INTRODUCTION: The normal function of the knee joint depends on the interaction of muscles, ligaments and articulating surfaces that act to balance the displacement forces. While the greatest mobility of the joint is in the sagittal plane (flexion – extension) mobility in the other degrees of freedom (coupled motion) is essential for its normal function. For instance, it has been shown that without accompanying motion in the transverse plane (posterior translation of the femur and internal rotation of the tibia) the range of knee flexion will be significantly limited. The term Center of Rotation (COR) of the knee has been introduced to describe the rotational motion in the transverse plane [1]. Asymmetry in the motion of the medial and lateral compartments determines the location of the COR. For example, greater motion in the lateral compartment will place the COR to the medial side (medial pivot) [2] whereas others found the knee to pivot laterally [1]. It has been suggested that knee motion is activity dependent and that the center of rotation might change its location depending on the loading condition [3]. In this study we intended to investigate whether the knee joint is subjected to medial or lateral pivot during common daily weightbearing activities (gait, stair climb, chair rise). This was done by comparing the excursions of the medial and lateral femoral condyles.

MATERIAL AND METHODS: Uninjured knees of eight subjects were tested during various activities with a dual fluoroscopic imaging system (DFIS). First, three-dimensional (3D) models were obtained by digitally outlining bony contours of the tibia, fibula and femur on MR images in solid modeling software. Each knee was then imaged using the DFIS during walking on a treadmill (at 1.5 mph), step ascent and chair rise. Next, the 3D models and the pairs of fluoroscopic images were imported into the modeling software where a virtual fluoroscopic environment was created reproducing the position of the fluoroscopes at the time of scanning. The in vivo positions of the tibia and femur were then reproduced by matching the projections of the tibial and femoral models to the fluoroscopic images. For each studied activity, the knee position was analyzed at every 10% of the activity performed. The medial and lateral pivot was determined by tracing the motions of the condylar centers located on the transepicondylar axis of the femur in the anteroposterior direction (Figure 1).

RESULTS: A medial pivot was observed during chair rise as the lateral femoral condyle demonstrated greater range of excursions in the anteroposterior direction than the medial femoral condyle (39.7±11.5 mm vs. 29.0±7.0 mm, respectively, p=0.03). Step ascent also resulted in a greater anteroposterior range of motion of the lateral femoral condyle (27.2±0.7 mm) than that of the medial condyle (18.0±4.1 mm, p=0.01). On the contrary, during walking, the anteroposterior excursions of the condylar centers when measured using the transepicondylar axis were significantly greater for the medial condyle (9.7±3.7 mm, Figure 2) than for the lateral condyle (4.0±2.7 mm, p=0.01).

DISCUSSION: The results of this study showed that during daily weightbearing activities the knee joint is subjected to both medial and lateral pivot motions. The type of pivot was activity dependent. During static activities such as stair climbing and chair rise, the knee exhibited greater lateral condylar motion implying medial pivot with the COR being located on the medial side of the joint, while during locomotive activity (gait) the knee was observed to pivot laterally with the COR located on the lateral side of the joint. These findings not only provide insight into the in vivo function of the knee but also reveal a possible factor contributing to failure of the contemporary joint replacement implants and ligament reconstruction techniques to restore the native knee motion since their design is aimed at restoration of rollback and medial pivot.

REFERENCES:

This study was financially supported by a grant from the National Institutes of Health (R01AR055612).