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The knee adduction moment and knee osteoarthritis symptoms: relationships according to radiographic disease severity

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SUMMARY

Objective: To investigate relationships between external knee adduction moment parameters (KAM) and osteoarthritis (OA) symptoms according to disease severity.
Design: 164 participants with symptomatic medial knee OA were included. Radiographic severity was graded by (1) Kellgren & Lawrence (KL) scale (Grade 2, $n = 49$; Grade, $n = 52$; Grade 4, $n = 63$) and; (2) medial tibiofemoral joint space narrowing (JSN) (Grade 1, $n = 47$; Grade 2, $n = 50$; Grade 3, $n = 67$). KAM-related parameters (peak KAM, KAM impulse and cumulative load) were determined from three-dimensional gait analysis and pedometry. Cumulative load was determined by multiplying KAM impulse by the average number of steps/day recorded over at least 5 days. Symptoms were assessed *via* numeric rating scale ((NRS), pain) and Western Ontario and McMaster Universities (WOMAC) Osteoarthritis Index (pain and physical function). Relationships between KAM parameters (independent variables) and symptoms (dependent variables) were evaluated by radiographic severity using linear models, adjusting for covariates.
Results: In mild disease (either KL Grade 2 or JSN Grade 1), there were no associations between KAM and symptoms. In moderate disease of KL Grade 3, higher KAM impulse was associated with greater WOMAC pain. In severe disease (KL Grade 4), higher KAM impulse was associated with less WOMAC pain (KL Grade 4), while higher peak KAM was associated with better function (KL Grade 4). Higher cumulative knee adduction load was associated with less pain on both NRS and WOMAC (JSN Grade 3) as well as better function (both JSN Grade 3 and KL Grade 4).
Conclusions: Relationships between KAM-related parameters and symptoms differ according to underlying radiographic OA severity.

Introduction

Knee osteoarthritis (OA) often results in pain and physical dysfunction that typically worsen over time[1]. There is some evidence[2–5], albeit it questionable[6], implicating the role of abnormal knee joint loading in the progression of structural knee OA. However, little is known about the relationship between measures of knee joint loading and symptoms including pain and physical function. Understanding the cross-sectional relationship between measures of knee joint loading and symptoms across subgroups of patients will help guide future prospective research to potentially optimise treatments, and identify patients most likely to gain clinical benefits with interventions.

Given *in vivo* measurement of knee load during gait is not yet feasible on a large scale, indirect measures from gait analysis are used to infer knee joint load. The external knee adduction moment (KAM), which reflects medial-to-lateral knee joint load distribution during gait, has emerged as an OA treatment target[7,8]. Although a meta-analysis has questioned the causal association between the

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KAM and structural OA progression[6], conclusions were limited by the relatively few available studies and the considerable heterogeneity amongst those included. Subsequently, two new studies have since reported an association between the KAM (peak and impulse) and reduced cartilage thickness in people with knee OA[3,4]. Cumulative knee adduction load is also of potential relevance[9]. This measure takes into account the "frequency" of knee loading by multiplying KAM impulse by the number of steps taken per day, to represent the accumulated load borne across the knee during walking.

Despite the use of the KAM as a biomechanical treatment target[8,10], there is relatively little research evaluating relationships between KAM-related parameters and knee OA symptoms. This is further hampered by the fact that findings from existing research are inconsistent. Some evidence shows positive associations between the KAM and knee pain. Specifically, a higher peak KAM has been associated with the onset of knee pain in elderly adults[11] while in people with established knee OA, cross-sectional studies show a higher peak KAM[5], KAM impulse[12], and mean KAM[13] are associated with greater pain, and cumulative knee adduction load is associated with greater pain frequency[14]. However, cross-sectional research has also demonstrated inverse associations between the KAM and pain[15]. With respect to physical function, evidence is also conflicting. While some studies indicate that a higher mean KAM[13] and higher KAM impulse[13] are associated with worse physical function, another study shows that a higher peak KAM is associated with better function[15]. Collectively, interpretation of these studies is limited by their often small sample sizes[12,13], concern that variable footwear during gait analysis may have influenced findings[12,15] and failure to adjust for confounding factors[5,12,13,15] such as walking speed.

Importantly, failure to consider that relationships between KAM-related parameters and symptoms may differ according to underlying structural disease severity may account for inconsistent findings of studies to date. Recent work investigating whether pain independently contributes to the KAM suggests that relationships between these variables may differ according to Kellgren & Lawrence (KL) grading of tibiofemoral OA[16]. To date, no research has evaluated how KAM-related parameters independently contribute to pain severity and physical function associated with medial knee OA, across different levels of radiographic OA severity. This information is important for targeting treatments to patient subgroups most likely to gain symptomatic benefits. Thus, the purpose of this study was to evaluate whether peak KAM, KAM impulse and cumulative knee adduction load independently associate with severity of pain and physical dysfunction of medial knee OA, and if these associations differ according to underlying radiographic OA severity.

Patients and methods

Patients

This study used baseline data (with the exception of pedometer data, see Methods) from 164 participants enrolled in a randomised controlled trial (RCT) evaluating the effects of unloading shoes[7]. Participants were recruited from August 2013 to May 2015 *via* community advertisements. People were eligible if they (1) were aged ≥50 years; (2) had knee pain on most days of the month; (3) had a minimum average pain score of four on an 11-point numerical rating scale (NRS, with terminal descriptors of 'no pain' and 'worst pain possible') in the past week while walking; (4) had definite radiographic tibiofemoral joint OA defined as KL grade ≥2[17]; (5) had definite radiographic medial tibiofemoral compartment OA (defined as ≥grade 1 medial osteophytes and ≥grade 1 medial joint space narrowing (JSN) that is greater than lateral JSN), according to a standard atlas[18].

People were not eligible if they (1) had lateral tibiofemoral compartment osteophytes greater than the medial, according to a standard atlas[18]; (2) had undergone intra-articular corticosteroid injection or knee surgery to either knee within the past 3 months; (3) had a systemic arthritic condition (e.g., rheumatoid arthritis); (4) had a knee joint replacement or high tibial osteotomy in the past, or planned to undergo surgery to either knee in the next 6 months; (5) had any other muscular, joint or neurological condition influencing lower limb function; (6) reported current or previous (within 6 months) use of shoe inserts, knee/ankle braces and/or customised shoes prescribed by a health professional; (7) were unable to walk unaided; (8) had a body mass index (BMI) ≥36 kg/m^2 or (9) reported ankle/foot pain/pathology. In participants where both knees were eligible, outcomes were obtained only from the most symptomatic knee. The Human Research Ethics Committee approved the study and all participants provided written informed consent.

Radiographs

Participants who did not have their own knee X-ray within the past 12-months at screening (n = 128, 78%) underwent a weight bearing semi-flexed knee X-ray at one of three study clinics using a standardised protocol. Disease severity was assessed in two different ways, using (1) the KL grading scale[17] and; (2) grading of medial tibiofemoral JSN using a radiographic atlas[18]. In the KL grading system, disease severity is rated on a five-point scale from Grade 0 (no sign of OA) to Grade 4 (severe OA)[17]. In the current study, KL grade ≥2 was used to determine eligibility, thus participants were graded as either "KL2" (definitive osteophytes with possible narrowing of joint space), "KL3" (moderate multiple osteophytes, definite narrowing of joint space and some sclerosis and possible deformity of bone ends), or "KL4" (large osteophytes, marked narrowing of joint space, severe sclerosis and definite deformity of bone ends)[17]. Given that the KL system has been criticised for its overemphasis of osteophytes, we also graded participants according to the severity of medial tibiofemoral JSN[18]. In the current study, JSN ≥1 was used to determine eligibility, thus participants were graded as "JSN1" (mild JSN), "JSN2" (moderate JSN) or "JSN3" (severe JSN)[18]. Grading of disease severity was conducted by two experienced researchers (RSH and KLB) whose intra-rater and inter-rater reliability (weighted kappa) is 0.83–0.87 and 0.87, respectively[19].

Anatomic knee alignment was determined using previously described methods[20]. Briefly, the anatomic axis was determined from digital or hard copy short films. The 3-point angle was formed from femoral and tibial (medio-lateral) bisections, 10 cm above or below the joint, and passed through the midpoint of the tibial spines. Varus and valgus malalignment were noted by values <180° and >180° respectively. Neutral anatomical alignment was denoted by 180°.

Pain and physical function

Pain was assessed using two instruments (1) a NRS[21] and; (2) Western Ontario and McMaster Universities (WOMAC) Osteoarthritis Index pain subscale[22]. Using an 11-point NRS with anchors of 'no pain' (score = 0) and 'worst pain possible' (score = 10), participants rated their overall average pain on walking over the previous week. The Likert version of the WOMAC was used to assess both pain and physical function. The pain subscale includes five questions, with overall scores ranging from 0 (no pain) to 20