

Decreased Isokinetic Strength of 1st Ray Plantar Flexion and Decreased Eversion Are Predictors of Unregenerated Peroneus Longus Tendon After 1 Year of Anterior Cruciate Ligament Reconstruction

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DOI: <https://doi.org/10.52403/ijrr.20220753>

ABSTRACT

Introduction: Anterior cruciate ligament (ACL) rupture is a sports-related knee injury that is quite often encountered. It is estimated that the annual incidence of these injuries reaches 5 to 8 per 10,000 individuals. There are various graft options for ACL reconstruction, such as hamstring tendon autograph, bone-patellar tendon-bone autograph (BPTB), and peroneus longus tendon autograft. Regeneration of the peroneus tendon can be assessed by several modalities, one of which is magnetic resonance imaging (MRI). One of the main concerns after PLT grafting is the potential for a decrease in plantar flexion strength and ankle eversion.

Purpose: of this study was to assess the regeneration capabilities of the peroneus tendon after ACL reconstruction and its relation to the function of the muscle. A better understanding of this topic may provide an alternative, and possibly a better intervention to detect the presence of peroneus tendon regeneration and increase functional output in ACL reconstruction patients.

Material and Methods: This study is an observational study using a case-control design. From the population of the study subjects, sampling was carried out that met the

requirements of research inclusion and then data collection was carried out. An examination of the isokinetic strength of the plantar ankle flexion and eversion, then the data obtained is processed using SPSS 25.

Results: Based on the results of the independent t test, it was found that the isokinetic strength of the 1st ray plantar flexion and ankle eversion is a predictor of regeneration of the peroneus longus ($p < 0,05$; $p < 0.05$).

Conclusion: The isokinetic strength of the ankle plantar flexion and eversion is a predictor of regeneration of the peroneus longus tendon as a "donor site" after 1 year post ACL reconstruction.

Keywords: ACL reconstruction, regeneration of peroneus longus, isokinetic strength of the ankle

INTRODUCTION

Anterior cruciate ligament (ACL) rupture is a common sport-related knee injury. It is estimated that the annual incidence of these injuries is 5 to 8 per 10,000 individuals. There are various graft options with peroneus longus tendon autograft is more popular because of less donor-site morbidity, less knee problems, and fewer

patellar tendon ruptures. However, postoperative problems such as ankle joint weakness are common and remain unresolved. Autograft and allograft can be used, currently the most popular are the hamstring graft (autograft), BPTB, and in the past decade the peroneus longus tendon is being debated about its use. Especially in terms of morbidity in the ankle joint. An ideal donor autograft should be of adequate strength and size and be easy and safe to harvest.¹

Peroneus longus tendon regeneration can be assessed by several modalities, one of which is magnetic resonance imaging (MRI). MRI can also assess the atrophy of the peroneus longus and the presence or absence of shifting of the musculotendinous boundary, which has been shown to be one of the factors affecting the functional capability of the ankle joint after surgery.^{2,3} One of the main concerns after PLT grafting is the potential for decreased strength of 1st ray plantar flexion and ankle eversion. In the examination of muscle strength, the isokinetic dynamometer examination can be considered as the "Gold Standard".⁴

The purpose of this study was to assess the regeneration capability of the peroneus tendon after ACL reconstruction and its relation to the function of the muscle.

MATERIALS & METHODS

This research is an analytic observational study with a case control study to analyze if isokinetic strength of 1st ray plantar flexion and eversion are predictors of peroneus longus tendon regeneration after 1 year of ACL reconstruction surgery. This research was conducted Sanglah General Hospital Denpasar, from January 2022 until February 2022. The research protocol for Ethical Clearance from the Research Ethics Commission at the Faculty of Medicine, UNUD / Sanglah Hospital Denpasar was submitted before the research was carried out. Subjects were given an explanation of the purpose of the study and were asked to fill out written informed consent.

The isokinetic strength of 1st ray plantar flexion and eversion were done clinically and the investigations were assessed with isokinetic

dynamometer. The case group is comprised of patients with decreased peroneus longus tendon strength based on isokinetic dynamometer measurement.

The incidence of foot and ankle charcot joints was done clinically and the investigations were assessed with plain radiographs. The case group is comprised of type II DM patients suffering from charcot joint foot and ankle diagnosed based on clinical pictures and plain radiographs. Patients' data and medical conditions (name, age, and gender) were obtained through anamnesis in the Outpatient Installation and Inpatient Installation of RSUP Sanglah and medical record.

An MRI 1 year after ACL reconstruction surgery was taken to assess the regeneration of the peroneus longus tendon based on the progress of the tendon ends visualized as hypointense areas on the T2 MRI sequence. MRI was performed at the Radiology Installation of RSUP Sanglah. Tendons are said to be regenerating when they appear in sections above 10 cm. Ankle isokinetic strength examination was performed using a dynamometer which assessed the invertor and evertor of the ankle in angular velocities of 60°/sec and 120°/sec. The patient's body is in a 85°-inclined back position, the upper body is fixed, the knees are flexed 60°, the tibia is horizontal, and the range of motion is from 20° inversions to 20° inversions. Meanwhile, the 1st ray plantarflexion test was carried out in an initial position of 15° dorsiflexion with a movement towards 35° plantarflexion of the 1st ray. For all measurements, the values of the measurement results were compared with the reference values based on the sex and age groupings.

The inferential analysis was used determine whether the results of this study can be generalized to the general population, using 95% CI and p-value <0.05 was considered as significant. The inferential statistical test used in this study was chi-square. Statistical Package for Social Sciences (SPSS) for Windows® version 20 program was used for data processing.

The sample size in this study was determined by consecutive sampling, namely by recording patients according to the inclusion and exclusion criteria until the number of participants according to the requirements of the analysis was met. A comparative case study and analytical control formula was used to calculate

the sample size. The inclusion criteria are female or male patients aged 18-55 years, patients with normal BMI (18.5 – 25 kg/m²), history of ACL reconstruction surgery at least 1 year using autograft of the peroneus longus tendon, no history of fracture in the knee area on the same side as the side that suffered the ACL rupture, there is no meniscus tear on the same side as the ACL ruptured side, and patients who routinely undergo ACL postoperative rehabilitation program. The exclusion criteria are patient loss to follow up, patients with comorbidities (Diabetes Mellitus, obesity, and connective tissue disorders), patients with a history of tearing the peroneus longus tendon after surgery caused by other factors (trauma),

patients with a history of using injection corticosteroid drugs in the tendon donor area, patients with bilateral ACL rupture.

RESULT

This study used a sample of patients who had isolated ACL injury and underwent ACL reconstruction using a peroneus longus graft and followed up at least 1 year after surgery. The distribution of the characteristics of the research subjects can be seen in Table 1. For age and BMI variables, the mean difference test was carried out with a paired t test because the data were normally distributed. As for the other variables, the proportion test was carried out with the chi square test.

Table 1. General characteristics of research subjects based on isokinetic strength of plantar flexion 1st ray

Variable	Decreased isokinetic strength of 1 st ray plantar flexion	Normal isokinetic strength of 1 st ray plantar flexion	P value
Age (year)	33,57 ± 9,46	33,28 ± 12,41	0,94
Gender			1
• Female	5 (17,9%)	5 (17,9%)	
• Male	9 (32,1%)	9 (32,1%)	
Smoking			0,70
• Smoking	6 (21,4%)	7 (25%)	
• No	8 (28,6%)	7 (25%)	
BMI	22,06 ± 2,10	21,99 ± 2,61	0,93

From the descriptive analysis, it was found that the mean and standard deviation of age in the study of the average age and standard deviation of the group with decreased plantar flexion 1st ray isokinetic strength was 33.57 ± 9.46, while the normal 1st ray plantar flexion isokinetic strength group was 33.28 ± 12.41. The male sex characteristics in the 1st ray plantar flexion isokinetic strength group decreased similarly to patients in the normal 1st ray plantar flexion isokinetic strength group with the number in each group being 9 out of a total of 28 people (32.1%). The female sex characteristics of patients in the 1st ray plantar flexion isokinetic strength group decreased similarly to patients in the normal 1st ray plantar flexion isokinetic strength group with the number in each group being 5 out of a total of 28 people (17.9%). Characteristics of patients who smoked in the decreased 1st ray plantar flexion isokinetic strength group were 6 out of a total of 28 people

(21.4%) while the normal 1st ray plantar flexion strength group was 7 (25%). Characteristics of patients who did not smoke in the 1st ray plantar flexion isokinetic strength group decreased by 8 out of a total of 28 people (28.6%) while in the group of patients with normal 1st ray plantar flexion isokinetic strength group was 7 people (25%). The mean and standard deviation of BMI in the group of patients with decreased 1st ray plantar flexion isokinetic strength was 22.06 ± 2.10, while the normal 1st ray plantar flexion isokinetic strength group was 21.99 ± 2.61. From all of the data above, it was obtained p value > 0.05 which indicates that there is no significant difference in the mean age, sex proportion, and smoking between the group with decreased 1st ray plantar flexion strength and the group with normal 1st ray plantar flexion isokinetic strength, or in other words, the two groups are comparable.

Table 2. General characteristics of research subjects based on isokinetic strength of ankle eversion

Variable	Decreased isokinetic strength of ankle eversion	Normal isokinetic strength of ankle eversion	P Value
Age (year)	32,35 ± 9,88	34,5 ± 11,97	0,61
Gender			1
• Male	5 (17,9%)	5 (17,9%)	
• Female	9 (32,1%)	9 (32,1%)	
Smoking			0,70
• Smoking	6 (21,4%)	7 (25%)	
• Non smoking	8 (28,6%)	7 (25%)	
BMI	22,19 ± 2,06	21,86 ± 2,63	0,71

From the descriptive analysis, it was found that the mean and standard deviation of age in the study of the mean age and standard deviation of the group with decreased isokinetic eversion strength was 32.35 ± 9.88, while the normal eversion isokinetic strength group was 34.5 ± 11.97. The male sex characteristics in the eversion isokinetic strength group decreased similarly to patients in the normal eversion isokinetic strength group with the number in each group being 9 out of a total of 28 people (32.1%). The female sex characteristics of patients in the eversion isokinetic strength group decreased similarly to patients in the normal eversion isokinetic strength group with 5 out of a total of 28 people (17.9%). Characteristics of patients who smoked in the decreased eversion isokinetic strength group were 6 out of a total of 28 people (21.4%) while the normal eversion

strength group was 7 out of a total of 28 people (25%). Characteristics of patients who did not smoke in the decreased eversion isokinetic strength group were 8 out of a total of 28 people (28.6%) while in the group of patients with normal eversion isokinetic strength it was 7 out of a total of 28 people (25%). The mean and standard deviation of BMI in the patient group with decreased isokinetic eversion strength was 22.19 ± 2.06, while the normal eversion isokinetic strength group was 21.86 ± 2.63. From the above data, a p value > 0.05 was obtained which indicates that there is no significant difference in the mean age, sex proportion, and smoking between the group with decreased eversion strength and the group with normal eversion isokinetic strength, or in other words, both groups are comparable.

Table 3. The results of the chi square test and the odds ratio for the variable isokinetic strength of the ankle plantar flexion 1st ray and the regeneration of the peroneus longus tendon

Variable	Isokinetic Strength of 1 st Ray Plantar Flexion		P Value	OR (95% CI)
	Decreased	Normal		
Peroneus Longus Tendon Regeneration				
• Non regenerative	9 (64,3%)	3 (21,4%)	0,022	6,6 (1,229-35,43)
• Regenerative	5 (35,7%)	11 (78,6%)		

The table above shows that decreased 1st ray plantarflexion isokinetic strength of the ankle is a predictor of non-regenerating peroneus longus tendon. There was a statistically significant difference (p=0.022, p<0.05) between the decreased 1st ray isokinetic strength of the ankle plantarflexion and the normal one. Further analysis found an Odds Ratio (OR) of 6.6 so

that patients with non-regenerating peroneus longus tendons had a 6.6-fold greater probability of producing a decreased 1st ray isokinetic strength of the ankle plantarflexion compared to the population of regenerated tendons. With 95% CI (1,220-35,43) and p value = 0.022, the Odds Ratio value can be generalized to the general population.

Table 4. The results of the chi square test and the odds ratio for the isokinetic strength variable of ankle eversion and peroneus longus tendon regeneration.

Variable	Isokinetic Strength of Ankle Eversion		Nilai p	OR (95% CI)
	Decreased	Normal		
Peroneus Longus Tendon Regeneration				
• Non regenerative	10 (71,4%)	2 (14,3%)	0,002	15 (2,25-99,63)
• Regenerative	4 (28,6. %)	12 (85,7%)		

The table above shows that decreased isokinetic strength of ankle eversion is a predictor of non-regenerating peroneus longus tendon. There was a statistically significant difference ($p=0.002$, $p<0.05$) between the decreased ankle eversion isokinetic strength and the normal one. Further analysis obtained an Odds Ratio (OR) of 15 so that patients with non-regenerating peroneus longus tendons were 15 times more likely to produce a decreased isokinetic strength of ankle eversion compared to the population of regenerated tendons. With 95% CI (2.25-99.63) and p value = 0.002, the Odds Ratio value can be generalized to the general population.

DISCUSSION

One of the main concerns following grafting of the peroneus longus tendon in ACL reconstruction surgery is the potential decrease in 1st ray plantarflexion strength and ankle eversion. However, previous studies revealed that the 1st ray plantarflexion deficit and ankle eversion were so minimal that they did not interfere with daily activities. Although MRI is the “gold standard” for soft tissue examination, it is hoped that isokinetic examination of plantar flexion and ankle eversion can be a predictor of healing at the donor site.

The results of this study indicate that the decreased isokinetic strength of the ankle plantar flexion 1st ray is a predictor of the occurrence of the peroneus longus tendon that does not regenerate. There was a statistically significant difference ($p < 0.05$) between the decreased and normal ankle plantar flexion 1st ray isokinetic strength. In this study, there was a difference in the isokinetic strength of the plantarflexion 1st ray on the regenerated donor site leg when compared to the non-regenerated donor site leg (p value < 0.05). This research is supported by the research of Khira et al., in this study, it was explained that after ACL reconstruction surgery using peroneus longus autograft, the results of isokinetic testing in the form of maximum plantar flexion at the ankle used as a donor site were significantly lower when compared to the contralateral ankle (p value < 0.05) with a mean decrease maximum flexion of 28+11% and 36+4% at 30 deg/sec and 120 deg/sec respectively.⁵ Contrary to the results of research Rhatomy et al., plantar flexion of the ankle at the donor site had the same outcome as movement of the healthy side or contralateral leg ($p = 0.68$) with a mean of

150.64+11.67N and 152.10+12.16 N. This study supports the peroneus longus as the autograft of choice in ACL reconstruction because of the similar good outcome to the donor site and the results of ACL reconstruction.⁶ In the study by Karanikas et al., plantar flexion of the ankle at the donor site had the same outcome as the movement of the contralateral leg or the healthy side ($p > 0.05$) with a mean of 73.7+21.5N and 78.9+25.5N.⁷ Similar findings were also found in Park's et al., split harvest of the peroneus longus tendon (PLT) did not cause a significant disturbance in the strength of the PLT when the ankle plantar flexion isokinetic test examination at the donor site had the same outcome as the movement of the contralateral leg or the healthy side ($p=0.517$) with mean 82.9+20.9 and 87.0+17.7.⁸

The results of this study indicate that the decreased isokinetic strength of ankle eversion is a predictor of the occurrence of the peroneus longus tendon that does not regenerate. There was a statistically significant difference ($p < 0.05$) between the decreased and normal ankle eversion isokinetic strength. In this study, there was a difference in plantarflexion isokinetic strength in the regenerated donor site leg compared to the non-regenerated donor site foot (p value < 0.05).

The results of this study are in line with the research of Anthong et al. In this study, it was explained that in the 7th month after ACL reconstruction surgery using an autograft peroneus longus, the results of isokinetic testing in the form of maximum eversion and inversion of the ankle used as a donor site were lower when compared to the contralateral ankle (p value < 0.05).⁹ Ankle muscle strength training is needed to avoid instability after ACL reconstruction using peroneus longus autograft. This is also supported by Watanabe et al., the primary finding of this study states that in eversion movement, peroneus longus m. showed a higher sEMG amplitude when compared to plantarflexion.¹⁰

The same thing was found by Rhatomy et al., ankle eversion and ankle plantar flexion strength at the donor site had the same outcome as the movement of the contralateral leg or the healthy side ($p=0.55$) with a mean of 65.87+7.63 N and 66.96+8.38 N.⁶ This study supports the peroneus longus as the autograft of choice in ACL reconstruction due to its favorable outcome on the donor site and the results of ACL

reconstruction. In the research of Park et al. also obtained similar results, the eversion of the ankle (30 deg/s and 60 deg/s) at the donor site had the same outcome as the movement of the contralateral leg or the healthy side ($p=0.913$ and $p=0.983$) with a mean of $28.3+7.8$ N; $28.1+6.5$ N and $22.4+5.4$; $22.4+6.3$.⁸ Kerimoglu studied 12 patients who underwent ACL reconstruction using a peroneus longus tendon graft with follow-up ranging from 18 to 96 months using MRI and found peroneus longus tendon regeneration and no impairment in ankle function and exercise.¹¹ Eriksson et al. reported that eight patients experienced tendon regeneration 7-28 months after the procedure.¹² This research, indirectly is not in line with the research conducted by Barzegar et al., in this controlled clinical trial, mediolateral, vertical, anteroposterior force examinations were carried out on the ankle joints used as donor sites. There was a good postoperative outcome, and it had no effect on gait or ankle joint instability.¹²

CONCLUSION

In conclusion, isokinetic strength of plantar flexion 1st ray is a predictor of regeneration of the peroneus longus tendon as a donor site after 1 year of ACL reconstruction and ankle eversion isokinetic strength is a predictor of peroneus longus tendon regeneration as a donor site after 1 year of ACL reconstruction.

ACKNOWLEDGEMENTS: We would like to thank Ketut Gede Mulyadi Ridia as Head of Orthopaedics and Traumatology Department, Faculty of Medicine Udayana University, Sanglah General Hospital for all the support regarding this study.

Funding: The author is responsible for funding this study without involving sponsors, grants, and various other funding sources.

Conflict of interest: The author states that there is no conflict of interest related to the material discussed in the manuscript.

Ethical approval: The research protocol for Ethical Clearance from the Research Ethics Commission at the Faculty of Medicine, UNUD / Sanglah Hospital Denpasar will be

submitted before the research is carried out. Subjects who met the study criteria were given an explanation of the purpose of the study and were asked to fill out written informed consent. Researchers have also attached a secondary data collection permit in the form of a medical record at Sanglah Hospital Denpasar.

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- How to cite this article: Cokorda Krishna Dalem Pemayun, I Gede Eka Wiratnaya, K G Mulyadi Ridia et.al. Decreased isokinetic strength of 1st ray plantar flexion and decreased eversion are predictors of unregenerated peroneus longus tendon after 1 year of anterior cruciate ligament reconstruction. *International Journal of Research and Review.* 2022; 9(7):495-501. DOI: <https://doi.org/10.52403/ijrr.20220753>
