studies will focus on the how effects such as anatomical differences, obesity, and sarcopenia (each of which are risk factors for knee OA) potentially affect the detailed dynamic mechanics of each component of the knee joint.

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MECHANICAL PROPERTIES OF BABOON CARTILAGE DEMONSTRATE A SIMILAR DECLINE WITH AGE AS HUMAN CARTILAGE

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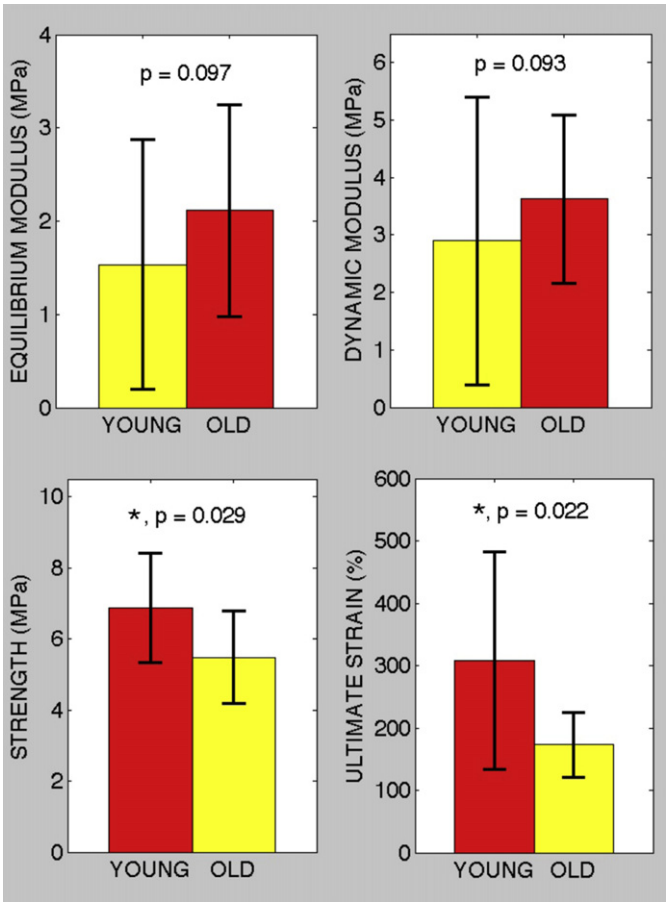
Purpose: Osteoarthritis (OA) is the most common form of arthritis and the major cause of activity limitation and physical disability in older people. It is widely believed that OA results from the local mechanical environment of the joint and, particularly, the cartilage, in combination with systemic susceptibility to the disease. Preliminary study of knee OA in the baboon demonstrated that knee OA occurs commonly and naturally in male and female adults and the frequency of OA in older baboons is comparable to that in older humans. The objectives of this study were to evaluate whether the mechanical properties of baboon cartilage follow similar trends with age and sex as humans, and whether the presence of affected cartilage leads to mechanical property degradation.
Methods: Sample groups were established based on combinations of age (i.e. young/old), sex (i.e. male/female), and overall femur OA status (i.e. affected/unaffected) (target $n = 5$ in each group combination). Baboons were categorized as young for age > 15 years (developmentally equivalent to 45 human years) and old for age > 22 years (developmentally equivalent to 66 human years). Overall femoral condyle OA status was determined based on established cartilage grading methods. Knee cartilage was obtained from the medial portion of the distal condyle of baboon right femurs collected at routine necropsy at the Southwest National Primate Research Center/Texas Biomedical Research Institute. Dogbone-shaped tensile specimens were prepared with the gage region oriented perpendicularly with the primary direction of collagen orientation. Specimens were kept hydrated and loaded under displacement control to 10% and 20% strain at 0.25%/sec and allowed to stress relax until equilibrium was reached, and finally loaded to failure. Equilibrium tensile modulus, dynamic tensile modulus, peak stress (strength) and strain at the point of peak stress were determined from the normalized load-displacement data. Wilcoxon rank sum tests were used to evaluate statistical significance of group differences.
Results: There were significant decreases between the young and old specimens in strength and strain at peak stress (Figure 1). Equilibrium modulus and dynamic modulus demonstrated increased stiffness for cartilage specimens from old animals; however, these differences were not statistically significant (Figure 1). Differences in cartilage properties based on sex and OA status were not statistically significant ($p > 0.187$ in all cases and $p > 0.259$ in all cases, respectively).
Conclusions: Despite the small sample sizes used in this study, statistical differences were demonstrated between cartilage specimens obtained from young and old baboons in both strength and the strain at peak stress. It is well documented that cartilage mechanical properties demonstrate decline with age in humans and our demonstration that baboon cartilage properties behave in a similar fashion further justifies the use of the baboon as a model for the human osteoarthritic condition, in addition to the physiological similarities between species. We expect that results obtained from larger sample sizes of cartilage specimens obtained from locations throughout the baboon knee joint will further elucidate the effects of age, sex, and OA involvement on the functional behavior of cartilage.



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KNEE JOINT LOADING RATE DURING WALKING AND DEGENERATIVE CHANGES ON MRI

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Purpose: The knee adduction moment (KAM) is an indicator of medial tibiofemoral loading during walking, and has been associated with the severity and progression of knee OA (osteoarthritis). While the KAM peak and impulse have been explored, the KAM loading rate has not yet been studied in relation to knee joint degenerative changes. This study aims to determine if there is a relationship between the KAM loading rate during walking and the severity of medial knee joint degenerative changes on MRI, and secondarily to compare the KAM loading rate to the KAM peak and impulse.
Methods: Research subjects were part of a study comparing knee loading in transfemoral amputees with age- and weight-matched non-amputee controls. All subjects underwent unilateral knee magnetic resonance imaging (MRI). The MRI scanning protocol and scoring of MRIs utilized the previously validated whole-organ magnetic resonance imaging score (WORMS) semiquantitative scoring methodology. Fourteen independent articular features were scored. The five features related to cartilage and bone characteristics were evaluated in 15 anatomical regions of the knee. Medial tibiofemoral joint sub-score was subsequently calculated. In addition, kinematic and kinetic data were collected while subjects walked at a controlled speed of 1.10 m/s (+/- 10%) in a motion analysis laboratory. Knee joint moments were calculated using a standard inverse dynamics approach, the magnitude of the peak KAM was identified, and the net positive impulse of the KAM was calculated. KAM loading rate was calculated as the maximum instantaneous value of the differentiated and smoothed KAM curve from gait initiation to the first KAM peak. Linear mixed effects regressions were carried out to assess the relationship between biomechanical loading variables and medial knee joint degeneration as represented by the medial tibiofemoral WORMS score. Additionally, the above models were carried out adjusting for weight or select KAM measures by adding these variables as independent covariates. Results are presented as slope of change in KAM per increase in WORMS score.
Results: Twenty-eight subjects (mean +/- SD age: 56.0 $\pm$ 8.7 years; weight: 83.3 $\pm$ 10.5 kg) were studied, including 14 amputees and 14 matched controls. Since there were no significant differences between amputee and control subjects in age, body weight, walking speed or biomechanical loading variables, all subjects were analyzed together. Subjects had a wide range of WORMS scores, with distribution of medial versus lateral tibiofemoral degeneration consistent with prior literature. Overall, there were statistically significant correlations between

medial tibiofemoral joint degeneration (as measured by medial WORMS score) and peak KAM (slope = 0.42 ± 0.20; P=.037) as well as KAM loading rate (slope = 12.3 ± 3.2; P=.0004). These relationships continued to be significant after adjusting for body weight (respective p-values of .019 and .0004). The relationship between medial WORMS score and KAM loading rate continued to be significant even after adjusting for peak KAM (P=.0001). However, the relationship between medial WORMS score and peak KAM was no longer significant after adjusting for KAM loading rate (P=.2). The relationship between medial WORMS score and KAM impulse was not statistically significant, even prior to adding covariates to the regression analysis (slope = 0.10 ± 0.10; P=.3).

Conclusions: These results provide insight into the dynamic loading characteristics associated with knee OA and support the hypothesis that KAM loading rate is strongly associated with the degree of medial tibiofemoral joint degeneration independent of KAM peak and impulse. This has potential implications for the development of treatments aimed at slowing the progression of knee OA. Further prospective designed studies could explore the potentially causal link between KAM loading rate and knee OA.

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HIP ABDUCTOR FUNCTION IN INDIVIDUALS WITH KNEE OSTEOARTHRITIS: IMPLICATIONS FOR MEDIAL COMPARTMENT LOADING DURING GAIT

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Purpose: Hip abductor muscles generate moments of force that control lower extremity coronal plane motion. Strengthening these muscles has been a recent trend in therapeutic intervention studies for knee osteoarthritis based on the theory that hip abductor strength influences knee joint loading. The current study investigated the relationship between hip abductor muscle function (strength and activation) and the net external knee adduction moment during gait in those with medial compartment knee osteoarthritis.

Methods: 54 individuals with moderate knee osteoarthritis walked at their self-selected velocity while gluteus medius electromyograms, lower extremity segment motions and ground reaction forces were recorded. The net external knee adduction moment (KAM) was calculated and amplitude normalized to body mass. Linear enveloped electromyographic profiles were generated and amplitude normalized to maximal voluntary isometric contraction amplitudes. Peak KAM was determined. Principal component analyses were applied to the KAM and electromyographic profiles. Hip abductor strength, subject anthropometrics and gait velocity were measured. Multiple regression models evaluated the relationship between anthropometric, velocity, strength and electromyographic variables and the KAM waveform characteristics. Statistical significance was determined at alpha = 0.05.

Results: A significant positive relationship was found between hip abductor strength and peak KAM (R2=16%, P=0.003). Walking velocity, early stance phase gluteus medius activity (PP2-scores) and height were positively associated with an increased difference between early and late stance KAM (PP2-scores)(R2=60%, P<0.001). Greater overall gluteus medius amplitudes were positively related to greater mid-stance net adduction moments (PP3-scores) (R2=16%, P=0.003).

Conclusions: Hip abduction muscle strength and gluteus medius activation characteristics explained significant variability in specific KAM variables during gait in individuals with moderate knee osteoarthritis. However; a large percentage of the variability was not explained by these variables, thus altering hip muscle function is only one small contributor to KAM characteristics.

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INTEGRATION OF DYNAMIC MECHANICAL ASSESSMENT IN THE MANAGEMENT OF KNEE OSTEOARTHRITIS PATIENTS

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Purpose: Dynamic local mechanical factors are known to be preponderant in the proximate progression of knee osteoarthritis (OA). However, it is difficult for physicians to address these factors in their clinical decision-making process due to the lack of easy-to-use measurement tools. A novel knee biomechanical assessment device (KneeKG™) validated for measuring 3D knee kinematics (flexion-extension; varus-valgus; internal-external tibial rotation) has shown utility for accurate measurement of knee function and objective quantification of the effect of conservative treatments. The purpose of this study was to determine if this assessment device can easily be integrated in a clinical setting and used by physicians to identify and address mechanical disorders involved in the development and progression of knee OA.

Table 1
Patient Characteristics

Number of patients	73
Female (%)	57 (78%)
Mean age (SD)	59.1 (11.1)
Mean Body mass index (SD) kg/m^2	29.1 (5.2)
Waist (SD) cm	99.8 (13.0)
Number of knee with Med Comp OA (Grade III-IV on KL scale)	97 (58)
Number of knee with Lat Comp OA (Grade III-IV on KL scale)	42 (14)
Number of knee with PF Comp OA (Grade III-IV on KL scale)	102 (25)
Total number of knees evaluated	109

Methods: 73 patients were recruited from a knee OA multidisciplinary program (Table 1). Weight bearing x-rays were used to grade the severity of OA according to the Kellgren-Lawrence (KL) classification. Local dynamic knee mechanical factors were assessed while the patient walked at comfortable speed on a treadmill with the KneeKG™ markers affixed to the knee. 3D kinematic data were automatically analyzed and a report generated highlighting known mechanical factors linked to the progression of knee OA. The patients were evaluated by 4 physicians in accordance with standard clinical protocols after which they were given a copy of the KneeKG™ report with the opportunity to comment and integrate the findings into their clinical decision-making process.

Results: The average duration of each evaluation was 20 minutes for one knee. Only 5 patients out of 73 (6%) could not perform the biomechanical assessment (3 due to inability to walk on a treadmill (mean age: 84 years old), 1 due to hyper-sensitivity of the skin, 1 due to attachment system not holding on the knee).

The initial clinical assessment of the remaining 68 patients indicated that static alignment was the main mechanical factor identified (fixed flexion in standing position, limb alignment). The physicians did not identify any dynamic mechanical deficits such as varus thrust or internal tibial rotation. After reviewing the KneeKG™ reports, the physicians concluded that 32 knees in 25 patients exhibited significant varus thrust (mean 3.3°, range 2.5° to 5.1°). The dynamic alignment (at initial contact, during loading or during stance) had a direct correlation to the affected knee compartment in 85% of the cases.

The clinical record of the 25 patients having a varus thrust showed modification of the initial treatment plan in order to address it, thereby indicating that the KneeKG™ report was interpreted and integrated by the physicians into their clinical decision-making process.

Conclusions: The assessment of local dynamic mechanical factors using the KneeKG™ allowed clinicians to address mechanical disorders that are involved in the proximate cause of knee OA and to enhance their therapeutic decision-making process in agreement with current clinical and scientific knowledge.

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REGAINING NORMAL AND SYMMETRICAL KNEE CONTACT FORCES AFTER ANTERIOR CRUCIATE LIGAMENT INJURY AND RECONSTRUCTION

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Purpose: To investigate longitudinal changes in knee contact forces after anterior cruciate ligament (ACL) reconstruction in order to better describe the time course of altered loading that may contribute to the development of osteoarthritis in these patients.

Methods: Six athletes (3 men, 3 women; age=33.6±10.4, BMI=25.6±2.0) with complete, unilateral ACL rupture were evaluated using motion analysis 6.3 (SD=4.9) weeks after injury (baseline) once initial impairments were resolved. Athletes underwent arthroscopic assisted ACL reconstruction an average of 13 (SD=8.4) weeks after injury and performed motion analysis 6, 12 and 24 months after ACL reconstruction. Motion analysis was used to obtain stance phase kinematics and kinetics at each testing session during natural cadence