Curvatures of the distal human femur: Functional implications

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Summary

This study aimed at investigating (i) relationships between the anterior and posterior radii of the femoral condyles and (ii) biomechanical factors underpinning these ratios. The underlying rationale was that there are biomechanical reasons for the knee's articular shapes. Specifically, it was thought that the radii of the anterior and posterior condyles would resemble a Fibonacci series and that the ratio would result in cruciate ligament tensions that would aid in maintaining knee stability at full extension.

Introduction

The knee is a compound synovial joint consisting of the tibiofemoral and patellofemoral joints. The former articulates in a manner that is consistent with the lengths and orientations of the cruciate ligaments. The anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) form a four-bar linkage (Figure 1).

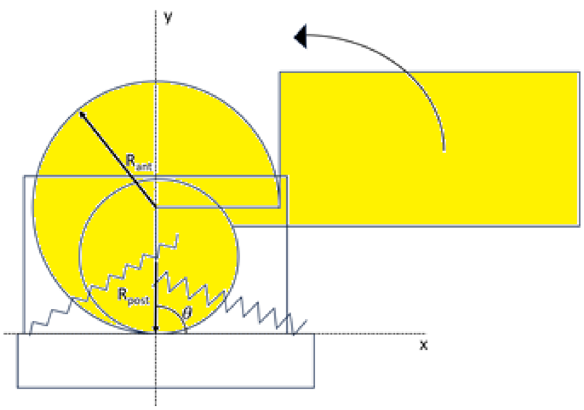

Figure 1. A sagittal plane model of the knee was created that allowed for, (i) sliding and rotation of the femur (shown in yellow) relative to the tibia, (ii) recreation of the ACL and PCL ligaments as a crossed four-bar linkage, and the ability to change the curvatures of the femoral condyles

In this study, we investigated the (i) distal antero- and posterior femoral curvatures, and (ii) the effects of changing the ratio of the articulating surfaces of the femoral condyles on the forces experienced on the ACL and PCL.

Methods

Data were obtained from twenty-three de-identified CT images of juvenile tibiofemoral joints without any knee pathologies and no bony abnormalities [1] All CT images were obtained from Akron Children's Hospital between 2016 and 2020 and were taken on a Toshiba Aquilion One. Measurements from landmark formations on the femoral condyles were used to create a coordinate system for the cruciate ligaments (with the level of adductor tubercle being the x-axis, and the periosteum of the femoral shaft the y-axis). The center of the ACL and PCL was found using the corresponding length and widths [2]. Subsequent knee models were created in ADAMS multibody analysis software. This allowed for ratios of posterior and anterior condylar radii to depart from the anatomical values.

Results and Discussion

For the lateral and medial femoral condyle measurements by Mallinos et al., (2023), the ratios of the anterior and posterior radii (Table 1) were 1.44 and 0.95 respectively. These are not statistically different from the Fibonacci ratios of 1 and 1.50. When the radii of the model were made according to the Fibonacci ratio, the ACL experienced an increase in force whereas the PCL decreased in force (Table 1). The ACL experienced an 8.07% increase in force and the PCL decreased by 8.96%. At full extension, the ACL had a peak tension of 559 N and the PCL had a peak tension of 2281 N. The Fibonacci model's PCL experienced less force than the ratio of unity model by an average of 3%.

Table 1. Knee ligament forces at varying curvature ratios.

Knee Models with varying ratios of Rant / Rpost				
	Angle	Ratio= 1	Ratio =1.44	Ratio =1.618
Peak ACL Tension (N)	80°	318	454	492
	90°	416	523	559
	100°	510	572	623
Peak PCL Tension (N)	80°	1697	1883	1618
	90°	2349	2571	2281
	100°	2989	3043	2926

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References

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