and 3) Examine concurrent validity by comparing values to an overground movement analysis system (gold standard).

Methods: 31 patients with knee OA and 16 healthy controls with no knee symptoms matched for age and BMI participated (Table 1). For the overground assessment (completed first), participants underwent 3D gait analysis with a 12-camera motion capture system (Motion Analysis Corporation, Santa Rosa, CA), a single floor mounted force plate (AMTI, Watertown, MA) and a modified Helen Hayes marker set. Participants walked barefoot along a 10-meter level floor at their self-selected pace while 3D camera (60Hz) and force plate (600Hz) data were collected during repeated walking trials. The treadmill based system included a force plate-instrumented dual belt treadmill (R-Mill, Motekforce Link, Amsterdam, NL), 10-camera motion capture system (Raptor-H, Motion Analysis Corporation, Santa Rosa, CA), 180° projection screen and accompanying software (D-flow, Motekforce Link, Amsterdam, NL). For these trials, existing markers over the right scapula, bilateral acromion processes, elbows and wrists were removed and additional markers were placed on T10, navel, xyphoid, sternum, bilateral PSIS, greater trochanters and 5th metatarsals. 3D camera (100 Hz) and force plate (1000 Hz) data were collected simultaneously for 10 gait cycles after subjects completed a 6 minute warm-up matched to their overground walking speed. Patients with knee OA also completed a second test session at least 24 hours later and within one week. For both systems, we calculated the knee adduction and flexion moments using inverse dynamics, expressed as the external knee moment in the frontal and sagittal plane relative to the tibial anatomical frame of reference. Knee joint angles and moments were normalized to 100% stance, heel-strike to toe-off. Peak values for knee angles and moments were determined and averaged over 5 trials for the affected limb. All peak values reported were identified using the waveform peaks from each trial analyzed. These peaks were then averaged to give a single value per limb per subject per variable. To estimate test-retest reliability, intraclass correlations coefficients ($ICC_{(2,1)}$) and standard errors of measurement (SEM) were calculated. To examine known-groups validity, patients and controls were compared using independent t-tests. To examine concurrent validity, Pearson correlation coefficients (r) were calculated.

Results: Ensemble averages for adduction and flexion angles and moments completed using the treadmill-based movement analysis system are displayed in Figure 1. ICCs were 0.94, 0.90, 0.94, 0.81, and 0.62 for the knee adduction angle, first peak knee adduction moment (PKAM), second PKAM, flexion angle, and flexion moment, respectively. Patients with knee OA had significantly higher first PKAMs than controls (mean difference = 0.64 %BW*ht, 95% CI 0.14, 1.14). Pearson correlations between systems ranged from 0.75–0.97.

Conclusions: Although highly correlated, there are substantial differences in knee angles and moments between the treadmill-based and overground movement analysis systems, suggesting values should not be used interchangeably. The present results suggest adequate reliability and validity of peak knee adduction and flexion angles and moments in patients with knee OA assessed using the treadmill-based system.

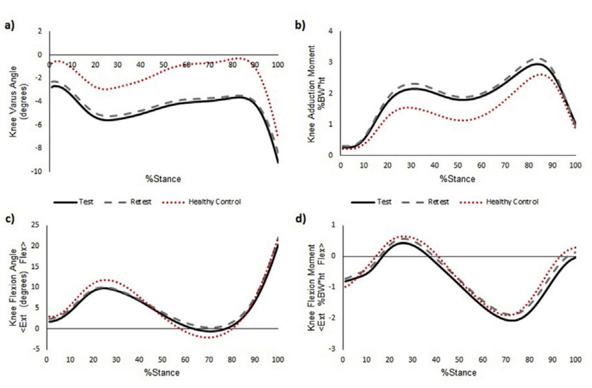

Figure 1. OA Patient test session 1 (n=31, solid line), OA patient test session 2 (n=31, grey dashed line) and healthy control (n=16, red dotted line) ensemble averages for knee (a) varus angle, (b) adduction moment, (c) flexion angle, and (d) flexion moment completed on the treadmill-based movement analysis system. BW = body weight, ht = height.

Table 1
Demographic and clinical characteristics for patients with knee osteoarthritis and controls

Subject characteristic	KOA (n = 31)	Healthy controls (n = 16
Age, yr	54.9 ± 7.5	53.2 ± 8.9
Sex, M/F	20/11	10/6
Height, m	1.75 ± 0.09	1.74 ± 0.11
Weight, kg	87.9 ± 19.3	78.8 ± 16.9
BMI, kg/m^2	28.4 ± 5.0	26.0 ± 4.8
Gait Speed, m/s	1.22 ± 0.17	1.20 ± 0.16
KL Grade	**Number of patients**	
1	1	-
2	18	-
3	8	-
4	4	-

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PRESSURE-BASED AUDITORY FEEDBACK TO REDUCE KNEE MOMENTS IN SUBJECTS WITH MEDIAL KNEE OSTEOARTHRITIS

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Purpose: The knee adduction moment (KAM) is a surrogate of medial compartment load during gait and is a target of conservative therapy for medial knee osteoarthritis (OA). Gait modifications have been shown to achieve KAM reduction, however, there has been limited experience with gait retraining methods outside the laboratory. In a previous study, we demonstrated that healthy subjects reduced KAM while walking with pressure-based feedback (PBF) that was designed to medialize center-of-pressure under the foot and impart a subtle gait modification. This prompted the current study, a longitudinal 6-week clinical trial of PBF for KAM reduction in subjects with mild to moderate medial knee OA. In this field study, subjects wear a fully integrated pressure-detecting shoe insole that communicates with a smartphone, which generates PBF in the form of auditory cues. Here, we report on the initial set-up, training, and response of subjects with medial knee OA to PBF in the lab. We tested the hypothesis that pressure-based feedback will reduce peak KAM (pKAM) in a significant majority of the subjects. We also compared the first peak of KAM (KAM1) and the second peak of KAM (KAM2) before and after PBF, and investigated potential adverse effect of PBF on knee flexion moment (KFM).

Methods: As a part of an ongoing clinical trial (NCT02955225), 13 subjects (KL-2&3) were recruited. On the day of the visit and prior to the gait tests, subjects were fitted with the same brand shoes and a pressure-detecting insole (Moticon GmbH, Munich, Germany). Two tests for acquisition of gait variables and plantar pressure were separated by an in-lab training session with PBF from the insole. The baseline gait test captured normal walk. PBF thresholds were calculated from baseline pressure data for two lateral sensors that correspond to the time-occurrence of KAM1 and KAM2. Subjects were then trained to walk with PBF for 30 min under the supervision of a physical therapist, after which the subjects underwent a second gait test while receiving PBF. The binomial distribution test was used to determine the chance probability for the observed proportion of subjects that experienced a reduction in pKAM. Paired *t*-tests were used to evaluate the change in knee moments and spatiotemporal variables (STP). Potential associations between moments and STP were gauged by Pearson's correlation coefficients.

Results: Subject characteristics are listed in **Table 1**. After training and while receiving PBF, 10 out of 13 subjects reduced pKAM ($P = .046$). These 10 subjects reduced pKAM by 11.8%, whereas the three remaining subjects increased pKAM by 7.9%. The entire cohort reduced KAM1 by 9.4% ($P = .008$) and maintained similar KAM2 ($P = .612$) (**Table 2**). The change in mean KFM was not significant ($P = .616$). Speed and cadence showed a 7.5% ($P = .019$) and 4.5% ($P = .018$) reduction, respectively, while stride length did not change significantly ($P = .090$). KAM reduction was not significantly correlated with changes in speed (r = .359, $P = .228$), stride (r = .273, $P = .368$), or cadence (r = .269, $P = .374$).

Table 1
Subject characteristics and results of clinical surveys; mean (range)

Index Knee (L/R)	8/5	KOOS	Pain	42.95 (8.33–80.56)
Gender (M/F)	3/10		Symptoms	38.46 (17.86–64.29)
Age (yrs)	63 (45–82)		ADL	39.93 (4.41–83.82)
Height (m)	1.67 (1.53–1.86)		Sports/Rec	62 (10–100)
Mass (kg)	87.35 (53.07–129.27)		QOL	66 (25–100)
BMI (kg/m^2)	31.48 (18.88–38.61)	**LEFS**		52.69 (6.25–93.75)

ADL: function in daily living; QOL: quality of life

Table 2
Gait variables before and after gait retraining using pressure-based feedback; mean (SD)

	Normal	Feedback	Significance
Spatiotemporal Parameters			
Speed (m/s)	1.20 (0.22)	1.11 (0.22)	0.019
Stride Length (m)	1.28 (0.17)	1.25 (0.19)	0.090
Cadence (strides/min)	55.65 (5.54)	53.12 (4.75)	0.018
Knee Loading Parameters (%BW*Ht)			
KAM1	2.90 (0.78)	2.65 (0.85)	0.008
KAM2	2.94 (1.00)	2.38 (1.04)	0.612
KFM	1.76 (0.91)	1.62 (0.89)	0.616

Conclusions: Initial data from this clinical trial suggest that most participants with knee OA can process auditory cues from PBF to reduce their pKAM. Ten of 13 subjects succeeded in this venture during the single visit, which is promising and is an initial indicator that those with knee OA can kinetically respond to the PBF. Most subjects reduced KAM1. Similar to pilot data with healthy subjects, the gait retraining strategy did not appear to negatively influence KFM, suggesting an overall reduction of compressive load at the medial knee. Participants of this clinical trial will continue to practice three times daily (5-minute periods) in their natural environment for the next three weeks before return to follow-up.

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THE EFFECT OF KNEE JOINT EFFUSION ON GAIT MECHANICS AND MUSCLE ACTIVATIONS IN INDIVIDUALS WITH MODERATE KNEE OSTEOARTHRITIS

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Purpose: *Knee osteoarthritis (OA) is the most common joint disease and is often characterized by pain, stiffness, swelling and limited tolerance to weight-bearing activities.* It has been shown to be associated with biological inflammatory processes in the synovium, synovitis, and mechanical insults that lead to the deterioration of the joint structures. Synovitis is usually characterized by knee joint swelling and the mechanical knee joint environment during a loading stimulus can be studied *in vivo* using state-of-the-art gait analyses. The study objective is to compare knee mechanics and muscle activation patterns during gait in individuals with knee OA who have and do not have knee joint swelling.

Methods: 45 patients diagnosed with moderate medial compartment knee OA were recruited. Knee swelling was measured at three locations (mid, medial, lateral) of the supra-patellar recess (SRD) using ultrasound imaging. A maximum depth, regardless of the location was determined. Effusion presence was defined as a SRD depth >4 mm. Knee joint motion was calculated from skin markers and net external moments calculated through inverse dynamics during walking on a dual-belt instrumented treadmill at self-selected speed. Electromyography (EMG) from vastus medialis (VM) and lateralis (VL), medial (MH) and lateral hamstrings (LH), medial (MG) and lateral gastrocnemius (LG) was recorded using standardized procedures. Two-sample unpaired *t*-tests were used to test for significant differences in sagittal plane knee joint angles, sagittal and frontal external moments, pain, Knee Osteoarthritis Outcome Scores, age, body mass index, stride characteristics, and knee extensor and flexor strength. Principal component analysis (PCA) was performed on the EMG waveforms to capture amplitude and temporal based features. Principal Pattern (PP)-scores were calculated from principal patterns that together explained >90% of the waveform variability. Two-way mixed-model Analysis of Variance models were performed on the *PP-scores* to identify muscle, group and interaction effects. Bonferroni corrected pairwise post-hoc comparisons were made. A *P*-value of 0.05 was used to determine statistical significance.

Results: Of the 45 participants, 25 had effusion (SRD > 4mm). No significant differences were found between groups in subject demographic and anthropometrics, questionnaire outcomes, and knee strength ($P > 0.05$). Both groups had a similar radiographic grade distribution. No biomechanical differences existed between both groups, however the effusion group had greater overall amplitudes of VM and VL (PP1-scores) and greater early stance activation of the gastrocnemius muscles (PP2-scores). No other group differences or group by muscle interactions existed.

Conclusions: These results, as shown in Figure 1, indicate that specific amplitude knee joint muscle activation patterns are altered in the presence of knee effusion during gait in individuals with knee OA. Greater stance phase amplitudes in the quadriceps and gastrocnemius muscles are consistent with responses aimed at providing neuromuscular knee joint support and increasing early stance active stiffness, respectively, in order to preserve knee function when effusion is present. These muscular adaptations have been previously reported with increased OA severity suggesting a possible link between gait mechanics and knee swelling as knee OA progresses. The 4 mm SRD threshold has previously been linked to a higher risk of knee OA progression, supporting findings of this study. Future studies can investigate different cut-off values for the detection of effusion sonographically to establish whether biomechanical subgroups may exist.

Figure 2 – Demographic Information of participants

	Mean ± SD	
	Non-Effusion Group (n=20)	Effusion Group (n=25)
Age	60 ± 6	63 ± 5.6
BMI	27.8 ± 3	29.9 ± 5.5
Radiographic KL Scores*	1(7) 2(5) 3(1)	1(6) 2(8) 3(4)
Walking Velocity	1.07 ± 0.1	1.05 ± 0.1
Knee Flexion Strength	72.1 ± 28	68.3 ± 25
Knee Extension Strength	110.3 ± 42	109.7 ± 33
KOOS Pain	67.6 ± 14	65.4 ± 20
KOOS Symptoms	59.8 ± 13	61.4 ± 16
KOOS Quality of Life	45.6 ± 18	44.3 ± 15
KOOS Activities of Daily Living	75.1 ± 15	72.3 ± 19