

# Sex differences in knee strength deficit 1 year after anterior cruciate ligament reconstruction

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**Abstract.** [Purpose] Little is known about the outcome differences between men and women after anterior cruciate ligament (ACL) reconstruction. Therefore, the present study aimed to compare knee muscle strength between men and women 1 year after ACL reconstruction. [Subjects and Methods] Retrospective and outcome study. Between 2012 and 2015, 35 males (mean age, 29.7 ± 010.7 years) and 35 females (mean age, 28.2 ± 11.3 years) who had undergone primary ACL reconstruction were recruited from Samsung medical centers. We assessed the strength deficit in the quadriceps (extensor) and hamstrings (flexor) at 60°/sec and 180°/sec with isokinetic testing equipment. Statistical analysis was conducted with a t-test to determine if sex differences existed in knee strength deficit. [Results] Significant differences were noted between men and women with respect to extensor muscle strength deficit. Women reported less extensor muscle strength than men did, at the angular velocities 60°/sec and 180°/sec. However, no significant sex differences were found at either velocity with respect to the strength deficit of the knee flexor muscles. [Conclusion] Compared to male patients, female patients reported significantly less extensor muscle strength and less improvement 1 year after reconstruction.

**Key words:** Anterior cruciate ligament, Sex, Female

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## INTRODUCTION

Injuries to the anterior cruciate ligament (ACL) can result in defective joint stability, functional limitations, and a decline in the quality of life. The overall aim of ACL reconstruction is to restore normal knee biomechanics and stability, return the patient to pre-injury activity levels, and to optimize the health-related quality of life. However, many factors, such as the fear of re-injury, persistent pain, instability, and weakness may be interrelated and could affect the patient's condition after ACL reconstruction<sup>1)</sup>. Many patients experience some degree of muscle weakness after ACL reconstruction, especially in the muscles that cross the knee. This can have a significant negative effect on their functional ability<sup>2)</sup>. Palmieri-Smith et al.<sup>3)</sup> reported deficits in isokinetic extensor strength ranging between 24% and 40.5%, 6 months after ACL reconstruction. As muscle strength deficits have been associated with the potential risk of future knee injury, increasing the muscle strength of the quadriceps and hamstrings is a key factor for successful return to sports after ACL reconstruction<sup>3,4)</sup>. For this reason, knee muscle strength has been shown to be correlated with good outcomes after ACL reconstruction<sup>5)</sup>.

The number of ACL injuries is greater in men; however, when comparing the rate of injury in the same sport, the risk for ACL injury in women is 2 to 8 times greater than that in men<sup>6)</sup>. Although women who sustain an ACL injury are more likely to report knee instability and significant functional disability<sup>7)</sup>, little is known about outcome differences between male and female patients after ACL reconstruction. For example, only a few studies have critically analyzed sex differences in clinical outcomes after ACL reconstruction. The majority of these studies are related to quality of life determined with self-reported functional scores or the effect of training programs aimed at preventing knee injuries in female athletes<sup>8,9)</sup>.

While these subjective indicators are important, there are few studies comparing knee muscle strength by using objective indicators such as isokinetic equipment. Therefore, the present study aimed to compare knee muscle strength between men and women 1 year after ACL reconstruction.

## SUBJECTS AND METHODS

Patients with acute rupture of the ACL were recruited from Samsung medical orthopedics centers between April 2012 and May 2015. Thirty-five males (mean age, 29.7 ± 10.7 years) and 35 females (mean age, 28.2 ± 11.3 years) were included. All patients underwent arthroscopically assisted ACL reconstruction using hamstring-tendon autograft. There were no significant differences between men and women with respect to age (Table 1). Exclusion criteria were previous ACL reconstruction, other ligament injuries, or any associated fractures in the same knee.

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**Table 1.** Subject characteristics

Group	Age (years)	Height (cm)	Weight (kg)	% fat
Female (n=35)	28.2 ± 11.3	163.2± 4.9	60.6±8.3	29.1±5.1
Male (n=35)	29.7 ± 10.7	174.5± 5.6	75.3±10.3	26.4±6.3

All patients underwent a knee strength test 1 year after ACL reconstruction. Prior to the knee strength examination, the patients warmed up on a cycle ergometer at 35 W for 10 min. Knee strength was assessed by using isokinetic parameters at angular velocities of 60°/sec (4 repetitions) and 180°/sec (20 repetitions), which were measured with a CSMI isokinetic dynamometer (CSMI Medical solution, Stoughton, Mass). Subjects were placed in the upright position with the hip flexed at 90°. To determine the height of the chair, the lateral femoral condyle was aligned with the rotational axis of the dynamometer. Before each test, the patient was instructed to perform 3 practice repetitions. The highest peak torque value for each velocity was determined, compared to the uninjured side, and described as percent of knee extensor and flexor muscles strength deficits.

Both groups went through the same rehabilitation program. Weight bearing was permitted as tolerated from day 1 postoperatively. After 2–4 weeks, closed kinetic chain exercises and stationary cycling were started. After 8 weeks, agility training and light jogging were permitted. After 10 weeks, increased agility workouts, maximum strength training, and sport-specific activities were allowed. After 6 months, return to full sports activities was allowed if the criteria of full range of motion, no effusion, normal muscle strength, and knee stability were fulfilled. However, the rehabilitation program was performed once for patients visiting at 3, 6, and 9 months, during which they learned how to perform the exercises at home.

All subjects provided written informed consent prior to their participation in accordance with the ethical standards of the Declaration of Helsinki. All data obtained in this study were analyzed with SAS statistical software, and a t-test was used to determine the effect of sex on knee strength deficit. Significance was evaluated at p-values less than or equal to 0.05.

## RESULTS

The side-to-side knee muscle strength deficits are presented in Table 2. No significant difference was found between men and women considering the side-to-side strength deficit of knee flexor muscle at either angular velocity. However, significant differences were noted between men and women with respect to extensor muscle strength deficits at 60°/sec ( $p = 0.019$ ) and 180°/sec ( $p = 0.007$ ). Furthermore, women showed slightly less strength deficits with respect to knee extensor strength.

## DISCUSSION

This study was performed to compare knee muscle strength between men and women 1 year after ACL recon-

**Table 2.** Isokinetic extensor and flexor muscles deficits

Speed movement, deg/sec	Male	Female
Extensor muscle deficits (%)		
60 deg/sec	15.8±9.4	22.9±14.8*
180 deg/sec	13.5±7.6	19.7±13.2*
Flexor muscle deficits (%)		
60 deg/sec	10.9±6.2	13.6±9.4
180 deg/sec	10.6±6.4	11.5±9.2

\* $p < 0.05$

struction. Women reported significantly greater knee extensor strength deficits than men. When analyzing previous studies, it appears that the incidence of ACL injury is higher in women, and some studies have suggested that women do not recover as well as men do after ACL reconstruction. Noojin et al.<sup>10</sup> reported increased pain and loss of extension in women compared to men. In addition, more men returned to their pre-injury activity levels than did women. Aglietti et al.<sup>11</sup> reported that patellofemoral problems are a frequent complication after patellar tendon ACL reconstruction and tend to occur more frequently in women than in men.

Recently, a systematic review demonstrated that the outcomes of ACL reconstruction were similar in male and female patients<sup>12</sup>) with no difference in knee laxity, graft failure risk, or patient-reported outcomes. In addition, Barber-Westin et al.<sup>13</sup>) found no differences between men and women with respect to scores from the ACL quality of life scale. This suggests that men and women showed similar functional outcomes with respect to physical and mental ACL insufficiency. As such, it appears that the results are not consistent between men and women after ACL reconstruction. Differences between our study and other studies may help to explain the varying results. There is no difference between studies that have compared sexes by using subjective factors such as self-reported scores and quality of life scales. ACL reconstruction has shown good results with regard to knee stability and subjective assessment scores; however, patients still have knee muscle weakness and functional deficits after ACL reconstruction. For this reason, subjective factors are difficult to accurately assess knee function, and recently, instrumented laxity and the Lachman score were shown to be poor predictors of subjective and functional outcome after ACL reconstruction<sup>14</sup>).

The current study used objective measurements (i.e., isokinetic testing) of knee muscle strength. Isokinetic testing provides an objective measure of knee extensor and flexor muscle strength, and it is extensively used in clinical settings. In this study, all the data suggested that quadriceps strength recovery occurs later in women than in men. We

found that women reported significantly greater deficits in knee extensor strength when compared to men (approximately 20%). Therefore, women should focus their effort on improving extensor muscle strength and should be careful to avoid re-injury.

This study had limitations in that the number of subjects is relatively small, and exercise may influence muscle strength evaluation. However, our study was not completely controlled due to the exercise and physical activity of the individual participants.

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