INTRODUCTION
The anterior cruciate ligament (ACL) has two distinct bundles, the anteromedial (AM) and posterolateral (PL) bundle, which work in concert throughout the range of motion of the knee to provide anteroposterior and rotational stability. There is a known association between ACL injury and future development of osteoarthritis (OA). Anatomic ACL reconstruction is designed to restore the native function of the ACL and can include one or both bundles. Previous dynamic studies have shown that knees, which have undergone single bundle ACL reconstruction are in more varus and more externally rotated than ACL intact knees during downhill running [1]. Abnormal knee kinematics are thought to induce an early onset of OA [2]. There is some evidence that double bundle ACL reconstruction more accurately restores rotation when compared to single bundle reconstruction. The purpose of this study was to compare in vivo knee kinematics after anatomic double bundle ACL reconstruction with intact native ACL during decline running and level walk.

METHODS
Ten patients four to 23 months following anatomic double bundle ACL reconstruction were recruited for this IRB approved study. High resolution CT scans of both knees were obtained and used to created 3D models of the femur and tibia. Biplane radiographic images were acquired at 150 frames per second during decline running and 100 frames per second during level walking. Images were collected for three trials per limb per activity. Using custom software, digitally reconstructed radiographs of 3D bone models were correlated with the biplane radiographic images to create 3D models of and track tibiofemoral motion with precision of ±0.2mm or better (Figure 1).

RESULTS
Comparing the intact ACL to anatomic double bundle ACL reconstruction no significant differences were found between limbs during decline running (affected limb mean ± std error, control limb mean ± std error, p value) in mean AP translation (10.4±1.3mm, 9.4±1.4mm, p=0.135), ML translation (1.2±0.7mm, 1.1±0.6mm, p=0.9), ab/adduction (-0.2±0.8°, -1.0±0.9°, p=0.06), internal/external rotation (2.7±2.2°, 2.6±1.0°, p=0.9). Additionally, no significant differences were found between limbs during level walking (affected limb mean ± std error, control limb mean ± std error, p value) in mean AP translation (8.3±1.1mm, 7.7±1.2mm, p=0.4), ML translation (1.4±0.6mm, 1.3±0.3mm, p=0.95) (Figure 2), ab/adduction (0.0±0.9°, 0.1±0.9°, p=0.71), internal/external rotation (-1.3±1.5°, -1.0±1.2°, p=0.85).

DISCUSSION
In this limited sample, anatomic double bundle ACL reconstruction restored the knee kinematics of the ACL intact native knee during level walking and decline running. The persistent varus and external rotation found previously following single bundle reconstruction was not seen following anatomic double bundle ACL reconstruction. It is possible that the addition of a distinct PL bundle, which is tightest in extension, helps to restore normal joint kinematics at the lower knee flexion angles seen following heel strike. Because the differences in ab/adduction between limbs during decline running approached significance (p=0.06) a larger sample size is needed to confirm the restoration of normal joint kinematics in anatomic double bundle ACL reconstruction. In addition, long-term follow up is needed to assess for the effect of restoring kinematics on future development of osteoarthritis.

SIGNIFICANCE
The present in vivo study provides evidence that anatomic double bundle ACL reconstruction restores knee kinematics during daily activities back to normal. The primary impact on cartilage and changed knee kinematics after ACL injury are thought to induce early onset of OA and thus, restoring normal knee kinematics by anatomic double bundle ACL reconstruction might prevent the early onset of knee osteoarthritis.

REFERENCES

Figure 1: Radiographs were recorded during daily activities such as level walk and decline run using two biplane, high-speed cameras. The radiographs were superimposed to 3D CT bone models, and 3D knee joint motion data were analyzed.

Tibiofemoral kinematic data points including medial/lateral and anterior/posterior translation, ab/adduction, and internal rotation were extracted every 20ms. Statistical analysis of the 100ms following heel strike, the period of highest joint loading, was performed using within-subject repeated measures ANOVA (SPSS GLM) with α=0.05 to evaluate differences between limbs.

Figure 2: Anterior-posterior translation and external-internal rotation during decline running. The average data of reconstructed knee (ACL double bundle) (red) and of contralateral uninjured, control knee (blue) are plotted. Error bars indicate the standard error.