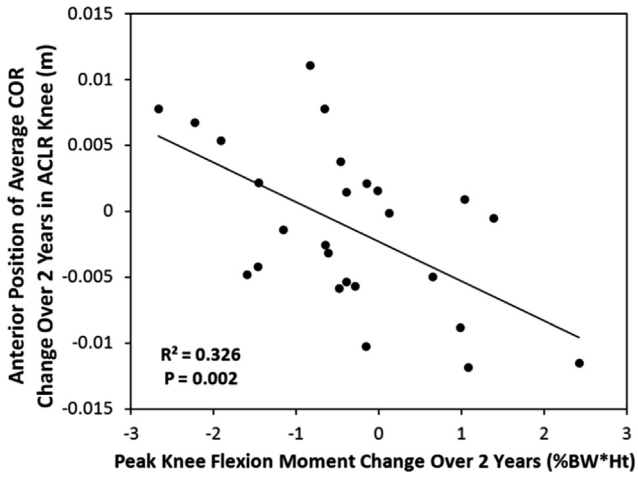

Figure 2. Correlation between changes in the anterior-posterior position of knee COR and changes in peak KFM from the nominal 2 year test to the 4 year follow-up. An anterior shift in COR over time is reported as a positive change in COR. Similarly, an increased KFM over time is reported as a positive 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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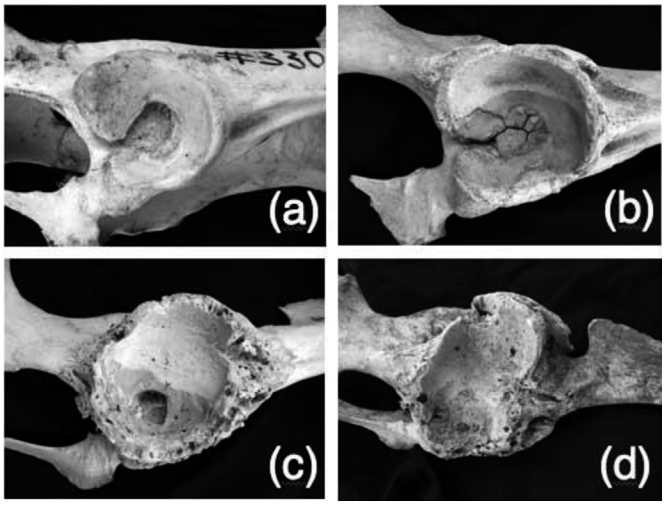
Purpose: Moose in Isle Royale National Park (MI, USA) exhibit the highest known prevalence of osteoarthritis (OA) among wild quadrupeds. Senescence-onset OA in this semi-isolated moose population is dependent on early nutrition. Perinatal malnutrition, indicated by

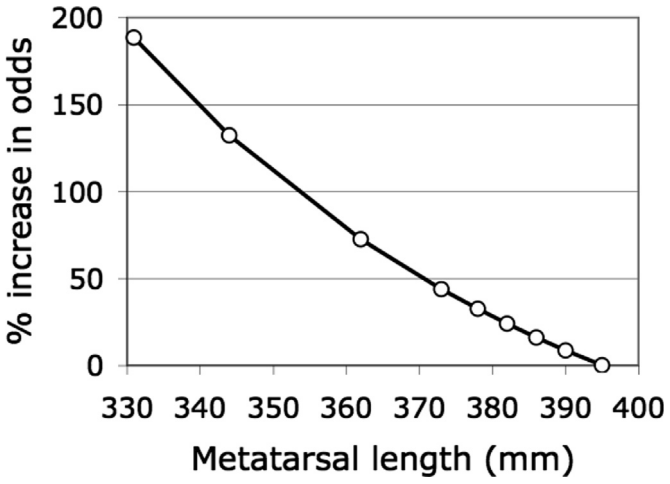
short metatarsus length, is correlated with higher prevalence of OA among moose that survive to at least nine years of age. Hip OA is four times more prevalent in old males than old females. We sought to evaluate structural integrity of femurs from high-risk (HR) and low-risk (LR) males at a young age, distinguished only by metatarsus length. We also tested the hypothesis that biomechanical loading differences arising from pelvis shape might explain the gender difference in OA risk.

Methods: Complete dry skeletons from 541 moose that died in a catastrophe (starvation due to an exceptionally severe winter) were evaluated for presence or absence of hip OA based on osteophytes and modification of the joint surface in the acetabulum. The sex of each moose was determined from skull morphology (presence of antlers) and age was estimated from counts of cementum annuli in teeth. Femurs from four young adult males each in HR and LR groups (metatarsus length in low 25th percentile and high 25th percentile, respectively, but without OA) were assessed for bone structural integrity using reference point indentation (BiodentTM, Active Life Sciences). For micron-scale indentation tests, a reference force of ~13N was applied to the medial surface of the diaphysis of the femur. Indentations were taken at 5 locations along the medial line (midpoint +/- 10mm and 20mm proximal and distal). The indentation test included a series of 20cycles at 2Hz to a force of 10N. For each group of moose, we calculated the average response with respect to total indentation depth increase (IDI), first cycle unloading slope, first cycle energy dissipation, first indentation distance, and total energy dissipation. For this moose population, we characterized the differences between sexes with respect to pelvis morphology on the basis of three angular measurements from the ishiatic arch, lesser sciatic notch, and pelvic brim.

Results: OA was identified in 107 (20%) of moose examined. There were no significant differences in diaphyseal cortical bone material properties of the femur between HR and LR groups. Pelvis morphology differed ($P<0.001$) by gender; for angular measurements, the ratio of female/male was 1.59 for ishiatic arch, 1.06 for lesser sciatic notch, and 0.90 for pelvic brim. The resulting gender difference suggest that females exhibited a more splayed-out lateral orientation of the acetabulum, which likely provides increased femoral head coverage and support for acetabular loading from the femur.

Conclusions: OA is a debilitating disease for moose that are preyed upon by wolves. A higher prevalence of hip OA in males correlates with a shorter average life span in males. This study suggests that acetabular joint loading differs by gender, with reduced acetabular coverage of the femoral head in males, resulting in more dorsal acetabular rim loading compared to female moose. Males also exhibit accelerated skeletal growth, greater tooth wear, and greater prevalence of osteoporosis and periodontal disease compared to females. A limited evaluation of cortical bone material properties did not reveal differences between HR and LR groups in young moose, even with evidence of early nutritional differences that are correlated with late-onset OA.





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MEDIALIZING FOOT CENTER OF PRESSURE WITH FLEXIBLE SHOES IS ASSOCIATED WITH A MEDIAL KNEE LOAD REDUCTION IN KNEE OSTEOARTHRITIS

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Purpose: Biomechanical treatments for individuals with medial compartment knee osteoarthritis (OA) often target the knee adduction moment (KAM). Foot-mediated biomechanical interventions for knee OA may operate through altering the foot center of pressure (COP). Flexible footwear has recently been shown to be effective at reducing the KAM, but the specific mechanisms underlying this reduction are not clear. The primary aim of this study is to determine if the reductions in KAM through use of flexible footwear are associated with a shift in foot COP. We hypothesize that by increasing foot mobility and foot pronation, flexible footwear may promote a medial shift in foot COP that is associated with reduction in the KAM.

Methods: Participants with symptomatic medial compartment knee OA (KL 2 and 3) and KAM greater than 2.2 %BW*Ht in their own shoes during gait analyses were evaluated. 3-D gait analysis and foot COP analysis was performed at baseline. All participants were provided flexible shoes (Dr. Comfort Flex-OA, Mequon, WI) and instructed to wear them at least 6 hours/day, 6 days/week. Gait analyses and COP analyses, were repeated after 12 weeks of wearing the shoes. The gait test consisted of five barefoot walking trials, five walking trials in subjects "own shoe", and five walking trials in the flexible shoe. During barefoot trials only, plantar pressure distribution was acquired simultaneously by mounting a pressure platform (Emed, Novel, Munich, Germany) onto a force plate (Bertec, Columbus, OH) and leveling the stacked assembly with the walkway. COP was quantified by determining the Medial to Lateral Pressure Index (MLPI) (Fig.1), with more negative values representing more medialized COP. The primary outcomes of interest for this analysis were the peak KAM and COP during the first half of stance. Paired samples t-tests were used to compare subjects' shifts in COP between baseline and 12 week visits and to compare changes in KAM in their own shoe at baseline and in the flexible shoe at 12 weeks. Spearman correlations were used to evaluate the association between the shift in COP and percent reduction in the KAM. Independent samples t-test was used to evaluate changes in COP between knee unloading responders vs non-responders.

Results: Fourteen participants were evaluated (mean age 59±6 yrs, 9 women, mean BMI 28±4 kg/m2). At 12 weeks, the KAM during the first half of stance in the flexible shoe was reduced by 8% compared to in their own shoes at baseline (2.55±0.63 %BW*Ht vs 2.78± 0.61 %BW*Ht, $p=0.032$). The barefoot COP, as measured with MLPI, was medialized at 12 weeks (13.03±10.34mm) compared to at baseline (19.68±13.61mm)($p=0.034$). The percent reduction in KAM during the first half of stance was significantly correlated with a medial shift in COP