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Paper #24

# In Vivo ACL Bundle Elongation Shows Complex Change During Walking and Running: Analysis Using Biplane Radiography System

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**Summary**:
This novel study investigating in vivo ACL bundle elongation over the full gait cycle during walking and running demonstrated that ACL elongation was dependent upon the type of activities, and that knee flexion angle alone was not sufficient to predict the complex ACL elongation during dynamic functional activities.

**Abstract**:

### Introduction

Direct measurement of in vivo anterior cruciate ligament (ACL) elongation is challenging and has only been accomplished using invasive procedures. By using a less invasive technique with MRI and biplane radiography, ACL elongation during quasi-static lunge and slow walking has been reported; however, ACL elongation during more dynamic activities such as walking and running remain unknown. Thus, the purpose of the present study was to investigate in vivo ACL (anteromedial bundle [AMB] and posterolateral bundle [PLB]) elongation over the full gait cycle during walking and running using a highly accurate biplane radiography system. The hypotheses were that (1) the maximum ACL bundle elongations during running would be greater than walking, (2) anterior tibial translation would be correlated with the ACL elongation during the stance phase.

### Methods

Ten healthy volunteers without any prior knee injuries (27 ± 4 y.o.) walked and ran at a self-selected pace (1.4 ± 0.2 m/s and 2.6 ± 0.4 m/s respectively) on an instrumented treadmill while biplane radiographs of the knee were acquired at 100 Hz (walking) and 150 Hz (running). Tibiofemoral kinematics were determined using a validated model-based tracking process that matches subject-specific 3D bone models to the biplane radiographs. The boundaries of femoral and tibial ACL insertions were identified using high-resolution MRI, then divided into AMB and PLB. The AMB and PLB centroid-to-centroid distance was calculated from the tracked bone motions during walking and running, and these ACL bundle lengths were normalized by their respective lengths during MRI. A paired t-test was performed to explore the difference in maximum ACL bundle elongation (%) between walking and running. Stepwise multiple regression was performed to explore the relationship between the ACL bundle elongations and the 6 degree-of-freedom kinematics during stance and swing phases. Significance was set as $P < 0.05$.

### Results

The AMB elongation had one peak, while PLB elongation had two peaks during the stance phase of walking and running. The maximum AMB elongation during running (6.7 ± 2.1%) was significantly greater than walking (5.0 ±

Paper #24

1.7%) (P =.044), while the maximum PLB elongation during running (1.1 ± 2.1%) was significantly smaller than walking (3.4 ± 2.3%) (P =.015). Multiple regression analysis showed that ACL bundle elongations were correlated with not only knee flexion angle but also other kinematic variables such as anterior tibial translation and internal tibial rotation during the stance phase. Even at the same knee flexion angle, ACL bundle elongations varied along the different phases of the gait during walking and running.

## Conclusion

In vivo ACL bundle elongations were dependent upon the type of functional activities, and the complex relationship between the ACL bundle elongation and knee kinematics were observed. Knee flexion angle alone was not sufficient to predict the complex elongation pattern of the ACL bundles during dynamic functional activities. These findings suggest that loading plays a significant role in ACL bundle elongations in vivo.

CLINICAL RELEVANCE: The current novel findings are valuable for improving ACL reconstruction, injury prevention and rehabilitation protocols, and for developing knee musculoskeletal computational models.