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Incidence of Subsequent Injury to Either Knee Within 5 Years After Anterior Cruciate Ligament Reconstruction With Patellar Tendon Autograft

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Background: The risk of subsequent anterior cruciate ligament injury to either knee after surgery based on sex, age, and activity has not been extensively studied.

Hypotheses: Women have a higher incidence of anterior cruciate ligament injury to the contralateral knee after surgery than men but do not have a difference in injuries to the reconstructed knee. Young, competitive athletes have a higher incidence of injury than older patients. The time to return to full activities does not affect injury rate.

Study Design: Cohort study (prognosis); Level of evidence, 2.

Methods: The authors prospectively followed 1820 patients after primary anterior cruciate ligament reconstruction to determine if patients suffered an injury to either knee within 5 years after surgery. Subsequent injury was evaluated based on sex, age, and activity level.

Results: Minimum 5-year follow-up was obtained on 1415 patients (78%). Seventy-five patients (5.3%) had an injury to the contralateral knee, and 61 patients (4.3%) suffered an injury to the reconstructed knee ($P = .2185$). Women suffered more injuries (7.8%) to the contralateral normal knee than men (3.7%; $P < .001$) but not more injuries to the reconstructed knee (4.3% vs 4.1%; $P = .5543$). The risk of subsequent injury to either knee was 17% for patients <18 years old, 7% for patients aged 18 to 25 years, and 4% for patients older than 25 years. There was no difference in injury rate between patients who returned before and after 6 months postoperatively.

Conclusion: Women have a higher incidence of anterior cruciate ligament injury to the contralateral knee than men after reconstruction. The incidence of injury to either knee after reconstruction is associated with younger age and higher activity level, but returning to full activities before 6 months postoperatively does not increase the risk of subsequent injury.

Keywords: anterior cruciate ligament reconstruction; reinjury; risk factors; sex; age; patellar tendon graft

The incidence of suffering a subsequent anterior cruciate ligament (ACL) injury after having an ACL reconstruction has not been studied extensively. There are 2 previous studies that prospectively evaluated the incidence of injury to either knee after ACL reconstruction.^{11,18} Wright et al¹⁸ evaluated the risk of ACL injury to either knee within the first 2 years after surgery in 235 patients who had follow-up

data and who had surgery performed by multiple surgeons using a variety of graft sources. Salmon et al,¹¹ in a group of 675 patients, evaluated the incidence of ACL injury to either knee within 5 years after surgery and evaluated the risk of injury related to activity level, graft source, intra-articular injuries, and sex. Both studies concluded that incidence of injury to either knee after ACL reconstruction is similar.

What is still unknown is if there are differences between men and women as to which knee becomes injured after surgery based specifically on age and activity level and if the timing of the return to activities is related to subsequent injury.

The purpose of this study was to determine the incidence of subsequent injury to either the reconstructed ACL graft or the ACL in the opposite normal knee within 5 years of an ACL reconstruction using a bone-patellar tendon-bone

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autograft. Specifically, we sought to determine the relationship between age, sex, and activity level and the risk of subsequent injury and if there was a difference in injury rate between patients who return to full activities before 6 months postoperatively and those who return after 6 months.

MATERIALS AND METHODS

This study was approved by the Institutional Review Board at the authors' institution, and all patients participating in this study gave informed consent. From 1992 through 2001 the senior author (KDS) performed 1820 primary ACL reconstructions on patients with a unilateral ACL injury and having no history of injury to the contralateral ACL as determined by patient report and physical examination of the contralateral knee.

Demographic information was collected from each patient and entered into a prospective database. All patients subsequently underwent an ACL reconstruction performed by the senior author using a bone-patellar tendon-bone autograft as has been previously described.^{12,15} Each patient then underwent an ACL rehabilitation program, also as previously described.^{2,14} The rehabilitation program was designed to take patients through a progression of steps that were not defined by time but, instead, by each patient's ability to achieve rehabilitation goals. The progression of rehabilitation postoperatively was as follows: (1) obtain full knee extension and flexion while limiting swelling, (2) increase leg strength, (3) perform sport-specific drills individually, (4) perform controlled team drills, (5) participate part-time in competition while monitoring swelling and knee range of motion, and (6) participate full-time in competition.

Data regarding activity level (see Appendix 1) were prospectively collected to record at what time patients reported that they returned to full sports or activities at their full capabilities. In addition, an activity rating survey¹³ asked patients what sports or activities they were participating in, and the patient then circled a choice of activity level (professional, collegiate, or elite competition, school-age competition, recreational competition or participation, work, or activities of daily living). The data were then scored on a scale from 1 to 10 according to the activity rating survey that ranks sports and activities based on risk for ACL injury and level of competition.¹³ An activity rating of level 10 indicated the patient participated in college, professional, or elite sports involving jumping, twisting, or pivoting that included sports such as basketball, soccer, football, volleyball, and snow skiing, which are known to be high-risk activities for ACL injuries.¹ An activity rating of level 9 indicated the patient participated in the same type of high-risk sports at the school-age or club level, and an activity rating of level 8 indicated the patient participated in high-risk sports at a recreational level. The activity rating survey was completed at regular follow-up office visits during the first year postoperatively and was sent to patients prospectively on a yearly basis after surgery and has been published previously.¹³

Information regarding whether the patient had sustained a subsequent ACL injury to either knee was obtained through several methods. We obtained information directly from patients when they returned for an evaluation after an injury. Patients were contacted yearly after surgery to complete subjective questionnaires, on which there were specific questions regarding injury to the previous ACL-reconstructed knee or injury to the opposite knee. If a patient reported a subsequent injury, he or she was contacted for more information, and medical records were obtained. Patients who did not respond to our request to complete a questionnaire were contacted by phone. A subsequent ACL injury was counted if it had been confirmed by physician examination or if the patient reported the ACL injury on a subjective survey or by phone.

Patients were evaluated based on age, sex, and time to return to full activities, and whether or not the injury that occurred was to the previously reconstructed ACL or to the ACL in the contralateral normal knee. When looking at age as a risk factor, patients were sorted into 3 different groups based on age: younger than 18 years old, 18 to 25 years old, and older than 25 years old. These groups were chosen to represent the different age groups based on potential levels of activity. Patients who were younger than 18 years old represented school-aged patients who were typically participating in high-level athletics as part of school and club or elite teams. The 18- to 25-year-old group represented young adults that included those participating in collegiate athletics or young adults that may or may not be very active still. The group of older than 25-year-olds was chosen to represent all other patients. These patients may still be very active, but they are often not participating in organized or competitive sports at high levels.

Furthermore, we evaluated the number of subsequent ACL injuries to either knee and compared the different injury rates between patients who returned to full activities before 6 months postoperatively and patients who returned to full activities after 6 months postoperatively.

Statistical Analysis

Descriptive statistics were obtained. The number of subsequent ACL injuries to either knee within 5 years after surgery was counted. Fisher exact test (2-tailed) was used to calculate if there was a statistically significant difference for binary data in contingency tables between groups based on sex, age, which knee was injured, and time to return to full activities. Analysis was performed using SAS statistical package (SAS Institute, Cary, North Carolina).

RESULTS

Of the 1820 possible patients who met the criteria for the study, complete follow-up and activity-related data were obtained on 1415 patients (78%) in the short term to determine ability to return to sports within the first year postoperatively and at a minimum of 5 years after surgery. The median age at the time of surgery was 21 years (mean,

TABLE 1
Preinjury and Maximum Postoperative Activity Rating Scores Based on Age Group

Age Group, y	Preinjury Activity Scores			Postoperative Activity Scores				
	Mean \pm SD	% Patients at Level 9 or 10	% Patients at Level 8	% Patients at Level 8, 9, or 10	Mean \pm SD	% Patients at Level 9 or 10	% Patients at Level 8	% Patients at Level 8, 9, or 10
<18 (n = 528)	8.6 \pm 0.9	82	10	92	8.7 \pm 1.0	69	23	92
18-25 (n = 350)	8.4 \pm 1.2	35	54	89	8.2 \pm 1.5	33	52	85
>25 (n = 537)	7.6 \pm 1.1	7	72	79	7.3 \pm 1.3	4	64	68

TABLE 2
Time to Return to Full Activities After Surgery

Age Group, y	n	Months, Mean \pm SD	Patients Returning to Full Activity Before 6 Months Postoperatively, n (%)
<18	528	4.6 \pm 1.9	379 (71.8)
18 to 25	350	5.5 \pm 2.2	194 (55.4)
>25	537	6.1 \pm 2.0	214 (39.8)
P value		<.0001	

21.6 \pm 3.6; range, 14-58); 37% of patients were younger than age 18.

Activity Level Before and After Surgery

Younger patients participated in higher-level activities before and after surgery than older patients (Table 1; $P < .0001$). There was no statistically significant difference between men and women for mean activity level within age groups either before or after surgery (all P values $> .5625$). For the <18-year-old group, 92% participated in high-risk sports before surgery and 92% returned to high-risk sports after surgery; 23% of the patients went on to compete in college athletics. The mean time to return to full activities at full capability was statistically significantly earlier for patients <18 years old (Table 2; $P < .0001$) compared with patients 18 to 25 years old and patients >25 years old.

Subsequent ACL Injuries to Either Knee

Of 1415 patients, 136 patients (9.6%) had a subsequent ACL injury to either knee (Table 3). Sixty-one patients (4.3%) had an injury to the ACL-reconstructed knee, and 75 patients (5.3%) had an injury to the contralateral normal knee ($P = .2531$). Women suffered 69 subsequent ACL injuries (12.5%), and men suffered 67 injuries (7.8%; $P = .004$). The mean time of ACL injury to the ACL-reconstructed knee was 19.2 \pm 15.7 months after surgery. The mean time of ACL injury to the contralateral normal knee was 28.2 \pm 13.9 months after surgery. There was no statistically significant difference between men and women for subsequent ACL tear to the ACL-reconstructed knee ($P = .5543$); however, women had a higher incidence

of subsequent ACL injury to the contralateral knee (7.8%) than men (3.7%; $P < .001$).

The highest risk of subsequent injury was in the <18-year-old age group, where there was 8.7% incidence of injuring the previously ACL-reconstructed knee and an 8.7% incidence of injuring the ACL in the contralateral knee. In the <18-year-old age group, girls had a statistically significantly higher rate of ACL injury in the contralateral knee than boys (11.6% vs 4.6%; $P = .0099$), but boys had a statistically significantly higher incidence of ACL graft tears than girls (10.6% vs 4.6%; $P = .02845$). The incidence of subsequent injury to either knee dropped sharply from 17.4% in patients <18 years old to 6.7% in patients 18 to 25 years old, and 3.9% in patients >25 years old ($P < .0001$).

Subsequent ACL injuries occurred most often with participation in the sports of basketball (52%) and soccer (15%); only 9 of 136 (6.6%) injuries occurred for a reason other than sports (Table 4). Ninety-two of the 136 subsequent ACL injuries occurred in patients younger than age 18 at the time of surgery, and 90 of them occurred in sports competition at the high school or collegiate level.

During the 5-year period postoperatively, patients who returned to full activity before 6 months postoperatively did not have a statistically significantly higher incidence of subsequent ACL injury to the ACL-reconstructed knee ($P = .6014$) or the contralateral knee ($P = .9051$) than patients who returned to full activities at >6 months after surgery (Table 5).

DISCUSSION

This study critically evaluated the differences between men and women and age groups for the risk of subsequent ACL injury within the first 5 years after ACL reconstruction and found that girls <18 years old have a higher rate of contralateral ACL injury than boys, and boys <18 years old have a higher rate of ACL graft injury than girls. Overall, the risk of subsequent injury to either knee was 17% for patients younger than 18 years old, 7% for patients 18 to 25 years old, and 4% for patients older than 25 years. This study also documented the timing of return to full activities within age groups and determined that the returning to sports at full capability before 6 months postoperatively did not affect the rate of subsequent injury.

Suffering an ACL injury is a major event in one's life. The younger and more active the patient is, the more emotionally devastating the injury can be. Some very common

TABLE 3
Subsequent ACL Injuries to Either Knee Based on Age Group and Gender^a

Age Group/Gender	n	ACL Tear to ACL-Reconstructed Knee		ACL Tear to Contralateral Knee		P Value (Difference in Tears Between Knees)
		n	%	n	%	
<18 years old	528	46	8.7	46	8.7	1.00
Female	310	23	7.4	36	11.6	.00998 ^b
Male	218	23	10.6	10	4.6	.02845 ^b
P value (difference in tears between genders)		.214		.0046 ^b		
18 to 25 years old	350	9	2.6	14	4.0	.3969
Female	103	2	1.9	5	4.9	.4450
Male	247	7	2.8	9	3.6	.800
P value (difference in tears between genders)		1.00		.5631		
>25 years old	537	6	1.1	15	2.8	.0754
Female	139	1	0.7	2	1.4	1.00
Male	398	5	1.3	13	3.3	.0925
P value (difference in tears between genders)		1.00		.3746		
Totals	1415	61	4.3	75	5.3	.2185
Female	552	26	4.7	43	7.8	.0459 ^b
Male	863	35	4.1	32	3.7	.8034
P value (difference in tears between genders)		.5543		.0014 ^b		

^aACL, anterior cruciate ligament.

^bStatistically significant difference between groups.

TABLE 4
Cause of Subsequent ACL Injury^a

Cause of Injury	Number of Injuries to ACL-Reconstructed Knee, n	Number of Injuries to Contralateral Normal Knee, n	Total Number of Injuries to Either Knee, n (%)
Basketball	37	34	71 (52)
Soccer	8	13	21 (15)
Football	3	8	11 (8)
Volleyball	2	6	8 (5.9)
Gymnastics	1	1	2 (1.5)
Wrestling	0	5	5 (3.7)
Snow-skiing	1	3	4 (2.9)
Baseball/softball	2	2	4 (2.9)
Track (hurdles)	0	1	1 (0.7)
Not related to sports	7	2	9 (6.6)
Total	61	75	136

^aACL, anterior cruciate ligament.

questions that patients with an ACL injury have are “How long will it be before I can compete again, and what is the risk for reinjury?” These questions are more common from young competitive athletes who feel an immediate desire and need to recover from the injury and get back to playing sports quickly.

For the total group of patients, the overall incidence of injury to the ACL-reconstructed knee was 4.3%, and the incidence of injury to the contralateral knee was 5.3%, which is similar to the studies by Salmon et al¹¹ and Wright et al.¹⁸ Wright et al¹⁸ evaluated the injury rate of 235 patients within 2 years after surgery and found a 3%

TABLE 5
Subsequent Injury to Either Knee Based on Time to Return to Full Activities

Time to Return to Full Activity	ACL Tear in ACL-Reconstructed Knee, n (%)	ACL Tear in Contralateral Knee, n (%)
<6 months (n = 787)	36 (4.6)	41 (5.2)
≥6 months (n = 628)	25 (4.0)	34 (5.4)
P value	.6014	

incidence of ACL injury to each knee after surgery. Salmon et al,¹¹ with 5-year follow-up of 612 patients, found an incidence of ACL injury of around 6% for each knee.

Although the overall rates of subsequent injury appear similar for both knees, there was a difference as to which knee was injured between men and women. This current study found that women had a 7.8% incidence of ACL injury in the contralateral knee compared with 4.3% in the ACL-reconstructed knee, whereas the incidence for injury to either knee was similar for men. Wright et al¹⁸ did not find a statistically significant difference between men and women as to which knee was injured; however, the raw numbers of their study may show a trend that mimics what we found in our current study. Wright et al¹⁸ found that 6 of the 7 (86%) subsequent injuries to the ACL-reconstructed knee occurred in men, and 5 of the 7 (71%) ACL tears to the contralateral knee occurred in women. Salmon et al¹¹ found an overall incidence rate of injury to the ACL-reconstructed knee as 8% for men and 4% for women; the rate of ACL injury to the contralateral knee was 7% for women and 5% for men.

The difference between men and women for subsequent injury to either knee was clearly evident in patients younger than 18 years old, in which girls suffered injuries mostly to the contralateral knee (11.6%), and boys suffered injuries to the ACL-reconstructed knee (10.6%). The statistical significance between injury rates to either knee or between the sexes was not present for patients 18 to 25 years or patients older than 25 years. It is possible that the different findings between our current study and that of Salmon et al¹¹ and Wright et al¹⁸ for the incidence rate of injury between sexes are due to the differences in ages for the patient populations between studies. The median age of patients in the current study was 21 years, whereas the median age in the study by Wright et al¹⁸ was 23 years, and the median age in the study by Salmon et al¹¹ was 28 years. Statistically significant differences between men and women may not be seen in studies that do not include a large number of patients participating in high school or college sports where the exposure rates would be the highest and at a time when women may be equally as active as men.

As shown in our study, there was a statistically significant difference in activity level between the age groups. Activity levels of 8, 9, and 10 relate to recreation, school-aged, and college and elite sports, respectively, and the exposure rates for injury are most likely different between activity levels. School-aged and collegiate athletes practice or compete 5 or 6 days per week for several hours each day during the season. Most athletes continue the same sport in the off-season through club teams or sport-specific athletic associations or as part of the year-round training in collegiate athletics. Level 8 or recreational athletes may participate in the same sport, but it is usually at a lower intensity, and exposure hours for injury are drastically reduced.

Eighty-two percent of patients younger than 18 years old participated in level 9 or 10 sports before injury and 69% returned to the same level. This decrease in activity level is logical given that about 20% of patients were high school seniors at the time of their surgery and some did not have the opportunity to return to their school sport. However, 23% of patients went on to participate in college athletics, which compares to a national average of 5% of all high school athletes.⁹ For patients aged 18 to 25 years, 33% returned to level 9 or 10 sports, and an additional 52% participated in the same sports at recreational level 8. Activity levels dropped after age 25, where only 4% were participating in level 9 or 10 sports, but an additional 64% were participating in the same high-risk sports at a recreational level.

Subsequent ACL injury rates to either knee found in this current study are mostly likely due to the high activity levels reported in our patient population. Salmon et al¹¹ found that patients who returned to moderate or strenuous activities had a 10% incidence of injury to the contralateral knee and 8% incidence of injuring the ACL-reconstructed knee, which was in contrast to patients who returned to light or sedentary activities, in which only 1% injured the contralateral knee and 4% injured the ACL-reconstructed knee. Although specific exposure rates were not recorded in this study, the higher activity level reported and the sports being played indicated that young patients participated in high school or club sports in which athletes are

competing in games and matches more often and at a higher intensity than older people. The data of Le Gall et al⁷ may confirm this concept because the data showed that in an 8-year study of elite soccer players, 10 of 12 ACL injuries occurred during matches versus practice.

The time of subsequent injury to either knee in this current study was 19 months for the ACL-reconstructed knee and 28 months for the contralateral normal knee, and these times are almost identical to what Salmon et al¹¹ found in their 5-year follow-up study. The time of subsequent injury was not reported in the study by Wright et al.¹⁸ Salmon et al¹¹ stated a concern that early ACL graft ruptures during the first 12 months after surgery may be because of graft weakness. The general consensus in the literature is that patients should wait 6 months before returning to sports after an ACL reconstruction.³ Therefore, we evaluated the incidence of subsequent injury based on when the patients reported that they returned to full sports as a means to determine whether patients who returned before 6 months had a higher incidence of ACL graft tears after surgery. The results of our study showed that patients who returned to sports before 6 months after surgery did not have a higher incidence of ACL graft tears (4.6%) than patients who waited until after 6 months to return to sports (4.0%; $P = .6014$).

For the young age group of <18-year-olds, in which more patients returned to sports earlier, boys had a tendency to suffer an ACL graft tear versus a contralateral ACL injury; the opposite was true for girls. We believe the difference as to which knee becomes injured after surgery may have more to do with ligament size. Dienst et al⁵ showed that women have smaller ACLs than men, and the mean cross-sectional area of the midsubstance of the ACL was 45.2 mm for women and 68.4 mm for men. Other investigators who used MRI to evaluate ACL width^{4,16} had similar findings: women have narrower ACLs than men and the intercondylar notch size correlates with ACL width. Davis et al⁴ found that the mean width of the ACL on a coronal MRI cut was 5.7 ± 1.1 mm (range, 2-8 mm) for women and 7.1 ± 1.2 mm (range, 5-10 mm) for men. In the current study, all patients, regardless of gender, received a 10-mm-wide patellar tendon graft for ACL reconstruction. This would mean that most women received an ACL graft that was larger than their native ACL in the contralateral normal knee but men received an ACL graft that may have been similar or just slightly smaller than their native ACL. Other theories such as different landing patterns^{6,10} and hormone levels^{8,17} have been proposed to explain why women may suffer more ACL injuries; however, these same factors are still present in women after surgery. Overall, women did have more subsequent ACL injuries after surgery, but the injury was twice more often to the contralateral knee, which most likely had a smaller native ACL. Ligament size is one factor that may be different between the 2 knees after surgery, especially for women, and each knee has the same exposure risk for injury. Future studies regarding ligament size and subsequent injury are warranted.

One weakness of this study is that we did not record actual exposure rates for the athletes; however, the activity rating scale we used assigned a rating score that was specific to sport and level of intensity of the sport based on whether the athlete was playing the sport at the high

school, club, college, or recreational level. The highest rating levels (9 and 10) were for the highest-risk sports for ACL injuries played at the high school, club, college, elite, or professional level where athletes participate at least 5 to 6 days per week for several hours a day. We believe that the higher rate of subsequent injury in the younger age group was due to the high level of intensity and increased exposures present in that age group.

CONCLUSION

Women have a higher incidence of ACL injury to the contralateral knee than men after ACL reconstruction but do not have a higher incidence of ACL-graft injuries after surgery. Patients younger than 18 years old have a higher subsequent ACL injury rate to either knee after surgery than older patients, and the increased injury rate is associated with higher activity levels. However, returning to full activities before 6 months postoperatively does not increase the risk of subsequent ACL injury.

REFERENCES

1. Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of the literature. *Am J Sports Med.* 1995;23:694-701.
2. Arnold T, Shelbourne KD. Perioperative rehabilitation program for anterior cruciate ligament injuries. *Phys Sportsmed.* 2000;28:31-44.
3. Campbell JD. The evolution and current treatment trends with anterior cruciate, posterior cruciate, and medial collateral ligament injuries. *Am J Knee Surg.* 1998;11:128-135.
4. Davis TJ, Shelbourne KD, Klootwyk TE. Correlation of the intercondylar notch of the femur to the width of the anterior and posterior cruciate ligaments. *Knee Surg Sports Traumatol Arthrosc.* 1999;7:209-214.
5. Dienst M, Schneider G, Altmeyer K, et al. Correlation of intercondylar notch cross-sections to the ACL size: a high-resolution MR tomographic in vivo analysis. *Arch Orthop Trauma Surg.* 2007;127:253-260.
6. Kernozek TW, Torry MR, Iwasaki M. Gender differences in lower extremity landing mechanics caused by neuromuscular fatigue. *Am J Sports Med.* 2008;36:554-565.
7. Le Gall F, Carling C, Reilly T. Injuries in young elite female soccer players: an 8-season prospective study. *Am J Sports Med.* 2008;36:276-284.
8. Liu SH, al-Shaikh RA, Panossian V, et al. Primary immunolocalization of estrogen and progesterone target cells in the human anterior cruciate ligament. *J Orthop Res.* 1996;14:526-533.
9. National Collegiate Athletic Association. Estimated probability of competing in athletics beyond the high school interscholastic level. http://www.ncaa.org/research/prob_of_competing/. Accessed June 25, 2007.
10. Rozzi SL, Lephart SM, Gear WS, Fu FH. Knee joint laxity and neuromuscular characteristics of male and female soccer and basketball players. *Am J Sports Med.* 1999;27:312-319.
11. Salmon L, Russell V, Musgrove T, Pinczewski L, Refshauge K. Incidence and risk factors for graft rupture and contralateral rupture after anterior cruciate ligament reconstruction. *Arthroscopy.* 2005;21(8):948-957.
12. Shelbourne KD. Mini-open ACL reconstruction using contralateral patellar tendon. *Tech Orthop.* 2005;20(4):352-360.
13. Shelbourne KD, Jari S, Gray T. Outcome of untreated traumatic articular cartilage defects of the knee. *J Bone Joint Surg Am.* 2003;85 Supplement 2:8-16.
14. Shelbourne KD, Klotz C. What I have learned about the ACL: utilizing a progressive rehabilitation scheme to achieve total knee symmetry after anterior cruciate ligament reconstruction. *J Orthop Sci.* 2006;11(3):318-325.
15. Shelbourne KD, Rask BP. Anterior cruciate ligament reconstruction using a mini-open technique with autogenous patellar tendon graft. *Tech Orthop.* 1998;13(3):221-228.
16. Staebli HU, Adam O, Becker W, Burgkart R. Anterior cruciate ligament and intercondylar notch in the coronal oblique plane: anatomy complemented by magnetic resonance imaging in cruciate ligament-intact knees. *Arthroscopy.* 1999;15:349-359.
17. Wojtyś EM, Huston LJ, Boynton MD, Spindler KP, Lindenfeld TN. The effect of the menstrual cycle on anterior cruciate ligament injuries in women as determined by hormone levels. *Am J Sports Med.* 2002;30:182-188.
18. Wright RW, Dunn WR, Amendola A, et al. Risk of tearing the intact anterior cruciate ligament in the contralateral knee and rupturing the anterior cruciate ligament graft during the first 2 years after anterior cruciate reconstruction. *Am J Sports Med.* 2007;35:1131-1134.