

# Female gender and time from injury to surgery as risk factors for decreased knee functions in ACL injury survivors

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## ABSTRACT

**Background:** Anterior cruciate ligament (ACL) injuries are serious orthopedic conditions that require long-term recovery and significant costs. This study aimed to assess the risk of decreased knee function among ACL injury survivors in the Indonesian ACL community.

**Methods:** This study used a prospective observational cohort design with a population of all members of the Indonesian ACL community who experienced ACL injury. The primary outcome of this study was a decrease in knee function was measured using the Lysholm knee score. We calculated univariate and multivariate analyses using logistic regression for each variable.

**Results:** The results showed that female gender and time from injury to surgery were significant factors that influenced poor knee function after ACL reconstruction. Women had a significantly higher risk (odd ratio (OR) = 15.28; adjusted OR (AOR) = 23.47;  $p$ -value < 0.010). In addition, the time between injury and surgery significantly affected postoperative knee function (AOR = 1.05;  $p$ -value = 0.049). Other factors such as age and body mass index did not show significant associations in either univariate or multivariate analyses.

**Conclusion:** This study confirmed that female gender and time from injury to surgery were important factors influencing poor knee function after ACL reconstruction. Timely intervention and focused rehabilitation programs are key steps to improve patient functional outcomes.

**Keywords:** Anterior cruciate ligament reconstruction, concomitant injuries, female gender, knee function, Lysholm knee score, time from injury to surgery.

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## INTRODUCTION

The anterior cruciate ligament (ACL) is one of the key cruciate ligaments in the knee, measuring approximately 32 mm in length and about 7 mm in diameter.<sup>1,2</sup> It plays a critical role in stabilizing the knee joint by preventing excessive forward movement and rotation.<sup>2,3</sup> ACL injuries are considered significant orthopedic conditions, often involving prolonged recovery periods and substantial costs. Each year in the United States, over 200,000 cases of anterior and posterior cruciate ligament injuries are reported, with nearly 150,000 requiring reconstructive surgery.<sup>4,5</sup> The cost of ACL reconstruction (ACLR) is estimated at around Rp. 70,000,000, with additional rehabilitation expenses typically involving at least three sessions per week for six

months amounting to approximately Rp. 15,000,000.<sup>6,7,8</sup> However, it is important to note that neither surgery nor rehabilitation completely eliminates the risk of reinjury.

The incidence of ACL tears is higher in women under the age of 21, but the incidence of injury in men is greater in those over the age of 21.<sup>9</sup> ACL injuries can occur only in the ACL or occur with other injuries, such as the medial collateral ligament, medial and lateral meniscus, lateral collateral ligament, and posterior cruciate ligament (PCL). However, PCL injuries rarely occur only in the PCL, usually together with other structures such as the ACL, medial collateral ligament, medial and lateral meniscus, and lateral collateral ligament.<sup>10</sup> Injuries occur more in men than in women.<sup>10</sup>

Two-thirds of ACL injuries occur

during non-contact situations, such as when an athlete is cutting, pivoting, accelerating, decelerating, or landing from a jump.<sup>11</sup> Non-contact refers to the absence of direct contact to the torn ACL in the knee or leg. Participation in sports like soccer, basketball, futsal, and rugby after surgery can increase the risk of re-injury if not accompanied by proper rehabilitation.

Decreased neuromuscular function in the knee is said to increase the risk of cruciate ligament injury. This condition is associated with decreased knee stabilization during sports activities.<sup>12</sup> Additionally, variations in neuromuscular training such as the inclusion of muscle-strengthening exercises can also reduce the risk of cruciate ligament injury during sports. Quadriceps muscle strength is very useful for increasing knee stability when

jumping by increasing knee flexion during landing.<sup>13</sup>

Recurrent injury after ACL surgery is associated with decreased function of the lower limbs, such as the knee, and the occurrence of early degeneration of knee tissue that results in inflammation of the knee joint (osteoarthritis). Damage to the cruciate ligament causes excessive translational movement of the tibia forward, backward, or rotation against the femur bone which damages tissues such as the meniscus and cartilage in the knee joint.<sup>14</sup> The risk of recurrent injury to the cruciate ligament after surgery is also common, especially in patients who return to sports activities and do not have good lower leg muscle function.<sup>15</sup>

Patients who experience recurrent injuries and have decreased lower limb function are generally associated with repeated ACL surgery. This study aimed to determine the risk of ACL injury conditions on decreased knee function in the Indonesian ACL community. Research in this area would be useful for designing rehabilitation programs to prevent recurrent injuries, improve physical health conditions, and prevent recurrent surgery.

## METHODS

This study used a prospective observational cohort design. It was a long-term investigation that followed the course of a disease. Its purpose was to determine the incidence of a particular condition in groups either exposed or not exposed to certain risk factors. The population for this study included all members of the Indonesian ACL community who had experienced ACL injuries.

This study was conducted within the ACL Indonesia Community, an online social media group headquartered in Jakarta. Data were collected from January 2019 to August 2024. The research sample comprised ACL Indonesia community members who had ACL injuries and met the inclusion and exclusion criteria. Inclusion criteria meant participants had to be willing to be research subjects from start to finish, had experienced (survived) ACL injuries, and had provided informed consent. Exclusion criteria involved not providing either magnetic resonance imaging (MRI) results or questionnaires,

or submitting questionnaires after the specified timeframe. The study protocol was approved by the Ethics Committee of the Institutional Review Board, Faculty of Medicine, Universitas Udayana, Denpasar, Bali, Indonesia, under permission number 1087/UN14.2.2.VII.14/LT/2022. All participants have given informed consent before included in this study.

Data on outcomes and risk factors were collected through X-ray and MRI results, questionnaires, and telephone interviews. The primary outcome of this study was a decrease in knee function. Knee function was measured using the Lysholm Knee Score, which ranges from 0 to 100. Higher scores show better function. This score looks at eight things weakness, support, pain, swelling, instability, locking, stair climbing, and squatting.

In this study, data analysis was conducted using descriptive methods. Continuous variables were summarized using means and standard deviations, while categorical variables were described using proportions. Furthermore, both univariate and multivariate analyses were carried out using SPSS version 26. Logistic regression was employed for each variable in both univariate and multivariate models. P-value of less than 0.05 was considered indicative of statistical significance.

## RESULTS

As presented in Table 1, the analysis of 55 patients who underwent ACLR revealed an average age of  $28.0 \pm 8.4$  years. The majority of these patients were male (43 patients, 78.2%). The mean body mass index (BMI) was  $24.1 \pm 3.0$  kg/m<sup>2</sup>, with an average height of  $168.3 \pm 7.6$  cm and an average weight of  $68.3 \pm 9.9$  kg. Regarding educational background, most patients had attained a college-level education or higher (29 patients, 52.7%). The average time from injury to surgery was  $18.3 \pm 27.6$  months, and the time from surgery to baseline measurement was  $17.5 \pm 19.4$  months. In terms of graft type, hamstring tendon grafts were the most frequently used (42 patients, 76.4%). The mean Lysholm knee score was  $2.3 \pm 11.5$ . Of these patients, 29 (52.7%) recorded a score below 80, indicating poor knee function, while 26 patients (47.3%) scored above 80. These findings provide a comprehensive demographic and clinical profile of the patients included in this study.

The findings from the univariate and multivariate logistic regression analyses summarized in Table 2, showed that female gender and time from injury to surgery were significant factors affecting poor knee function after ACLR. Women had a significantly higher risk (odds ratio (OR) = 15.28; adjusted OR (AOR) = 23.47;

**Table 1. Characteristics of patients after anterior cruciate ligament reconstruction (n=55)**

Characteristics	Mean±SD or N (%)
Age, years	28.0±8.4
Gender, female	43 (78.2)
Body mass index, kg/m <sup>2</sup>	24.1±3.0
Height, cm	168±37.6
Weight, kg	68±39.9
Level of education	
College or higher	29(52.7)
Senior High School	26(47.3)
Time from injury to surgery, months	18.3±27.6
Time from surgery to initial evaluation	17.5±19.4
Graft type	45,6±63.6
Hamstring Tendon	42 (76.4)
Peroneal tendon	11 (20.0)
Patellar tendon	2 (3.6)
Lysholm knee score, 0-100	2.3±11.5
Score <80	29 (52.7)
Score >80	26 (47.3)

Cm, centimeter; kg, kilograms; kg/m<sup>2</sup>, kilograms per meter squared; n, number of participants; SD, standard deviation.

**Table 2. Univariate and multivariate logistic regression analysis to predict poor knee function after ACL reconstruction (n=55)**

Characteristics	OR (CI 95%), p-value	AOR (CI 95%), p-value
Age, years	1.00 (0.94-1.06), 0.924	0.96 (0.88-1.06), 0.436
Gender, female	15.28 (1.81-129.19), 0.012	23.47 (2.23-247.52), 0.009
Body mass index, kg/m <sup>2</sup>	0.90 (0.75-1.09), 0.276	0.86 (0.69-1.08), 0.202
Time from injury to surgery, months	1.03 (0.99-1.06), 0.130	1.05 (1.00-1.10), 0.049

AOR, adjusted odds ratio; kg/m<sup>2</sup>, kilograms per meter squared; OR, odds ratio.

$p < 0.01$ ). In addition, the time between injury and surgery significantly affected postoperative knee function (AOR = 1.05;  $p = 0.049$ ). Other factors such as age and body mass index did not show significant associations in either univariate or multivariate analysis.

## DISCUSSION

Gender differences have been identified as significant factors influencing outcomes following ACLR. Anatomical and biomechanical disparities between men and women contribute to the varying risk of ACL injuries.<sup>16</sup> Studies have shown that women generally have 30% smaller knee flexor muscle size and 25% smaller knee extensor muscle size compared to men. However, the vastus lateralis and biceps femoris muscles are relatively larger in women.<sup>17</sup> These differences, along with lower hamstring muscle strength, result in reduced knee joint stability and an increased susceptibility to ACL injuries. Furthermore, women exhibit a lower knee flexor to knee extensor strength ratio (50% in women versus 56% in men) and smaller sartorius and gracilis muscles (44% and 42%, respectively). Since the sartorius and gracilis muscles play a crucial role in resisting valgus forces on the knee, their reduced size and strength may further elevate the risk of ACL rupture in women.<sup>17,18</sup>

Beyond morphological differences, hormonal variations, neuromuscular control, and psychological responses such as anxiety and emotional stress also influence post-injury and post-operative outcomes. Previous research has indicated that women tend to experience poorer knee function compared to men after undergoing ACLR.<sup>20</sup> Distinct anatomical characteristics in women such as variations in muscle belly length ratios, quadriceps angle, and smaller bone dimensions may

also contribute to a heightened risk of ACL injury.<sup>21</sup> Although certain muscles like the vastus lateralis and biceps femoris may be relatively larger in women, they are often insufficient to compensate for the overall smaller size of the knee flexor and extensor muscles, thereby compromising joint stability and increasing the likelihood of injury.<sup>22</sup>

Apart from that, hormonal factors can also influence it. Some studies suggest that hormonal changes, such as those associated with the menstrual cycle, can affect joint stability and ligament strength, possibly affecting post ACLR recovery.<sup>23</sup> Women may have lower risk perception or less awareness of injury risk, which may influence behavioral decisions when exercising.<sup>24</sup> Anxiety and psychological stress have been observed in women following injuries, leading to the emergence of mental conflict. Additionally, emotional stress plays a significant role in shaping their coping mechanisms.

The interval between injury and surgery has also emerged as a critical factor in determining functional knee outcomes. Both theoretical and empirical evidence suggest that the longer the delay between the occurrence of an ACL injury and its surgical reconstruction, the greater the likelihood of secondary damage to other intra-articular structures, such as the meniscus and articular cartilage.<sup>25</sup> Prolonged joint instability resulting from an untreated ACL injury may lead to repetitive microscopic trauma, causing progressive degeneration. Although this degeneration may not be clinically apparent in the early stages, it can significantly compromise the potential for optimal functional recovery following surgery. Furthermore, delays can worsen overall knee condition, with increased risk of muscle atrophy, chronic swelling, and further damage to internal knee structures.<sup>19</sup> The longer the delay, the

greater the likelihood of reduced knee function after surgery.

Moreover, an extended preoperative period can adversely affect the patient's neuromuscular condition, including quadriceps muscle atrophy and altered proprioception. Severe preoperative muscle atrophy contributes to postoperative weakness, thereby prolonging the rehabilitation phase and increasing the risk of long-term dysfunction. Consequently, the timing of surgical intervention after injury is crucial. Several clinical guidelines recommend performing ACLR within 3 to 6 months post-injury to minimize secondary complications. However, emerging evidence suggests that even slight delays in surgical timing can have a significant clinical impact. These insights highlight the importance of early surgical management to minimize complications and support faster recovery.<sup>26,27</sup>

Overall, the association between female sex and delayed surgery with poor functional outcomes following ACLR is multifactorial and complex. A combination of biological, biomechanical, and behavioral factors must be considered when developing individualized treatment approaches. These findings underscore the importance of personalized planning in both surgical decision-making and postoperative rehabilitation, particularly for women and those experiencing delayed access to surgical care.

This study had several limitations that warrant consideration. Firstly, the sample was limited to members of the Indonesian ACL community, which may have introduced selection bias and constrained the generalizability of the results to wider populations. Second, the use of self-reported questionnaires and retrospective data, such as MRI reports, may be prone to recall bias and inaccuracies. Third, although the study investigated key variables such as gender and the time

interval between injury and surgery, other potentially influential factors such as psychological readiness were not evaluated. Future research should aim to include a more diverse and representative population and consider longitudinal study designs to monitor knee function over extended periods.

## CONCLUSION

This study confirmed that female gender and time from injury to surgery were important factors influencing poor knee function after ACLR. Timely intervention and focused rehabilitation programs are key steps to improve patient functional outcomes. For further study, we suggest integrating objective clinical assessments and exploring psychological and social determinants may offer a more comprehensive understanding of the factors influencing postoperative knee function following ACL injury.

## ETHICAL CONSIDERATION

The study protocol was approved by the Ethics Committee of the Institutional Review Board, Faculty of Medicine, Universitas Udayana, Denpasar, Bali, Indonesia, under permission number 1087/UN14.2.2.VII.14/LT/2022.

## CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this study.

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## AUTHOR CONTRIBUTIONS

IK designed the study, collected data, processed it, and wrote the manuscript. NPDW, AAAAPD, FFAK, KTS, DAAASA, and LGE collected data and revised the manuscript.

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