Official Title: Effects of Toe-out Gait Modification on Clinical and Biomechanical Measures in People with Knee Osteoarthritis

NCT Number: NCT02019108

Document Date: November 25, 2013

Methods

Participants

Community-dwelling individuals were recruited via an existing laboratory database as well as advertisements in print media. Inclusion criteria were: (i) definitive medial tibiofemoral osteophytes on x-ray; (ii) joint space narrowing greater in the medial tibiofemoral compartment compared to the lateral compartment; (iii) history of knee pain longer than six months; and (iv) average knee pain of at least 3 out of 10 over the one month period prior to initial screening. Exclusion criteria were: (i) knee surgery or intra-articular pain relief injection within six months; (ii) current or past (within six months) oral corticosteroid use; (iii) history of knee joint replacement or tibial osteotomy; (iv) any other condition affecting lower limb function; (v) participation in a new structured exercise program within the past three months, or planning to commence exercise or other treatment for knee OA in the next four months; and, (vi) an inability to travel to the university to attend testing and training sessions. The study was approved by the Institution's Clinical Research Ethics Board and all participants provided written informed consent.

Sample size was determined based on randomization with stratification, and covarying for baseline values in the statistical analysis. Using effect size estimates of 0.8 for WOMAC pain and 1.0 for KAM impulse, based on pilot data using a similar design, it was determined that participants in each group was required to attain 90% power to detect significant differences in pain and KAM outcomes between groups with an alpha of 0.05. Using a conservative estimate of 10% attrition, the aim was to recruit 73 participants for this study.

Study Design

This was a parallel group, assessor-blinded, randomized controlled trial. Interested participants were initially screened for inclusion and exclusion criteria over the telephone and eligible individuals then underwent a physical screen. Screening was overseen by a researcher not involved in data collection or analysis.

This physical screen was conducted to confirm the presence of knee pain, and to perform a preliminary walking assessment to assess self-selected foot progression angle. Participants performed three trials of self-selected, over ground walking while three reflective skin markers tracked the movement of the sacrum, the second toe, and posterior calcaneus of the study limb (defined as the self-declared osteoarthritic limb in those with unilateral symptoms, or the most painful limb in the case of bilateral symptoms). The mean foot progression angle across the three trials was calculated. As the goal of the toe-out modification program was to increase the self-selected, baseline foot progression angle by 15° in the toe-out direction, 15° of toe-out at the physical screening was selected as the threshold. This was done due to (i) the difficulty in achieving toe-out angles of 30° by people with knee OA, and (ii) the fact that those who already exhibit large amounts of toe-out would likely not be candidates for toe-out gait modification in the clinical setting.

Those who passed physical screening 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.

Individuals who met the radiographic criteria listed above were invited to the laboratory for a baseline (Week 0) testing session where self-report questionnaire, objective physical function, and biomechanical data were collected. Following completion of baseline testing, the randomization procedure was conducted by a study biostatistician who was not involved in any aspect of data collection or training. Randomization was initiated by the study research coordinator, who provided the biostatistician with each participant's study ID, sex, and KL grade. The biostatistician then responded via email with the group allocation, and maintained the randomization parameters and list offsite. Group allocations were determined prior to study commencement, and randomization was stratified by sex (male, female) and disease severity (mild or moderate grouped together, severe).

Participants returned to the university the following week (Week 1) to begin their training program, and were informed of their group allocation at this time. Each home-based program lasted four months and was supplemented with eight training sessions with the study trainer at Weeks 1, 2, 4, 6, 8, 10, 12 and 15 of the intervention, with typical sessions lasting 20 minutes in Week 1 and increasing to 40 minutes by Week 15. All training sessions, regardless of group allocation, were conducted by the same trainer in the same rehabilitation gymnasium. The first training session for each participant was always a one-on-one session with the trainer, with subsequent sessions conducted in groups of one to three individuals; in cases of group sessions, only individuals from the same group allocation were present in the gymnasium to prevent cross-contamination of groups.

Follow-up testing occurred four months after baseline testing, with a final retention testing session conducted one month later. The same outcome measures, completed in the same testing order, and by the same blinded assessor, were collected at each testing session. No training or instructions of any kind were provided between these final two testing sessions.

Interventions

For both groups, the intent was to increase the weekly amount of walking out in the community by 40% over and above that exhibited prior to enrollment. Initial values were assessed via discussion with participants at the first training session, and prescribed weekly increases were determined individually at each training session in consultation with the trainer.

Toe-out (TO) gait modification program

Participants randomized to the TO program were trained to perform walking with 15° more toe-out than the self-selected amount measured at the baseline testing session. Our previous pilot study showed modest improvements of 6.7° in self-selected toe-out angle following 10-weeks of toe-out gait retraining intending to increase toe-out by 10°, that resulted in marginally statistically significant improvements in late stance KAM ($p=0.04$) and self-reported pain

(p=0.02), and non-significant decreases in KAM impulse (p=0.20). Thus, a larger toe-out increase was selected for this study.

Toe-out modification during the training sessions was facilitated with mirror-guided biofeedback of performance. Participants placed their study foot on a protractor device at the target toe-out angle for that session, and verbally instructed the therapist in the placement of a piece of green tape on the mirror to best cover the reflection of the foot in this target position. The tape remained on the mirror during the training session to guide foot placement during treadmill walking. To promote motor learning, a faded feedback paradigm was used with removal of real-time biofeedback commencing at session 4 (mean percentage of walking time with feedback: Week 6 = 90%; Week 8 = 75%; Week 10 = 60%; Week 12 = 45%; Week 15 = 35%). Self-reported difficulty in achieving the target angle was recorded at each training session using an 11-point numerical rating scale (NRS) with terminal descriptors of 0 = "no difficulty" and 10 = "unable to perform"). Participants were instructed to maintain the increased toe-out angle outside the training sessions whilst walking in the community.

Progressive walking (PW) program

Participants randomized to the PW program underwent all training procedures as those in the TO group, with the exception of receiving no training or instruction related to toe-out walking. This included walking on the treadmill in front of a mirror during training sessions, but without foot placement guide tape as per the TO training protocol.

Outcome measures

Pain and physical function

At each testing session, participants completed the Western Ontario and McMaster Universities Arthritis Index (WOMAC) Likert version[22]. Average knee pain over the previous week was also assessed using an 11-point NRS with terminal descriptors of 0 = "no pain" and 10 = "worst pain imaginable". Overall perceived change at follow-up compared to baseline was assessed using a 15-point Likert scale (-7 = "a very great deal worse" 0 = "about the same", +7 = "a very great deal better"). Finally, participants completed the timed stair climb test where they were instructed to ascend 12 stairs "as quickly as possible", and the fastest time from the two attempts was recorded.

Gait biomechanics

Gait data were recorded for barefoot, over ground walking trials at a self-selected speed. Twenty-two retro-reflective markers were affixed to the participant according to a modified Helen Hayes marker set, and their movements were captured using twelve high-speed digital cameras (Motion Analysis Corp., Santa Rosa, CA) sampling at 100 Hz. An initial standing static trial was collected using additional markers placed over the medial malleoli and femoral epicondyles to determine segment orientations and joint centres of rotation. Kinematic data from the cameras were synchronized with two force platforms (OR6-6, Advanced Mechanical Technologies Inc.) visually concealed in the floor of a 10m walkway and sampling data at 2000 Hz. Participants

were provided no instructions pertaining to walking mechanics during any of the gait assessments.

Inverse dynamics techniques and commercially available software (Orthotrak, Motion Analysis Corp.) were used to calculate gait variables including: KAM (early stance peak, late stance peak, impulse), peak external knee flexion moment (KFM) during stance, and mean foot progression angle during foot-flat (positive values = toe-in orientation, negative values = toe-out orientation). The mean value from five walking trials was calculated for each biomechanical variable.

Adherence, concurrent treatments, and adverse events during interventions

Adherence to both training programs was assessed as the total number of supervised walking sessions attended for each participant. Compliance with the prescribed walking increases was obtained from log book data completed by participants detailing their daily amount of walking for the duration of the study, and weekly totals (in hours) were calculated. Additionally, an 11-point NRS (0 = "not confident at all", 10 = "very confident") in the log book was used to assess self-reported confidence in the ability of those in the TO group to maintain the increased toe-out angle whilst walking in the community. Finally, concurrent treatments and adverse events reported during the intervention were assessed using open-ended questions in the log book maintained by the participants. For the purposes of analysis, adverse events were defined as those lasting longer than two weeks in duration, or requiring additional treatment.

Statistical analysis

The primary outcomes were WOMAC pain, KAM impulse, and foot progression angle, and the primary endpoint was the follow-up assessment. All other biomechanical and clinical outcomes were considered secondary in nature. Between-group comparisons were the primary analyses, with within-group comparisons used for informational purposes. Analysis of covariance (ANCOVA) models were fit predicting each outcome variable evaluated at both time points (follow-up and retention), with group as predictor, and while controlling for baseline values. For biomechanical outcomes (knee adduction and flexion moments, as well as foot progression angle), additional models were computed while additionally controlling for concurrent gait speed at the associated time point (follow-up or retention). For baseline data, crude means were computed. Adjusted least squares means (LS means) with standard errors and 95% confidence intervals were computed for each group at both follow-up and retention. Adjusted LS means were computed in similar models for within-group (delta) scores. Finally, model-adjusted group effects were computed, along with p-values and 95% confidence intervals, for all outcomes.

All data were analyzed using an intention-to-treat analysis, and the primary analyses assumed that data were missing completely at random (MCAR). In sensitivity analyses, multiple imputation was performed as per the methods described by van Buuren. Results and conclusions were compared to the MCAR analysis, and any differences noted. All statistical analyses were conducted by a biostatistician blinded to group allocation and who was not involved in any other aspect of the study. Analyses were performed using SAS v9.4 (SAS Institute, Cary, North Carolina).