

High Risk of New Knee Injuries in Female Soccer Players After Primary Anterior Cruciate Ligament Reconstruction at 5-to 10-Year Follow-up

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High Risk of New Knee Injuries in Female Soccer Players After Primary ACL Reconstruction at 5- to 10-Years Follow-up

ABSTRACT

Background: A new anterior cruciate ligament (ACL) injury after ACL reconstruction is a feared outcome.

Purpose: To study the risk of new knee injuries in female soccer players 5–10 years after primary unilateral ACL reconstruction, and compare players who returned to soccer with (1) players who did not return and (2) knee-healthy controls.

Study Design: Cohort study.

Methods: Demographic, soccer-specific, and surgical data were recorded at baseline for 317 female soccer players (mean age \pm SD, 20.1 \pm 2.7 years) 1.6 \pm 0.7 years after ACL reconstruction, and for 119 matched controls (19.5 \pm 2.5 years). Data on new knee injuries and soccer playing status were collected 5–10 years after ACL reconstruction through a questionnaire.

Results: Among players with ACL reconstruction, 222 (70%) responded at a mean 6.5 \pm 1.0 years after primary ACL reconstruction. We compared 3 different cohorts: (1) 163 players with ACL reconstruction who returned to soccer; 68 (42%) sustained 44 re-ruptures and 29 contralateral ruptures; (2) 59 players with ACL reconstruction who did not return to soccer; 11 (19%) sustained 9 re-ruptures and 2 contralateral ruptures; and (3) 113 knee-healthy controls; 12 (11%) sustained 13 ACL injuries. Players who returned had more than a 2-fold risk of a new ACL injury than players who did not return (risk ratio [RR] 2.24; 95% CI, 1.27–3.93; P = .005), and 4-fold higher risk than controls (RR 3.93; 95% CI, 2.23–6.91; P < .001). A new ACL, meniscus, or cartilage injury was the most frequent new knee injury. Among players who returned to soccer, 68% reported a new knee injury and they had 2–5 times higher risk of any new knee injury and knee surgery than players who did not return and controls.

Conclusions: Two-thirds of female soccer players with ACL reconstruction who returned to soccer sustained a new knee injury within 5–10 years; 42% had a new ACL injury. Their risk of new knee injury and knee surgery was 2–5 times greater than for players who did not return and for knee-healthy controls. New injury may have negative consequences for long-term knee health and should be a critical consideration in the decision to return to play.

Keywords: female; football; soccer; anterior cruciate ligament; return to sport; re-injury; retear

What is known about the subject: Anterior cruciate ligament (ACL) injury is a severe injury in female soccer players. Return to sport after ACL reconstruction (ACLR) is often a desirable outcome for the injured athlete. More than half of players return to soccer after ACLR, but with a high risk of further ACL injury. To accurately describe the risk of new knee injuries in the long-term among female soccer players with ACLR, it is important to differentiate between those who return to soccer and those who quit soccer after ACLR. An age-matched control group would also be needed to establish the normal course of a female soccer player's participation in soccer and risk of knee injuries.

What this study adds to existing knowledge: Forty-two percent of female soccer players who returned to soccer after primary ACLR sustained a new ACL injury within 5–10 years after surgery. This was more than 2-fold and 4-fold higher risk compared with those who did not return to soccer and with knee-healthy controls, respectively. Among players who returned, 68% reported a new knee injury (including ACL injuries) and 53% had additional knee surgery after primary ACLR, which was a 2–5 times higher risk compared with players who did not return and with knee-healthy controls. Female soccer players with ACLR are at high risk of new knee injuries, which must be considered in the decision to return to play. More efforts toward secondary prevention strategies are needed.

INTRODUCTION

Anterior cruciate ligament (ACL) injury is a severe injury and female soccer players are particularly at risk.³⁸ Many athletes choose surgical treatment of the ACL injury to be able to return to sport (RTS) at the same level as before the injury.¹⁶ However, ACL reconstruction (ACLR) does not always ensure RTS and only about 46% to 67% of a female population with ACLR return to soccer.^{4, 5, 12, 31, 32} Younger players and those playing at high level are more likely to return to soccer.³¹ Returning to soccer after ACLR is paired with a high risk of new ACL injury to both knees, especially among young females.^{4, 5, 14, 28, 29, 38, 42} Up to one-third of female soccer player who return to soccer after ACLR sustain a new ACL injury within the first 3.5 years after ACLR.^{4, 14} The incidence of new ACL injury, especially re-ruptures, seems to be highest in the first 2 to 3 years after ACLR.¹ A high risk for other knee injuries has also been reported in soccer players with ACLR followed for 1 to 2 seasons.^{14, 26, 36} However, studies that report the incidence of all new knee injuries in the long-term – not only new ACL injuries – in female soccer players with ACLR, including knee-healthy controls, and distinguishing between those who return and those who do not return to soccer after ACLR are lacking. This is important since sport exposure is a key risk factor for new injury.

Knowledge about the risk of sustaining new knee injuries in female soccer players depending on whether they return to soccer or not is important for clinicians to be able to inform and advise patients before primary ACLR, in the rehabilitation process, and RTS decision. Therefore, long-term follow-up of the results regarding subsequent knee injuries after treatment and RTS is warranted.

The aim was to study the risk of new knee injuries in female soccer players, with a focus on new ACL injury, within 5–10 years after primary unilateral ACLR, and compare players who returned to soccer with (1) players who did not return and (2) knee-healthy controls. Our

hypothesis was that players with ACLR who returned to soccer would have a higher risk of new knee injuries compared with players who did not return to soccer and compared with knee-healthy controls.

METHODS

This was a cohort study exploring new knee injuries among female soccer players 5 to 10 years after ACLR and among knee-healthy controls. Short-term data with 2-years follow-up (43.7 ± 8.7 months after ACLR) have been published previously for 117 players (111 included in the current study) who returned to soccer after ACLR and for 119 controls.¹⁴

Participants

Female soccer players (playing at any level) aged 16 to 25 years with primary unilateral ACLR performed 6 to 36 months earlier (2010–2014) were identified from the Swedish National Knee Ligament Register (SNKLR) and additional advertising in 3 regional soccer districts. SNKLR captures >90% of all ACLRs in Sweden.²³ Exclusion criteria were having an associated posterior cruciate ligament injury and/or surgically treated injuries to either the medial or lateral collateral ligament. We identified 534 potentially eligible players in the SNKLR, and an additional 16 active players were recruited via advertisements (total $n = 550$). A baseline survey was sent to the 550 players at the soccer pre-season (January to April) each new season from 2013 to 2015. Surgery data regarding the primary ACLR were collected from the SNKLR. Three hundred and seventeen players responded (mean age \pm SD, 20.1 ± 2.7 years) 1.6 ± 0.7 years after ACLR and answered the baseline demographic and soccer-specific questions. These players (Figure 1) were then contacted for the long-term follow-up, 5–10 years after ACLR, with questions about soccer playing status and if they had sustained any new knee injuries, specifically ACL injuries and, if applicable, the circumstances and details about the injury. Significant new knee injuries were recorded by

player self-reported in the survey based on the following two questions: 1) "Have you injured your ACL again or do you have ACL injuries in both knees?" and 2) "Have you sustained any other knee injuries after the first ACLR in any of the knees?" Both had binary response options yes or no. If the answer was "Yes" there were fixed response options with the possible responses: meniscus, ligament (MCL, LCL), PCL, patella luxation, cartilage or other injury (with options to specify and comment). Player-reported new ACL injuries were confirmed from the SNKLR or medical charts and at the same time other knee injuries that the players reported were also verified.

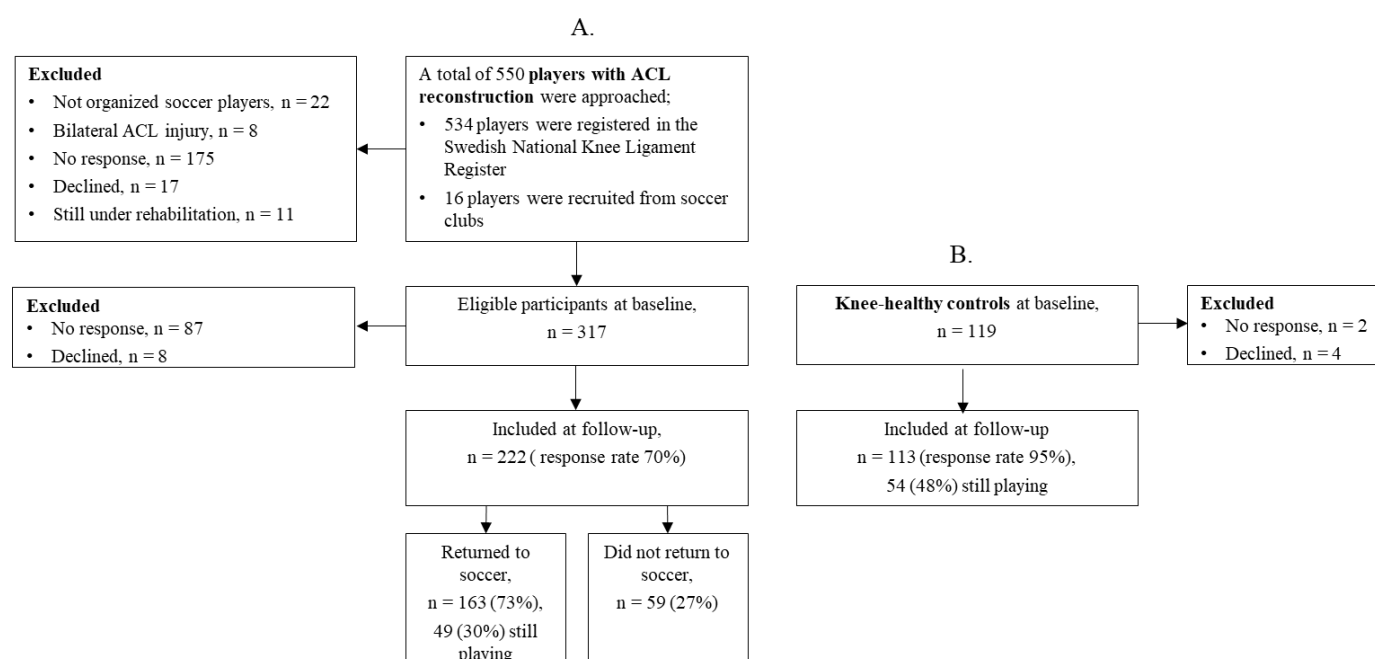


Figure 1. Study flowchart of female soccer players with anterior cruciate ligament (ACL) reconstruction (A) and the knee-healthy controls (B).

A matched control group regarding age was needed to establish the normal course of a female soccer player's participation in soccer and risk of subsequent knee injuries.³⁵ Therefore, coaches recruited 119 knee-healthy controls to ensure similar age, soccer exposure, and playing position from the same teams as 117 of the active players with ACLR.¹⁴

All players received written information about the study and signed written consent. The study was approved by the Swedish Ethical Review Authority (Dnr 2012/24–31, 2013/75–32, 2017/324-32 and 2020-01093) and the SNKLR board.

Statistical Methods

All statistical analyses were performed in SPSS Statistics for Windows (IBM SPSS Statistics for Windows, Version 26.0. IBM, Armonk, NY). Descriptive statistics are presented as mean \pm SD or median with interquartile range (IQR), and range. Normality and homogeneity of variance were evaluated for continuous data. Between-group comparisons of continuous data were analyzed with Student's *t* test if appropriate or the Mann-Whitney *U* test. Chi-squared test or Fisher's exact test was utilized for between-group comparisons of categorical data. The risk of (1) new ACL injuries, (2) other new knee injuries, and (3) knee injuries treated with surgery were compared between players who returned to soccer after ACLR and the 2 other groups (players who did not return to soccer after ACLR and knee-healthy controls). Between-group risk ratios (RRs) with a 95% confidence interval (CI) are presented. Baseline data are presented in different strata regarding the risk of sustaining a new ACL injury: (1) age at primary ACLR, (2) time between injury and primary ACLR, (3) graft diameter, (4) concomitant injury at primary ACLR, (5) ACLR in the dominant limb (preferred kicking leg) or nondominant limb, (6) body mass index (BMI) categorized according to World Health Organization nutritional status,⁴⁰ and (7) level of play. The risk was calculated as $[N_{\text{with new ACL injury}}/N_{\text{total for the group}}] \times 100$. The significance level was set at $P < .05$.

RESULTS

Of the 317 eligible players with ACLR, 222 responded (response rate 70%) at mean \pm SD 6.5 ± 1.0 years (range, 5.0–9.9 years) after ACLR. Of the 119 controls, 113 (response rate 95%) answered the questionnaire (Figure 1). For the players with ACLR and for the controls,

the mean \pm SD time since answering the baseline questionnaire was 4.8 ± 0.8 and 5.0 ± 0.7 years, respectively.

The 3 cohorts thus consisted of (1) 163 players with ACLR who returned to soccer after primary ACLR, of whom 49 (30%) were still active soccer players at follow-up; (2) 59 players who never returned to soccer after the primary ACLR; and (3) 113 knee-healthy controls, of whom 54 (48%) were still active soccer players at follow-up (Figure 1).

Non-responders

Non-responders at baseline ($n = 95$) did not differ significantly from responders ($n = 222$) regarding age at the time of ACLR, time between injury and primary ACLR, graft diameter at primary ACLR, presence of concomitant injuries at primary ACLR or additional ACLR according to the SNKLR at follow-up ($P > .05$). However, there were significantly more hamstring grafts (98% vs 92%, $P = .005$) among the responders, and significantly more responders returned to soccer compared with non-responders, 73% vs 44% ($P < .001$).

Baseline Data

Descriptive data for players with ACLR and the knee-healthy controls are presented in Table 1.

TABLE 1

Demographic Data in Female Soccer Players with ACLR Who Did or Did Not Return to Soccer and Knee-Healthy Controls^a

	Players with ACLR				Knee-Healthy Controls (n = 113)	
	Returned to Soccer (n = 163)		Did Not Return to Soccer (n = 59)		Baseline	Follow-up
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up
Age, years	20.0 ± 2.6	24.9 ± 2.7	20.1 ± 2.9	24.9 ± 3.1	19.5 ± 2.5	24.5 ± 2.6
Height, cm	168 ± 5.0	168 ± 5.0	167 ± 6.0	168 ± 6.0	167 ± 6.0	167 ± 6.0
Body mass index, kg/m ²	22.3 ± 2.2 ^b	23.2 ± 2.6	22.6 ± 2.3 ^c	23.5 ± 3.5	22.1 ± 2.0	22.8 ± 2.4
Occupation						
Worker	110 (31) ^b	108 (66)	12 (26) ^d	39 (66)	30 (27)	77 (68)
Student	49 (69)	55 (34)	35 (74)	20 (34)	83 (73)	36 (32)
Dominant limb						
Right	147 (90)		56 (95)		109 (96)	
Left	16 (10)		3 (5)		4 (4)	

^aValues are reported as means ± SD or n (%). ACLR, anterior cruciate ligament reconstruction; SD, standard deviation.

^bMissing data, n = 4.

^cMissing data, n = 13.

^dMissing data, n = 12.

Factors related to the primary ACL injury for the players with ACLR who returned to soccer and those who did not are presented in Table 2.

TABLE 2

Baseline Data at Primary ACLR in Female Soccer Players Who Did or Did Not Return to Soccer^a

	Players with ACLR		<i>P</i> Value
	Returned to Soccer (n = 163)	Did Not Return to Soccer (n = 59)	
Age at ACLR, mean ± SD, years	18.4 ± 2.6	18.4 ± 2.9	.977
Time between injury and ACLR, median (IQR; range), months	4.5 (5; 0-68)	6 (9; 2-87)	.001
<3 months	56 (34)	7 (12)	
3–12 months	93 (57)	35 (59)	
>12 months	14 (9)	17 (29)	
Graft: all autografts			.601
Hamstrings			
1- to 4-strand semitendinosus	76 (48)	31 (55)	
Semitendinosus gracilis	84 (52)	25 (45)	
Patellar tendon	2 (1)	1 (2)	
Quadriceps tendon	1 (1)		
Graft diameter			.020
<8.0 mm	60 (37)	32 (54)	
≥8.0 mm	103 (63)	27 (46)	
Fixation in femur			.015
Cortical suspension devices	153 (96) ^b	50 (85)	
Intratunnel fixation	7 (4)	9 (15)	
Fixation in tibia			.423
Cortical suspension devices	64 (40) ^c	27 (46)	
Intratunnel fixation	97 (60)	32 (54)	
Index knee ACLR			.977
Right	86 (53)	31 (53)	
Left	77 (47)	28 (47)	
ACLR in the dominant limb (preferred kicking leg)	90 (55)	32 (54)	.897
Presence of concomitant injuries at ACLR			
Meniscal surgery medial, repair	14 (9)	5 (8)	.979
Meniscal surgery medial, resection	9 (6)	7 (12)	.139
Meniscal surgery lateral, repair	8 (5)	5 (8)	.338
Meniscal surgery lateral, resection	26 (16)	5 (8)	.156
Articular cartilage injury	14 (9)	7 (12)	.461
Surgically treated (% of cartilage injuries)	1 (1)	0 (0)	

^aValues are reported as n (%) unless otherwise stated. ACLR, anterior cruciate ligament reconstruction; SD, standard deviation; IQR, interquartile range. Bolded *P* values indicate statistically significant between-group differences.

^bMissing data, n = 3.

^cMissing data, n = 3.

New ACL Injury During Follow-up

During follow-up, 68 players (42%) with ACLR who returned to soccer sustained 73 new ACL injuries (44 re-ruptures; 29 contralateral ruptures). Of the 73 new ACL injuries, 59

(81%) occurred when playing soccer and 39 of those (66%) were non-contact. Twenty-three players (34%) returned to soccer after the second ACL injury and 3 (4%) had the intention to return (still under rehabilitation). In players who did not return to soccer after ACLR, 11 (19%) sustained 11 new ACL injuries (9 re-ruptures; 2 contralateral ruptures). In the knee-healthy control group, 12 players (11%) sustained 13 ACL injuries, 11 (85%) occurred in soccer and 9 of those (82%) were non-contact.

Players with ACLR who returned to soccer had more than a 2-fold higher risk of a new ACL injury compared with players who did not return (RR, 2.24; 95% CI, 1.27–3.93; $P = .005$), and 4-fold higher risk compared with the knee-healthy control group (RR 3.93; 95% CI, 2.23–6.91; $P < .001$) (Table 3).

Time from primary ACLR to a new ACL injury was median 25 (IQR 32, range 8–95) months for players who returned to soccer, and 25 (IQR 18, range 2–67) months for players who did not return ($P = .357$) (Figure 2). Time from primary ACLR to re-rupture was median 25 (IQR 21, range 2–67) months and for a contralateral ACL injury 27 (IQR 36, range 9–95) months ($P = .189$) (Figure 3). Among the players with ACLR, 60 of the 84 new ACL injuries (71%) were reconstructed. In the knee-healthy control group, 11 of the 13 ACL injuries (85%) were reconstructed.

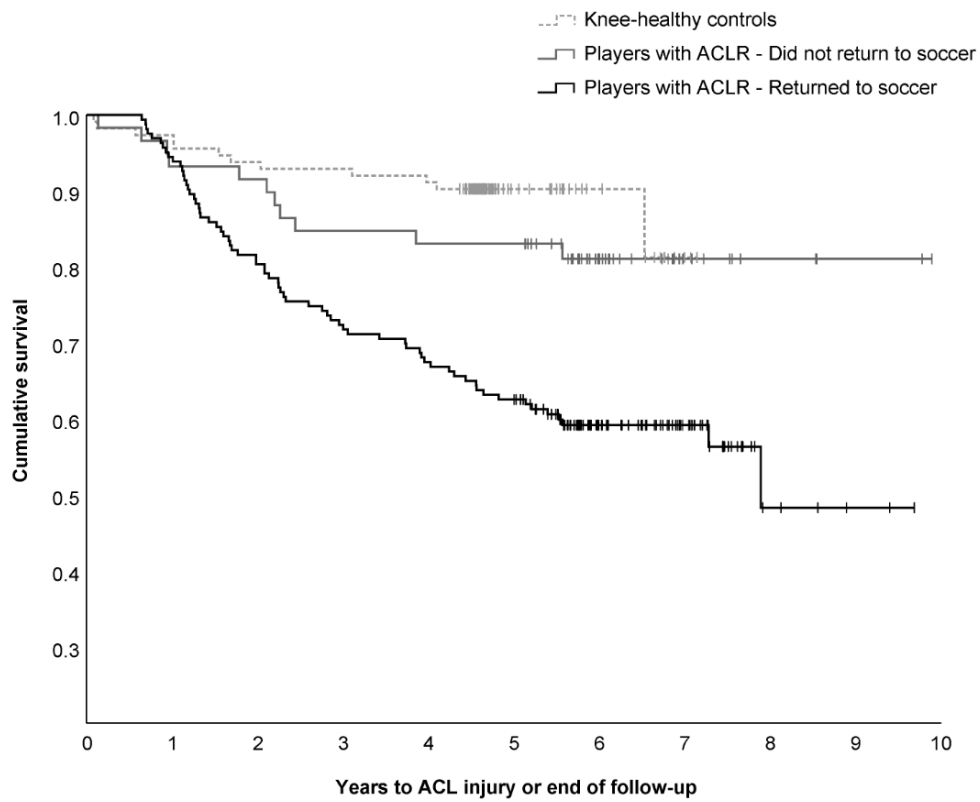


Figure 2. Kaplan-Meier curve showing years from primary anterior cruciate ligament (ACL) reconstruction (ACLR) to new ACL injury in players with ACLR who did or did not return to soccer. Knee-healthy controls are reported from baseline.

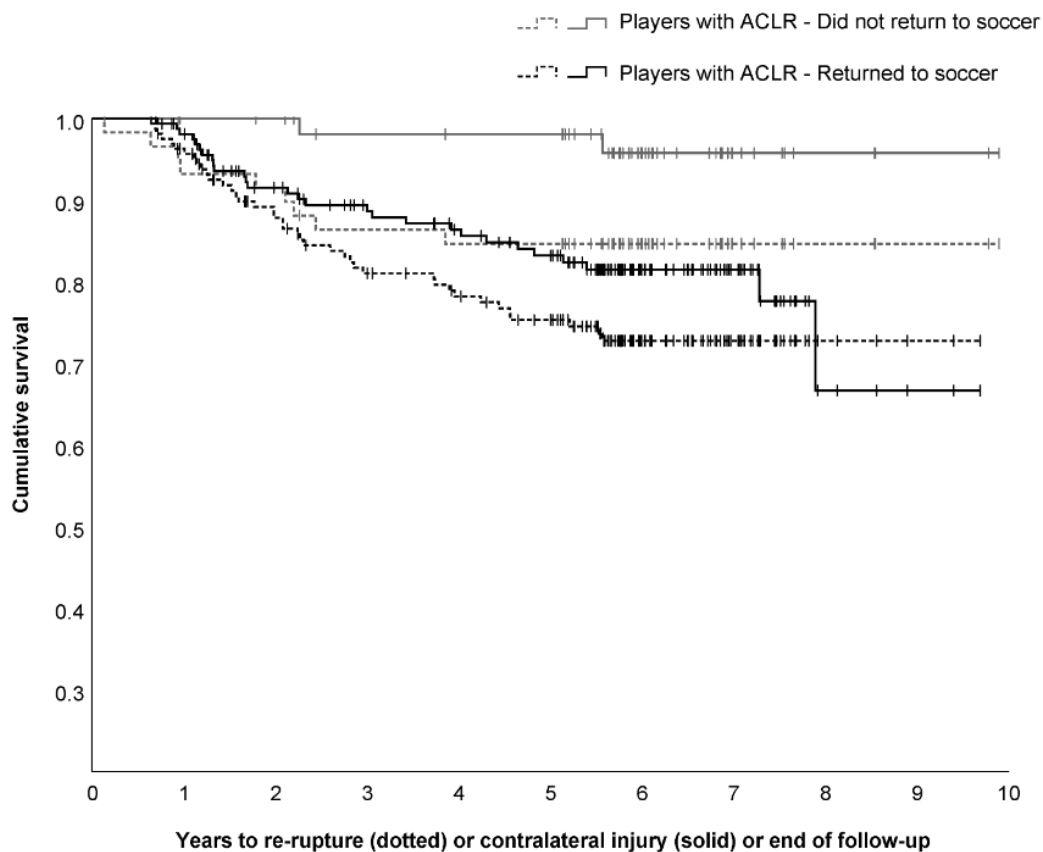


Figure 3. Kaplan-Meier curve showing years from primary anterior cruciate ligament (ACL) reconstruction (ACLR) to re-rupture (dotted lines) or contralateral ACL injury (solid lines) in players with ACLR who did or did not return to soccer.

New Knee Injury During Follow-up

New knee injury (including ACL injury) during follow-up was reported by 111 players (68%) who returned to soccer compared with 20 players (34%) who did not return (RR, 2.01; 95% CI, 1.39–2.91; $P < .001$), and by 29 players (26%) in the knee-healthy control group (RR 2.65; 95% CI 1.91–3.69; $P < .001$). Other new knee injuries (excluding ACL injury) during follow-up were reported by 77 (47%) players who returned to soccer compared with 15 players (25%) in the group who did not return (RR, 1.86; 95% CI, 1.17–2.96; $P = .009$) and by 18 players (16%) in the knee-healthy control group (RR, 2.97; 95% CI, 1.88–4.67; $P < .001$). The proportion of other non-ACL knee injuries that were treated surgically did not differ between players who returned (68 of 106 injuries, 64%) and those who did not return

(12 of 25 injuries, 48%) ($P = .136$), but was higher compared with the knee-healthy controls (4 of 23 injuries, 17%) ($P < .001$) (Table 3).

The risk of a new ACL injury stratified according to different baseline factors for players with ACLR who returned to soccer or not and knee-healthy controls is presented in Table 4. In players with ACLR who returned to soccer, the stratification of the risk of new ACL injury based on different baseline factors showed that the youngest age group (59% risk), those playing at elite level (60% risk), those with no associated concomitant injury at primary ACLR (46% risk), and players with a quick primary ACLR (< 3 months after injury, 50% risk) had a high risk of new ACL injury. In players with ACLR who did not return to soccer, those who had a quick primary ACLR had a noteworthy high risk of new ACL injury (57%).

1
2

TABLE 3

New Knee Injuries Reported from Baseline to 5–10 Year Follow-Up in Players with ACL Reconstruction and Knee-Healthy Controls^a

	Players with ACLR				Knee-Healthy Controls (n = 113)		Risk ratio (95% CI); <i>P</i> value	
	Returned to Soccer (n = 163)		Did Not Return to Soccer (n = 59)				Returned vs Did Not Return	Returned vs Controls
	No.	%	No.	%	No.	%		
Total no. of players with new ACL injury	68	42	11	19	12	11	2.24 (1.27-3.93); <i>P</i> = .005	3.93 (2.23-6.91); <i>P</i> < .001
Re-rupture	44	27 ^b	9	15			1.79 (0.93-3.44); <i>P</i> = .080	
Contralateral rupture	29	18 ^c	2	3	1	1 ^d	5.25 (1.29-21.32); <i>P</i> = .020	
Total no. of players with new knee injury	111	68	20	34	29	26	2.01 (1.39-2.91); <i>P</i> < .001	2.65 (1.91-3.69); <i>P</i> < .001
Only new ACL injury	34	21	5	8	11	10		
New ACL injury + other knee injury	34	21	6	10	1	1		
Other knee injury only (excl. ACL)	43	27	9	15	17	15		
Total no. of players with new knee injury (excl. ACL)	77	47	15	25	18	16	1.86 (1.17-2.96); <i>P</i> = .009	2.97 (1.88-4.67); <i>P</i> < .001
1 injury	56	34	6	10	15	13		
2 injuries	16	10	8	14	1	2		
3 injuries	3	2	1	2	2	2		
4 or 5 injuries	2	1						
Total no. of players treated with knee surgery	85	52	16	27	12	11	1.92 (1.23-3.00); <i>P</i> = .004	4.91 (2.82-8.56); <i>P</i> < .001
No. and specification of new knee injuries	ACLR knee	Contra-lateral	ACLR knee	Contra-lateral	Non-dominant	Dominant		
ACL injury	44	29	9	2	6	7		
Meniscus lesion	46	6	11	1	1	3		
Medial or lateral collateral ligament injury	7	6	7	1	4	5		
Cartilage lesion	18	1	2		1			
Patella subluxation	2			1		2		
Joint sprain-unspecified					1			
Baker's cyst			1					
Graft problems (fixation, scar tissue)	4							
Pain, instability, locking	5	5				6		
Loose body	2		1					
Jumper's/runner's knee	3	1						

^aValues are reported as n (risk %) unless otherwise stated. ACLR, anterior cruciate ligament reconstruction; CI, confidence interval. Bolded *P* values indicate statistically significant between-group differences.^b4 players sustained 2 ACL injuries during follow-up.^c1 player sustained 2 ACL injuries during follow-up.^d1 player sustained 2 ACL injuries.3
4
5
6

TABLE 4

Risk of New ACL Injury in Players with ACLR and Knee-Healthy Controls, Stratified into Different Baseline Factors and Specified as Re-rupture or Contralateral ACL Injury in Players Who Returned^a

Baseline data	Players with ACLR											Knee-Healthy Controls (n = 113)						
	Returned to Soccer (n = 163)										Did Not Return to Soccer (n = 59)							
	N	New ACL injury									N	New ACL Injury (n = 11)			N	ACL Injury (n = 12)		
		Re-rupture or CACL Injury (n = 68)			Re-rupture (n = 44)			CACL Injury (n = 29)				n	Risk (%)	(95% CI)		n	Risk (%)	(95% CI)
		n	Risk (%)	(95% CI)	n	Risk (%)	(95% CI)	n	Risk (%)	(95% CI)		n	Risk (%)	(95% CI)		n	Risk (%)	(95% CI)
Age at primary ACLR																		
<16 years	29	17	59	(41-77)	9	31	(14-48)	10	34	(17-52)	16	3	19	(0-38)				
16-18 years	72	30	42	(30-53)	19	26	(16-37)	13	18	(9-27)	19	5	26	(7-46)	57 ^b	7	12	(4-21)
19-21 years	42	12	29	(15-42)	8	19	(7-31)	5	12	(2-22)	16	1	6	(0-18)	28 ^b	3	11	(0-22)
≥21 years	20	9	45	(23-67)	8	40	(19-61)	1	5	(0-15)	8	2	25	(0-55)	28 ^b	2	7	(0-17)
Time between injury and primary ACLR																		
<3 months	56	28	50	(37-63)	22	39	(26-52)	9	16	(6-26)	7	4	57	(20-94)				
3-12 months	93	36	39	(29-49)	20	22	(13-30)	17	18	(10-26)	35	4	11	(1-22)				
>12 months	14	4	29	(5-52)	2	14	(0-33)	3	23	(0-46)	17	3	18	(0-36)				
Graft diameter																		
<8.0 mm	60	27	45	(32-58)	16	27	(15-38)	13	22	(11-32)	32	8	25	(10-40)				
≥8.0 mm	103	41	40	(30-49)	28	27	(19-36)	16	16	(9-23)	27	3	11	(0-23)				
Concomitant injury at primary ACLR																		
Yes	56	19	34	(22-46)	12	21	(11-32)	8	14	(5-23)	20	4	20	(2-38)				
No	107	49	46	(36-55)	32	30	(21-39)	21	20	(12-27)	39	7	18	(6-30)				
ACLR side																		
Nondominant	73	28	38	(27-50)	20	27	(17-38)	11	15	(7-23)	27	4	15	(1-28)				
Dominant	90	40	44	(34-55)	24	27	(18-36)	18	20	(12-28)	32	7	22	(8-36)				
Level of play ^c																		
Elite (top 2 divisions)	15	9	60	(35-85)	7	47	(21-72)	3	20	(0-40)					13	2	15	(0-35)
3 rd -6 th division	123	49	40	(31-48)	30	24	(17-32)	21	17	(10-24)	29	6	21	(6-35)	88	10	11	(5-18)
Lowest division or youth play	20	6	30	(10-50)	5	25	(6-44)	2	10	(0-23)	16	3	19	(0-38)	12	0	0	
Body mass index, kg/m ^d																		
<24.9, normal weight	135	57	42	(34-51)	37	27	(20-35)	25	19	(12-25)	37	8	22	(8-35)	97	11	11	(5-18)
≥25.0, overweight	24	8	33	(14-52)	6	25	(8-42)	2	8	(0-19)	9	1	11	(0-32)	16	1	6	(0-18)

^aValues are reported as n, % risk, and 95% CI. ACLR, anterior cruciate ligament reconstruction; CACL, contralateral anterior cruciate ligament; CI confidence interval.

- 11 ^bAge reported at baseline.
- 12 ^cMissing data for players with ACLR who returned, n = 5, and did not return, n = 14.
- 13 ^dMissing data for players with ACLR who returned, n = 4, and did not return, n = 13.

DISCUSSION

Returning to a sport that involves contact and pivoting after an ACLR resulted in a high risk of sustaining subsequent new knee injuries in our cohort of female soccer players. Two-thirds of the players who returned to soccer after primary ACLR sustained a new knee injury, and 42% sustained a new ACL injury, within 5 to 10 years. Half of the players who returned after primary ACLR had additional surgical treatment for new knee injuries.

We found a 2-fold risk of new ACL injury in players who returned to soccer after ACLR compared with those who did not return, and a 4-fold higher risk compared with knee-healthy soccer playing controls. The alarmingly high risk of new ACL injury (42%) after primary ACLR and return to soccer is concerning, and even higher than in previous reports. Depending on the time of follow-up (2–10 years), previous studies have shown a risk of new ACL injury ranging from 20% to 34%^{1, 4, 5, 14, 31} after return to soccer in females with ACLR. In line with our results, the risk of new ACL injury in those who did not return is reported to be significantly lower, ranging from 4% to 15%.^{1, 4, 31} Our results confirm the high risk of new ACL injuries after ACLR in the long term, which is disappointing given that surgical techniques³⁰ and rehabilitation approaches are constantly evolving, and stresses the importance of implementing effective secondary prevention strategies. Sprinting skills are becoming more and more important in modern soccer with faster players,²⁰ potentially leading to more high-risk actions being performed at higher speeds, and higher sporting demands may partly explain the lack of decline in subsequent ACL injuries after primary ACLR.

In our study, more re-ruptures (27%) were reported compared with contralateral injuries (18%). The re-ruptures occurred in a median 25 months after primary ACLR compared with 27 months for the contralateral injuries. There are conflicting reports on whether the risk of re-rupture and contralateral injury differs after primary ACLR and return to contact sports.^{1, 5,}

^{17, 29, 42} Contralateral ruptures/reconstructions often occur later than re-ruptures/revisions after primary ACLR,^{1, 13} and relatively more contralateral ruptures are reported in longer follow-up studies.^{1, 24, 31} Therefore, more contralateral ruptures could be expected to occur in future follow-ups of our cohort.

Players who returned to soccer had a 5 times higher risk of contralateral ACL injury compared with players who did not return, and the risk difference for a re-rupture was lower (risk ratio, 1.79; non-significant). Previous studies report conflicting results regarding players who returned or did not return and differences in re-ruptures and contralateral ruptures, where only difference in the rate of re-ruptures,¹ contralateral ruptures²⁴ or both re-ruptures and contralateral ruptures³¹ are reported.

Nearly 50% of the players who returned to soccer reported a new knee injury other than ACL injury, predominately to the menisci, cartilage, collateral ligaments, or patella, or reported other knee problems such as gradual onset pain and instability, with a 2- to 3-fold higher risk than those who did not return and the controls. Approximately half of the reported knee injuries were treated with surgery compared with 17% of the knee injuries in the control group, indicating that more serious injuries were incurred in players with ACLR. Grindem et al¹⁷ reported that patients with ACLR who returned to high-level pivoting sports had a more than 4 times higher rate of re-injury – with the meniscus being the most frequently injured knee structure – compared with patients who returned to sports that were less demanding on the knees within the first 2 years after ACLR. The high rate of new knee injuries after return to soccer after ACLR is equally concerning, because meniscal injury or meniscectomy increases the risk of osteoarthritis.³⁹ One of the reasons for undergoing ACLR of the injured ACL is to avoid additional injury to the meniscus and cartilage.¹¹ Our data clearly show that the discussion should also be directed toward the high risk of further knee injury associated with return to pivoting sports after ACLR and the potential long-term negative effects.

Our stratification of the risk of new ACL injury based on different baseline factors showed that players of younger age, playing at elite level, having no associated concomitant injury at primary ACLR, and with a quick primary ACLR (less than 3 months after injury) had the highest risk of sustaining a new ACL injury. This finding is in line with previous reports showing that young age,^{13, 42} playing at elite level,^{36, 37} and short time from injury to ACLR¹³ increase the risk of subsequent ACL injury. We have previously shown that these same factors are associated with a high rate of return to soccer after ACLR¹² and probably reflects a group of highly motivated females who desire a rapid return to soccer, but also obviously have an alarmingly high risk of new ACL injury.

Associated concomitant injury at primary ACLR negatively affects the likelihood of patients returning to soccer 1 year after ACLR.¹⁹ Therefore, having no associated concomitant injury could mean that the player's rehabilitation is quicker, risking a premature RTS⁹ and insufficient time for rehabilitation and graft healing. RTS before 8 to 9 months after ACLR increases the risk for new knee injuries.^{9, 17} However, a previous report on meniscus injuries at primary ACLR did not predict subsequent ACL injury in either knee.²²

Other factors such as limb dominance of the primary ACLR and BMI had no association with risk of new ACL injury. This is in contrast to a previous study reporting that primary ACLR on the nondominant side increased the risk for contralateral ACL injury in soccer players.⁵ There are studies in general populations reporting differences regarding high BMI, with lower,¹⁰ higher,³⁴ or no difference in risk of new ACL injury.²¹ In our study, the graft size in players who did not return to soccer graft was smaller compared with those who returned and had a higher risk of new ACL injury (25% vs 11%). This is in line with previous reports regarding hamstring graft size <8 mm with higher risk of re-rupture,¹⁸ early ACL revision,³³ and lower RTS.¹⁸

The discussion about the surgical procedure and subsequent ACL injuries must also continue. In our study, 98% had hamstring tendon autografts which makes comparisons with other graft options meaningless. It is likely that ACLR needs to be performed with respect to different treatment options and in a more individual way (e.g. patient functional demands)³⁰ and based on surgeon preference and experience.⁴¹

Studies imply that many ACL re-injuries can be prevented with optimal rehabilitation.^{6, 7} Self-perceived function, functional performance, and strength improve 9 to 24 months after ACLR, indicating that recovery is ongoing even after RTS.⁸ Nyland et al²⁷ reported that a supplemental RTS training program aiming to bridge the gap between standard physical therapy and release to unrestricted sports performance after ACLR with a 6.8 ± 3.2 years follow-up was associated with low re-rupture rates (1.3%) and contralateral injury (2.7%). Prevention programs for a secondary knee injury are not well investigated, but the prevention programs used for primary ACL injury also seem to be effective for secondary ACL injury prevention.¹⁵ Thus, it is imperative that female soccer players with ACLR should continue with additional preventive training for the duration of their soccer career.

Strengths of our study include the reporting of all new knee injuries after ACLR, analyzed in relation to return to soccer or not, and the risk comparison with knee-healthy players. This was done in a relatively large homogeneous cohort regarding age, sex, follow-up time, and sport participation, and performed in modern times (2010–2014), which contrasts with most studies on outcomes after returning to sport after ACLR.^{2, 42} Another strength was the confirmation of reported new ACL injuries both from a national knee ligament register and from medical charts. This allowed analysis of the overall risk of new ACL injuries, which is impossible in pure surgical register-based studies because only additional ACLRs are reported.¹³ The relatively long follow-up after ACLR of 5 to 10 years is also a strength, because the risk of additional ACL injury is confounded by time.^{1, 28, 29, 42} The response rate

was excellent for the controls (95%) and acceptable for players with ACLR (70%). The careful dropout analysis between responders and non-responders is a strength and showed no major differences.

Our study also has some limitations. The inclusion procedure with participants recruited via advertisement on the homepages of 3 regional soccer districts, in addition to the SNKLR, might have led to a selection bias and overestimation of players who returned to soccer. However, the main purpose was not to report the RTS rate, and we believe that the influence on our overall results is minimal. We included players at a range of 6–36 months after ACLR because the time point of return to sport can vary widely. Most additional ACLR registered in the SNKLR occur within the first 3 post-operative years.¹³ Thus, at baseline many players had already “survived” the most critical period for additional ACLR, because we did not send the survey to players registered for additional ACLR. We have no detailed data about soccer exposure during the follow-up, which is a limitation because soccer exposure time is a key risk factor for new injury. Previous studies show that players with ACLR have less match exposure than controls,^{3, 25} indicating that the true risk of subsequent knee injury after ACLR in female soccer athletes may be even higher than that reported in our study. Finally, since this was a long-term follow-up of a previously established cohort of soccer players with ACLR and knee-healthy controls, we did not perform an a priori sample size calculation. We do, however, believe our study is adequately sized for our main research question.

CONCLUSIONS

Two-thirds of female soccer players with ACLR who returned to soccer sustained a new knee injury, and 42% sustained a new ACL injury, during the 5- to 10-year follow-up. Their risk of new knee injury and knee surgery was 2 to 5 times greater than for players who did not return and for knee-healthy controls. The alarmingly high risk of new knee injuries after

ACLR in female soccer players, with potential negative effects on long-term knee health, should be a critical consideration in the decision to return to play decision. More efforts for secondary prevention are needed.

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