Results: BMI ranged from 27 to 41 kg/m2 (mean = 33.4 kg/m2). Alignment distribution was: varus, 48%; neutral 27%; valgus, 25% (range: −11 deg valgus to 21 deg varus). After adjusting for walking speed and gender, there was not a significant interaction between BMI and knee alignment on the knee joint forces, or on the internal knee abduction moment. However, alignment had a significant ($p < 0.0001$) association with the internal knee abduction moment, independent of BMI. BMI had significant associations ($p < 0.01$) with the peak knee compressive and shear forces and peak knee muscle forces, independent of alignment.
Conclusions: A higher BMI was associated with greater peak knee compressive, shear, and muscle forces, regardless of alignment, and alignment was associated with the internal knee abductor moment, independent of BMI. Hence, BMI and alignment influence different joint loading measures that have both been linked to disease progression.

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INCREASED TRUNK LEAN GAIT MODIFICATION FOR MEDIAL KNEE JOINT LOAD REDUCTION IN PEOPLE WITH MEDIAL KNEE OSTEOARTHRITIS

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Purpose: To evaluate the immediate effect of varying amounts of lateral trunk lean gait modification on medial knee load, as measured by the external knee adduction moment (KAM), and on knee pain in individuals with medial knee osteoarthritis (OA). Influence of participant characteristics (knee mechanical alignment and WOMAC pain) and timing of peak trunk lean on load-modifying effects of trunk lean were also investigated.
Methods: People with clinical and radiographic medial knee OA were recruited (13F, 9M; age 68.4yrs±10.2; mass 78.3kg±16.1). Standard weight-bearing AP radiographs were used to confirm OA and evaluate mechanical knee alignment. Participants underwent 3-D gait analysis along a 10m walkway (8-camera VICON, 3 AMTI force plates) using a standard lower body Plug-In-Gait marker set, with three additional trunk markers (manubrium, spinous processes of T2 and T10). A repeated measures experimental study was conducted with four gait conditions (5 trials each). Following natural walking trials, a physiotherapist instructed participants to lean their trunk towards the symptomatic limb during ipsilateral stance. Real-time biofeedback of trunk lean was provided to participants via a projector screen placed at the end of the walkway. Biofeedback comprised of the frontal plane trunk angle as a scrolling trace, with a shaded target area for each modification condition. Trunk lean conditions were recorded at natural gait speed in random order, where participants attempted the following lean angles: small (6°); medium (9°); and large (12°). Knee pain during each condition was evaluated via an 11-point numeric rating scale. Measures of medial knee load, the knee adduction moment (KAM) peaks (early and late stance), and KAM impulse, were primary outcomes. Effects of the modification on load measures were evaluated using linear mixed models, with participants as the random factor and peak lean angle as the fixed factor. Interactions with the independent variable were used to assess contributions of participant characteristics (mechanical alignment and WOMAC pain) and timing of peak trunk lean to the extent of load reduction. Change in pain was evaluated using repeated measures analysis of variance.
Results: Participants successfully performed the gait modification to the desired amount (gait data shown in Table 1). Increased trunk lean reduced all KAM measures ($p < 0.001$), with larger lean angles achieving greater reductions (early stance peak $F=107.6$; late stance peak $F=129.5$; and impulse $F=264.5$). Efficacy of joint load reduction was improved by an earlier peak trunk lean for early stance KAM and impulse ($F=5.21$, $p=0.02$; $F=10.37$, $p=0.001$ respectively), and a later peak lean for late stance KAM ($F=6.32$, $p=0.01$). Participant characteristics did not influence load-reduction and there was no change in pain across test conditions ($p > 0.05$).
Conclusion: Increased lateral trunk lean is an easily implemented gait modification that reduces medial knee load. A dose-response relationship between trunk lean and load reduction was found. Results suggest that timing of lean should coincide with peak knee loading to optimise load reduction. This modification did not immediately influence knee symptoms. Further research should determine if longer-term implementation can modify symptoms and structural disease progression.

Table 1. Descriptive data relating to natural gait and lateral trunk lean gait conditions

	Natural Gait	Attempted 6° lean	Attempted 9° lean	Attempted 12° lean
Lateral trunk lean				
Peak lateral trunk lean angle (°)	2.04 (0.32)	6.12 (0.31)	8.74 (0.31)	11.14 (0.31)
Timing of peak trunk lean (%stance)	51.55 (2.36)	37.72 (2.29)	37.66 (2.29)	38.49 (2.30)
Trunk lean at early stance peak KAM (°)	0.85 (0.39)	5.09 (0.38)	7.55 (0.38)	9.26 (0.38)
Trunk lean at late stance peak KAM (°)	0.84 (0.45)	3.01 (0.44)	4.38 (0.43)	5.56 (0.44)
Gait Characteristics				
Speed (m/s)	1.24 (0.04)	1.25 (0.04)	1.24 (0.04)	1.23 (0.04)
Knee Load				
Early stance peak KAM (Nm/Bw*Ht%)	3.75 (0.24)	3.40 (0.24)	3.33 (0.24)	3.19 (0.24)
Timing-early stance peak KAM (%stance)	26.59 (0.83)	25.20 (0.80)	25.10 (0.80)	24.58 (0.81)
Late stance peak KAM (Nm/Bw*Ht%)	2.05 (0.19)	1.71 (0.19)	1.69 (0.19)	1.56 (0.19)
Timing-late stance peak KAM (%stance)	77.74 (1.70)	77.05 (1.67)	77.76 (1.66)	77.68 (1.67)
KAM Impulse (Nm.s/Bw*Ht%)	1.22 (0.11)	1.05 (0.11)	1.03 (0.11)	0.96 (0.11)

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CHANGES IN PERIARTICULAR MUSCLE ACTIVATION PATTERNS DURING WALKING ARE CONSISTENT WITH PROGRESSIVE STRUCTURAL CHANGES IN KNEE OSTEOARTHRITIS SEVERITY

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Purpose: Knee osteoarthritis (OA) is considered a failure of joint structure that can have considerable affects on joint function. Radiographic scoring based on the Kellgren-Lawrence ordinal scale (KL-scores) has been used to identify progressive structural alterations and subsequent disease severity. While differences in neuromuscular patterns have been previously reported between asymptomatic individuals and those with moderate versus those with severe OA, no study has looked at whether these changes occur along a disease spectrum within a mild to moderate OA grouping. This study tested the hypothesis that amplitude and temporal periarticular muscle activity characteristics would be altered with disease presence and in a progressive manner with knee OA radiographic severity.
Methods: After obtaining informed consent, four groups were identified: 35 asymptomatic subjects and 82 patients with medial compartment knee OA (38-KLII (mild), 33-KLIII (moderate), 11-KLIV (severe moderate)). Subjects were excluded if they were unable to perform a series of functional tasks and were scheduled for total knee athroplasty. A single experienced, blinded observer assigned KL-scores using standing anterior-posterior and lateral radiographs. Surface electromyographic (EMG) recordings were acquired from the lateral and medial gastrocnemius, vastus lateralis, medialis, and rectus femoris and the lateral and medial hamstrings using an AMT-8™ EMG measurement system (Bortec Inc.) during walking at a self-selected velocity using standard procedures. EMG signals were corrected for resting subject bias, gains, full wave rectified, low-pass filtered (Butterworth-6 Hz), amplitude normalized using the maximal voluntary isometric contraction method and time normalized to one complete gait cycle. Principal Component Analysis extracted predominant amplitude and temporal waveform features that together explained greater than 90% of the waveform variability for each muscle group. ANOVAs tested for main effects and interactions (alpha = 0.05). Post hoc testing was employed using Bonferroni procedures.
Results: Walking velocity and age were similar between the four groups. Body mass index and Western Ontario McMaster Osteoarthritis index (WOMAC) scores were similar among OA groups. Three features for each muscle grouping explained over 94% of the waveform variance. Significant group main effects ($P < 0.05$) were found for all three quadriceps PP-scores, for two hamstrings PP-scores and for one gastrocnemius PP-score. For all other scores significant group by muscle interactions ($p < 0.05$) were found. Post hoc testing revealed differences associated with disease presence and among disease severities. Specifically, medial gastrocnemius, lateral hamstring and

quadriceps magnitudes and temporal patterns were influenced by disease presence and severity. Activation imbalances between the lateral:medial gastrocnemius and hamstrings were found with greater radiographic severity ($p < 0.05$).

Conclusions: Despite similarities in walking velocity, age and WOMAC scores, these findings show that characteristics of periarticular muscle activity are altered in a progressive manner with knee structural severity illustrating an association between joint structure and function. These results have implications for understanding the OA disease process and associated functional deficits.

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GENDER DIFFERENCES IN KNEE JOINT LOADS WITH INCREASING BODY MASS

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Purpose: The incidence of knee OA is higher among females than males – an observation that at large remains unexplained. Knee joint loadings are thought to be of particular importance in the pathogenesis of knee OA and correspondingly, obesity and overweight increase the risk of knee OA development. One possible explanation for the higher incidence of female knee OA could be that females fail to adapt their knee joint loads with increasing body mass. The purpose of this study was to investigate the changes in knee joint compression forces with experimental weight gain in healthy lean females compared to healthy lean males.

Methods: In 15 healthy lean females and 15 healthy lean males knee joint compression forces were evaluated by three dimensional gait analyses and subsequent biomechanical modeling. Bare footed gait analyses were performed at self-selected walking speeds with and without body mass modulations. Body mass modulations were accomplished by means of a weight vest adding first 2.5 and later 5.0 BMI points to the subjects. The extra mass was distributed with 60% on the front and 40% on the back of the subjects. Bivariate ANOVA procedures and spearman correlations were used to evaluate whether gender influences changes in knee loads with increasing body mass.

Results: When walking with 2.5 extra BMI points the females increased the knee compression force by 198.7 N (95% CI 120.7 to 276.7) and the males increased the knee compression force by 209.4 N (95% CI 78.8 to 339.9). The gender difference in the increase was not statistically significant ($P = 0.88$). When adding additional 2.5 extra BMI points (for a total of 5 BMI points added) the females increased the knee compression force by an additional 158.8 N (95% CI 90.3 to 227.4), whereas the males increased the knee compression force by an extra 29.8 N (95% CI −193.3 to 252.9). The gender difference in the additional increase was not statistically significant ($P = 0.25$). There were no differences in walking speed across genders and body mass conditions ($P = 0.97$). When adding 2.5 BMI points the magnitude of the extra body mass was positively correlated with the increase in knee joint compression force in females ($r = 0.51$, $P = 0.05$, Figure 1) but not in males ($r = 0.24$, $P = 0.38$, Figure 1). When adding 5 BMI points the magnitude of the extra body mass was positively correlated with the increase in knee joint compression force in females ($r = 0.63$, $P = 0.01$, Figure 2) but not in males ($r = 0.19$, $P = 0.51$, Figure 2).

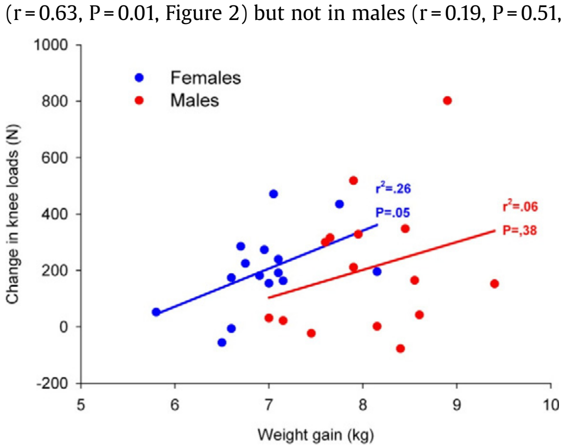

Fig. 1. Effects of experimental weight gain, corresponding to 2.5 kg/m^2, on knee compressive forces in 15 healthy lean females (blue) and 15 healthy lean males (red) with Spearman correlation coefficients (r^2). Level of significance $p < 0.05$.

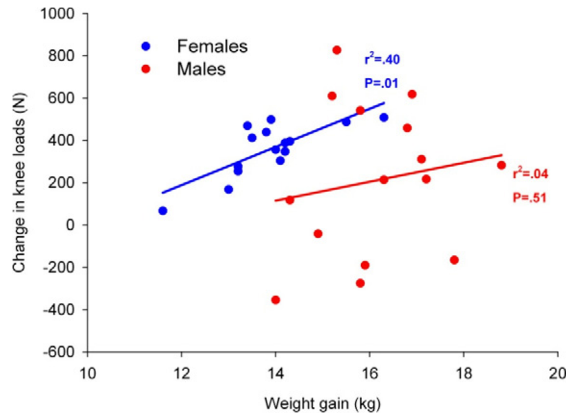

Fig. 2. Effects of experimental weight gain, corresponding to 5.0 kg/m^2, on knee compressive forces in 15 healthy lean females (blue) and 15 healthy lean males (red) with Spearman correlation coefficients (r^2). Level of significance $p < 0.05$.

Conclusions: These data suggest that among females the knee joint compressive forces are coupled with increases in body mass, whereas the males manage to adapt their walking pattern to the extra body mass without a direct increase in joint loads – particularly at higher body mass increases. In the light of the relationship between obesity and knee OA development and the overrepresentation of females among knee OA patients, these data suggest that the higher female knee OA incidence may be due to neuromechanical gender differences in the adaptations to increased body mass. The adaptations in movement patterns with body mass changes are possible targets for future research.

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DIFFERENCES IN TIBIAL ROTATION DURING WALKING IN PATIENTS WITH ANTERIOR CRUCIATE LIGAMENT DEFICIENCY AND KNEE OSTEOARTHRITIS

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Purpose: The aim of the present study was to compare tibial external rotation during the stance phase of walking: 1) in the affected and contra-lateral unaffected limbs of patients with unilateral anterior cruciate ligament (ACL) deficiency and concomitant tibiofemoral knee osteoarthritis (OA), and 2) in subgroups of patients with mild and severe OA.

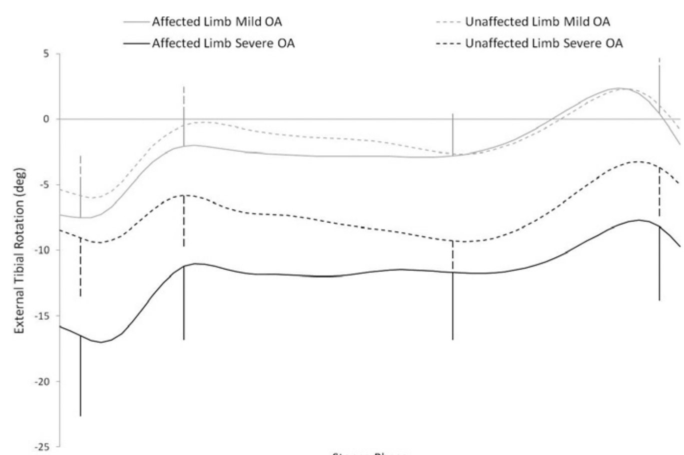

Fig. 1. Difference in internal-external tibial rotation throughout stance between affected limbs (ACL deficient and OA) and contra-lateral unaffected limbs in patients with mild or severe OA. Ensemble average curves represent all patients in each group with 95% confidence limits at four time points during stance: heel strike, mid-stance, terminal extension and toe-off.

Methods: 68 patients with confirmed unilateral ACL deficiency and medial knee OA underwent radiographic assessment and three-dimensional gait analysis with an optical motion capture system.