Mechanical Properties of the Femur and Tibia are Impaired in the Reconstructed Leg 1-6 Years Following Anterior Cruciate Ligament Reconstruction

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Summary

Post-traumatic knee osteoarthritis affects approximately 50% of individuals following an anterior cruciate ligament tear and reconstruction (ACLR). Bone tissue is essential for joint function, as it helps to distribute loading during locomotion. However, evidence is limited regarding whether the bone tissues in the reconstructed leg have a diminished ability to transfer forces during weight-bearing activities post-ACLR. Using peripheral quantitative computerised tomography imaging to infer mechanical properties of the bone, our findings indicate that at 66% of the tibia, and at 20% and 50% of the femur, the resistance to rotational and compressive forces is reduced in the reconstructed leg. These results may have implications for how forces are distributed at the knee joint, potentially contributing to the deterioration of joint health following ACLR.

Introduction

Post-traumatic knee osteoarthritis (PTOA) affects approximately 50% of individuals following an anterior cruciate ligament tear and reconstruction (ACLR). The pathogenesis of osteoarthritis is driven by both pathomechanical and physiological changes, resulting in a pro-catabolic state that leads to the progressive degradation of joint tissues. Bone tissue plays a critical role in joint function by distributing loads during locomotion. This study aimed to investigate whether the resistance to torsional and compressive forces is diminished in the reconstructed leg compared to the uninjured contralateral leg.

Methods

This study gained favorable opinion from a National Health Service Research Ethics Committee (IRAS: 304181). Thirty-two men and women (Sex: 14 male, 18 female: Age: 26 ± 6 years, Body Mass Index: 25.12 + 3.95 kg/m^2) 1-6 years following and ACLR. Participants underwent six (three per leg) pQCT scans, conducted at 66% of the tibia length relative to the distal growth plate (tibia$^{66\%}$), and the femur scanning sites were conducted at 20% (femur$^{20\%}$) and 50% (femur$^{50\%}$) of the femur relative to the distal growth plate. Strength Strain Index (SSI) was calculated to estimate the bone's ability to resist bending or torsional forces. Polar Second Moment of Area (IPo) was used to measure the bone's resistance to torsional and bending forces based on how its mass is distributed around its central axis. Bone Strength Index for Compression (bSId) was used to measure compressive strength and the concentration of the compressive forces elicited on the bone. These indices have been validated in previous research [1].

Results and Discussion

SSI, iPo, and bSId, were significantly lower in the reconstructed leg in comparison to the uninjured leg at tibia$^{66\%}$, femur$^{20\%}$ and femur$^{50\%}$, aside from iPo at femur$^{50\%}$ (Table 1). For each variable, effect sizes indicated the greatest deficits in the reconstructed leg existed at the femur$^{20\%}$ scan site.

Conclusions

Impaired axial and shear force transfer across the femur and tibia of the reconstructed leg may induce exposure to atypically higher forces in key soft tissues, such as cartilage. This may potentially negatively influence cartilage homeostasis, which is metabolically driven through mechanotransduction. Our results may provide insight into contributing factors for knee PTOA following ACL injury and reconstruction, with further longitudinal research required.

References

[1] Kontulainen SA, et al (2008). J Musculoskelet Neuronal Interact. 8(4): 401-9.

Table 1. Comparison of resistance to torsional and compressive forces between the ACLR leg and contralateral uninjured leg

		Reconstructed	Uninjured Contralateral	Test Statistics
Strength Strain Index	Tibia$^{66\%}$	2683.93 ± 699.91	2746.37 ± 710.42	p = 0.02, 95% CI = -118.54 to -6.34, d_z = -0.40
	Femur$^{20\%}$	3382.79 ± 757.10	3480.62 ± 774.78	p = 0.0004, 95% CI = -150.88 to -44.77, d_z = -0.66
	Femur$^{50\%}$	2983.66 ± 803.08	3029.00 ± 805.13	p = 0.048, 95% CI = -99.19 to 8.51, d_z = -0.30
Polar Second Moment of Area	Tibia$^{66\%}$	59308.64 ± 21709.55	61003.25 ± 21891.06	p = 0.03, 95% CI = -3472.59 to 83.39, d_z = -0.34
	Femur$^{20\%}$	74883.05 ± 24650.32	76587.33 ± 24864.54	p = 0.02, 95% CI = -3360.76 to -47.78, d_z = -0.37
	Femur$^{50\%}$	56411.94 ± 19872.87	56870.45 ± 19516.02	p = 0.22, 95% CI = -2040.00 to 1122.97, d_z = -0.10
Bone Strength Index for Compression	Tibia$^{66\%}$	3.05 ± 0.67	3.12 ± 0.64	p = 0.04, 95% CI = -0.16 to 0.01, d_z = -0.33
	Femur$^{20\%}$	2.47 ± 0.61	2.64 ± 0.66	p < 0.0001, 95% CI = -0.24 to -0.10, d_z = -0.89
	Femur$^{50\%}$	4.44 ± 0.68	4.57 ± 0.68	p = 0.003, 95% CI = -0.22 to -0.04, d_z = -0.53