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Incidence of Contralateral and Ipsilateral Anterior Cruciate Ligament (ACL) Injury After Primary ACL Reconstruction and Return to Sport

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Abstract

Objective—Incidence rate (IR) of an ipsilateral or contralateral injury after anterior cruciate ligament reconstruction (ACLR) is unknown. The hypotheses were that the IR of anterior cruciate ligament (ACL) injury after ACLR would be greater than the IR in an uninjured cohort of athletes and would be greater in female athletes after ACLR than male athletes.

Design—Prospective case–control study.

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Setting—Regional sports community.

Participants—Sixty-three subjects who had ACLR and were ready to return to sport (RTS) and 39 control subjects.

Independent Variables—Second ACL injury and sex.

Main Outcome Measures—Second ACL injury and athletic exposure (AE) was tracked for 12 months after RTS. Sixteen subjects after ACLR and 1 control subject suffered a second ACL injury. Between- and within-group comparisons of second ACL injury rates (per 1000 AEs) were conducted.

Results—The IR of ACL injury after ACLR (1.82/1000 AE) was 15 times greater [risk ratio (RR) = 15.24; $P = 0.0002$) than that of control subjects (0.12/1000AE). Female ACLR athletes demonstrated 16 times greater rate of injury (RR = 16.02; $P = 0.0002$) than female control subjects. Female athletes were 4 (RR = 3.65; $P = 0.05$) times more likely to suffer a second ACL injury and 6 times (RR = 6.21; $P = 0.04$) more likely to suffer a contralateral injury than male athletes.

Conclusions—An increased rate of second ACL injury after ACLR exists in athletes when compared with a healthy population. Female athletes suffer contralateral ACL injuries at a higher rate than male athletes and seem to suffer contralateral ACL injuries more frequently than graft re-tears. The identification of a high-risk group within a population of ACLR athletes is a critical step to improve outcome after ACLR and RTS.

Keywords

incidence rate; anterior cruciate ligament reconstruction; second injury; subsequent injury

INTRODUCTION

Anterior cruciate ligament (ACL) injury is a devastating injury that occurs with high frequency during sport athletic participation. More than 200 000 ACL injuries are estimated to occur in the United States annually.[1–3] Previously identified high-risk populations include athletes participating in pivoting and cutting sports and female athletes. Previous studies indicate that high school female athletes suffer ACL injuries at a rate of 1 in 60 to 100 athletes.[4,5] Typical management of ACL injury is by an anterior cruciate ligament reconstruction (ACLR) because approximately 90% of patients who sustain an ACL injury in the United States eventually have an ACLR.[6]

Despite the high percentage of ACLR after ACL injury, outcomes may be less than optimal with increased risk of subsequent injury and future knee osteoarthritis. Several reports of ACLR outcomes indicate that a subsequent ACL injury occurs with higher frequency than previously thought.[7–9] Wright et al[9] prospectively studied subsequent ACL injury within 2 years after ACLR and found that 1 in 17 (6%) sustained a second ACL injury. Of these, an equal occurrence of ipsilateral re-tears and contralateral tears was observed. Higher rates of second ACL injury have been reported in studies with a longer follow-up period after ACLR. In a retrospective case series study, Salmon et al[8] investigated the clinical rate of second ACL injury after ACLR in a population with a median age of 28 years (range, 14–

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62) and found that within 5 years of reconstruction, 1 in 8.3 (12%) patients incurred a second ACL injury. In a 10-year follow-up study of this same cohort, Pinczewski et al[7] reported that 1 in 3.7 (27%) suffered a second ACL injury. The average age of individuals in these study cohorts was significantly older (median ages of 23–25 years; range, 11–62 years)[7–9] and as such may be significantly less active compared with young active individuals who typically incur the greatest number of ACL injuries (mean age, approximately 16 years).[10] Further, these studies reported incidence estimates based on proportion rather than rate of patients at risk. The incidence rate (IR) is a more sensitive measure of injury risk as it adjusts for actual extent of athletic participation[11] because sports participation after ACLR may vary due to age, confidence, fear of reinjury, residual impairments, or other factors.[12]

A prospective investigation of IR in young active individuals is needed. Thus, the purpose of this study was to determine the IR of a second ACL injury in either the ipsilateral or contralateral knee, using a denominator that would account for actual extent of athletic exposure (AE) at risk of injury, during the first 12 months after return to sport (RTS) after ACLR in a young active population. Based on previous reports, we expected that the occurrence of a subsequent ACL injury after ACLR and RTS would be greater than the incidence of ACL injury in an uninjured cohort of young athletes. We also hypothesized that the IR of a second ACL injury after an ACLR would be greater among female than male athletes.

MATERIALS AND METHODS

Subjects

A prospective case–control design was used to identify and compare the incidence of a second ACL injury (ipsilateral or contralateral) after primary ACLR and RTS with the incidence of ACL injury in an uninjured control group. A total of 102 subjects were evaluated. Sixty-three young athletes (42 female and 21 male athletes) who recently sustained a primary ACL injury, underwent surgical reconstruction, completed rehabilitation, and were released to return to their previous level of activity participated in this study. Inclusionary criteria required the subjects be between 10 and 25 years, have no history of contralateral ACL injury and no history of bilateral lower extremity or low back injury during the previous 12 months, and were released by both their physician and physical therapist to return to their preinjury participation level in a pivoting or cutting (level 1 or 2)[13] sport for at least 50 h/y (Figure 1). In addition, only patients who suffered noncontact or indirect contact primary ACL injuries were included. Indirect contact injuries were defined as an injury that occurred in conjunction with contact to a body part other than the involved extremity (ie, trunk).[3] Contact injuries, which were operationally defined as injuries that occurred as a result of direct contact to the injured extremity, were excluded. Anterior cruciate ligament injuries that occurred during the follow-up period were confirmed with arthroscopy or magnetic resonance imaging. The referent group consisted of 39 healthy subjects (30 female subjects and 9 male subjects) recruited from the local high school, collegiate, and athletic communities. An attempt was made to recruit a referent group comparable with the ACLR group with respect to activity level and primary sport

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participation. In addition to having no history of ACL injury, these subjects met identical inclusionary and exclusionary criteria as the ACLR group and also participated in a minimum of 50 hours of pivoting and cutting sports per year in comparable sports.

The study was approved by the Cincinnati Children's Hospital Medical Center and Rocky Mountain University of Health Professions Institutional Review Boards, and informed consent was obtained from all subjects and guardians (if applicable) before testing.

Data Collection

Subject Demographics—At the time of RTS, demographic and anthropometric data, including age, height, and mass, were collected from the ACLR group. Identical data were collected in the referent group at the time of initial testing.

Injury Surveillance and Exposure—Subjects were enrolled into the study between June 2007 and October 2008. After the initial testing session, subjects in both groups were contacted individually by e-mail or phone every 2 to 4 weeks for the following 12 months.

Injuries—At each point of contact, subjects were asked to report any knee injury since their RTS, particularly ACL injuries. All the second ACL injuries in the ACLR group and initial injury in the referent group were included only if they represented noncontact or indirect contact injuries.[3]

Participation Exposure—At each subject contact, subjects in the ACLR and referent groups were also asked to report the number of AEs in which they participated since the previous contact date. An AE[11] was defined as participation in a game or practice session in a pivoting or cutting sport within their individual or team sport.

Statistical Methods

Select baseline characteristics were compared between ACLR and referent groups, as well as between sexes within each group, with independent *t* tests (alpha significance level < 0.05). Incident rates were calculated for ACLR and referent groups. For the ACLR group, the second ACL injury rate was the number of new ACL injuries per 1000 AEs at risk. Only AEs that occurred before the new ACL injury during the 12 months after their RTS were counted. For the referent group, the ACL injury rate was the number of initial new ACL injuries per 1000 AEs at risk. Only AEs up to the initial new ACL injury during the 12-month study period were counted. These rates were also calculated separately for male participants and female participants. For the ACLR group, we also calculated separate rates for contralateral and ipsilateral injuries.

Incidence rate ratios (RRs) with 95% confidence intervals (CIs) were calculated to compare the incidence of new ACL injury in the ACLR group with the incidence of initial new ACL injury in the referent group. Similar incidence RRs and 95% CIs were calculated for contralateral and ipsilateral ACL injury comparison in the ACLR group only. For comparison with previous studies, we also calculated percent of athletes injured without regard to extent of participation. Differences between male participants and female participants were calculated for all injury RR and risk proportion comparisons. All data were

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analyzed using PASW (SPSS version 17.0; SPSS, Chicago, Illinois) and STATA (version 5.0; STATA Corp, College Station, Texas) statistical packages.

RESULTS

Independent *t* tests indicated no significant mean differences in baseline age, height, or body mass between ACLR and referent groups ($P > 0.05$) (Table 1). No significant group differences in age, height, or body mass were observed when evaluated separately for male participants and female participants ($P > 0.05$). A similar distribution of sports participation was observed among ACLR and referent groups (Figure 1).

During the 12 months after testing, 16 (25.4%) subjects from the ACLR group and 1 (2.6%) subject from the referent group sustained an ACL injury. All ACL injuries represented noncontact or indirect contact injuries.[3] Of the 16 ACLR subjects with subsequent ACL injury, 12 (75%) sustained contra-lateral ACL injuries and 14 (87.5%) were female participants (Table 2). A higher proportion of ACLs sustained during the 12-month period were incurred during games than in practices (Figure 2). Table 2 summarizes injury rates (per 1000 AEs) for a 12-month period. The rate of ACL injury was 15 times (RR = 15.24; 95% CI, 2.4–639.2; $P = 0.0002$) higher among those in the ACLR group (1.82/1000 AEs) than those in the referent group (0.12/1000 AEs). For female participants, a similar pattern was observed; the rate of ACL injury for female patients in the ACLR group was 16 times greater (RR = 16.02; 95% CI, 2.4–677.3; $P = 0.0002$) than the female patients in the referent group. For male participants, IRs of ACL injury between ACLR and referent groups could not be determined due to the absence of any ACL injury sustained by the male referent subjects. For the ACLR group, the risk of a second ACL injury by a female subject was nearly 4 times greater (RR = 3.94; 95% CI, 0.9–35.8; $P = 0.05$) than in male participants.

Of the 16 second ACL injuries sustained in the ACLR group, 12 were to the contralateral knee and 4 to the ipsilateral (graft rupture) knee. Although not statistically significant, the rate of second ACL injury was almost 3 times (RR = 2.58; 95% CI, 0.8–11.0; $P = 0.09$) greater in the contralateral knee (1.38/1000 AEs) than in the ipsilateral knee (0.54/1000 AEs) (Table 3). Among female participants, the rate of second ACL injury had a similar trend and was also 3 times (RR = 3.03; 95% CI, 0.8–16.9; $P = 0.08$) greater in the contralateral knee compared with the ipsilateral knee. The rate of second ACL injury to the contralateral knee was significantly 6 times (RR = 6.21; 95% CI, 0.9–267.1; $P = 0.04$) higher among female participants (1.98/1000 AEs) than male participants (0.32/1000 AEs) ($P = 0.04$). No significant differences were found between rates of second ACL injury in the ipsilateral knee among male participants and female participants ($P = 0.64$).

For comparison purposes, we calculated RRs using units of percent of athletes injured. Twelve subjects (19%) in the ACLR group suffered a contralateral injury with the proportion among female participants (26%) observed to be 5 times greater (RR = 5.50; 95% CI, 0.8–39.8; $P = 0.048$) than male participants (4.8%). Conversely, 6% (n = 4) of the subjects in the ACLR group suffered an ipsilateral injury (graft re-tear) with a similar proportion between female participants (7.1%) and male participants (4.8%) ($P = 1.00$).

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DISCUSSION

The findings of this current study support the hypothesis that the IR of ACL injury after ACLR is significantly higher than the IR of initial new injury among a cohort of young healthy subjects. Subjects who underwent ACLR and then incurred a second ACL injury within the first 12 months of activity after RTS were approximately 15 times more likely to sustain an ACL injury than a subject with no history of an ACL injury. Although nonsignificant, our data indicated patterns that after ACLR, higher rates of second ACL injury occurred at the contralateral knee rather than an ipsilateral ACL graft rupture, and female athletes may be more likely to sustain a second ACL injury than their male counterparts.

To our knowledge, this study represents the first report of subsequent ACL injury IR focused on the outcomes of young active patients who return to sport after ACLR. Further, to our knowledge, this study represents the first attempt to report IR of a second ACL injury after ACLR adjusted for actual sport participation exposure. Our results indicate that young athletes, particularly young female athletes, who return to pivoting and cutting sports after ACLR have a 15-fold greater risk of an ACL injury than healthy subjects. Because male participants in the referent group did not incur an initial injury, we were unable to formally statistically evaluate the IRs between male participants in the ACLR and referent groups. However, the IR for the entire referent cohort was in the range of previously reported rates. In a meta-analysis of the incidence of initial ACL injury rate, Marshall et al[3] reported ACL injury rates between 0.011 and 0.49 per 1000 AEs for recreational, high school, and collegiate female soccer and basketball players. These authors also reported an ACL injury rate range of 0.007 and 0.12 per 1000 AE for similar male athletes. These findings are comparable to the IR of our overall (0.12/1000 AE) and female (0.16/1000 AE) referent groups but are significantly less than the ACLR group (1.82/1000 AE) and the female ACLR group (2.50/ 1000 AE). Interestingly, female athletes were at nearly 4 times greater risk of injury than male athletes after ACLR. This is comparable to previous reports of healthy female athletes who were 4 to 6 times more likely to suffer an ACL injury than healthy male athletes.[3,14] These data indicate that relative risk of ACL injury may not change from preoperative to postoperative status in female athletes.

For comparative purposes to previous reports, we also calculated incidence proportions for both groups. The incidence proportion of a second ACL injury for those in the ACLR group within the first 12 months after RTS was 25.3% compared with 2.6% of an initial ACL injury in a cohort of young healthy referents during the same period. The incidence proportion of a second injury after an ACLR is similar to that reported by Pinczewski et al[7] (27% at a 10-year follow-up) but higher than that previously reported in 2- and 5-year follow-up studies by Wright et al[9] (6%) and Salmon et al[8] (12%), respectively. The higher incidence proportion reported in our study is likely explained by a younger more active patient population than previously reported by others. The greater prevalence of ACL injury in a younger population is consistent with previous studies, which indicated that the greatest number of ACL injuries occurred between the ages of 16 and 18 years.[10,15] Variability in AEs after ACLR limits the ability to compare incidence proportion between studies. In our study, the reported IR, adjusted for actual sports participation at risk for injury, provides a

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more accurate risk estimate of future ACL injury after ACLR. Using AEs as an accurate denominator to measure injury risk, our findings indicated that the risk of a subsequent injury was highest for female athletes after ACLR with a rate of 2.50 per 1000 AE. In addition, this rate was particularly high due to the high rate of contralateral injuries in female athletes after ACLR with a rate of 1.98 per 1000 AE.

Within the cohort of all subjects after ACLR, and the cohort of female subjects, most second ACL injuries occurred in the contralateral limb. However, these differences were only nonsignificant trends ($P = 0.08–0.09$), probably due to the small sample size and low number of second ACL injury among the male participants in the ACLR group. An equal rate of contralateral and ipsilateral second ACL injuries was seen in the male cohort after ACLR; however, the smaller sample size of male participants may limit the generalizability of the findings of the male subjects. Most notable within young female athletes after ACLR is that 26% suffered a contralateral injury within the first 12 months after RTS. The higher rate of an additional injury to a new body part relative to a reinjury is consistent of findings reported by Rauh et al,[16] which noted a similar pattern in high school female athletes. The mechanism of this high rate of contralateral ACL injuries in female athletes after ACLR is probably multifactorial, inclusive of unresolved preoperative risk factors and residual impairments present at the time of RTS and the tendency of many athletes to overstress the uninvolved limb when returning to sport play.

Recent studies are consistent in reporting that young healthy female athletes who participate in pivoting and cutting sports suffer ACL injuries 4 to 6 times more often than their male counterparts.[14,17–19] In addition, biomechanical and neuromuscular risk factors are often identified as the mechanism underlying this risk.[20,21] Current surgical interventions for ACL injury may adequately address the pathoanatomy; however, they do not affect these underlying preoperative risk factors, which may persist after ACLR. Rehabilitation after ACLR, if focused on postoperative impairments of the involved limb, may neglect to address these modifiable risk factors in both limbs in female athletes after ACLR. Various studies have identified training programs that have successfully reduced the rate of ACL injury in young healthy female athletes.[18,22–25] Future research should examine the efficacy of these interventions at the end stages of rehabilitation after ACLR at reducing the rate of a second ACL injury.

Residual impairments in the involved limb at the time of RTS after ACLR are well documented, including quadriceps femoris weakness,[26,27] altered postural stability,[27–29] and altered performance on hop testing.[27,30] Abnormal loading patterns and altered movement patterns have also been identified after ACLR. Paterno et al[31] reported significantly higher vertical ground reaction force during the landing phase of a drop vertical jump maneuver on the uninvolved limb of young female athletes 2 years after ACLR. Others have identified altered loading patterns[32] and compensatory movement patterns[33,34] after ACLR, which may result in increased load on the uninvolved limb during dynamic movement patterns after ACLR. This increased load on the contralateral limb after ACLR, coupled with unaddressed risk factors in female athletes, may place the young female athlete after ACLR at even higher risk for a contralateral ACL injury, as our findings indicate.

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POTENTIAL STUDY LIMITATIONS

Although an important strength of our study was the use of a prospective cohort study design, several limitations should be noted. A relatively small sample size of 102 subjects was enrolled in this study, which limited our ability to examine subgroup analyses of additional variables of interest; particularly the smaller sample of male athletes may limit the generalizability of these findings among young male athletes after ACLR. In addition, the cohort represented only young athletes who planned to return to pivoting and cutting sports. This may limit the generalizability of our results to other athletic populations, particularly those who elect to return to nonpivoting types of sports.

CONCLUSIONS

The results of this prospective case–control study indicate an increased rate of second ACL injury (contralateral or graft re-tear) in the first 12 months after ACLR and RTS when compared with a healthy referent population in pivoting and cutting sports, especially for female athletes. Although we recommend additional research to support our findings, our data provide early evidence for the reexamination of current protocols for end-stage rehabilitation and RTS guidelines after ACLR.

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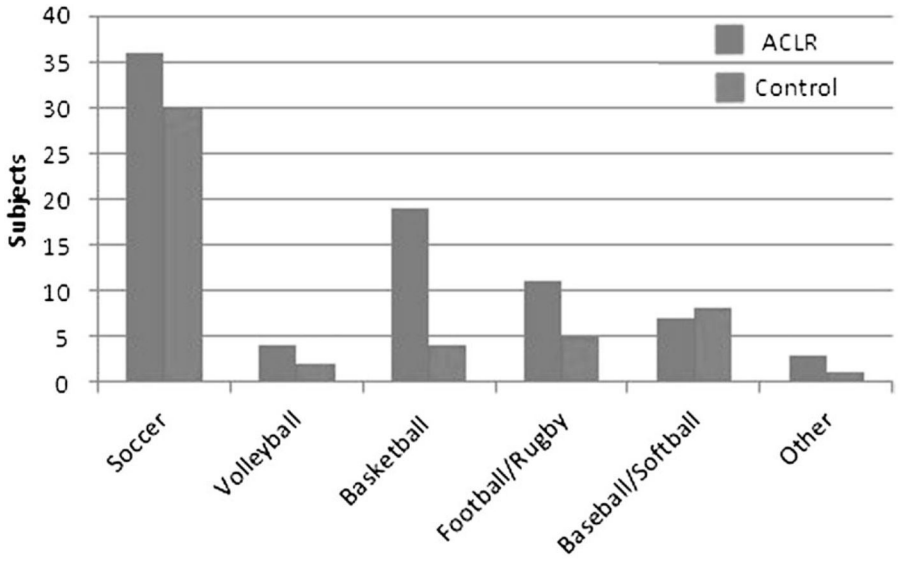

FIGURE 1.

Distribution of sport participation by ACLR Group. Some athletes participated in multiple sports, which is reflected in this figure.

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FIGURE 2.
Distribution of injury by game versus practice.

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TABLE 1

Subject Demographic Data

Variable	ACLR (n = 63) Mean (SD)	CRTL (n = 39) Mean (SD)	*P**
Age, y			
Total	16.3 (2.9)	16.6 (2.2)	0.59
Female participants	16.1 (2.1)	16.9 (1.9)	0.11
Male participants	16.7 (4.0)	15.6 (2.9)	0.46
Height, cm			
Total	166.9 (11.3)	165.5 (7.4)	0.52
Female participants	164.2 (6.4)	164.4 (5.6)	0.88
Male participants	172.2 (16.4)	169.3 (11.1)	0.64
Mass, kg			
Total	65.7 (17.5)	60.3 (11.6)	0.09
Female participants	61.5 (9.8)	59.1 (7.5)	0.26
Male participants	74.2 (25.4)	64.4 (20.4)	0.31

*Independent *t* test used for between-group comparison of means between ACLR and CTRL groups.

ACLR, group with initial ACLR; CTRL, referent group.

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TABLE 2

Summary of the IR of ACL Injury

	Total			Female participants			Male participants				
Injury Type	**No.**	**AEs**	**Rate***	**No.**	**AEs**	**Rate***	**No.**	**AEs**	**Rate***	**RR**	**95% CI**
ACLR											
Second ACL	16	8788	1.82	14	5621	2.50	2	3167	0.63	3.94	0.9–35.8†
Control											
Initial ACL	1	8372	0.12	1	6432	0.16	0	1940	0.00	0.00	NA
ACLR/CTRL RR			15.24			16.02			0.00		
95% CI			2.4–639.2‡			2.4–677.3§			NA		

*Rate, ACL injury rate per 1000 AEs.

†RR ACLR: second ACLR female/second ACLR male ($P = 0.05$).

‡RR total: second ACL/initial ACL ($P = 0.0002$).

§RR female participants: second ACL/initial ACL ($P = 0.0002$).

AE, each time an athlete took part in a practice or competition without limitation of ACL injury, thus being exposed to the risk of ACL injury; CTRL, control group; NA, not applicable.

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TABLE 3

Summary of the IR of Contralateral Versus Ipsilateral ACL

	Contralateral			Ipsilateral				
Injury Type	**No.**	**AEs**	**Rate***	**No.**	**AEs**	**Rate***	**RR**	**95% CI**
Total								
Second ACL	12	8683	1.38	4	7468	0.54	2.58	0.8–11.0†
Female participants								
Second ACL	11	5550	1.98	3	4590	0.65	3.03	0.8–16.9‡
Male participants								
Second ACL	1	3133	0.32	1	2878	0.35	0.92	0.1–72.1
Female/Male RR			6.21				1.88	
95% CI			0.9–267.1§				0.2–98.9	

*Rate, ACL injury rate per 1000 AEs.

†RR total second tear: contralateral/ipsilateral ($P = 0.09$).

‡RR female second tear: contralateral/ipsilateral ($P = 0.08$).

§RR contralateral tear: female/male ($P = 0.04$).

AE, each time an athlete took part in a practice or competition without limitation of ACL injury, thus being exposed to the risk of ACL injury.