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CHANGES IN KNEE JOINT LOADING INDICES FROM BEFORE TO 12 MONTH AFTER ARTHROSCOPIC PARTIAL MEDIAL MENISCECTOMY

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Purpose: Arthroscopic partial medial meniscectomy (APMM) may cause increased medial compartment knee joint loading. Increased medial compartment loading in APMM patients may be associated with high risk of knee osteoarthritis (OA). The aim of this study was to investigate potential changes in knee joint loading indices in the leg undergoing APMM compared to the contralateral un-injured leg from before to 12 month after APMM.

Methods: We investigated indices of knee joint loading using 3D gait analysis in 21 patients (15 men, mean [SD] 45.9 [6.4] years, 177 [8] cm, 81.3 [11.7] kg, 25.9 [3.6] kg/m2) undergoing APMM for a medial meniscus tear. All patients had no radiographic knee OA (i.e. K/L grade 0 or 1) in the leg undergoing APMM and in their uninjured control leg at the baseline assessment prior to surgery. Exclusion criteria were: previous knee surgery, back problems or other co-morbidities affecting lower extremity function, low activity level (i.e. only indoor walking). Walking gait data were collected (100 Hz) using a 6-camera Vicon MX system (Vicon, Oxford, UK) with the Plug-in-Gait marker set. Ground reaction forces were recorded in synchrony with the cameras (1000 Hz) using two force plates (AMTI, OR6-7-1000, Watertown, MA, USA). External peak knee adduction moment (KAM) and KAM impulse (i.e. the positive area under the KAM-time curve) were calculated using inverse dynamics and reported relative to body size (height and weight). Gait data were collected barefoot at patients' self-selected walking speed prior to APMM. Variables were calculated for each trial, and then averaged over five trials. At follow-up, 12 months after APMM, patients were instructed to walk at the same speed as baseline, allowing a margin of ± 5%. Paired t-tests were used to test for differences in change of knee joint loading indices between operated and contralateral legs from before to 12 month after APMM and to evaluate potential differences between the operated and contralateral legs at baseline.

Results: A significant difference in change, showing increased loading, in the operated compared to the contra-lateral leg was observed from before to 12 months after surgery in KAM impulse ($p=0.001$, Table 1). A tendency towards a larger increase in peak KAM was also observed in the operated compared with the control leg ($p=0.06$, Table 1). No differences in loading indices were observed between control knees and the knee undergoing APMM prior to surgery (peak KAM, $p=0.68$; KAM impulse, $p=0.52$).

Conclusions: The present data indicate that APMM is associated with increased medial compartment knee joint loading in comparison to the contra-lateral leg from before to 12 month after surgery. Further investigation is needed to determine if this change is influenced by changes in pain status or is the result of the APMM per se.

Table 1. Knee joint loading indices before and 12 month after APMM (n=21)

	Operated leg		Control leg		
	PRE	POST	PRE	POST	Difference in change*
Peak KAM (Nm/BW*HT%)	3.06 (2.81-3.31)	3.26 (2.91-3.62)	3.15 (2.74-3.57)	3.02 (2.64-3.40)	0.34 (-0.01-0.70)
KAM impulse (Nms/BW*HT%)	1.15 (1.03-1.28)	1.31 (1.15-1.47)	1.22 (1.06-1.37)	1.18 (1.01-1.35)	0.19 (0.09-0.30)

Values are mean (95% CI)

APMM = Arthroscopic Partial Medial Meniscectomy, KAM = external Knee Adduction Moment

*Difference in change between PRE-POST changes in the operated vs. control leg.

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PROSPECTIVE CHANGES IN THE KNEE JOINT CENTER OF ROTATION RELATIVE TO THE CONTRALATERAL KNEE AND OVER TIME PROVIDE A COMPREHENSIVE VIEW OF KINEMATIC CHANGES FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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Purpose: Although anterior cruciate ligament (ACL) reconstruction surgery successfully restores knee stability, approximately 50% of ACL reconstructed (ACLR) patients progress to detectable radiographic osteoarthritis (OA) at 10-15 years after injury. Several studies have identified common kinematic changes to the internal-external (IE) rotation angle of the knee during walking following ACLR. It has been suggested that these kinematic changes can shift the location of the repetitive joint contact loads occurring during walking to regions of cartilage not conditioned for altered load; and if cartilage in new regions cannot adapt to the altered load, a degenerative pathway is initiated. Given the potential importance of kinematics in the development of OA following ACL injury, it is useful to consider assessing changes in the center of rotation (COR) in the plane of the tibial plateau since this measure provides a more comprehensive assessment of both translation and rotation. Further, given the fact that only 50% of patients with ACLR develop OA, it is possible that over time some patients adopt changes in gait mechanics that change the position of the COR. Thus, the purpose of this study was to test the hypothesis that there are differences in the COR between the ACLR and contralateral knee, and that the COR of the ACLR knee would change between 2 and 4 years post-surgery.

Methods: Twenty-six participants (31±6.3 years old, 1.72±0.08 m, 73.5±11.3 kg, 2.6±1.9 months between injury and surgery, 11 females) with unilateral ACLR and no other history of serious lower limb injury participated in this study after providing IRB approved informed consent. Subjects were tested at nominal 2 year (2.19±0.29) and 4 year (4.34±0.29) follow-up after ACLR. Participants completed 10 m gait trials at their preferred walking speed. Knee COR was determined by projecting the trans-epicondylar axis of the femur onto the transverse plane of the tibia using the coordinate transformation matrix relating the femoral and tibial anatomical coordinate systems. The average COR was calculated over the entire stance phase, yielding medial-lateral (ML) and anterior-posterior (AP) coordinates of the average transverse plane COR during stance. Cross-sectional differences between the ACLR and contralateral knees and longitudinal changes in ML and AP coordinates of COR were compared using paired t-tests.

Results: The average COR of the ACLR knee was more lateral than the contralateral knee at 2 years but moved medially over time, exhibiting no difference with the contralateral knee at 4 years (Figure 1). The COR was also more anterior in the ACLR knee compared to the contralateral knee at both time points, though there was no significant change over time (Figure 1) due to a large variability in the change_13 of 26 shifted COR anteriorly with the other 13 shifting posteriorly over time. Given that the flexion moment (KFM) is associated with net quadriceps muscle contraction, and force generated by the quadriceps influence knee kinematics, a post-hoc analysis was performed and showed that the changes in the AP position of COR was significantly correlated with changes in peak KFM over time (Figure 2).

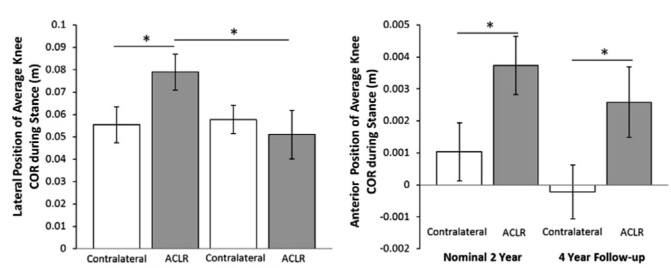

Figure 1. Medial-lateral and anterior-posterior position of the average knee COR of the contralateral and ACLR knees at nominal 2 year and 4 year follow-up after ACL reconstruction. Lateral and anterior directions are reported as positive values. *Indicates significant differences ($P<0.05$) for cross-sectional and/or longitudinal comparisons.

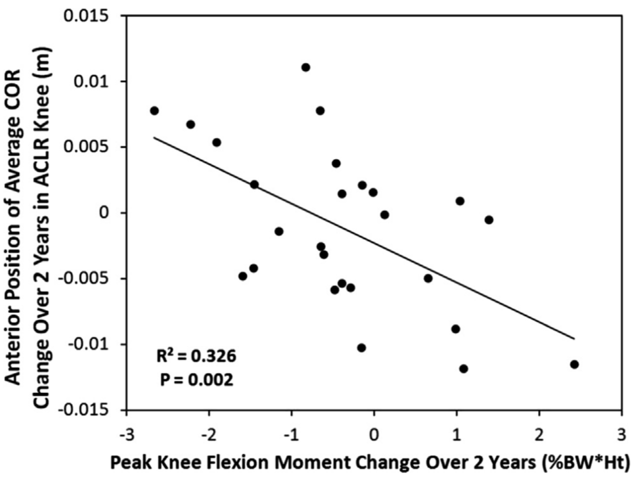

Figure 2. Correlation between changes in the anterior-posterior position of knee COR and changes in peak KFM from the nominal 2 year test to the 4 year follow-up. An anterior shift in COR over time is reported as a positive change in COR. Similarly, an increased KFM over time is reported as a positive change in KFM.

Conclusions: The differences in the knee COR between the ACLR and contralateral knee found in this study at the nominal 2 and 4 year follow-up provide new insight into the nature of the kinematic changes that are associated with ACLR. The greater lateral COR in knees at the 2 year follow-up suggest that there is greater motion on the medial plateau due to pivoting about a more lateral COR and could help explain the incidence of medial OA in this population. Additionally, the longitudinal change from the nominal 2 to the 4 year follow-up in the ML position of the COR suggests that the knee may be moving towards bilateral symmetry over time in many subjects. One of the most striking findings of this study was in the post-hoc analysis that identified the potential influence of the quadriceps muscles on kinematics. The relationship between the change in the AP position of the COR and change in peak KFM suggests that changing quadriceps contraction over time past surgery will change the AP position of the COR. Given the potential that COR can influence the location of contact between the femur and tibia, these findings suggest a mechanism for quadriceps contraction controlling contact location in a manner that could influence progression to OA following ACLR.

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USING AUDITORY FEEDBACK FROM PRESSURE INSOLES TO LOWER MEDIAL KNEE COMPARTMENT LOADS

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Purpose: Knee osteoarthritis (KOA) is a debilitating and progressive joint disease which has a large biomechanical component. Gait alterations are a proven methodology to change the local biomechanics at the knee joint and slow the progression of the disease. While effective, learning a gait modification such as a medial thrust gait can be challenging, time consuming, and an uncomfortable task. Also, decreasing the frontal plane torque at the knee during medial thrust gait often occurs at the expense of increasing other joint moments, specifically the knee flexion moment in the sagittal plane. Here we explore the use of an insole-based feedback device for gait retraining to reduce the peak knee adduction moment (pKAM), a measure of frontal plane torque at the knee and considered a strong biomarker of medial KOA progression. This study compares medial thrust gait with auditory feedback from shoe insoles to medialize plantar pressure. The overall hypothesis of this study is that walking with medialized plantar pressure using feedback will result in a significant reduction in the pKAM and this reduction will be similar to medial thrust gait without increasing the knee flexion moment.

Methods: Healthy subjects underwent a single session of 3-D gait testing. Five normal walking trials were acquired followed by trials 5 trials each of two gait alterations: (1) walking with medial thrust gait and (2) walking while receiving plantar pressure based audible feedback that cued the subjects to medialize plantar pressure. Thus, each subject completed 15 total walking trials and the order which subjects performed the two gait alterations was randomized. For all trials, subjects walked at a self-selected normal speed and only right sided data were analyzed. During the pressure-feedback training, no verbal cues were offered to subjects other than to follow the audible cues while walking. For medial thrust gait, all subjects were trained by a licensed physical therapist. Kinetic and kinematic data were acquired using 28 reflective markers on bony landmarks, 12 optoelectric cameras (Qualysis, Gothenberg, Sweden), and 1 ground-embedded force plate (Bertec, Columbus, OH, USA). A Pedar Insole System (Novel, Munich, Germany) was used to acquire plantar pressure and provide feedback for medialization, a strategy has been based on earlier findings about the relationship of center of pressure location and KAM. All systems were synced and acquired at 100Hz. Paired T-Tests were used for comparisons.

Results: 22 subjects (26.2 yrs ± 3.75 years, 10F,12M) were evaluated. The order which subjects performed the gait alterations had no effect on the change in pKAM ($p>0.33$). Means and SDs of the test results are presented in Table 1. Speed decreased with medial thrust gait ($p<0.001$) and remained unchanged with feedback gait ($p=0.177$). Compared to normal gait, walking with medial thrust gait resulted in a mean pKAM reduction of 0.413 %Bw*Ht ($p<0.001$) and walking with pressure-based feedback resulted in a mean KAM reduction of 0.438 % Bw*Ht ($p<0.001$); these reductions corresponded with a 13.9% and 14.7% pKAM reduction, respectively. Pressure-based feedback resulted in 20 of 23 subjects successfully reducing their pKAM while medial thrust gait resulted in 17 of 23 subjects successfully reducing their pKAM. In contrast, the peak knee flexion moment (pKFM) increased 1.02 %Bw*Ht with medial thrust gait ($p=0.02$) while it remained similar (with a slight decrease on average) for the feedback group ($p=0.34$).

Conclusions: This study demonstrates that medializing plantar pressure is associated with a redistribution of frontal plane loads through the tibiofemoral joint. Feedback from a pressure-detecting insole can be used as a training tool to reduce the pKAM and is as effective as medial thrust gait without increasing sagittal plane loads. Pressure-based feedback may be an effective future treatment modality for subjects with medial compartment knee OA.

Table 1. Peak knee adduction moment, peak knee flexion moment, and speed for each walking condition

	Normal Walk	Medial Thrust Walk	Insole Feedback Walk
Speed(m/s)	**1.47**(0.173)	**1.30**(0.16)	**1.43**(0.20)
Peak Knee Adduction Moment(pKAM) (%Body weight*Height)	**2.97**(0.87)	**2.56**(0.93)	**2.53**(0.87)
Peak Knee Flexion Moment(pKFM) (%Body weight*Height)	**2.91**(1.48)	**3.93**(2.29)	**2.71**(1.26)

*Values are mean (±standard deviation). Bold highlights significant differences compared to Normal ($p<0.05$).

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JOINT BIOMECHANICS AND BONE MATERIAL PROPERTIES RELATIVE TO OA RISK IN WILD MOOSE (*ALCES ALCES*)

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Purpose: Moose in Isle Royale National Park (MI, USA) exhibit the highest known prevalence of osteoarthritis (OA) among wild quadrupeds. Senescence-onset OA in this semi-isolated moose population is dependent on early nutrition. Perinatal malnutrition, indicated by