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Effects of a 10-week toe-out gait modification intervention in people with medial knee osteoarthritis: a pilot, feasibility study

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SUMMARY

Objective: To examine the feasibility of a 10-week gait modification program in people with medial tibiofemoral knee osteoarthritis (OA), and to assess changes in clinical and biomechanical outcomes.
Design: Fifteen people with medial knee OA completed 10 weeks of gait modification focusing on increasing toe-out angle during stance 10° compared to their self-selected angle measured at baseline. In addition to adherence and performance difficulty outcomes, knee joint symptoms (Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain subscale and total score, numerical rating scale (NRS) of pain), and knee joint loading during gait (late stance peak knee adduction moment (KAM)) were assessed.
Results: Participants were able to perform the toe-out gait modification program with minimal to moderate difficulty, and exhibited significant increases in self-selected toe-out angle during walking ($P < 0.001$). Joint discomfort was reported by five participants (33%) in the hip or knee joints, though none lasted longer than 2 weeks. Participants reported statistically significant reductions in WOMAC pain ($P = 0.02$), NRS pain ($P < 0.001$), WOMAC total score ($P = 0.02$), and late stance KAM ($P = 0.04$).
Conclusions: These preliminary findings suggest that toe-out gait modification is feasible in people with medial compartment knee OA. Preliminary changes in clinical and biomechanical outcomes provide the impetus for conducting larger scale studies of gait modification in people with knee OA to confirm these findings.

Introduction

Osteoarthritis (OA) is one of the most common musculoskeletal impairments and is currently one of the leading causes of chronic physical disability in adults[1]. The knee is the weight-bearing joint most commonly affected with OA. Given that quality of life decreases and the economic burden increases with more severe symptoms, it is imperative to implement treatment approaches that effectively slow disease progression. Excessive loading and alterations in load distribution within the joint are believed to play major roles in the breakdown of articular cartilage indicative of knee OA progression[2–5]. Accordingly, there has been increased interest in the knee OA literature to develop treatments that target abnormal loading patterns within the knee joint.

The knee adduction moment (KAM) is generally regarded as an important proxy for medial tibiofemoral compartment loading during walking[3,6,7]. Further, the overall peak KAM has been shown to be associated with clinical outcomes unique to medial compartment knee OA including lower limb malalignment[8,9], medial compartment disease severity[10,11], and tibial bone mineral density ratios[12]. Importantly, Miyazaki *et al.*[13] showed that an approximate 25% increase in overall peak magnitude of the KAM at baseline was associated with 6.6 times the risk of radiographic medial compartment disease progression over 6 years while Bennell *et al.*[14], showed that the total area under the KAM–time curve (KAM impulse) at baseline was predictive of loss of cartilage volume over 12 months using magnetic resonance imaging. Taken together, these findings point to an important role for quantification of the KAM in knee OA research, and many studies aiming to examine the effectiveness of load-reducing treatments for knee OA have reported the KAM.

One such treatment is gait modification. A recent systematic review has shown consistent changes in KAM magnitudes following single-session gait modifications such as altering toe-out

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angle[15]. These findings are consistent with previous cross-sectional studies that have shown significant inverse correlations between late stance KAM magnitudes and toe-out ($r > -0.26$) magnitudes during walking[16]. Previous studies have examined the effects of changing toe-out (foot progression) angle on late stance KAM magnitudes in young, healthy individuals without knee OA[17–19] or in those with radiographic evidence of knee OA[19,20]. Though the methodologies differed, consistent findings of reductions in the late stance KAM magnitude suggest a beneficial effect on medial compartment load with toe-out gait modification. Though the clinical relevance of the late stance peak KAM is still unclear (most early studies reported the early stance peak KAM only), increases in toe-out angle have been shown to have a protective role against knee OA progression.

Chang *et al.*[21] studied 56 people with radiographic knee OA over the course of 18 months and assessed gait biomechanics as well as radiographic features of knee OA. As a group, each 5° increase in baseline toe-out angle had an associated odds ratio of 0.60 (95% CI: 0.37, 0.98) for medial tibiofemoral progression. These findings are consistent with the known effects of toe-out gait modification on knee joint load parameters – specifically the late stance peak KAM – and suggest that toe-out gait modification may have longer-term biomechanical and clinical benefits for people with knee OA.

Despite the potential treatment benefits of toe-out gait modification, there are no published studies of the effects of longer-term (i.e., more than one session) toe-out modification in people with knee OA. However, Shull *et al.* recently reported significant improvements in biomechanical and clinical outcomes following 6 weeks of *toe-in* gait retraining guided by haptic feedback[22]. Their study provided initial confirmation of the potential benefits of gait retraining for people with knee OA. However, despite their findings, much is still unknown about gait retraining as a treatment strategy for those with knee OA. First, they chose toe-in rather than toe-out for modification in their study. Thus, the effects of a toe-out only modification remain unknown. Further, the effects of any load-reducing gait modification on joints other than the knee have received little interest. Specifically, given that modification of a given gait characteristic will involve changes at more than one joint or body segment (increasing the toe-out angle, for example, will involve external rotations at the ankle, knee, and hip), positive benefits at the knee could be associated with concurrent negative consequences at other joints. Finally, the feasibility of delivering a longer-term toe-out gait modification program to people with knee OA is unknown.

Therefore, the primary objective of this exploratory, pilot study was to evaluate the efficacy, safety, and adherence to a 10-week toe-out gait modification program in a group of individuals with knee OA. Our secondary objective was to obtain pilot data pertaining to the effect of a longer-term toe-out gait modification intervention on clinical and biomechanical outcomes relevant to knee OA. We hypothesized that individuals would adhere to the program and perform the toe-out gait modification with minimal to moderate difficulty. We also hypothesized that changes in knee joint loading and pain could be achieved with minimal reports of pain at adjacent lower limb joints.

Methods

Participants

Community-dwelling individuals with medial tibiofemoral OA were recruited from our laboratory participant database and via advertisements in print media. Inclusion criteria included: (1) definitive medial tibiofemoral osteophytes; (2) joint space narrowing greater in the medial tibiofemoral compartment compared to the lateral compartment; (3) predominance of pain over the medial aspect of the knee; (4) history of knee pain longer than 6 months; and (5) average knee pain of at least 3 out of 10 (using an 11-point numerical rating scale (NRS) with terminal descriptors of 0 = "no pain" and 10 = "worst pain imaginable") over the 1 month prior to initial screening. Exclusion criteria included: (1) knee surgery or intra-articular pain relief injection within 6 months; (2) current or past (within 6 weeks) oral corticosteroid use; (3) history of knee joint replacement or tibial osteotomy; (4) any other condition affecting lower limb function; and (5) participation in a new structured exercise program (defined as at least 45 min of continuous, planned exercise 3 or more days per week) within the past 3 months or planning to commence exercise or other treatment for knee OA in the next 3 months. The study was approved by the Institution's Clinical Research Ethics Board and all participants provided written informed consent.

Study design

Interested participants were initially screened for inclusion and exclusion criteria over the telephone and eligible individuals were referred for radiographic evaluation. Standing, semi-flexed, postero-anterior radiographs were obtained and graded for disease severity using the Kellgren and Lawrence (KL) OA classification system[23]. Individuals who met the radiographic criteria listed above were invited to the laboratory for a baseline (Week 0) testing session where self-report, objective physical function, and biomechanical data were obtained. Participants returned to the laboratory the following week (Week 1) to begin the gait modification program. This program lasted 10 weeks and involved six training visits with the study therapist at Weeks 1, 2, 3, 5, 7, and 9 of the intervention. Follow-up testing occurred upon completion of the intervention (Week 11). 10 weeks was chosen as an appropriate intervention length based on previous exercise studies in the knee OA population (typically lasting approximately 8–12 weeks), and to provide sufficient time to establish motor re-learning of the new gait modification.

Gait modification intervention

Participants were instructed to increase the toe-out angle of their study limb (most painful in the case of bilateral involvement) by 10° over and above the self-selected amount measured at baseline. 10° was chosen based on self-reported difficulty in obtaining 15–20° of toe-out increase by those with knee OA (unpublished data), and previous research indicating an approximate 40% reduction in risk of radiographic disease progression over 18 months for every 5° increase in baseline toe-out angle[21]. Toe-out modification was facilitated through the use of real-time biofeedback of performance[24–26] at each treatment visit. Participants walked on a treadmill in their own walking shoes at a speed similar to their over ground walking speed, and were provided with tracking data pertaining to their toe-out angle (transverse plane angle of line connecting toe and heel with respect to line of forward progression of the body) in real-time. Twenty-two retro-reflective markers were affixed to the participant according to a modified Helen Hayes marker set[27], and their movements were captured using ten high-speed digital cameras (Motion Analysis Corp., Santa Rosa, CA) sampling at 120 Hz. An initial standing static trial was collected using additional markers placed over the medial malleoli and femoral epicondyles to determine segment orientations. During the treadmill walking, toe-out angle was calculated in real-time using the Biofeedtrak option within Cortex software (Motion Analysis Corp., Santa Rosa, CA) and displayed graphically in front of