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Combined effects of knee brace, laterally wedged insoles and toe-in gait on knee adduction moment and balance in moderate medial knee osteoarthritis patients

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ABSTRACT

Objective: To test the hypothesis that toe-in gait (TI) will further reduce first peak (Knee Adduction Moment) KAM and decrease balance when combined with a knee brace (KB) and laterally wedged insoles (LWI) in medial knee osteoarthritis (kOA) patients.
Participants: Twenty patients with bilateral symptomatic medial kOA.
Interventions: 4-point leverage-based KB, full-length LWI with 5° inclination and toe-in gait (TI).
Main outcome measures: First and second peak knee adduction moment (fKAM and sKAM respectively), balance and pain.
Methods: The fKAM and sKAM were determined from 3-dimensional gait analysis with six randomized conditions: (1) N (without any intervention), (2) KB, (3) KB + TI, (4) LWI, (5) LWI + TI, (6) KB + LWI + TI. Balance was assessed by Biodex Balance System using three stability settings, (i) Static (ii) Moderate dynamic setting for fall risk (FR12) and (iii) High dynamic setting for fall risk (FR8).
Results: The reduction in fKAM and sKAM was greatest (19.75% and 12%) when TI was combined with KB and LWI respectively. No change in balance was observed when TI combined with KB, and LWI and when used concurrently with both the orthosis at static and FR12 conditions. Significant balance reduction was found at FR8 for KB + TI (22.22%), and KB + LWI + TI (35.71%). Pain increased significantly for KB (258%), KB + TI (305%), LWI + TI (210%) and KB + LWI + TI (316%). LWI showed no effect on pain.
Conclusions: There is a synergistic effect of TI when combined with KB and LWI concurrently in sKAM reduction. However, the concurrent use of TI, KB and LWI decreases balance and pain as assessed on a highly dynamic platform.

1. Introduction

Knee osteoarthritis (kOA) is the most commonly occurring type of osteoarthritis in the world [1], largely because of the knee joint's load-bearing characteristics during gait. kOA inflicts an irreversible damage to the joint structures, including bone, cartilage, and joint capsule [2]. The considerably higher tendency of affecting the medial compartment of the knee joint in this disease, as compared with the lateral compartment, is the prime outcome of a higher load share (~70%) borne by the medial compartment [3]. A resulting varus alignment of the knee joint is not only a major risk factor in medial compartment kOA progression but it also further aggravates the aforementioned imbalance of load distribution between the medial and lateral compartments of the knee joint [4]. The external knee adduction moment (KAM), when calculated through 3D gait analysis of kOA patients, has proven this imbalanced load distribution across the joint [5,6]. Across these analyses, KAM has been accepted as a fairly reliable and accurate surrogate measure of the load exerted on the medial compartment of the knee joint [6–9]. It is also reported to be highly related to kOA severity and progression, and as a result, to the knee joint damage [9,10]. Because of

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this, the aim of most of the conservative treatment techniques for kOA is to reduce KAM during gait. Generally, conservative treatments include the use of a knee brace (KB), laterally wedged insoles (LWI), and gait retraining methods. The KB is designed on 3- or 4-point pressure principle to either push or pull the knee joint into a lesser-degree varus position during both stance and swing phases of the gait cycle [11]. The LWI attempts to reduce KAM by laterally shifting the center of pressure (CoP) at the base of the foot and increasing the subtalar joint valgus moment. This lateral shifting of CoP and the counteractive moment lead to a decrease in the ground reaction force (GRF) lever arm, thereby decreasing KAM [12–14].

Currently, it is a matter of interest among researchers that an alteration in gait may result in a reduced joint load and a symptomatic relief among kOA patients [15–18]. The gait alterations include increased mediolateral trunk sway [19–21], reducing the walking speed [18,22], increasing the step-width [23], and altering the foot progression angle (FPA) [24–26]. A mediolateral trunk sway of up to 13.8° is reported to efficiently reduce peak KAM values [21]. This gait modification, however, is not prioritized by the participants, as reported by studies reporting multiparameter gait retraining programs [27–29]. The reported adverse effects of trunk sway include imbalance, lower back discomfort, and difficulty in posture maintenance [27–29]. Changing the walking speed also has significant effects on KAM. As a rule of thumb, increasing the walking speed increases peak KAM, whereas decreasing the speed tends to reduce peak KAM values [18]. There, however, exists a tradeoff between this reduction in peak KAM and the duration of load exposure to the knee joint [18]. The time integral of KAM, knee adduction angular impulse (KAAI), is found to be inversely related to the walking speed [41]. This study, therefore, focuses on the most widely probed gait retraining method, that is, changing the FPA.

A decrease in the FPA, commonly called toe-in (TI) gait, is found to reduce the GRF lever arm by shifting the CoP laterally, just around heel-strike [18]. Validated results from several studies suggest that KB, LWI, and gait retraining methods are effective in KAM reduction individually [30–35]. As the next step, there is a growing research interest in the synergistic effect of these conservative treatment techniques when they are used in a combination [17,36]. One of such studies examined the combined effect of KB and LWI and found further reductions in KAM with their combined usage [37]. Another study has shown that the combined effects of TI and LWI also lead to a better reduction in KAM [17]. However, the combined effect of all three conservative treatment techniques (KB, LWI, and TI) on KAM has not been tested yet.

Another hitherto unexplored effect of conservative treatment techniques is their effect on proprioception of the patients. Because wearing an orthosis or changing the foot's natural FPA dislocates the body's center of pressure, a potentially adverse effect of these techniques may be reducing the already compromised balance of the kOA patients [50,51]. This potentially increased fall risk needs to be avoided, especially for the elderly, because of highly reported fall-induced injuries [38–40], hospitalization [41], and even fatalities [42]. Moreover, the fundamental aim of conservative treatment techniques is to facilitate the performance of the activities of daily living (ADLs). Since maintaining balance and reducing fall risk is a major contributor in performing ADLs, the therapists should make sure that the prescribed conservative techniques are not impairing the proprioception of the patient.

Therefore, our primary objective is to test the immediate effects of the simultaneous use of KB, LWI, and TI on KAM. Our secondary objective is to test immediate effects of the simultaneous use of KB, LWI, and TI on balance in patients with medial kOA. We hypothesize that TI would reduce the first peak KAM further when combined with KB and LWI while decreasing the balance for knee osteoarthritis patients.

2. Materials and methods

2.1. Participants

Twenty participants with bilateral symptomatic medial kOA were recruited from the Department of Sports Medicine, University of Malaya Medical Centre (UMMC). Medial compartment knee OA was confirmed through radiographic evidence and was graded according to the Kellgren-Lawrence scoring system. The patients' diagnosis was confirmed through clinical evidence at the UMMC. The experiment was conducted at the Body Performance Laboratory, University of Malaya.

2.2. Inclusion and exclusion criteria

Participants aged between 50 and 70 years, having a BMI of less than 30 kg/m^2 (non-obese) [43] were included in the study. The bilateral kOA participants were of Kellgren-Lawrence grades II and III. The participants were required to ascend and descend a 10-step flight of stairs and jog 5 m safely. The participants were also screened through a clinical evidence-based diagnosis by a medical specialist from University of Malaya Medical Centre. The participants were excluded on the basis of any neurological or musculoskeletal disorder, cardiovascular or respiratory disease, lower-limb fracture/surgery in the past 12 months or inability to adapt TI gait pattern.

2.3. Sample size

The sample power calculations were based on KAM variables from previous studies [17,37] and considered an F-test statistical design for repeated-measures (within-participants effects), with a moderate effect size of 0.25 [44], a power of 80%, and an alpha error of 5%, suggesting at least 20 participants for this study.

2.4. Ethical approval

Ethical approval was obtained from UMMC Medical Research Ethics Committee (MREC) (MECID.NO: 20161–2070). All participants provided written informed consent for the study.

2.5. Interventions

2.5.1. Knee brace

The study uses a 4-point leverage based knee brace (Donjoy OA Adjuster™ 3, USA), as depicted in Fig. 1(a). We used the more symptomatic leg for knee brace application.

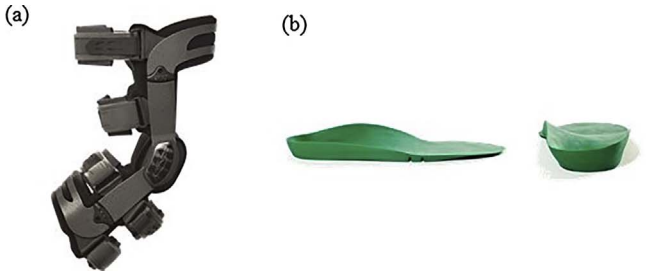

Fig. 1. Interventions used as conservative techniques for knee osteoarthritis treatment. (a) knee brace (Donjoy OA AdjusterTM 3, USA), (b) laterally wedged insole (SalfordinsoleTM, UK), (c) toe-in foot position, where θ is the foot progression angle, which is 15° lesser than natural.