

# Investigation of Muscle Passive Mechanical Properties and Strength: A Long-term Post-Surgery Analysis

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## Summary

This study aimed to investigate the muscle passive mechanical properties and strength in the involved and uninvolved limbs of 23 male participants (mean age: 26.65±4.10 years) after ACL reconstruction. Quadriceps and hamstring strength were assessed using a hand-held dynamometer, while muscle mechanical properties were evaluated with a digital palpation device. Significant deficits in muscle strength, tone, stiffness, and elasticity were found in the involved limb, particularly in the hamstrings. The findings suggest that persistent impairments in muscle mechanical properties may contribute to reinjury risk. Targeted rehabilitation strategies focusing on restoring muscle mechanical properties are essential for optimizing recovery and preventing secondary injuries.

## Introduction

Anterior cruciate ligament (ACL) injuries are common among athletes who participate in landing- and pivoting-based sports. Arthroscopically assisted ACL reconstruction using an autograft is one of the most common orthopedic procedures performed to restore the mechanical stability of the knee [1]. However, while passive knee laxity is often corrected following ACL reconstruction, dynamic knee stability is not always fully restored, which may contribute to the high risk of secondary ACL injuries. Persistent deficit in lower extremity muscle strength after ACL reconstruction are well-documented [2]. However, there is limited information on how passive muscle mechanical properties change in the long term after reconstruction. This study aims to investigate the passive mechanical properties and muscle strength of both the involved and uninvolved limbs at least one year after ACL reconstruction.

## Methods

Twenty-three male participants (mean age: 26.65±4.10 years; mean height: 1.79±0.07 m; mean body mass index: 27.30±3.61 kg/m<sup>2</sup>) were recruited for this study. The mean time after surgery of participants was 45.17±18.05 months. Quadriceps and hamstring muscles strength were evaluated with a hand-held dynamometer and muscle passive mechanical properties were evaluated with a hand-held and digital palpation device. The mechanical properties of the quadriceps muscle, including the rectus femoris (RF), vastus medialis obliquus (VMO), and vastus lateralis (VL), as well as the hamstring muscle, including the biceps femoris (BF) and semitendinosus (ST), were separately assessed and recorded. The Wilcoxon test was used to compare the muscle

strength and mechanical properties between involved and uninvolved sides.

## Results and Discussion

Compared to the uninvolved limb, the involved limb exhibited a significant decrease in peak torque for both the quadriceps ( $p = 0.010$ ) and hamstrings ( $p < 0.001$ ). Significant differences in muscle tone were observed in the VL ( $p = 0.034$ ), BF ( $p = 0.010$ ), and ST ( $p = 0.002$ ) between the involved and uninvolved sides. Additionally, muscle stiffness significantly differed between limbs in the RF ( $p = 0.005$ ), BF ( $p = 0.033$ ), and ST ( $p = 0.042$ ). Significant differences in muscle elasticity were also found in the RF ( $p = 0.005$ ) and BF ( $p = 0.039$ ) (Table 1).

**Table 1.** Comparison of muscle mechanical properties between involved and uninvolved side.

N=23		Involved Side Mean ±SD	Uninvolved Side Mean ±SD	p
Tone	RF	12.30±1.12	12.62±1.79	0.260
	VMO	11.83±1.16	11.52±0.98	0.175
	VL	12.91±1.32	13.44±1.42	<b>0.034*</b>
	BF	12.05±1.23	12.49±1.43	<b>0.010*</b>
	ST	12.10±1.61	12.99±2.20	<b>0.002*</b>
Stiffness	RF	208.00±40.00	226.13±42.99	<b>0.005*</b>
	VMO	197.13±40.05	194.47±43.63	0.891
	VL	247.13±39.01	252.08±37.44	0.715
	BF	191.00±45.91	206.47±50.07	<b>0.033*</b>
	ST	194.17±50.01	216.69±53.44	<b>0.042*</b>
Elasticity	RF	23.41±2.67	22.31±2.64	<b>0.005*</b>
	VMO	23.46±2.70	23.96±3.41	0.475
	VL	21.80±2.58	21.37±2.39	0.386
	BF	23.44±2.72	22.56±3.15	<b>0.039*</b>
	ST	22.29±3.00	21.74±3.15	0.236
<b>Abbreviation:</b> RF: Rectus Femoris, VMO: Vastus medialis obliquus, VL: Vastus lateralis, BF: Biceps femoris, ST: Semitendinosus. *: $p < 0.05$ , Wilcoxon Signed Ranks Test				

## Conclusions

These findings showed that ACL reconstruction leads to persistent deficits in muscle strength, tone, stiffness, and elasticity. Targeted rehabilitation strategies focusing on restoring muscle mechanical properties are crucial for improving long term outcomes.

## References

- [1] KCC et al. (2017) *Clin Sports Med.* 36:1-8.
- [2] LC et al. (2019) *Sports health* 11.2: 163-17