



# An Increasing Trend in the Number of Anterior Cruciate Ligament Reconstruction in Korea: A Nationwide Epidemiologic Study

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**Background:** Most epidemiologic studies of anterior cruciate ligament reconstruction (ACLR) to date have been conducted in Western populations, whereas no studies have been conducted in Asian populations. In this study, the incidence and trend of ACLR in Korea were investigated through an epidemiological big data analysis.

**Methods:** The data were collected by the Health Insurance Review and Assessment Service from 2008 to 2016 in Korea. Patient records with the coding of cruciate ligament reconstruction were allocated, and ACLR patients were further refined by medical diagnosis coding. The total number and incidence of ACLR procedures per 100,000 person-years were investigated and more detailed analysis was conducted according to sex and age. Furthermore, concomitant surgical procedures performed during ACLR were investigated.

**Results:** The total number and incidence of ACLR procedures rose from 10,248 and 21.8 to 14,500 and 29.1 between 2008 and 2016, respectively. The incidence of ACLR procedures increased by 33.5% over this 9-year period. Over this period, the total number and incidence increased from 8,543 and 36.4 to 11,534 and 46.4, respectively, in males and from 1,705 and 7.2 to 2,966 and 11.9, respectively, in females. ACLR was performed more frequently in males than in females; however, the increase rate was higher in females than males. ACLR was performed most frequently in patients in their 20s, followed by patients in their 30s, 40s, and 10s. The most frequent concomitant procedures performed during ACLR were meniscectomy (13.6% in 2008 and 9.8% in 2016) and meniscal repair (5.8% in 2008 and 8.8% in 2016).

**Conclusions:** The incidence of ACLR consistently rose between 2008 and 2016 in Korea. The current study will enhance our understanding of the epidemiology of ACLR, which is needed to devise cost-effective preventive measures.

**Keywords:** *Knee, Anterior cruciate ligament, Reconstruction, Epidemiology, Incidence*

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A better understanding of the epidemiologic patterns of anterior cruciate ligament reconstruction (ACLR) is vital in devising effective prevention and treatment strategies. A thorough epidemiological study will help not only to prevent injuries and diseases by enabling the identification of high-risk individuals based on known risk factors but also to rebuild prevention programs targeting those high-risk individuals. Analysis of National Health Insurance (NHI) data can provide optimal information on epidemiological

patterns of certain diseases.

There are a few studies that investigated epidemiologic data of ACLR in the United States and European countries.<sup>1-3)</sup> In the United States, the number of ACLR rose from 32.94 per 100,000 person-years in 1994 to 43.48 per 100,000 person-years in 2006.<sup>3)</sup> Among Scandinavian countries, between 2004 and 2007, the annual incidence of primary ACLR was 34 per 100,000 person-years in Norway, 38 per 100,000 person-years in Denmark, and 32 per 100,000 person-years in Sweden.<sup>1)</sup>

However, to our knowledge, there has been no report on the epidemiologic pattern of ACLR in the Asian population. As there are significant differences in social, cultural, and economic aspects between Asian and Western countries, epidemiologic data of Asian countries would be different from that of Western countries and highly beneficial to understand unique characteristics of ACLR epidemiology in Asian population and establish proper public health care systems in Asian countries.

The Health Insurance Review and Assessment Service (HIRA) data are health insurance claims data, which is also called NHI data, as it is generated in the process of reimbursing claims for healthcare services under the NHI system in Korea (Fig. 1). The HIRA data contains the medical billing data of the entire Korean population (97% health insurance and 3% medical care).<sup>4,5)</sup> It is mandatory to upload patient medical record to the HIRA database. This HIRA database allows a comprehensive big data analysis of ACLR in Korea.

The purposes of this study were as follows: (1) to determine the total number of cases per year and incidence per 100,000 per year between 2008 and 2016, (2) to determine the demographics of ACLR, and (3) to determine the

most frequent concomitant surgical procedures. With the increase of physical activities in both children and elderly population, the authors hypothesized that there would be an increase in the incidence of ACLR between 2008 and 2016.

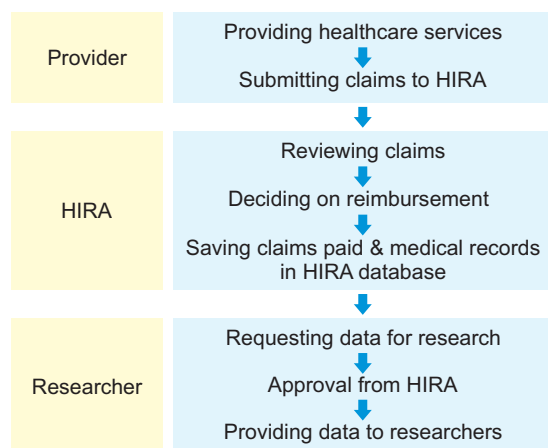
## METHODS

The study protocol was reviewed and approved by the Institutional Review Board (IRB) of our institute, and the study was conducted anonymously without prior informed consent following a waiver of consent granted by the IRB (IRB No. PAIK 2018-07-010).

The HIRA research data consists of six files: (1) the general information file, (2) the healthcare services file, including inpatient prescriptions, (3) the diagnoses file, (4) the outpatient prescriptions file, (5) the drug master file, and (6) the provider information file. The healthcare services file has specific and detailed information on healthcare services such as procedures, diagnostic tests, treatments, and inpatient prescriptions. In the diagnoses file, diagnoses are coded in compliance with Korean Standard Classification of Diseases version 7 (KCD 7), which is based on the International Classification of Diseases 10th revision.<sup>6)</sup>

The codes of cruciate ligament reconstruction (N0880 and N0881) (Table 1) were not divided into anterior and posterior cruciate ligament (PCL); thus, patients who received ACLR should be defined as patients meeting the following two criteria; (1) patients with a cruciate ligament reconstruction (N0880 or N0881) and (2) patients with a diagnosis defined by KCD 7 codes for ACL injury (S8350, S8352, M2353, M2363, M2383, or M2393) (Supplementary Table 1). The patients with an ACL repair procedure code (N0882) were excluded.

ACLR data were extracted and further analyzed as follows: (1) the total number of cases per year and incidence of ACLR per 100,000 (person-years), (2) epidemiological trend of ACLR between 2008 and 2016, (3) sex and age distribution of ACLR patients, and (4) the most



**Fig. 1.** Flowchart of data generation of the Health Insurance Review and Assessment Service (HIRA) database in Korea.

**Table 1.** Surgical Procedure Codes for Cruciate Ligament Reconstruction of the HIRA

Code	Surgical procedure
N0880	Simple cruciate ligament reconstruction
N0881	Complex cruciate ligament reconstruction*

HIRA: Health Insurance Review and Assessment Service.

\*Complex surgery includes (1) remnant preserved reconstruction, (2) reconstruction using an additional accessory portal (including anteromedial or anterolateral), (3) double-bundle reconstruction, and (4) revision reconstruction.

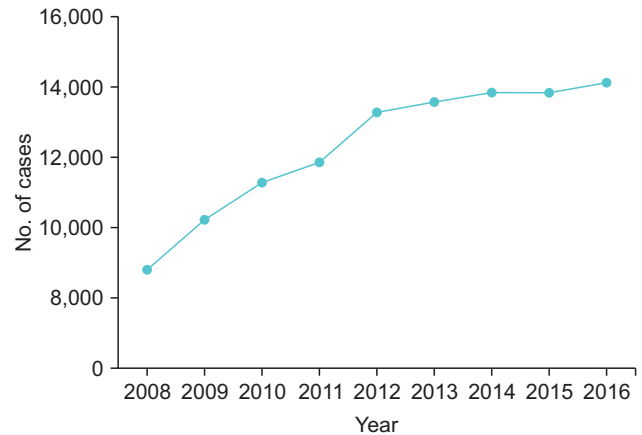
frequently performed concomitant surgical procedures at the time of ACLR and their rates during the study period (Supplementary Table 2). Incidence per 100,000 person-years was based on additional information from the survey, including basic epidemiologic data as per the Korean National Statistics.

## RESULTS

The epidemiologic data and trends of ACLR between 2008 and 2016 in Korea is shown in Table 2. The total number of ACLR procedures was 10,248 in 2008, which increased to 14,500 in 2016 (Fig. 2). The incidence per 100,000 person-years was 21.8 in 2008, which increased to 29.1 in 2016 (Fig. 3). The number and incidence of ACLR procedures increased by 41.5% and 33.5%, respectively, over this 9-year period.

Among males, the total number of cases and incidence per 100,000 person-years were 8,543 and 36.4, re-

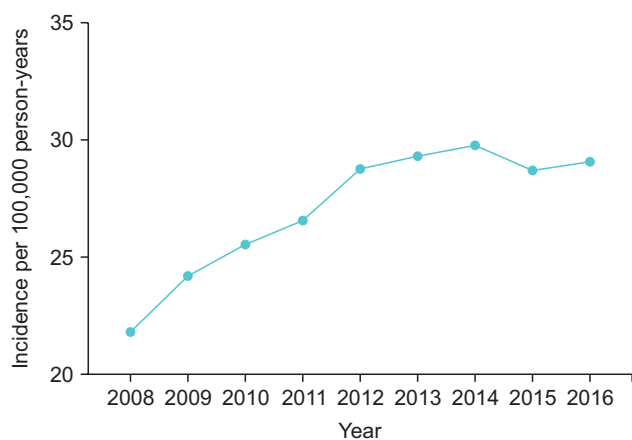
spectively, in 2008, which significantly increased to 11,534 and 46.4, respectively, in 2016 (Fig. 4 and 5). The number of ACLR procedures increased by 35.0% over this 9-year



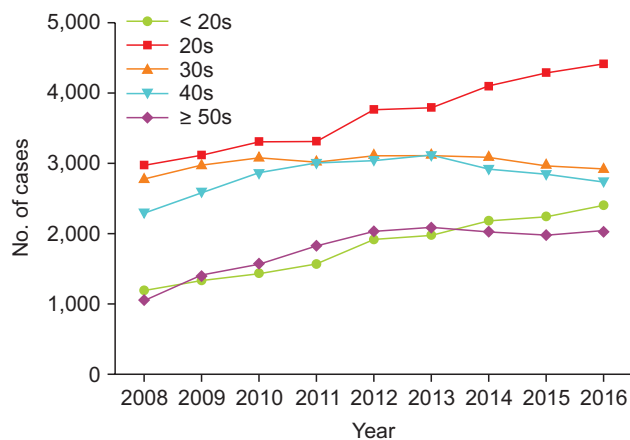
**Fig. 2.** Total number of anterior cruciate ligament reconstruction from 2008 to 2016 in Korea.

**Table 2.** Epidemiologic Data and Trends of Anterior Cruciate Ligament Reconstruction in Korean Population

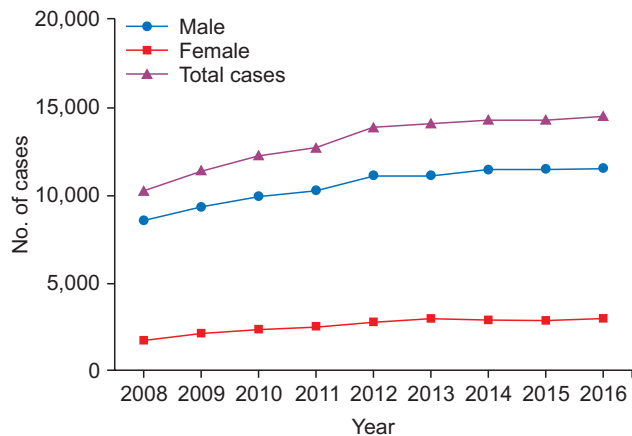
Variable	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total case	10,248	11,378	12,228	12,698	13,840	14,073	14,285	14,281	14,500
Sex									
Male	8,543	9,300	9,914	10,231	11,096	11,125	11,439	11,450	11,534
Female	1,705	2,078	2,314	2,467	2,744	2,948	2,846	2,831	2,966
Age (yr)									
< 20	1,185	1,332	1,430	1,560	1,916	1,980	2,174	2,235	2,392
20–29	2,963	3,100	3,302	3,309	3,763	3,791	4,099	4,277	4,416
30–39	2,775	2,966	3,076	3,016	3,103	3,116	3,082	2,961	2,915
40–49	2,281	2,582	2,856	2,995	3,032	3,109	2,915	2,840	2,738
≥ 50	1,044	1,398	1,564	1,818	2,026	2,077	2,015	1,968	2,039
Incidence (per 100,000 person-year)	21.8	24.2	25.5	26.5	28.8	29.3	29.8	28.7	29.1
Sex									
Male	36.4	39.6	41.6	42.9	46.5	46.7	48.0	46.1	46.4
Female	7.2	8.8	9.6	10.2	11.4	12.2	11.8	11.4	11.9
Age (yr)									
< 20	9.8	11.0	12.7	13.9	17.1	17.6	19.4	22.2	24.3
20–29	40.4	42.3	50.1	50.2	57.1	57.5	62.2	66.7	68.3
30–39	33.8	36.1	39.5	38.7	39.8	40.0	39.5	40.0	40.1
40–49	28.4	32.2	34.8	36.5	37.0	37.9	35.5	33.5	32.6
≥ 50	9.2	12.3	11.0	12.8	14.3	14.7	14.2	11.4	11.4



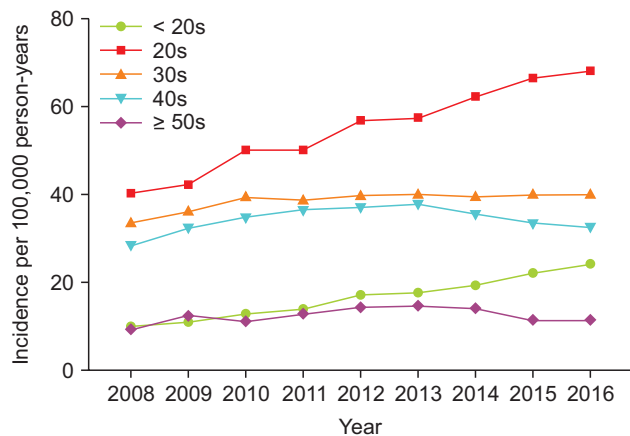
**Fig. 3.** Incidence of anterior cruciate ligament reconstruction per 100,000 person-years from 2008 to 2016 in Korea.



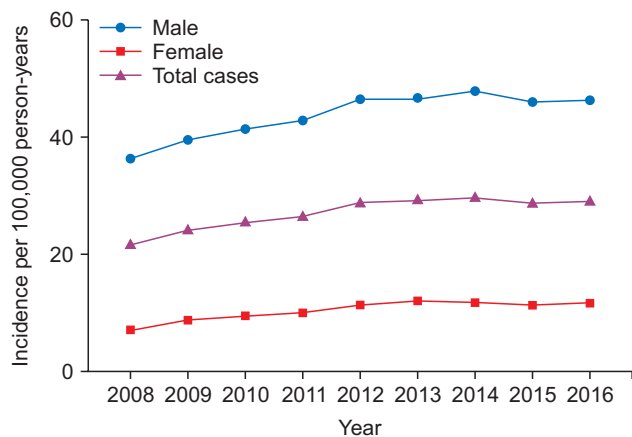
**Fig. 6.** Total number of anterior cruciate ligament reconstruction from 2008 to 2016 stratified by age in Korea.



**Fig. 4.** Total number of anterior cruciate ligament reconstruction from 2008 to 2016 stratified by sex in Korea.



**Fig. 7.** Incidence of anterior cruciate ligament reconstruction per 100,000 person-years from 2008 to 2016 stratified by age in Korea.



**Fig. 5.** Incidence of anterior cruciate ligament reconstruction per 100,000 person-years from 2008 to 2016 stratified by sex in Korea.

period in males. Among females, the total number of cases and incidence per 100,000 person-years were 1,705 and

7.2, respectively, in 2010, which increased to 2,966 and 11.9, respectively, in 2016 (Figs. 4 and 5). The number of ACLR procedures increased by 69.5% over this 9-year period in females. ACLR procedures were approximately four times more frequently performed among males than females; however, the increase rate was higher in females than males.

In terms of age distribution, the total number of cases and incidence per 100,000 person-years increased from 1,185 and 9.8, respectively, in 2008 to 2,392 and 24.3, respectively, in 2016 in patients less than 20-year-old; from 2,963 and 40.4, respectively, in 2008 to 4,416 and 68.3, respectively, in 2016 in patients in their 20s; from 2,775 and 33.8, respectively, in 2008 to 2,915 and 40.1, respectively, in 2016 in patients in their 30s; from 2,281 and 28.4, respectively, in 2008 to 2,738 and 32.6, respectively, in 2016 in patients in their 40s; and from 1,044 and 9.2, respectively, in 2008 to 2,039 and 11.4, respectively, in 2016 in patients

over 50-year-old (Figs. 6 and 7). The peak of the total number of cases and incidence was observed in patients in their 20s. The following is the order of age groups according to the total number of cases and incidence of ACLR in each group: 20s, 30s, 40s, and 10s.

The most frequent concomitant procedure was meniscectomy, which was performed in 1,397 patients (13.6%) in 2008 and 1,419 patients (9.8%) in 2016, followed by meniscus repair, which was performed in 594 (5.8%) patients in 2008 and 1280 (8.8%) patients in 2016 (Table 3).

## DISCUSSION

The main purposes of this study were to investigate the overall incidence of ACLR and the recent epidemiological trend of ACLR in Korea. The important findings of this study included the following: (1) the total number of cases and incidence per 100,000 persons of ACLR procedures were 10,248 and 21.8, respectively, in 2008, which significantly increased to 14,500 and 29.1, respectively, in 2016. The number of ACLR procedures increased by 41.5% over this 9-year period; (2) ACLR was performed more frequently in males than in females; however, the increase rate was higher in females than males; (3) ACLR was performed most frequently in patients in their 20s, followed by patients in their 30s, 40s, and 10s; (4) the most frequent concomitant procedure performed during ACLR was meniscectomy; however, the rate of meniscectomy decreased and the rate of meniscus repair increased during the follow-up period. The results of this study are consistent with the initial hypothesis that there would be an increase in the incidence of ACLR between 2008 and 2016, reflecting increased physical activities in children and the older population in recent years.

In Korea, there is a legal obligation to include patient medical records in the HIRA database. Hence, claim codes for surgical procedures in Korea are prospectively recorded in the HIRA data. The authors obtained and

analyzed data associated with the claim codes for cruciate ligament reconstruction from this nationwide database. Furthermore, the number of ACLR procedures was standardized as incidence per 100,000 person-years to compare with those of other countries. This study on the Korean population is the first epidemiologic report of ACLR in Asian populations based on a nationwide database.

Compared to our study, a few countries have used different methodologies to collect national-level databases and to investigate the overall effect of ACL injury and its consequences after reconstruction. In the United States, Mall et al.<sup>3)</sup> reported the incidence of ACLR using the National Hospital Discharge Survey and the National Survey of Ambulatory Surgery, which are the most relevant nationwide databases in determining epidemiologic figures of a certain disease. According to the report, the number of ACLR rose from 32.94 per 100,000 person-years in 1994 to 43.48 per 100,000 person-years in 2006. Granan et al.<sup>1)</sup> also reported the outcomes of ACLR from 2004 to 2007 in Scandinavian countries, which are using the same registries, including the main function, similarities, and preliminary baseline results. The annual incidence of primary ACLR was 34 per 100,000 person-years in Norway, 38 per 100,000 person-years in Denmark, and 32 per 100,000 person-years in Sweden. The present study found an incidence of 29.1 per 100,000 person-years in 2016; thus, the incidence in Korea was lower than that of the United States and Scandinavian countries. Basically, higher engagement in physical and sports activities will lead to a higher chance of ACL injury.<sup>7)</sup> It can be presumed that the number of people engaging in high-level athletics is higher in Western countries than in Korea.

With respect to sex differences, the total number of cases and incidence per 100,000 person-years in males were 11,534 and 46.4, respectively, in 2016. In females, the total number of cases and incidence per 100,000 person-years were 2,966 and 11.9, respectively, in 2016. ACLR procedures were approximately four times more frequently performed among males than females. It can be presumed

**Table 3.** Concomitant Surgical Procedures during Anterior Cruciate Ligament Reconstruction

Surgical procedure	2008	2009	2010	2011	2012	2013	2014	2015	2016
Meniscectomy	1,397 (13.6)	1,608 (14.1)	1,630 (13.3)	1,691 (13.3)	1,687 (12.2)	1,806 (12.8)	1,657 (11.6)	1,521 (10.7)	1,419 (9.8)
Meniscus repair	594 (5.8)	694 (6.1)	774 (6.3)	896 (7.1)	997 (7.2)	1,128 (8.0)	1,143 (8.0)	1,073 (7.5)	1,280 (8.8)
Cartilage repair	142 (1.4)	207 (1.8)	176 (1.4)	186 (1.5)	258 (1.9)	175 (1.2)	142 (1.0)	147 (1.0)	113 (0.8)
Meniscus transplantation	10 (0.1)	0	0	0	19 (1.9)	13 (0.1)	13 (0.1)	10 (0.1)	12 (0.1)

Values are presented as number (%).

that males are more likely to engage in high-level athletics or high-risk activities than females. However, the increase rate was higher in females (69.5%) than males (35.0%) over this 9-year period. The number of female patients who underwent ACLR has steadily risen since 2008 from 1,705 to 2,966, corresponding to a rate of 7.2 to 11.9 per 100,000 person-years. It means that female individuals engaged in sports activities had increased in Korea during this period. In the United States, female patients accounted for 32% of the ACLR performed in 1994 and 42% of those performed in 2006, with a near doubling of ACLR incidence from 10.36 to 18.06 per 100,000 person-years during the same period.<sup>8)</sup> The present study demonstrated a relatively lower incidence of ACLR in females in Korea compared to that in the United States although the rate of ACLR steadily increased in Korea. Since Title IX of the Education Amendments ACT of 1972 stating “No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance,” female high school participation in sports had reached nearly 3 million by 2006, which is more than 1,000% increase.<sup>9)</sup> On the other hand, in Korea, the interest and participation in sports and other physical activities among females had been lower than those in Western countries. However, women’s engagement in sports in Korea has recently increased, and this increase may explain the recent increase of ACLR among Korean women.<sup>10-13)</sup>

The age group with the highest prevalence of ACLR in Korea in 2016 was those in their 20s (68.3 per 100,000 person-years), followed by 30s, 40s, and 10s. On the contrary, the age group with the highest prevalence in the United States was those younger than 20 years; the prevalence in this group increased from 12.22 per 100,000 person-years in 1994 to 17.97 per 100,000 person-years in 2006.<sup>3)</sup> The potential cause of this difference is the differences in academic and educational environment. Students in the United States are encouraged to participate in sports activities during classes and after-school sports activities, and their engagement in those activities during high school is considered as an important attribute in the college admission process.<sup>11)</sup> However, sports activity in middle and high school in Korea has dropped dramatically as scores in physical education are not considered as an important attribute in the notoriously competitive college admission process.<sup>12)</sup> Koreans engage in sports and other physical activities most in their 20s and 30s. This difference in age groups with a high level of physical activities between the Korean and Western populations would explain the dif-

ferences in the age distribution of patients with ACLR in Korea.

Injuries of the ACL are frequently accompanied by concomitant injuries, the most common being meniscus, cartilage, and other ligament injuries. The current study found that the most frequent concomitant procedure was meniscectomy with 1,397 (13.6%) in 2008 and 1,419 (9.8%) in 2016, followed by meniscus repair, which increased in frequency from 594 (5.8%) in 2008 to 1,280 (8.8%) in 2016. In particular, the rate of concomitant meniscus repair procedures rose by 51.7%, whereas the rate of concomitant meniscectomy decreased 27.9% over this 9-year period. This reflects that surgeons in Korea increasingly prefer repair procedures to simple resections. In the United States, the most and second frequent concomitant surgeries were arthroscopic excisions of joint structures and excisions of the meniscus.<sup>3,14,15)</sup>

The importance of our study lies in the fact that this is the first study investigating the nationwide trends of ACLR based on a national database in Asian countries, which have different social and cultural backgrounds and health care systems compared to Western countries. This national database is one of the most accurate national databases in the world as it covers the entire Korean population, including all ACLR records, and is managed by the Korean government.

The present study is clinically relevant as a higher rate of engagement in physical and sports activities will lead to a higher chance of ACL injury in population, and it can be presumed that there will be an increasing trend of the number of ACLR procedures in the future. It will contribute to understanding the epidemiology of ACLR in Korea and will aid in the development of national health-care policies and cost-effective preventive programs with regard to demographics including sex and age.

However, several limitations exist in the current study. First, HIRA data was collected for administrative purposes, not for research; therefore, many important data attributes related to this ACL investigation (such as ACL vs PCL, limb laterality, and revision) were not available. However, this issue was not only found in HIRA data, but also in other claims databases. Second, the ACLR cases in our analysis did not include occupational injury cases; however, the total number of occupational injury cases is much smaller than that recorded in the HIRA database. Third, both primary and revision reconstruction cases were included in our analysis as these two were recorded under the same claim code in the HIRA database.

In conclusion, the incidence of ACLR procedures increased by 33.5% from 2008 to 2016 in Korea. ACLR is

performed approximately four times more frequently in men than women. The incidence of ACLR was highest in the age group 20s and second highest in the age group 30s. The current study will enhance our understanding of the epidemiology of ACLR, which is needed to devise cost-effective preventive measures.

### CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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### SUPPLEMENTARY MATERIAL

Supplementary material is available in the electronic version of this paper at the CiOS website, [www.ecios.org](http://www.ecios.org).

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