INTRODUCTION: Incidence of knee joint OA, especially on the medial side that often carries larger share of internal compression in gait, is rising with ageing and obesity in population. Knee adduction moment (KAM) is commonly introduced as a surrogate measure of load on the medial plateau and hence as a marker the reduction of which is the main focus of various interventions (e.g., orthoses, shoe insoles, gait modification, osteotomy) that aim to prevent the development and progression of OA. However, some recent in vivo studies using instrumented implants have questioned such direct relationship and qualified the correlation between KAM and the medial compartment load as poor to average [1, 2]. Similarly, questions have been raised on the association between pain/symptoms and reduction in KAM when wearing wedged insoles [3]. We use here a lower extremity hybrid musculoskeletal model [4] driven by gait kinematics-kinetics of asymptomatic subjects to compute the effects of changes in the knee adduction rotation (KAR) (by one standard deviation, ±SD) versus changes in KAM (by one ±SD) on the knee joint response in general and medial/lateral load partitioning in particular. It is hypothesized that the internal load distribution is influenced by changes in KAR than in KAM.

METHODS: A validated finite element model of the entire knee joint consisting of bony structures and their compliant articular cartilage layers as well as menisci, major tibiofemoral (TF) (ACL, PCL, LCL, MCL) and patellofemoral (MPFL, LPFL) ligaments and patellar tendon is used [4]. Cartilage and menisci tissues are represented by nonlinear depth-dependent fibril-reinforced tissues while ligaments are modeled with nonlinear properties in tension and initial strains. This detailed knee model is introduced in a musculoskeletal model of the lower extremity including uni- and bi-articular muscles as well as hip (3D) and ankle (1D) as frictionless spherical joints. Muscle forces are evaluated iteratively with optimization and applied as additional external forces along with ground reaction forces, leg/foot weights and in vivo kinematics/kinetics reported for asymptomatic subjects [5] at stance phase of gait. To investigate the effect of changes in KAR and KAM on results, analyses are repeated under identical kinematics and kinetics except that KAR or KAM is altered one at a time at each stance period by one ±SD based on reported measurements [6] (see Fig. 1 for KAM).

RESULTS: Unlike quadiceps and gastrocnemius forces, forces in hamstrings altered substantially as KAR varied. Overall, larger KAR markedly increased forces in medial hamstrings but reduced those in lateral hamstrings at all periods of stance. The effect was less pronounced when changing KAM. Changes in KAR, unlike KAM, had substantial effects on compartmental loads and medial/lateral load partitioning ratio; an increase in KAR rotation markedly increased this ratio by augmenting load on the medial compartment while at the same time reducing that on the opposite lateral compartment (even to nil) (Fig. 2). Reverse trend was found when KAM decreased. Changes in KAM had however much smaller and less consistent effects (Fig. 3).

DISCUSSION: Computed results clearly support the hypothesis that the internal load distribution in knee joint is influenced mainly by changes in KAR when compared to equivalent changes in KAM and this despite similar variations by one ±SD in measured data of both measures. Changes in KAR alone substantially alter forces in medial and lateral hamstrings and the medial/lateral load partitioning ratio; this ratio markedly increases as KAR increases and diminishes as KAR decreases (Fig. 2). Such dramatic changes are due solely to the substantial alterations in the passive moment resistance of the knee joint in the frontal plane as KAR varies [7, 8]. For example at 75% stance, the drop in KAR reduced the medial contact force by 25% and the medial/lateral load and contact area ratios by 65% and 40%, respectively, while the equivalent decrease in KAM reduced those same measures by 1%, 35% and 8%, respectively. These results clearly demonstrate that the relative partitioning and absolute inter-compartmental contact loads are influenced primarily by changes in KAR and only slightly by changes in KAM. As a consequence and for effective assessments, the present findings emphasize the importance of recording KAR and tibiofemoral alignment [9] and changes therein in various interventions that aim to reduce the joint medial load.

SIGNIFICANCE: Alteration in KAR markedly influences active and passive response of the knee joint. In particular and during all periods of stance, larger or smaller KAR significantly increases or decreases the medial/lateral load partitioning ratio, respectively. Changes in KAM has, however, much smaller and less consistent effects. These findings explain the poor correlation between KAM and tibiofemoral compartment loading suggesting that KAR should instead be used as the primary measure of joint loading and treatment outcome.