INTRODUCTION:
Quantitative knowledge of the male and female knee biomechanics is important for understanding gender related dimorphism in knee pathology and advancing related surgical treatments such as total knee and patellofemoral arthroplasty. Previously we reported on gender differences in the rotational kinematics of the tibiofemoral joint, including more external tibial rotation at low flexion and greater range of tibial rotation in females [1]. Based on these results we hypothesized that gender differences in the rotational kinematics of the tibiofemoral joint may affect the in vivo patellar tendon orientation and patellar tracking. In this study, we investigated the 3D orientation of the patellar tendon (PT) and patellofemoral (PF) kinematics in healthy male and female knees during weight-bearing knee flexion-extension.

METHODS:
Eighteen male (age 31.2 ± 11.0 yrs) and thirteen females (age 29.8 ± 9.9 yrs) were recruited for this study following IRB approval and informed patient consent was obtained. Magnetic resonance images of the subjects’ knee were obtained using a 3.0T magnet and used to construct 3D models of the knee, including tibia, femur and patella. Additionally, the insertion sites of the PT at the tibial tubercle and the patella were also identified. Next a dual fluoroscopic system was used to image the knee as the subject performed a single leg lunge from full extension to maximal flexion. The 3D models of the tibia, femur and patella were then imported into a virtual environment and matched to their projections on the fluoroscopic images to recreate the knee motion [2]. The insertion sites of the PT on the tibial tubercle and the patella were divided into three portions and joined together using straight lines to represent the medial, central and lateral portions of the PT. Changes in the 3D orientation of the PT were measured using the image matched models of the patella and tibia. Sagittal and coronal plane orientations of the PT were measured relative to tibial long axis, and transverse plane orientation (twist) was measured relative to tibial mediolateral axis, defined as line joining the medial and lateral plateau centers [2]. The kinematics of the patella relative to the femur was measured from the image matched models of the femur and patella. Patellar tilt and rotation were defined as angles between femoral transpectondylyar axis and patellar mediolateral axis, projected onto the transverse and coronal planes of the femur, respectively. Mediolateral motion of the patella was defined as motion of patella center along femoral transpectondylyar axis [3]. Measured parameters were compared between male and female knees using t-test for independent samples with significance level taken as p ≤ 0.05.

RESULTS:
In the sagittal plane, females showed greater anterior orientation of the central portion of the PT at 30° flexion (15.3° vs. 11.8°, p = 0.02), and the lateral portion of the PT at 0° (22.0° vs. 17.4°, p = 0.031) and 30° flexion (13.3° vs. 9.6°, p = 0.01). In the coronal plane, the female PT was oriented significantly more medially at 0°, 30°, 60°, 90° and 105° flexion (p < 0.04, Fig. 1). Females also showed greater external twisting (internal = +ve) of the PT at 30° (6.6° vs. 6.1°, p = 0.015) and 105° flexion (12.6° vs. 17.0°, p = 0.024). Patellar flexion and patellar tilt were similar between the genders (p ≥ 0.19 and p ≥ 0.24, respectively). However, females showed slightly more mediolateral patellar shift at 75° (6.0 mm vs. 7.9 mm, p = 0.037) and 90° flexion (6.4 vs. 8.6 mm, p = 0.023). When normalized by femoral mediolateral size there continued to be a trend towards greater mediolateral patellar shift in females. This was however not statistically significant (p ≥ 0.11). In females, a trend towards more valgus patellar rotation at low flexion angles was also noted. However, this gender difference was not statistically significant (p ≥ 0.06, Fig. 2).

DISCUSSION:
Statistically significant gender differences were observed in the three-dimensional orientation of the patellar tendon. Both the greater medial orientation and the increased external twisting of the PT in females are consistent with our previous study, which showed that female knees were more externally rotated (females 5.1° vs. males 1.3°, at full extension) [1]. Increased external rotation of the tibia would place the tibial tubercle in a more lateral and externally rotated position relative to the patella. This would lead to a greater medial orientation and increased external twisting of the PT in female knees. In vitro studies have suggested that increased external rotation of the tibia and the resultant increase in the lateral pull of the patellar tendon can increase the contact pressure on the lateral patellofemoral facet [4,5]. The effect of the gender differences seen herein on the in vivo patellofemoral contact pressures remains to be investigated.

While patellar flexion and patellar tilt were similar between male and female knees, subtle gender differences were noted in patellar mediolateral shift and patellar rotation. Females showed a trend towards slightly greater medial patellar shift and valgus patellar rotation at low flexion. However, these differences were not statistically significant. Future studies with larger sample sizes may be required to investigate these observations further. These data regarding PT orientation and PF kinematics could aid in the analysis of factors that underlie the increased risk of patellofemoral problems in females, the improvement of surgical procedures and the design of implants for arthroplasty.

REFERENCES
[1] Li G et al. Trans 54th Annual ORS Meeting, 2008, paper #189