Knee joint instability in knee osteoarthritis
effect on gait biomechanics and motor control

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Results: Non-traumatic knee OA group was associated with higher overall amplitudes (*PC1-scores*) of vastus lateralis (b=-75.21, p=0.01), vastus medialis (b=-81.80, p=0.04), and rectus femoris (b=-49.89, p=0.04) compared to the post-traumatic knee OA group after controlling for disease severity, alignment, and presence of lateral OA (Figure 1A). Furthermore, non-traumatic knee OA was associated (b=-36.74, p=0.04) with prolonged lateral hamstring activation during mid-stance (*PC2-score*; Figure 1B). There were no other significant relationships between EMG *PC-scores* and OA group including for the gastrocnemius muscles.
Conclusions: Muscle activation during gait differs between participants with non-traumatic and post-traumatic knee OA. Participants with non-traumatic knee OA had higher quadriceps EMG, and higher and prolonged lateral hamstring EMG during gait. These differences might be an attempt to off-load the medial compartment or increase knee stability. Such neuromuscular adaptions indicate that muscle activation might play a greater role in disease progression in patients with non-traumatic knee OA since increased muscle activation leads to higher joint loads and muscle co-activation is related to disease progression. Longitudinal studies are needed to confirm this hypothesis.

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DETERIORATING SUBCHONDRAL BONE MICROSTRUCTURE ACCELERATES OSTEOARTHRITIS PROGRESSION IN DEVELOPMENTAL DYSPLASIA OF THE HIP THAN IN PRIMARY OSTEOARTHRITIS

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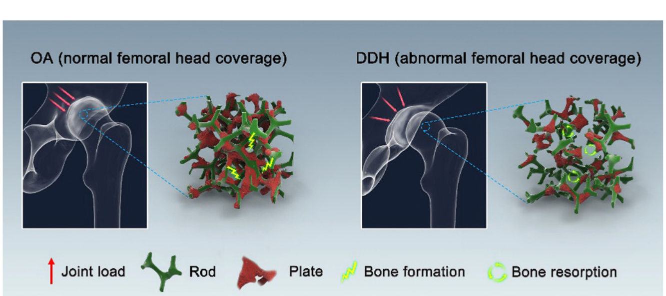
Purpose: Developmental dysplasia of the hip (DDH) is recognized as a frequent cause of secondary osteoarthritis (OA). Compared with primary hip OA, DDH often causes changes in the anatomical hip structure and leads to more severe symptoms and imaging manifestations. However, the subchondral bone microstructure and biomechanical property of patients with DDH has not been previously evaluated. Thus, we aimed to analyze the subchondral bone and its association with articular cartilage damage in DDH and primary hip OA through a novel technique for microstructural observation, the individual trabecula segmentation (ITS) analysis. We hypothesized that the changes of subchondral bone in DDH could partly account for the acceleration of OA progression.
Methods: Thirty-three femoral head specimens obtained from patients underwent total hip arthroplasty (DDH, n=17; primary OA, n=16) were scanned using Micro-CT, and the selected volume of interest (VOI) was processed by ITS to obtain the microstructural types of subchondral bone. The biomechanical property of VOI was analyzed by micro-finite element analysis (μFEA) and cartilage damage was evaluated by the histology. Moreover, the linear regression analysis was utilized to indicate the association between microstructures, biomechanical property and articular cartilage.
Results: Compared with the OA group, the DDH group showed lower total bone volume fractions (BV/TV) and plate bone volume fractions (pBV/TV) by the ITS-based analysis ($p<0.05$). The plate-to-rod ratio was significantly higher in the OA group than in the DDH group ($p<0.05$). Remarkably, there were varying degrees of discrepancy between the two groups in pTb.N/rTb.N (plate/rod trabecular number), pTb.Th/rTb.Th (plate/rod trabecular thickness), pTb.S/rTb.L (plate surface area and rod length) and P-P Junc.D/R-R Junc.D/P-R Junc.D (junction density with different trabecular modes). Moreover, the μFEA, histology and linear regression analysis revealed that the subchondral bone in patients with DDH had inferior biomechanical property, and the cartilage damage was severer than patients with OA due to the different subchondral bone microstructures.



Conclusions: In this study, our findings detected a less connected, more widely separated trabecular network and deteriorating subchondral bone microstructure in patients with DDH than those with primary OA. The mass and type changes of subchondral bone may contribute to worsening biomechanical property and cartilage damage, thus leading to the acceleration of OA progression in patients with DDH.

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KNEE JOINT INSTABILITY IN KNEE OSTEOARTHRITIS: EFFECT ON GAIT BIOMECHANICS AND MOTOR CONTROL

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Purpose: Knee joint instability is often present in people with knee osteoarthritis (KOA). Moreover, knee joint instability might be a factor for progression or initiation of KOA, since history of a instability-related injury (anterior cruciate lesion or meniscus tear) is highly associated with development of KOA. Stability of the knee joint during a movement is maintained by a combination of the passive structure (capsule, ligaments and other tissues in or surrounding the knee) and motor control (muscle activations, muscle forces and sensory system). A better understanding of the differences in biomechanics and motor control of the unstable joint compared to a stable joint enables us to investigate the role of knee joint instability in KOA and to improve treatment options for knee joint instability. Therefore, the aim was to compare the gait biomechanics and motor control of KOA patients with and without self-reported knee joint instability.
Methods: Individuals with KOA were included in the “instability” group (KOA-I, n=20) if they had experienced episode(s) of instability in the knee in the last four weeks. Otherwise, they were included in the “stability” group (KOA-S, n=10). Characteristics of the patients were obtained: anthropometrics, age, gender, history of knee injury, Kellgren & Lawrence (K&L) grades, muscle strength, walking speed, proprioception and questionnaires on pain and function. Gait biomechanics (spatiotemporal, kinematic and kinetic parameters) were measured using an instrumented treadmill (MotekForce link, Amsterdam, the Netherlands) and a motion capture system (VICON, Oxford, United Kingdom) during level walking at a comfortable fixed speed. Moreover, motor control of the knee (i.e. muscle activation patterns) was captured using surface electromyography (Cometa, Milan, Italy). The muscle activation patterns were amplitude-normalized to peak activation during gait and time-normalized to percentage gait cycle. Analysis of variance models were performed between the groups on the patient characteristics, spatiotemporal parameters and discrete values of the kinematic, kinetic and muscle activation gait waveforms (for example: peak, range of motion (ROM), mean activation or co-contraction index (CCI)).
Results: Patient characteristics between the groups were similar, except for the gender distribution (KOA-I: 60% female, KOA-S: 30% female) and a lower score on the Knee Outcome Survey (KOS) symptoms subscale in the KOA-I group (i.e. more affected by symptoms, 14%, p = 0.02). History of knee injury was present in 80% of the people in the KOA-I group and in 50% of the KOA-S group. A trend was observed towards a lower overall proprioception (both legs combined) in the KOA-I group compared to the KOA-S group (8%, p = 0.06). Walking speed was similar between the groups. No differences were present in the spatiotemporal or the kinetic parameters. In the kinematic parameters there was only a difference in the peak during swing of the knee flexion angle (higher in KOA-I, 3°, p= 0.02). The muscle activation patterns were comparable between groups, except for a lower vastus medialis (VM) activation at heel strike in the KOA-S group (5%, p= 0.04) and a trend towards a lower mean medial hamstring activation in the KOA-S group (5%, p=0.06). Co-contraction of the muscles surrounding the knee was similar between the groups.

Conclusions: The KOA-I group demonstrated comparable gait biomechanics and motor control during level walking at comfortable fixed speed as the KOA-S group. Only a few small differences (knee flexion angle and VM activation) were noticed between the groups. So it seems that comfortable walking on a treadmill allows the KOA-I patients to compensate for the possible effects of knee joint instability on our outcome measures. Therefore, external perturbations during gait (i.e. movable platform or obstacles) are likely needed to evoke the episodes of uncompensated knee joint instability that patients experience in daily life.

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INCREASES IN ACTIVITY DO NOT RESULT IN INCREASES IN CUMULATIVE MEDIAL KNEE LOADING WITH LATERAL WEDGE INSOLES

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Purpose: Lateral wedge insoles are simple, inexpensive biomechanical interventions for medial knee osteoarthritis. Numerous studies have identified biomechanical changes with the devices and also recently, it has been demonstrated that when biomechanical responders are selected a small pain reduction is seen. Physical behaviour data from the same study showed that activity levels were generally increased in comparison to the neutral insole. When looking at both of these outcomes together, an increase in overall load may be one of the reasons for the small effect size in pain from the interventions. Cumulative medial knee loading (CKL) measures the total exposure to joint loading during physical activity. Despite lower levels of physical activity, previous authors have found that the CKL is nearly two times greater in individuals with knee OA compared to healthy subjects due to higher medial knee loads. However, no study which has evaluated CKL in individuals with medial knee OA during an intervention period with the aim to reduce medial knee loads. We hypothesised that the cumulative loading would not be different between the lateral wedge insoles compared to the neutral insoles.

Methods: This ancillary study was part of the InRespond trial (ISRCTN55059760) a randomised AB cross-over clinical trial assessing the effectiveness of lateral wedge insoles. Biomechanical and activity data were collected during the on-treatment phases of the trial. Individuals with medial knee OA were recruited for the study and underwent motion analysis to determine to determine the KAM reduction in the LWI compared to the neutral and their own shoe. Individuals who values were decreased by at least 2% ('responders') were randomised to wedge or neutral insoles for 8 weeks, had an 8 week washout period after which they were crossed over to the other treatment for 8 weeks. Physical activity data was collected with the ActivPAL activity monitor at baseline, within treatment 1 and within treatment 2. Each of the three ActivPAL monitoring 'sessions' captured approximately 7 days' worth of activity data (mean number of days monitored = 6.92; SD = 0.17). Cumulative knee loading was calculated for the two insoles (neutral and lateral wedge) by multiplying the baseline normalised knee adduction angular impulse (KAAI) by the number of study leg steps taken (i.e. total steps ÷ 2) within the allocated treatment period. The cumulative medial knee loading for the patients' own shoes was calculated by multiplying the baseline normalised KAAI by the baseline number of steps taken. Mixed effects linear models were used to compare cumulative loading between the three treatment conditions (own shoe, neutral insole, and lateral wedge insole). The model used cumulative knee loading as the model outcome, and used treatment condition as the predictor. Patient identifier was modelled as a random effect, accounting for the within-person correlation due to repeat observations.

Results: Of the 62 individuals who were randomised, 50 individuals had motion analysis and activity data for at least two of the three conditions of interest (mean number of observations per patient = 2.45), with 23 patients in the neutral insole first group (AB group), and 27 in the lateral wedge first group (BA group) Mean age of the sample was 64.74 years (SD 8.93), mean BMI was 27.82 (SD 3.46), and 36% were female. Mean pain in the last week (0-10 Numerical Rating Scale) at baseline visit was 5.12pts (SD 1.60), with both groups appearing similar (AB group mean = 4.91; SD = 1.88; BA group mean = 5.30; SD = 1.32).

There were no significant differences in cumulative knee loading between the lateral wedge insole and the neutral insole (difference between treatments = 133.58 Nm/kg·s·steps; 95% CI -516.14 to 783.30; p = 0.69; table 2), however both insoles showed significantly lower cumulative loading compared with the patients' own shoes (table 1).

Calculating the cumulative loading using external knee adduction moment (EKAM) rather than KAAI showed similar trends: non-significant differences between treatments(difference between treatments = 221.89 Nm/kg·steps; 95% CI -1347.98 to 1791.75; p = 0.78), but overall lower cumulative loading versus patients' own shoes.

Conclusions: The use of insoles, both lateral wedge and neutral, reduced cumulative medial knee loading. We found no difference in cumulative knee loading during periods of treatment, although small increases in activity in the lateral wedge condition were seen. However, this loading is decreased when compared to the individual's own shoe. Differences in cumulative loading appear to be primarily driven by activity levels, with KAAI/EKAM having a lesser influence. Assessing cumulative medial knee loading during intervention trials is beneficial to understand the physical activity and loading environment effects of treatment.

Table 1 Comparison of Cumulative Loading after 8 Weeks' Treatment with Neutral/Lateral Wedge Insole

Variable	Own Shoe (taken from baseline visit)	Neutral Insole (taken from baseline/post-washout visit)	Lateral Wedge Insole (taken from baseline/post-washout visit)	Tests for Differences Between Conditions					
				Lateral Wedge Insole vs Own Shoe		Neutral Insole vs Own Shoe		Neutral Insole vs Lateral Wedge Insole	
	LS mean (95% CI)	*LS mean (95% CI)*	*LS mean (95% CI)*	*LS mean (95% CI)*	*p*	*LS mean (95% CI)*	*p*	*LS mean (95% CI)*	*p*
Total number of study leg steps taken	26555.28 (23352.46 to 29758.10)	21855.94 (18555.36 to 25156.53)	22043.35 (18710.44 to 25376.25)	-4511.93 (-7140.06 to -1883.81)	0.001	-4699.34 (-7239.22 to -2159.46)	<0.001	-187.40 (-2916.71 to 2541.90)	0.89
External knee adduction moment (EKAM; Nm/kg)	0.51 (0.47 to 0.55)	0.51 (0.47 to 0.55)	0.48 (0.44 to 0.52)	-0.03 (-0.04 to -0.01)	<0.001	0.00 (-0.02 to 0.01)	0.77	0.03 (0.01 to 0.04)	0.001
Knee adduction angular impulse (KAAI; Nm·s)	0.21 (0.19 to 0.23)	0.21 (0.19 to 0.23)	0.20 (0.18 to 0.22)	-0.01 (-0.02 to -0.01)	0.001	0.00 (-0.01 to 0.01)	0.75	0.01 (0.00 to 0.02)	0.002
Cumulative loading - EKAM-based (Nm/kg·strides)	13646.94 (11441.16 to 15852.72)	10968.70 (8714.78 to 13222.61)	10746.81 (8477.33 to 13016.30)	-2900.13 (-4411.79 to -1388.48)	<0.001	-2678.25 (-4136.17 to -1220.33)	<0.001	221.89 (-1347.98 to 1791.75)	0.78
Cumulative loading - KAAI-based (Nm/kg·s·strides)	5438.22 (4647.00 to 6229.44)	4381.02 (3567.24 to 5194.80)	4247.44 (3426.24 to 5068.64)	-1190.78 (-1816.41 to -565.16)	<0.001	-1057.20 (-1661.52 to -452.88)	0.001	133.58 (-516.14 to 783.30)	0.69

LS mean = least-squares mean taken from mixed-effects model; CI = Confidence Interval