administered patient questionnaires, the Knee Injury and Osteoarthritis Outcome Score questionnaire and the Short Form 36-item health survey. Joint space narrowing and osteophytes were graded according to the radiographic atlas of the Osteoarthritis Research Society International. The cutoff value to define radiographic knee OA approximated a Kellgren/Lawrence grade of 2.**

Results. **Of the available cohort of 103 female soccer players, 84 (82%) answered the questionnaires and 67 (65%) consented to undergo knee radiography. The mean age at assessment was 31 years (range 26–40 years) and mean body mass index was 23 kg/m^2 (range 18–40 kg/m^2). Fifty-five women (82%) had radiographic changes in their index knee, and 34 (51%) fulfilled the criterion for radiographic knee OA. Of the subjects answering the questionnaires, 63 (75%) reported having symptoms affecting their knee-related quality of life, and 28 (42%) were considered to have symptomatic radiographic knee OA. Slightly more than 60% of the players had undergone reconstructive surgery of the ACL. Using multivariate analyses, surgical reconstruction was found to have no significant influence on knee symptoms.**

Conclusion. **A very high prevalence of radiographic knee OA, pain, and functional limitations was observed in young women who sustained an ACL tear during soccer play 12 years earlier. These findings constitute a strong rationale to direct increased efforts toward prevention and better treatment of knee injury.**

Women's soccer is a rapidly growing sport, particularly in North America. In the US there are more than 17 million players participating in organized soccer, of whom 7 million are female. Women's soccer has attracted the most participant growth among US student-athletes for a number of years. More than 40,000 female players, or 20% of all soccer players, are registered in the Swedish Soccer Association, making women's soccer the second largest sport in Sweden. The rate of injury in soccer is estimated to be between 14 and 35 injuries per 1,000 game hours and between 2 and 8 injuries per 1,000 practice hours (1–4). The overall injury rate is the same for male and female soccer players, but injury patterns are different. The risk of anterior cruciate ligament (ACL) injury is 3–4 times higher per game hour in female players than in male players (2,5–7). Female soccer players sustain their knee injuries at a younger age, with an average age at injury of 19 years, compared with 23 years for male players (7). The risk of an ACL injury in junior soccer was estimated to be 4–5 times higher for girls compared with boys (6).

A major knee injury will often have severe short-term consequences such as an interrupted soccer career (7–10). The risk of knee osteoarthritis (OA) with onset at a young age, resulting in life-long disability, is a

Supported by the Swedish Rheumatism Association, the Swedish Soccer Federation, the Swedish Sports Confederation (Sports Research Council), the Swedish Research Council, the Zoega Foundation, the Gorthon Foundation, the Kock Foundation, the King Gustaf V 80-Year Anniversary Foundation, the Faculty of Medicine of Lund University, and Region Skåne.

L. S. Lohmander, MD, PhD, A. Östenberg, PT, PhD, M. Englund, MD, PhD, H. Roos, MD, PhD: Lund University, Lund, Sweden.

Address correspondence and reprint requests to L. S. Lohmander, MD, PhD, Department of Orthopedics, Lund University Hospital, SE-221 85 Lund, Sweden. E-mail: stefan.lohmander@ort.lu.se.

Submitted for publication February 6, 2004; accepted in revised form July 19, 2004.

reality. Thus, posttraumatic OA was present in ~50% of patients 15 years after a major knee injury, and was similarly noted in 50% of the participants of a long-term followup study after an isolated meniscus tear and total meniscectomy (11,12). However, to date, no information has been published on the long-term consequences of an ACL injury among female players. The objective of this study was to assess, for the first time, the long-term consequences of an ACL tear in female soccer players with regard to the development of radiographic knee OA, level of activity, and subjective symptoms.

PATIENTS AND METHODS

Subjects. In Sweden, all soccer players participating in league soccer carry obligatory insurance with Folksam Insurance Company. All 338 players (106 of whom were female) with an ACL injury sustained while playing league soccer in Sweden in 1986 were identified through the insurance company archives (7). The injury was, in the majority (86%) of the women, diagnosed through open or arthroscopic surgery, while in the remainder of women, an ACL tear was identified by clinical examination (7). In 1998, all 106 female players with an ACL tear were contacted by mail and asked to complete questionnaires and have their knees examined by radiography. Two players had died and 1 could not be located. The study was approved by the Research Ethics Committee at the Medical Faculty of Lund University.

Radiographic examination. All radiographs were obtained by the same standardized technique, with standing anteroposterior radiographs obtained from both knees at 15° of flexion (film-focus distance 1.4 meters) (12). An axial view of the patellofemoral joint was obtained with a vertical beam, with the patient standing with the knee in ~40° of flexion. The frontal view of the tibiofemoral joint and the axial patellofemoral image from both knees were classified according to the recommendations of the Osteoarthritis Research Society International (OARSI), using a radiographic atlas (13). Joint space narrowing (JSN) and osteophytes were graded on a scale from 0 to 3 (with 0 indicating no evidence of JSN or bony changes). All radiographs were evaluated by the same reader (HR). A previous study showed high agreement between the evaluations of this reader and those of an independent reader (12). All films were read without prior knowledge of the injured side. However, the surgical procedures related to ACL reconstruction were detectable on the radiograph films that revealed the side injured.

We considered radiographic OA to be present in a knee if any of the following criteria was achieved in any of the 2 tibiofemoral compartments or in the patellofemoral compartment: either a JSN grade of $\geq$2 or a sum of $\geq$2 for the 2 marginal osteophyte grades from the same compartment, or a JSN grade of at least 1 in combination with an osteophyte grade of at least 1 in the same compartment (14–16). This cutoff for defining radiographic OA approximates grade 2 knee OA based on the Kellgren/Lawrence scale (17). We regarded the presence of either JSN grade 1 or a single grade 1 osteophyte as too nonspecific to be classified as radiographic OA. However, recent findings suggest that a Kellgren/Lawrence grade of 1 may reflect emergent knee OA (18,19).

Knee Injury and Osteoarthritis Outcome Score (KOOS). The KOOS is a self-administered knee-specific questionnaire containing 5-item Likert scales. The KOOS covers 5 patient-relevant dimensions: pain, other symptoms, activities of daily living (ADL), function in sports and recreation (Sports/Rec), and knee-related quality of life (QOL) (20). The validated Swedish version of the KOOS was used (21).

Two reference groups were used for comparison with the results of the KOOS provided by the study cohort. The first reference group comprised Swedish female soccer players (n = 108, mean age 20 years [range 14–30 years]) with no knee injury (22). The players in this reference group were identified in 1996 and were representative of all different levels of women's league soccer (23). The second reference group consisted of 55 subjects (n = 15 women, mean age 55 years [range 36–79 years]) with intact cruciate ligaments, no radiographic tibiofemoral or patellofemoral OA, and no previous knee surgery. This reference group was identified from the Swedish National Population Records for use in a study of OA after meniscectomy (12,23).

We used an operational definition for a symptomatic knee, based on the patient's self-reported responses from the KOOS questionnaire, to identify individuals likely to seek medical care (15). The definition of a symptomatic knee required that the value for the KOOS QOL subscale and the value for 2 of the 4 additional subscales should be equal to or less than the score obtained as follows: at least 50% of the questions within the subscale had an answer that was at least a 1-step decrease from the best response (e.g., no pain/best possible function) on the 5-point Likert scale. After conversion to a scale of 0–100 (for worst–best), the cutoff values to define a symptomatic knee were as follows: for pain $\leq$86.1, for symptoms $\leq$85.7, for ADL $\leq$86.8, for function in Sports/Rec $\leq$85.0, and for QOL $\leq$87.5. Patients who fulfilled the criteria for being symptomatic and for having radiographic OA of the knee (as defined above) were classified as having symptomatic radiographic knee OA.

Short Form 36-item (SF-36) health survey. The SF-36 is a widely used generic measure of health status, comprising 8 subscales: physical functioning, role-physical, bodily pain, general health, vitality, social functioning, role-emotional, and mental health (24). The SF-36 has been used in subjects with ACL injury (25). We used the Swedish Acute version 1.0, and, for comparison, we used reference data provided in the Swedish manual from a sample of Swedish women ages 25–34 years (n = 896) (26).

The subjects answered additional questions about their present physical activity level, and whether they had undergone any surgery on the injured knee. Occupational workload was graded as clerical work/unemployed/retired, light labor, moderate labor, or heavy labor. Examples from each category were given. Current leisure-time activity was self-reported on a scale from 0 to 6 (modified from the method provided by S. Edworthy, McCraig Centre for Joint Injury & Arthritis Research, Calgary, Alberta, Canada), with 0 defined as a minimum level of recreational activities and 6 as active participation in competitive sports (23) (Table 1).

Statistical analysis. Continuous data between 2 groups were analyzed using the Mann-Whitney U test. Binary data in

Table 1. Assessment of leisure-time physical activity*

Level	Description
6	Competitive sports: soccer, racquet sports, track and field, skiing, etc.
5	Recreational sports: jogging, skiing, racquet sports, etc.
4	Golf, dancing, hiking, water aerobics.
3	Heavy yard work, heavy household work, walking on even ground.
2	Light yard work, light household work, shopping.
1	Minimal household work, card games, sewing.
0	No household work, television, reading.

* The patients were instructed to answer the following question: "Which description describes your current recreational activities the best? Please mark *one* alternative."

2×2 tables were evaluated with Fisher's exact test. A confidence interval of 95% (95% CI) was used when comparing the study population with the reference groups for the SF-36 results. To obtain a multivariate-adjusted odds ratio (OR), with 95% CI, when evaluating reconstructive ligament surgery as a candidate risk factor, a logistic regression model was used, with all variables entered (age [continuous], current body mass index [continuous], surgically treated meniscal injury, workload, and spare-time activity level). A similar model was used to evaluate the influence of a surgically treated meniscal injury.

RESULTS

Response rate and demographics. Of the 103 available injured players, 84 answered the questionnaires (82%). The mean age of the respondents at the time of injury was 19 years and at the followup assessment was 31 years (range 26–40 years). The mean body mass index at assessment was 23 kg/m^2 (range 18–40 kg/m^2). Twenty-seven of these women (32%) played top-level soccer (first or second league in Sweden) at the time of injury. Thirty-four (40%) of the players with ACL-injured knees had associated meniscus injuries that required surgery, which was performed either at the same time as the ACL surgery or separately as an arthroscopic procedure. Fifty-two (62%) of the 84 players had undergone ACL reconstruction; the most common surgical method was an autologous patellar tendon graft (65%) (7). The surgical reconstruction was performed an average of 3 years (range 0–11 years) after the injury. The left knee was the injured index knee in 46 subjects (55%).

Sixty-seven of the 103 players (65%) consented to undergo radiographic examination. Of those who did not undergo radiography, 3 were pregnant, 5 were unable to participate due to their work schedule, 3 lived too far away, and 6 gave no reason. We did not obtain a patellofemoral image of the index knee in 1 patient. Radiographs of the contralateral knee were not obtained for 2 patients, and 1 subject did not undergo radiographic examination of the patellofemoral joint of the contralateral knee. The 17 players who answered the questionnaires but declined to undergo a radiographic examination did not differ in age, weight, and height or in their KOOS or SF-36 score compared with those who had radiographs obtained. The 10 players who, despite repeated letters and calls, declined to participate in any part of the study did not differ in age compared with those who participated.

At the followup examination 12 years after injury, 7 of the 84 players (8%) still participated in organized soccer, whereas more than 50% of the players never had returned to organized soccer after their ACL injury. Only 13 subjects (15%) estimated their current activity level to be the same as or higher than that prior to their injury. The women's median current occupational workload was moderate (the level of, for example, a nurse, cleaner, or preschool teacher), and the median spare-time activity level was 4 (the level of, for example, golf, dancing, hiking, or water aerobics). The occupational workload and spare-time activity levels were similar between ACL-reconstructed players and nonsurgically treated players.

Radiographic findings. Radiographic patellofemoral or tibiofemoral OA was present in 34 (51%) of 67 index (injured) knees, of which 2 knees had isolated radiographic patellofemoral OA and 7 knees had mixed OA (combined patellofemoral and tibiofemoral OA). Seven subjects had both tibiofemoral and patellofemoral radiographic OA in the index knee. Grade 1 JSN or grade 1 osteophytes was recorded as the only feature in another 20 index knees. Thus, 55 (82%) of the 67 examined female soccer players had radiographic changes in either the tibiofemoral or the patellofemoral joint (Table 2).

In the contralateral knee, radiographic tibiofemoral OA was present in 5 of 65 knees (8%), of which all but 1 knee had known injuries (3 ACL and 1 meniscus injury). No patient had radiographic patellofemoral OA in the contralateral knee. Grade 1 JSN or grade 1 osteophytes was present as the only feature in another 19 contralateral knees (29%). Thus, 24 of 65 patients (37%) had radiographic changes in the contralateral knee (Table 2).

The prevalence of radiographic knee OA in the group of players treated with ACL reconstruction was 23 of 41 (56%) in the index knee compared with 11 of 26 (42%) in those who had not undergone reconstructive surgery ($P = 0.3$). In the group treated with ACL

Table 2. Radiographic changes in the index and contralateral knees among female soccer players 12 years after injury to the anterior cruciate ligament (ACL) treated with or without surgical reconstruction of the ligament*

	Radiographic change in the index knee/contralateral knee, no. (%)		
	All subjects (n = 67)	ACL surgery (n = 41)	No ACL surgery (n = 26)
Radiographic knee OA	34 (51)/5 (7)	23 (56)/2 (5)	11 (42)/3 (12)
Radiographic tibiofemoral OA	32 (48)/5 (7)	21 (51)/2 (5)	11 (42)/3 (12)
Radiographic patellofemoral OA	9 (13)/0 (0)	8 (20)/0 (0)	1 (4)/0 (0)
Any radiographic change†	55 (82)/24 (37)	38 (93)/14 (35)	17 (65)/10 (40)
Osteophyte grade ≥1	49 (73)/22 (34)	35 (85)/12 (30)	14 (54)/10 (40)
JSN grade ≥1	31 (46)/9 (14)	18 (44)/6 (15)	13 (50)/3 (12)

* See Patients and Methods for definition of radiographic knee osteoarthritis (OA). For all subjects, n = 65 for the contralateral knee; for ACL surgery, n = 40 for the contralateral knee; for no ACL surgery, n = 25 for the contralateral knee. JSN = joint space narrowing.
† Defined as JSN grade ≥1 or osteophyte grade ≥1 in the patellofemoral and/or the 2 tibiofemoral compartments.

reconstruction, 8 patients had patellofemoral radiographic OA compared with 1 subject among those without surgery ($P = 0.14$) (Table 2). Significantly more patients with an ACL-reconstructed knee had radiographic changes in the patellofemoral joint compared with nonsurgically treated patients (25 of 41 [61%] versus 7 of 25 [28%]; $P = 0.01$). ACL-injured players who also underwent meniscus surgery had a higher prevalence of radiographic knee OA than those without such surgery (18 of 26 [69%] versus 16 of 41 [39%]; $P = 0.02$).

Symptomatic radiographic knee OA. Among the 84 patients who answered the KOOS questionnaire, 63 (75%) were classified as symptomatic. Of the patients with radiographic knee OA in the index knee, 28 (82%) of the 34 were considered symptomatic, compared with 24 (73%) of the 33 patients without radiographic knee OA ($P = 0.4$) (Table 3). Among those subjects who had undergone ACL reconstruction, 19 of 41 (46%) had symptomatic radiographic knee OA, and the corresponding proportion among those who had not received surgery was 9 of 26 (35%) ($P = 0.2$). Among all 84 players, equal proportions (75%) were considered to be symptomatic regardless of whether the subject had undergone reconstructive ACL surgery. There was no difference in either the radiographic or the symptomatic outcome between those who had received reconstructive ACL surgery within 1 year from their injury and those who had the reconstruction performed later (data not shown).

KOOS results. The ACL-injured soccer players scored significantly worse ($P < 0.001$) in all 5 dimensions of the KOOS compared with the reference group of female soccer players with a mean age of 20 years (Figure 1). The largest differences were seen in Sports/Rec function and knee-related QOL, with mean scores of 54 for both subscales among the injured players and mean scores of 89 for both subscales in the uninjured

Table 3. Knee Injury and Osteoarthritis Outcome Score in women with anterior cruciate ligament injury with or without radiographic tibiofemoral or patellofemoral osteoarthritis (OA)*

	Total study group (n = 84)	No radiograph (n = 17)	Radiographic knee OA (n = 34)	No radiographic knee OA (n = 33)	P†
Pain	83 ± 19	83 ± 15	80 ± 16	87 ± 12	0.03
Other symptoms	76 ± 19	73 ± 19	70 ± 21	84 ± 12	0.004
ADL	92 ± 10	90 ± 13	91 ± 11	93 ± 9	0.15
Sports/Rec	54 ± 27	52 ± 25	48 ± 26	60 ± 29	0.11
QOL	54 ± 20	51 ± 24	52 ± 20	57 ± 18	0.4

* See Patients and Methods for definition of radiographic knee OA. Except where indicated otherwise, values are the mean ± SD subscale score. ADL = activities of daily living; Sports/Rec = sports and recreation function; QOL = knee-related quality of life.
† Subjects with radiographic knee OA versus those without radiographic knee OA, by Mann-Whitney U test.

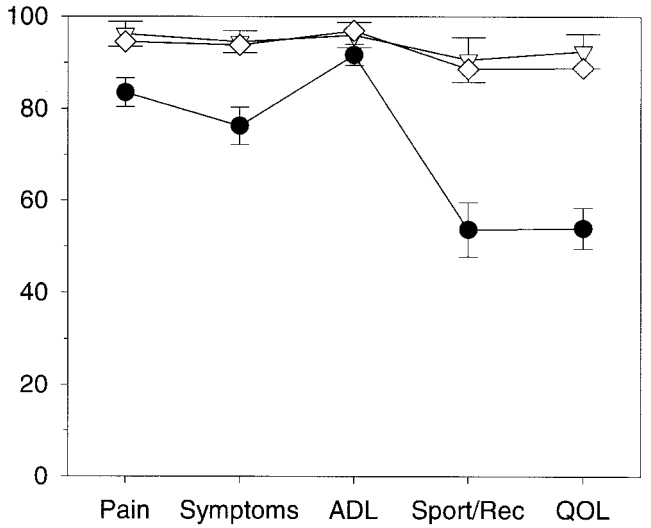

Figure 1. The Knee Injury and Osteoarthritis Score (KOOS) profile. Results are the mean scores and 95% confidence intervals for the KOOS subscales pain, other symptoms, activities of daily living (ADL), function in sports and recreation (Sport/Rec), and knee-related quality of life (QOL), reported as an outcome profile for the anterior cruciate ligament injury group (solid circles; n = 84, mean age 31 years), the reference group without radiographic knee osteoarthritis (open reverse triangles; n = 55, mean age 55 years), and the reference group of uninjured female soccer players (open diamonds; n = 108, mean age 20 years). For the latter reference group, the 95% confidence intervals were too small to be visualized.

reference group. The ACL-injured soccer players also scored significantly worse ($P < 0.001$) in all dimensions of the KOOS, except the ADL subscale, in comparison with the other reference group (without radiographic knee OA, mean age 55 years, 27% women). The largest differences were again found in Sports/Rec function and knee-related QOL. As reported in the KOOS questionnaire, the knee problems resulted in a modified lifestyle in 50% of the injured players, and a lack of confidence in the index knee was reported by 70% of those with an ACL injury.

The women defined as having radiographic knee OA scored lower on all of the KOOS subscales compared with individuals without radiographic OA. However, the differences were only statistically significant for the subscales on pain ($P = 0.03$) and other symptoms ($P = 0.004$) (Table 3). There were no significant differences in the KOOS dimensions in terms of whether or not the patient had undergone surgical reconstruction of the ACL ($P \geq 0.2$).

SF-36 results. The injured players scored significantly worse than the reference group of Swedish women ages 25–34 years in the physical functioning subscale of the SF-36 questionnaire. However, the players scored better than the reference group in the subscale on social functioning. In the other 6 subscales of the SF-36 there were no significant differences between the groups (Table 4).

Table 4. Short Form 36-item health survey subscale scores in women 12 years after injury to the anterior cruciate ligament during soccer play*

	Study group (n = 84)	Swedish female population ages 25–34 years (n = 896)
Physical functioning	82 (80–85)	93 (92–94)
Role-physical	80 (72–87)	87 (85–89)
Bodily pain	73 (68–78)	77 (76–79)
General health	81 (77–84)	80 (79–82)
Vitality	66 (62–70)	66 (65–68)
Social functioning	94 (91–96)	89 (88–90)
Role-emotional	86 (80–92)	87 (85–89)
Mental health	82 (79–85)	80 (79–81)

* Values are mean (95% confidence interval).

Multivariate analyses. Using multivariate models, we evaluated the influence of reconstructive ACL surgery on the radiographic outcome and on the likelihood of being symptomatic as assessed by the KOOS. Reconstruction of the ACL did not significantly influence the prevalence of definite radiographic knee OA, nor did it influence whether the subject was symptomatic. However, there was a tendency toward an increased likelihood to have radiographic patellofemoral OA de-

Table 5. Influence of surgical reconstruction of the anterior cruciate ligament (ACL) on the radiographic outcome and the self-reported outcome in female soccer players 12 years after the ACL injury*

	ACL reconstruction	
Outcome	Crude OR	Adjusted OR (95% CI)†
Radiographic knee OA‡	1.7	1.7 (0.6–5.0)
Radiographic tibiofemoral OA	1.4	1.3 (0.5–3.9)
Radiographic patellofemoral OA	5.8	14 (0.9–224)
Symptomatic§	1.0	0.8 (0.3–2.6)
Symptomatic radiographic knee OA§	1.5	1.7 (0.5–5.3)

* For radiographic outcome, n = 67, of whom 41 were ACL reconstructed. For self-reported outcome, n = 84, of whom 52 were ACL reconstructed. Odds ratios (OR) with 95% confidence intervals (95% CIs) are from logistic regression, using subjects without reconstructive ACL surgery as the reference category.
† Adjusted for age at assessment, body mass index, surgically treated meniscal injury, occupational workload, and spare-time activity level.
‡ Either tibiofemoral or patellofemoral radiographic osteoarthritis (OA) (see Patients and Methods for definition).
§ Symptomatic as assessed by the Knee Injury and Osteoarthritis Outcome Score (see Patients and Methods for definition).

tected after reconstruction of the ACL (Table 5). Reconstructive surgery remained significantly associated with patellofemoral radiographic changes (JSN or osteophyte grade ≥1) (OR 4.0, 95% CI 1.3–13).

The presence of surgically treated meniscal injury in the ACL-injured knee also remained significantly associated with radiographic knee OA (OR 3.6, 95% CI 1.2–11) and with symptomatic radiographic knee OA (OR 4.8, 95% CI 1.5–16), compared with no such injury. All of the results remained essentially the same with or without adjustment for the current occupational workload and spare-time activity level.

DISCUSSION

In this cohort of 26–40-year-old female soccer players who sustained an ACL injury 12 years earlier, slightly more than 50% of the subjects had radiographic OA in their injured knee, and ~80% had a radiographic feature related to OA (JSN or osteophyte OARSI grade ≥1). The majority (75%) of the 84 women had knee symptoms that substantially affected their knee-related QOL, and 28 subjects (42%) were defined as having symptomatic radiographic knee OA.

The present study reflects the severe consequences of an ACL injury in young women, with results being consistent with those from other long-term studies on ACL injury (27–30). If we had used more liberal criteria for the definition of radiographic OA, by including knees with a single definite osteophyte, the proportion diagnosed with OA would have been even higher (18,19). Indeed, in one review, 50–70% of patients with a major knee injury were noted to have radiographic knee changes at 15–20 years after the injury (11). Comparisons between studies on OA prevalence after knee injury are difficult, due to different types of injuries and the use of various radiographic techniques and classifications. However, when the same radiographic technique and criteria as in the present study were used, a radiographic knee OA prevalence of 55% was found ~20 years after total meniscectomy in 170 patients (mean age 54 years, 23% women) (14–16). A prospective study demonstrated that the relative risk of knee OA by age 65 years was increased 3-fold in participants who had a knee injury during adolescence and young adulthood (31).

A recent 14-year followup of ACL-injured male soccer players showed a prevalence of radiographic OA of 41% (32). The patients in the male soccer player study were recruited by the same method as in the present study, and the radiograph films were assessed by the same reader. However, the radiographic criteria for OA were more conservative than in the present study, and the retrospective, observational character of both studies limits our ability to make strong inferences about the relative risks of OA for men compared with women following ACL injury. However, if the risk per injury is at least as high for women as for men, female soccer players would be expected to show a higher prevalence of postinjury OA than male players, due to the their higher rate of ACL injuries (2,5–7).

Subjects with radiographic knee OA reported more pain and other symptoms than those without radiographic OA. However, the differences were relatively minor. Of the 34 individuals with radiographic knee OA, 28 had significant knee-related symptoms, fulfilling the criteria for symptomatic radiographic knee OA (15). Twenty-four of 33 subjects without radiographic OA fulfilled the same criteria, in accordance with earlier reports of a limited correlation between knee symptoms and radiographic OA (33).

There were no significant differences in the prevalence of radiographic knee OA, symptoms, or functional limitations between the subjects who had undergone reconstructive ACL surgery and those who had not. However, we noted an increased frequency of radiographic changes in the patellofemoral joint of ACL-reconstructed players. Whether this finding is related to the specific surgical reconstruction method used in the majority of the patients in this study, or whether it was more generally related to the knee surgery is uncertain and warrants further investigation. It is possible that if treated with current surgical methods, a greater proportion of the injured female players could have returned to soccer (34). However, a recent 8-year followup of ACL-injured handball players noted that more of the nonsurgically treated players returned to their preinjury activity level (27). An increased ability to return to soccer following surgical reconstruction may be disadvantageous with regard to the risk for development of knee OA (34,35).

Almost all surgical procedures in the present study were performed as open reconstructions. Current arthroscopic procedures may be associated with less morbidity in the short-term postoperative period (36). However, despite advances in the surgical technique, a recent prospective, randomized study with independent observers and self-administered questionnaires showed that following ACL reconstruction, only 60% of the patients had normal or nearly normal knee function (37). These observations imply that the outcome of reconstructive ACL surgery done in the late 1980s, as

was the time period in this study, may not necessarily be different from the outcome of surgery performed currently.

The results of the present study suggest that additional meniscus injury requiring surgery may influence long-term symptoms and OA prevalence. The loss of meniscal function in an ACL-injured knee may contribute to increased cartilage contact stress through decreased load distribution, shock absorption, and joint stability (38,39).

The study cohort was homogeneous, with the same type of knee injury in women sustained during the same sports activity, and with the same followup time. The response rate was 82% for the questionnaires, and the proportion of subjects undergoing radiographic examination was 65%. Radiographs were obtained with a standardized technique and evaluated by the same reader. The KOOS and the SF-36 questionnaires are validated outcome instruments for ACL injury, and are intended for use in physically active patients (23,25). This was a retrospective, observational cohort study, with the limitations associated with such studies. Some selection bias may have occurred, in which the presence of knee symptoms among those subjects invited into the study could have generated a greater interest to participate. Furthermore, the subjects were not randomized with regard to treatment of their ACL injury, and bias may thus have directed patients with more functional or mechanical instability or more severe associated injuries to undergo surgical treatment. Finally, the patients with the highest motivation for returning to play division-level soccer may have preferred surgery. However, no difference in age, in types of injuries associated with the ACL injury, or level of soccer was noted when subgroups treated with or without surgery were compared. The small number of subjects limited the power of the multivariate analyses that assessed additional risk factors for OA.

The already very high prevalence of radiographic OA in conjunction with pain and functional limitations among these young ACL-injured women at ages 26–40 years is alarming. For many of these women, the OA disease process can be expected to progress over time, and the need for an osteotomy or knee arthroplasty may arise well before the age of 50 years in many of the subjects (30). Although joint replacement may be an efficient treatment for knee OA, the risk of aseptic implant loosening and revision is more than 3-fold higher in the patients operated on while younger than age 65 years, than if older than 75 years (40).

To our best knowledge, the results shown herein represent the first long-term, female-specific study on radiographic OA, symptoms, and functional limitations following an ACL injury in the soccer player. We show that this injury leads to a high risk of knee OA with onset at a young age. The injury and the development of OA, irrespective of the treatment offered to these patients, resulted in knee-related symptoms that severely affect the quality of life of the young individual.

Our findings, coupled with the particularly high risk of knee injuries in female soccer players, constitute a strong rationale for increasing efforts aimed at prevention and better treatment of knee injury. Randomized, controlled trials are needed in which different surgical techniques and rehabilitation protocols are compared directly with the best nonsurgical treatment. Independent observers monitoring the outcome should, whenever possible, be blinded to the type of treatment given, and validated patient-relevant outcome measures used. Such trials would help define the best treatments and identify responders and nonresponders. An accurate and early diagnosis is important. Significant metabolic changes occur in the acutely injured joint (41–44). The long-term significance of these changes is not well understood. However, the early phase after an ACL injury may constitute an as-yet-unrecognized window of opportunity in which the long-term effects of interventions directed against the acute inflammation and joint destruction can be explored.

REFERENCES

1. Arnason A, Gudmundsson A, Dahl HA, Johannsson E. Soccer injuries in Iceland. Scand J Med Sci Sports 1996;6:40–5.
2. Engstrom B, Johansson C, Tornkvist H. Soccer injuries among elite female players. Am J Sports Med 1991;19:372–5.
3. Ekstrand J. Soccer injuries and their prevention [thesis]. Linköping: Linköping University; 1982.
4. Luthje P, Nurmi I, Kataja M, Belt E, Helenius P, Kaukonen JP, et al. Epidemiology and traumatology of injuries in elite soccer: a prospective study in Finland. Scand J Med Sci Sports 1996;6: 180–5.
5. Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of literature. Am J Sports Med 1995;23:694–701.
6. Bjordal JM, Arnly F, Hannestad B, Strand T. Epidemiology of anterior cruciate ligament injuries in soccer. Am J Sports Med 1997;25:341–5.
7. Roos H, Ornell M, Gardsell P, Lohmander LS, Lindstrand A. Soccer after anterior cruciate ligament injury: an incompatible combination? A national survey of incidence and risk factors and a 7-year follow-up of 310 players. Acta Orthop Scand 1995;66: 107–12.
8. Engstrom B, Forssblad M, Johansson C, Tornkvist H. Does a major knee injury definitely sideline an elite soccer player? Am J Sports Med 1990;18:101–5.
9. Sandberg R, Balkfors B, Nilsson B, Westlin N. Operative versus non-operative treatment of recent injuries to the ligaments of the

knee: a prospective randomized study. J Bone Joint Surg Am 1987;69:1120–6.
10. Soderman K, Pietila T, Alfredson H, Werner S. Anterior cruciate ligament injuries in young females playing soccer at senior levels. Scand J Med Sci Sports 2002;12:65–8.
11. Lohmander LS, Roos H. Knee ligament injury, surgery and osteoarthrosis: truth or consequences? Acta Orthop Scand 1994; 65:605–9.
12. Roos H, Lauren M, Adalberth T, Roos EM, Jonsson K, Lohmander LS. Knee osteoarthritis after meniscectomy: prevalence of radiographic changes after twenty-one years, compared with matched controls. Arthritis Rheum 1998;41:687–93. Erratum in: Arthritis Rheum 2003;48:2185.
13. Altman RD, Hochberg M, Murphy WA Jr, Wolfe F, Lequesne M. Atlas of individual radiographic features in osteoarthritis. Osteoarthritis Cartilage 1995;3 Suppl A:3–70.
14. Englund M, Paradowski PT, Lohmander LS. Association of radiographic hand osteoarthritis with radiographic knee osteoarthritis after meniscectomy. Arthritis Rheum 2004;50:469–75.
15. Englund M, Roos EM, Lohmander LS. Impact of type of meniscal tear on radiographic and symptomatic knee osteoarthritis: a sixteen-year followup of meniscectomy with matched controls. Arthritis Rheum 2003;48:2178–87.
16. Englund M, Lohmander LS. Risk factors for symptomatic knee osteoarthritis fifteen to twenty-two years after meniscectomy. Arthritis Rheum 2004. In press.
17. Kellgren JH, Lawrence JS. Radiological assessment of osteoarthritis. Ann Rheum Dis 1957;16:494–501.
18. Lachance L, Sowers MF, Jamadar D, Hochberg M. The natural history of emergent osteoarthritis of the knee in women. Osteoarthritis Cartilage 2002;10:849–54.
19. Hart DJ, Spector TD. Kellgren & Lawrence grade 1 osteophytes in the knee: doubtful or definite? Osteoarthritis Cartilage 2003;11: 149–50.
20. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS): development of a self-administered outcome measure. J Orthop Sports Phys Ther 1998;28:88–96.
21. Roos EM, Roos HP, Ekdahl C, Lohmander LS. Knee Injury and Osteoarthritis Outcome Score (KOOS): validation of a Swedish version. Scand J Med Sci Sports 1998;8:439–48.
22. Ostenberg A, Roos EM, Ekdahl C, Roos H. Physical capacity in female soccer players: does age make a difference? Adv Physiother 2000;2:39–48.
23. Roos EM, Roos HP, Lohmander LS. Western Ontario and McMaster Universities Osteoarthritis Index: additional dimensions for use in subjects with post-traumatic osteoarthritis of the knee. Osteoarthritis Cartilage 1999;7:216–21.
24. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992;30:473–83.
25. Shapiro ET, Richmond JC, Rockett SE, McGrath MM, Donaldson WR. The use of a generic, patient-based health assessment (SF-36) for evaluation of patients with anterior cruciate ligament injuries. Am J Sports Med 1996;24:196–200.
26. Sullivan M, Karlsson J. SF-36 hälsoenkät: Swedish manual and interpretation guide. Gothenburg: Health Care Research Unit, Medical Faculty, Gothenburg University; 1994.
27. Myklebust G, Holm I, Maehlum S, Engebretsen L, Bahr R. Clinical, functional, and radiologic outcome in team handball players 6 to 11 years after anterior cruciate ligament injury: a follow-up study. Am J Sports Med 2003;31:981–9.
28. Segawa H, Omori G, Koga Y. Long-term results of non-operative treatment of anterior cruciate ligament injury. Knee 2001;8:5–11.
29. Gillquist J, Messner K. Anterior cruciate ligament reconstruction and the long-term incidence of gonarthrosis. Sports Med 1999;27: 143–56.
30. Roos H, Adalberth T, Dahlberg L, Lohmander LS. Osteoarthritis of the knee after injury to the anterior cruciate ligament or meniscus: the influence of time and age. Osteoarthritis Cartilage 1995;3:261–7.
31. Gelber AC, Hochberg MC, Mead LA, Wang NY, Wigley FM, Klag MJ. Joint injury in young adults and risk for subsequent knee and hip osteoarthritis. Ann Intern Med 2000;133:321–8.
32. Von Porat A, Roos EM, Roos HP. High prevalence of osteoarthritis 14 years after an anterior cruciate ligament tear in male soccer players: a study of radiographic and patient relevant outcomes. Ann Rheum Dis 2004;63:269–73.
33. Lethbridge-Cejku M, Scott WW Jr, Reichle R, Ettinger WH, Zonderman A, Costa P, et al. Association of radiographic features of osteoarthritis of the knee with knee pain: data from the Baltimore Longitudinal Study of Aging. Arthritis Care Res 1995; 8:182–8.
34. Good L, Odensten M, Gillquist J. Precision in reconstruction of the anterior cruciate ligament: a new positioning device compared with hand drilling. Acta Orthop Scand 1987;58:658–61.
35. Roos H, Lindberg H, Gardsell P, Lohmander LS, Wingstrand H. The prevalence of gonarthrosis and its relation to meniscectomy in former soccer players. Am J Sports Med 1994;22:219–22.
36. Cameron SE, Wilson W, St Pierre P. A prospective, randomized comparison of open vs. arthroscopically assisted ACL reconstruction. Orthopedics 1995;18:249–52.
37. Eriksson K, Anderberg P, Hamberg P, Olerud P, Wredmark T. There are differences in early morbidity after ACL reconstruction when comparing patellar tendon and semitendinosus tendon graft: a prospective randomized study of 107 patients. Scand J Med Sci Sports 2001;11:170–7.
38. Markolf KL, Bargar WL, Shoemaker SC, Amstutz HC, Moreland JR, Grant TT. The role of joint load in knee stability. J Bone Joint Surg Am 1981;63:570–85.
39. Shoemaker SC, Markolf KL. The role of the meniscus in the anterior-posterior stability of the loaded anterior cruciate-deficient knee: effects of partial versus total excision. J Bone Joint Surg Am 1986;68:71–9.
40. Knutson K, Lewold S, Robertsson O, Lidgren L. The Swedish knee arthroplasty register: a nation-wide study of 30,003 knees 1976-1992. Acta Orthop Scand 1994;65:375–86.
41. Rosen MA, Jackson DW, Berger PE. Occult osseous lesions documented by magnetic resonance imaging associated with anterior cruciate ligament ruptures. Arthroscopy 1991;7:45–51.
42. Lohmander LS, Hoerrner LA, Lark MW. Metalloproteinases, tissue inhibitor, and proteoglycan fragments in knee synovial fluid in human osteoarthritis. Arthritis Rheum 1993;36:181–9.
43. Lohmander LS, Ionescu M, Jugessur H, Poole AR. Changes in joint cartilage aggrecan metabolism after knee injury and in osteoarthritis. Arthritis Rheum 1999;42:534–44.
44. Lohmander LS, Atley LM, Pietka TA, Eyre DR. The release of cross-linked peptides from type II collagen into human joint fluid is increased early after joint insult and in osteoarthritis. Arthritis Rheum 2003;48:3130–9.