

# Early Outcomes of Trans-portal Anatomical Single Bundle ACL Reconstruction Using Autogenous Hamstring Graft: A Single Center Study

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Trans-portal anatomical single bundle ACL reconstruction using autogenous hamstring graft for ACL tear is a widely practiced standard procedure. From September 2015 to March 2016, 43 patients were treated for ACL tear using this technique at B&B Hospital. An analytical study of the early outcome (Post op 3 months) of the procedure is reported using Lysholm score. Different factors associated with the condition i.e. age, sex, height/weight of pt., side of the injury, BMI, mode of injury, duration of injury is analyzed.

Results were Mean Lysholm score 78.05 (13.35) with minimum of 37 and maximum of 100 at an average of three months. Age, gender, BMI and time of injury preceding surgery had no effect in the outcome after ACL reconstruction up to three months after surgery.

**Keywords:** acl tear, early outcomes, trans-portal anatomic acl reconstruction.

**A**nterior Cruciate Ligament (ACL) is the most commonly injured ligament of the Knee, and ACL tears represent more than 50% of all knee injuries.<sup>1</sup> This injury affects more than 200,000 people in the United States each year, with direct and indirect costs greater than \$7 billion annually.<sup>1</sup> Data regarding incidence and prevalence of ACL injury in Nepal is not available.

Surgical reconstruction of the torn ACL ligament is the standard treatment worldwide and has the highest success rate.<sup>2</sup> Arthroscopic trans-tibial ACL reconstruction was being done at B&B Hospital since 2001. With better understanding of anatomy and biomechanics of the Cruciate ligament, techniques of surgical reconstruction have improved. Cadaveric studies have shown that Anteromedial trans

portal drilling of the femoral socket allow better restoration of anatomy of ACL compared to conventional trans tibial drilling techniques.<sup>3</sup> Since 2015 in B&B hospital, ACL reconstruction has been carried by the anatomic transportal technique using single bundle autogenous hamstring graft.

Majority of arthroscopic surgeons worldwide prefer Hamstring as primary graft for ACL reconstruction mainly because of its ease of harvest, minimal morbidity at donor site and ease of fixation.<sup>4</sup> We also use Autogenous Hamstring graft for our primary ACL reconstruction except for some elite athlete where we prefer to use BPTB autograft for earlier incorporation of the graft and return to play.

A prospective observational study to evaluate the early outcomes of arthroscopic transportal anatomical single bundle ACL reconstruction using autogenous hamstring graft was conducted at the B&B hospital from September 2015 to March 2016.

**Materials and Methodology**

From September 2015 to March 2016, 43 patients were enrolled in the study after approval from the Institutional Review Committee (IRC) of the B&B hospital. All patients who met the inclusion criteria and Exclusion criteria were included (**Table 1**).

Data was collected preoperatively filling up a proforma and Lysholm knee scoring system at 3 months after surgery.

**Treatment Protocol**

All the patients underwent routine preoperative imaging, including plain radiographs anteroposterior (AP) and lateral view and MRI, of the knee.

Prophylactic antibiotic intravenously (cefazolin injection 1g 30-60 minutes before surgery) was administered. Surgery was performed under either Spinal anesthesia or General anesthesia under a tourniquet control. Patient was operated in Supine position using a standard anterolateral, anteromedial and far accessory anteromedial portal. Semitendinosus (ST) and Gracilis (GT), were used to make a quadrupled graft to make the graft diameter size of 8 mm or more and at least a length size of 8 to 9cm. The graft was fixed with an endobutton on the femoral side, and a bio absorbable interference screw on the tibial side. Torn meniscus was repaired using the outside-in technique with the suture-shuttle technique using orthocord (braided metal) sutures. Partial meniscectomy was performed for irreparable menisci.

**Postoperative rehabilitation**

Postoperative rehabilitation was started on the first postoperative day. Knee ROM was started doing heel slides aiming to achieve 90 degrees flexion within 2 weeks and 120 degrees

<b>Inclusion criteria</b>	<b>Exclusion criteria</b>
1. Patients undergoing transportal anatomic single bundle ACL reconstruction using hamstring autograft.	1. Patients who had previous knee surgeries
2. Age 17-58 years	
3. Patients providing written consent	

*Table 1: Inclusion and exclusion criteria*

gradually within 6 weeks. The patient was advised for ankle pump, static quadriceps exercises and heel hanging to achieve neutral extension. Pts were discharged on the 5<sup>th</sup> post op day after gaining 90 degrees flexion. Patients were advised for ambulation with crutches and use of hinge braces. Crutches were discarded in 4 to 6 weeks. However, weight-bearing were avoided for 4 to 6 weeks if the patient underwent meniscal repair. Patients were followed up every 6 weeks to assess the progress for initial 3 to 6 months.

**Data Analysis**

SPSS version 20 was used for data analysis. Frequency and percentage were calculated for (1) Gender, (2) Good to Excellent Outcome and (3) BMI. Mean and standard deviation was calculated for (1) age of patient, (2) duration of injury, (3) Lysholm score, (4) height, and (5) BMI. Effect modifiers like age, gender, duration of injury and BMI were dealt with using post-stratification. Chi square test was applied. P-value of <0.05 was taken as significant.

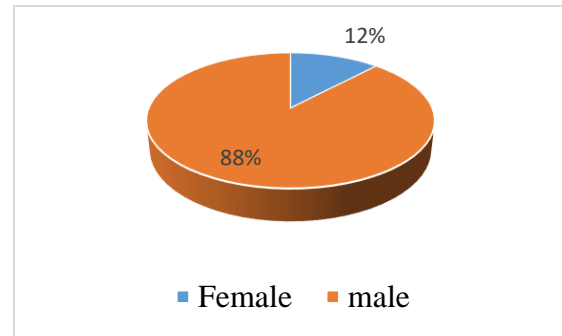
**Results**

A total of 43 patients were included in this study. One patient was lost to follow up. Stratification was done based on the age, gender, duration of injury and Body Mass Index (BMI) of the patients.

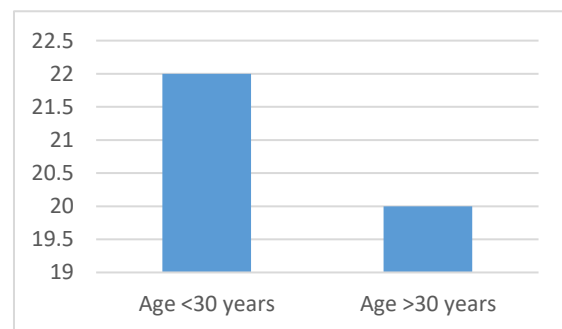
Male predominance was found in patients who undergo ACL reconstruction: 88% of the patients were male and 12% were female shown in **Figure 1**.

**Figure 2** shows stratification of the participants

according to their age group: 52% were aged below 30 years and 48% were aged above 30 years.



*Figure 1: Gender wise distribution of the participants (n=42)*



*Figure 2: Age wise distribution of the participants*

**Table 2** shows baseline characteristics of the patients who underwent anatomic ACL reconstruction. The mean age of treatment for ACL reconstruction in this study is 31.3 years (SD 8.66) with minimum age being 17 years and maximum 58 years. Mean height of the patients was 164.8 (SD 7.27) with minimum height of 150 cm and maximum height of 177 cm. Mean weight was 67.38 kg (SD 9.53) with minimum of 54 kg and maximum of 88 kg. It was found that the patients presented very late at a mean of 28.48 months (SD 54.44) with minimum time of 36 days and maximum 20 years. Mean BMI was 24.76 (SD 2.71) with minimum BMI 19.71 and maximum 29.94. The study had only one patient who belonged to

Variables	Minimum	Maximum	Mean	SD
Age (in years)	17	58	31.33	8.66
Height (in cm)	150	177	164.80	7.27
Weight (in kg)	54	88	67.38	9.53
BMI (kg/m <sup>2</sup> )	19.71	29.94	24.76	2.71
Time of presentation (months)	0.1	240	28.48	54.44

Table 2: Baseline characteristics of participants (N=42)

	Frequency	Percentage
Medial Meniscus	12	28.5
Lateral Meniscus	7	17
Isolated ACL	20	48
MCL, LCL	3	7
PCL	0	0

Table 3: Associated injuries confirmed in Arthroscopy

	Frequency	Percentage
Excellent (95-100)	4	10
Good (85-94)	11	26
Fair (65-84)	24	57
Poor (<65)	3	7

Table 4: Lysholm Scoring at average of 3 months post-op

obese (BMI >30 subgroup). Majority of the patients (57.14%) were within the normal weight range (BMI 18.5 – 24.9) and 42.86% were overweight (>25-30).

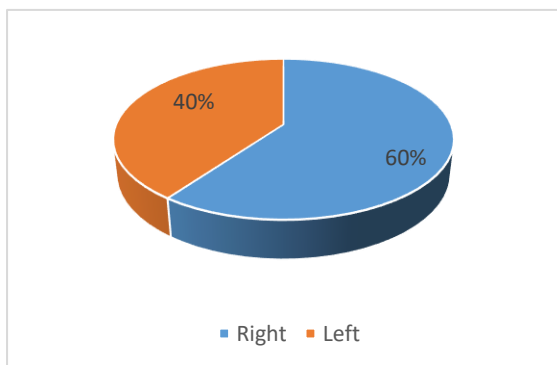


Figure 3: Side of injury

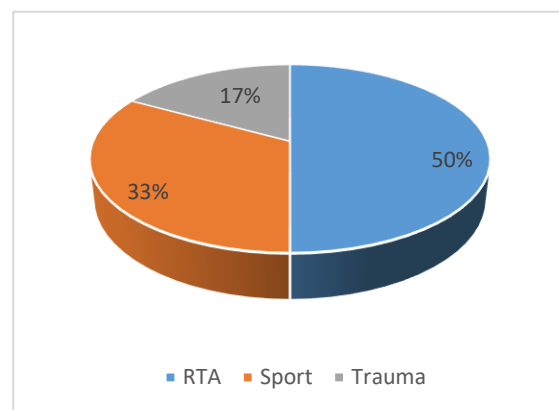


Figure 4: Mode of injury

Figure 3 shows that right side ACL injuries were common than left side ACL injuries. The causes show that 50% were due to road traffic

Age group	Lysholm score				Total	Chi square	P-value
	≥95	85-94	65-84	<65			
≤30	3	6	11	2	22		
	13.6%	27.3%	50%	9.1%	100%		
>30	1	4	14	1	20	2.003	0.596
	5%	20%	70%	5%	100%		
<b>Total</b>	4	10	25	3	42		

Table 5: Outcome analysis based on age of the patients

accidents (RTA), 33% were due to sports injuries, and the remaining 17% were due to trauma shown in **Figure 4**.

**Table 3** shows that ACL injuries occurred in isolation in 48% of the cases, while 45.5% had associated meniscal injuries. The remaining 7% cases had collateral injuries in this study.

Mean Lysholm score was 78.05 (13.35) with minimum of 37 and maximum of 100 at an average of three months.

It was found that majority of the patients (57%) had fair results followed by good results (26%) while 10% had excellent results and 7% of participants had poor results shown in **Table 4**.

**Table 5** shows that patients aged less than 30 and more than 30, both had fair to good results in the highest proportion of patients. In patients aged less than 30, the results were excellent in 13.6%, good to fair in 77.3%, and poor in 9.1%. In patients aged more than 30, the results were excellent in 5%, good to fair in 90% and poor in 5%. Age did not have a significant effect in the outcome after ACL reconstruction (p=0.596).

**Table 6** shows Lysholm score in female and male patients. All female patients (100%) had fair to good results, but no female patients had

excellent or poor results. In male patients, 11.1% had excellent outcome, 81% had fair to good results, and 8.3% had poor results. Gender did not affect the outcome.

Patients within the normal weight range (BMI 18.5-24.9) had fair to good results in 82% of the cases. It was excellent in 13% while only 4% had poor results. Similarly, patients who were overweight had excellent results in 5.9%, good to fair results in 81.5% and 11.8% had poor results. BMI did not affect the outcome (**Table 7**).

**Table 8** shows outcome after ACL reconstruction depending on the time the patients presented after injury. When patients presented less than six months after ACL injury, 9.5% had excellent results and 90.5% attained good to fair results. When the patients presented from six months to a year after ACL injury, 20% had excellent results and 80% had good to fair results. Presentation after one year eight weeks following the implantation is critical as the hamstring tendon graft increases strength and stiffness<sup>14-16</sup> and the muscle follows specific biochemical, mitochondrial and neurological adaptations.<sup>17,18</sup> However, the eight-week duration has also been considered

Sex	Lysholm score				Total	Chi square	P-value
	≥95	85-94	65-84	<65			
Female	0	1	5	0	6	1.983	0.532
	0%	16.7%	83.3%	0%	100%		
Male	4	9	20	3	36	1.983	0.532
	11.1%	25%	55.6%	8.3%	100%		
<b>Total</b>	4	10	25	3	42		

Table 6: Outcome analysis based on gender

BMI group	Lysholm score				Total	Chi square	P-value
	≥95	85-94	65-84	<65			
18.5-24.9	3	6	14	1	24	1.239	0.765
	13%	21.7%	60.9%	4.3%	100%		
≥25	1	5	10	2	18	1.239	0.765
	5.9%	23.5%	58.8%	11.8%	100%		
<b>Total</b>	4	11	24	3	42		

Table 7: Outcome analysis based on BMI

Duration	Lysholm score				Total	Chi square	P-value
	≥95	85-94	65-84	<65			
≤6 months	2	3	16	0	21	9.323	0.152
	9.5%	14.3%	76.2%	0%	100%		
6 months- 1 year	1	2	2	0	5	9.323	0.152
	20%	40%	40%	0%	100%		
>1 year	1	5	7	3	16	9.323	0.152
	6.2%	31.2%	43.8%	18.8%	100%		
<b>Total</b>	4	10	25	3	42		

Table 8: Lysholm score based on time of presentation

Complications	Frequency	Percentage
Laxity grade I (hard end point)	26	78.8%
Anterior skin pain and numbness	3	9.1%
Extension Lag (5 degrees)	2	6.1%
Graft donor site pain	1	3%
Clicks	1	3%

Table 9: Complications

as a critical time in establishing strength or more of ACL injury showed excellent results in only 6.2%, fair to good results in 74%, and 18.8% had poor results. However, it was not statistically significant.

Grade I Lachman test was found in 62% of cases with hard end point, anterior knee pain in 7% cases, extension lag in 4.6% cases, graft donor site pain in 2.3% cases, and clicks in knee in 2.3% cases in **Table 9**.

### Discussion

An ACL injury predisposes a patient to significant disability and untreated will lead to subsequent meniscal tear, chondral damage in the long run and thus is important to reconstruct the ligament. The choice of graft varies upon the surgeon's expertise and options available. ACL reconstruction success rate largely depends on technical expertise, choice of graft and its size, tunnel position and graft fixation and post-operative rehabilitation. Outcome goals should be consistent although the choice of graft is surgeon dependent. Mascarenhas et al with the systemic analysis showed that there is no difference between allograft and autograft in graft failure rate and clinical outcome, but the same study with a lower quality meta-analysis showed that allograft has a higher failure rate.<sup>5</sup> The most commonly chosen grafts are bone patellar tendon bone or hamstring tendon. Many studies showed similar outcomes between these two grafts. Princzewski showed OA changes after BTB (18%) autograft over Hamstring graft (4%).<sup>6</sup>

There are many other studies which show no change in long term result of BTB vs. hamstring autografts. In short term studies, there is less post-operative stiffness and faster recovery with hamstring autograft. However, taking hamstring graft is not free from complications like injury to infrapatellar branch of saphenous nerve, infection, flexion/extension deficit, recurrence of instability, intra-articular adhesions, hemarthrosis, and painful hardware. Similarly, there is risk of patellar fracture and anterior knee pain with BTB autograft.<sup>7-9</sup>

There are no significant differences between double bundle and single bundle ACL reconstruction in terms of function, translation, and complications rates.<sup>10</sup> An anatomic orientation of ACL reconstruction with femoral tunnel drilled from anteromedial port provides better tibial translation.<sup>11,12</sup>

Our study had 42 patients who underwent trans-portal anatomic ACL reconstruction using quadrupled hamstring autograft. The graft was anchored with interference screw on the tibial side and an Endobutton on the femoral side. The participants of the study included 88% male patients and 12% female patients aged between 17 and 58 years old. The mean age was 31 years. The injury involved 59.9% on the right side and 39.5% on the left. In contrast to other studies like Hewett et al, our study showed that 50% of ACL injury was due to RTA, 33% due to sports injury and 16.3% due to other kind of minimal trauma.<sup>13</sup>

This study had a short follow up and tended to measure functions using Lysholm score after

three months of average follow up. The first stimulus on weak quadriceps muscle following ACL reconstruction.

There are few studies which have been conducted to show Lysholm score after three months of surgery. Largely these studies have reported in context to show efficacy and adequacy of the type of muscle strengthening exercises of the quadriceps muscle. The rating system of Lysholm questionnaire is well established as an alternative mechanism to gather data on outcome when evaluating knee ligament injuries.<sup>19,20</sup>

A study by Maria et al<sup>21</sup> showed that at eight weeks after ACL reconstruction using hamstring graft with cross eccentric exercise, the Lysholm score was 92.95(+/- 4.35) at three days per week quadriceps strengthening exercise, and 90.57 (+/- 6.16) with five days per week quadriceps strengthening exercise with statistical significance.

The study by Bitun et al<sup>22</sup> measured Lysholm score and IKDC score in patients treated with patellar tendon and hamstring tendon grafts after ACL reconstruction in one month, three months and six months, with an interference screw on both tibia and femur. The Lysholm score was 71.6 after one month, 89.1 after three months and 96.6 after six months in patients who were treated with hamstring autograft.<sup>22</sup> The patients in our study had a mean score of 78.05 after three months. Therefore, these results are slightly inferior, this may be due to Endobutton anchorage on femoral side and may improve when the graft attaches to the femur in the future during the recovery process.

Those who had ACL reconstruction performed

with the anteromedial portal for femoral tunnel, which makes tunnel more anatomical, had returned to athletic activities a month and a half prior to those who had the reconstruction performed using the trans tibial technique. In contrast, no difference has been noted between the groups that underwent ACL reconstruction utilizing tunnels either through the trans tibial technique or through the anteromedial tunnel using BTB graft, in terms of VAS scale for pain, Lysholm, Tegner, and SF-12.<sup>23</sup> The femoral tunnel was made using anteromedial portal for our study as well. A longer follow up time is required to assess when the participating patients will return to their pre-injury status. Our study did not include ACL reconstruction in athletes who wanted to return to sports. Our study shows if age, sex, body mass index, and the time of presentation affect the Lysholm score and association between delayed ACL reconstruction and changes in other structures inside the knee joint with delayed presentation. A greater exposure to strenuous environments amongst males makes the ACL injury incidence higher in the male population as explained by Brown et al.<sup>24</sup> Likewise, in our study, 88% of the patients were male and only 12% were female. In a study by D. Ferrari et al found no difference in outcome in male and female patients with BTB graft.<sup>25</sup> However, they found slight increased difference for quadrupled hamstring grafts (0.87 v 2.46mm). This could directly influence functional outcome in female patients who undergo ACL reconstruction using autogenous hamstring graft. Hence, female patients could have inferior results. However, there was no statistically significant



Lysholm score difference. Our study had a smaller number of female participants (n=5) than the Male participants (n=37), and results could have been masked. The result of our study is consistent with the results of the study conducted by Aldhen et al who found that there was no significant difference between male and female in Lysholm score after ACL reconstruction using hamstring tendon in larger series of 141 male and 103 female participants in a two year follow up.<sup>26</sup>

Our study found no difference in outcome after ACL reconstruction using quadrupled hamstring autograft between patients with a normal BMI and a high BMI. This study was consistent with Ballal et al<sup>27</sup> which comprised of two groups of patients: the first 49 patients with normal BMI (18.5-24.9) and the second of 43 patients with a high BMI (>25). They matched mean age, male to female ratio, injury side, smoking status, duration before surgery, and same surgical technique with the same surgeons. They measured Lysholm score at 3,6 and 12 months. The score was 75.66, 87.17, and 88.12 respectively. They found no difference in the outcome.<sup>27</sup> In our study, 57% of the patients had normal BMI, remaining 43% had a high BMI. Only one patient had BMI >30. This study showed that there was no difference in outcome up to three months after surgery. More than 95% had fair to excellent results with normal BMI and almost 90% had fair to excellent results. But it was not statistically significant.

Some studies have shown an increased complication risk in patients with high BMIs, showing that patients with high BMIs have an

increased prevalence of wound complications and symptomatic venous thromboembolism.<sup>28,29</sup>

### Conclusion

Age, gender, BMI and time of injury preceding surgery had no effect in the outcome after ACL reconstruction up to three months after surgery. This study found higher meniscal injuries with late presentation in up to 45% patients in the study with mean time of presentation at 28.4 months +/- 54.4. In this study, the mean Lysholm score was 78.05 +/- 13.35 in three months after anatomic ACL reconstruction using quadrupled hamstring autograft. Thus, anatomic ACL reconstruction using quadrupled hamstring autograft is a safe operation with minimal complications, and it improves quality of life. However, longer follow up is required to see how these patients perform and to establish the result of ACL reconstruction.

### Limitation

It is a short follow up study of only three months. To see and establish the outcome of anatomic ACL reconstruction, a longer follow up is necessary. Besides, there can be many variables like patient occupation, history of smoking, patient taking some drugs, which can have different outcomes, which is not considered in this study. Using Lysholm score in the context of Nepal is also difficult as it was designed for people from western part of the world with different lifestyle. People are considerably less involved in athletic activities in Nepal which is a part of Lysholm questionnaire. So it sometimes created dilemma

while scoring. That difference might affect the results of this study. This study involves heterogenous group of people so study could have been improved by including a homogenous population and increasing the sample size.

**References**

1. Kaeding CC, Léger-St-Jean B, Magnussen RA. Epidemiology and diagnosis of anterior cruciate ligament injuries. *Clin Sports Med.* 2017;36:1–8.
2. Samitier G, Marcano AI, Alentorn-Geli E, Cugat R, Farmer KW, Moser MW. Failure of anterior cruciate ligament reconstruction. *Arch bone Jt Surg.* 2015;3:220.
3. Bedi A, Musahl V, Steuber V, Kendoff D, Choi D, Allen AA, et al. Transtibial versus anteromedial portal reaming in anterior cruciate ligament reconstruction: an anatomic and biomechanical evaluation of surgical technique. *Arthrosc J Arthrosc Relat Surg.* 2011;27:380–90.
4. Lee YHD, Kuroda R, Chan KM. Anterior cruciate ligament reconstruction: A 2015 global perspective of the Magellan Society. *Asia-Pacific J Sport Med Arthrosc Rehabil Technol.* 2015;2:122–8.
5. Mascarenhas R, Erickson BJ, Sayegh ET, Verma NN, Cole BJ, Bush-Joseph C, et al. Is There a Higher Failure Rate of Allografts Compared With Autografts in Anterior Cruciate Ligament Reconstruction: A Systematic Review of Overlapping Meta-analyses. *Arthrosc J Arthrosc Relat Surg [Internet].* 2015;31:364–72. Available

from:

<https://www.sciencedirect.com/science/article/pii/S0749806314006173>

6. Pinczewski LA, Deehan DJ, Salmon LJ, Russell VJ, Clingeleffer A. A five-year comparison of patellar tendon versus four-strand hamstring tendon autograft for arthroscopic reconstruction of the anterior cruciate ligament. *Am J Sports Med.* 2002;30:523–36.
7. Kartus J, Magnusson L, Stener S, Brandsson S, Eriksson BI, Karlsson J. Complications following arthroscopic anterior cruciate ligament reconstruction A 2–5-year follow-up of 604 patients with special emphasis on anterior knee pain. *Knee Surgery, Sport Traumatol Arthrosc.* 1999;7:2–8.
8. Barrett GR, Field LD. Comparison of patella tendon versus patella tendon/Kennedy ligament augmentation device for anterior cruciate ligament reconstruction: study of results, morbidity, and complications. *Arthrosc J Arthrosc Relat Surg.* 1993;9:624–32.
9. Lee GH, McCulloch P, Cole BJ, Bush-Joseph CA, Bach Jr BR. The incidence of acute patellar tendon harvest complications for anterior cruciate ligament reconstruction. *Arthrosc J Arthrosc Relat Surg.* 2008;24:162–6.
10. Kongtharvonskul J, Attia J, Thamakaisorn S, Kijkunasathian C, Woratanarat P, Thakkinstian A. Clinical outcomes of double-vs single-bundle anterior cruciate ligament reconstruction: A systematic review of randomized control trials. *Scand*

- J Med Sci Sports. 2013;23:1–14.
11. Kaseta MK, DeFrate LE, Charnock BL, Sullivan RT, Garrett WE. Reconstruction Technique Affects Femoral Tunnel Placement in ACL Reconstruction. *Clin Orthop Relat Res* [Internet]. 2008;466:1467–74. Available from: <https://doi.org/10.1007/s11999-008-0238-z>
  12. Gavriilidis I, Motsis EK, Pakos EE, Georgoulis AD, Mitsionis G, Xenakis TA. Transtibial versus anteromedial portal of the femoral tunnel in ACL reconstruction: A cadaveric study. *Knee* [Internet]. 2008;15:364–7. Available from: <https://www.sciencedirect.com/science/article/pii/S0968016008000859>
  13. Hewett TE, Myer GD, Ford KR. Anterior cruciate ligament injuries in female athletes: Part 1, mechanisms and risk factors. *Am J Sports Med*. 2006;34:299–311.
  14. Karlson JA, Steiner ME, Brown CH, Johnston J. Anterior cruciate ligament reconstruction using gracilis and semitendinosus tendons: comparison of through-the-condyle and over-the-top graft placements. *Am J Sports Med*. 1994;22:659–66.
  15. Snyder-Mackler L, De Luca PF, Williams PR, Eastlack ME, Bartolozzi 3rd AR. Reflex inhibition of the quadriceps femoris muscle after injury or reconstruction of the anterior cruciate ligament. *J Bone Joint Surg Am*. 1994;76:555–60.
  16. Wilk KE, Reinold MM, Hooks TR. Recent advances in the rehabilitation of isolated and combined anterior cruciate ligament injuries. *Orthop Clin*. 2003;34:107–37.
  17. Majima T, Yasuda K, Tago H, Tanabe Y, Minami A. Rehabilitation after hamstring anterior cruciate ligament reconstruction. *Clin Orthop Relat Res*. 2002;397:370–80.
  18. Morrissey MC, Harman EA, Johnson MJ. Resistance training modes: specificity and effectiveness. *Med Sci Sports Exerc*. 1995;27:648–60.
  19. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res*. 1985;198:43–9.
  20. Ploutz LL, Tesch PA, Biro RL, Dudley GA. Effect of resistance training on muscle use during exercise. *J Appl Physiol*. 1994;76:1675–81.
  21. Papandreou MG, Billis E V, Antonogiannakis EM, Papaioannou NA. Effect of cross exercise on quadriceps acceleration reaction time and subjective scores (Lysholm questionnaire) following anterior cruciate ligament reconstruction. *J Orthop Surg Res*. 2009;4:1–9.
  22. Bitun PB, Miranda CR, Escudero RB, Araf M, Souza DG de. Comparison of grafts for anatomical reconstruction of the ACL: patellar versus semitendinosus/gracilis☆. *Rev Bras Ortop*. 2015;50:50–6.
  23. Azboy I, Demirtaş A, Gem M, Kiran S, Alemdar C, Bulut M. A comparison of the anteromedial and transtibial drilling technique in ACL reconstruction after a short-term follow-up. *Arch Orthop Trauma Surg*. 2014;134:963–9.
  24. Brown TN, Palmieri-Smith RM, McLean

- SG. Sex and limb differences in hip and knee kinematics and kinetics during anticipated and unanticipated jump landings: implications for anterior cruciate ligament injury. *Br J Sports Med.* 2009;43:1049–56.
25. Ferrari JD, Bach Jr BR, Bush-Joseph CA, Wang T, Bojchuk J. Anterior cruciate ligament reconstruction in men and women: an outcome analysis comparing gender. *Arthrosc J Arthrosc Relat Surg.* 2001;17:588–96.
26. Ahldén M, Sernert N, Karlsson J, Kartus J. Outcome of anterior cruciate ligament reconstruction with emphasis on sex-related differences. *Scand J Med Sci Sports.* 2012;22:618–26.
27. Ballal MS, Khan Y, Hastie G, Hatcher A, Coogan S, Cooke C, et al. Outcome of primary hamstring anterior cruciate ligament reconstruction in patients with different body mass index classes. *Muscles, Ligaments Tendons J.* 2012;
28. Furukawa A, Kasai Y, Akeda K, Nii E, Uchida A. Influence of obesity on outcomes of surgery for lumbar spinal canal stenosis. *Open Spine J.* 2010;2.
29. Azodi OS, Bellocco R, Eriksson K, Adami J. The impact of tobacco use and body mass index on the length of stay in hospital and the risk of post-operative complications among patients undergoing total hip replacement. *J Bone Joint Surg Br.* 2006;88:1316–20.