

The static knee adduction moment measured from static radiographs correlates with dynamic moments measured during gait

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INTRODUCTION: Most failures of total knee arthroplasties (TKA) have a mechanical origin [1]; therefore, understanding the knee joint loads is of paramount importance to improve implant longevity. Nevertheless, routine presurgical planning for TKA remains focused on restoring alignment without considering its effects on joint loading. The knee adduction moment (KAM) is the most important biomechanical marker for the medial-lateral load distribution between knee compartments. However, measuring the KAM requires a costly, time consuming, and highly specialized test in a dedicated motion analysis laboratory (MAL), hampering its routine clinical use. As a first step in developing a radiographic-based static KAM measure to routinely evaluate TKA patients, our goal was to determine if the static KAM obtained radiographically can be used as a surrogate of dynamic knee joint loading.

METHODS: Four male TKA patients (age 48–76 years, BMI 22.6–30.3 kg/m²) were enrolled in this IRB-approved pilot study and walked barefoot preoperatively and 6 weeks postoperatively in our institution's MAL. We simultaneously measured whole-body kinematics by tracking skin surface reflective markers with 12 cameras at 100 Hz (Motion Analysis Corporation, Santa Rosa, CA) and ground reaction forces (GRF) with four floor-embedded force plates at 2,000 Hz (AMTI, Watertown, MA; Bertec, Columbus, OH). Marker data and GRF were low-pass filtered at 50 Hz using Butterworth filters with phase correction. We calculated the dynamic KAM in the tibial frontal plane [2] by multiplying the GRF and the perpendicular distance from its line of action to the knee center, defined as the midpoint between medial and lateral epicondylar markers. The same four patients underwent standard-of-care biplanar radiographs at the same timepoints during bipedal and single leg stance (Fig. 1). Radiographs were synchronized with force plate measurements of each leg's GRF (ACS Dual, AMTI, Watertown, MA). The radiographic KAM was computed in the frontal plane by multiplying the GRF and its distance to the knee center, defined similarly to the dynamic KAM from the same epicondylar skin markers that were retained from the MAL. We compared the peak dynamic KAM (wherever it occurred during the gait cycle) against the static radiographic KAM during both bipedal and single leg stance.

RESULTS: Preoperatively, the dynamic KAM range was 2.4%–4.4% of the subject's bodyweight (BW) times height (Ht), and only two subjects exhibited the "double-peak" profile characteristic of healthy gait (Fig. 2-a). Postoperatively, the dynamic KAM was lower (1.6%–2.9% BW·Ht), and only one subject retained the double-peak profile (Fig. 2-b). For all subjects and timepoints, the radiographic KAM during single leg stance (preoperative: 0.8%–4.6% BW·Ht; postoperative: 1.8%–3.4% BW·Ht) was larger and showed better correspondence with the dynamic KAM (Fig. 3) than during bipedal stance (preoperative: 0.4%–1.0% BW·Ht; postoperative: 0.4%–2.0% BW·Ht).

DISCUSSION: In our initial clinical study, we observed a promising correspondence between the radiographic static KAM during single leg stance and the peak dynamic KAM during gait. While the sample size was small, the single leg KAM obtained showed a strong correspondence with the peak dynamic KAM, especially postoperatively and can be a promising metric to quantify the burden placed in the knee after TKA. Our next steps include increasing the sample size and analyzing other timepoints in the gait cycle.

SIGNIFICANCE/CLINICAL RELEVANCE: (1-2 sentences): Radiographic measurement of the KAM with standard of care radiographs has the potential of enhancing current radiographic evaluation of TKA patients with gait-level metrics of joint loading.

REFERENCES: [1] AJRR Annual Report, 2022; [2] Shull, et al., J Biomech. 2013.

IMAGES AND TABLES:

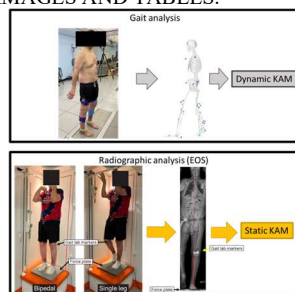


Fig. 1 – Gait and radiographic analysis to measure the dynamic and static KAM.

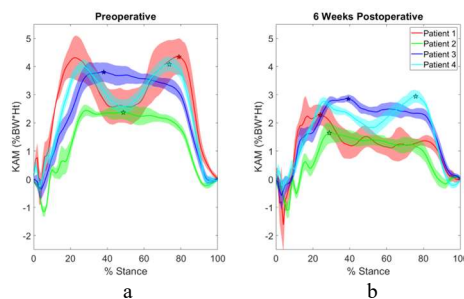


Fig. 2 – (a) preoperative and (b) postoperative dynamic KAM.

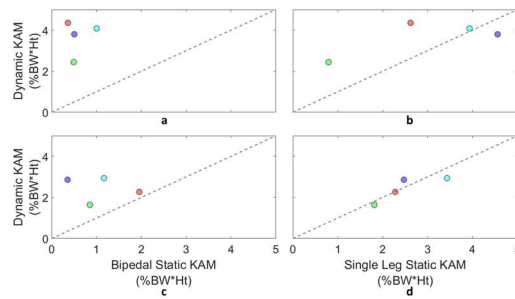


Fig. 3 – Comparison of the static and peak dynamic KAM for the four subjects preoperatively (a–bipedal; b–single leg) and 6 weeks postoperatively (c–bipedal; d–single leg). Each color represents a different subject.