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Combining valgus knee brace and lateral foot wedges reduces external forces and moments in osteoarthritis patients

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ABSTRACT

Osteoarthritis progression can be related to the external knee adduction and flexion moments during walking. Lateral foot wedges and knee braces have been used as treatment for osteoarthritis, but little is known about their influence on knee joint moments generated in the sagittal and frontal planes. Therefore, the aim of the present study was determine the effects of the isolated and combined use of valgus knee brace and lateral wedge foot orthotic on peak forces and moments during gait in knee osteoarthritis patients. Twenty four males (age: 62.1 ± 2.0 years) with varus alignment, symptomatic medial compartment knee osteoarthritis participated in this study. Subjects walked over ground at preferred speed in four conditions: (1) no assistive device (control); (2) using lateral wedges, (3) using knee braces, and (4) using both lateral wedges and knee braces. Ground reaction forces (GRF) and moments, as well as lower limb kinematics were recorded. Peak GRF, vertical loading rate, free moment, external knee adduction and flexion moments were compared across conditions. The concurrent use of lateral wedge and knee brace reduced the first peak GRF in the vertical (6%, $p = 0.002$), anterior-posterior (30%, $p = 0.028$) and medial-lateral directions (44%, $p = 0.029$). Moreover, the use of these devices reduced the peak external knee adduction moment (25%, $p = 0.019$), but not the external flexion moment and free moment ($p > 0.05$). The combined use of lateral wedges and knee braces can reduce medial-lateral knee joint loading, but despite reduced peak forces in the sagittal plane, these device do not reduce joint moments.

1. Introduction

Knee osteoarthritis may become the eighth most common global cause of disability in the world by 2020 [1], affecting about 10% of people over the age of 55 years [2] and inducing pain, reduced mobility and low quality of life. During walking, 60–80% of the contact forces are transferred through the medial knee compartment [3]. This imbalance induces a 10-fold increase in the propensity for osteoarthritis to affect the medial rather than lateral knee compartment [4]. There is an enlarged imbalance in the knee load distribution in individuals with genu varum [5], thus this condition is an important risk factor for medial compartment knee osteoarthritis. The external knee adduction moment generated during walking is relevant to describe dynamic loading in the medial compartment of the knee and osteoarthritis disease progression [6].

Non-invasive treatments with minimal side effects are encouraged as early intervention for individuals with knee osteoarthritis [7]. Foot orthotics and knee braces are common examples of such interventions, in which both valgus knee braces [8] and lateral wedge foot orthotics [8] can reduce knee adduction moments generated during walking. However, these interventions induced only limited improvements in pain and function [9]. Recent evidence showed that valgus braces can reduce knee medial compartment load and muscle co-contraction [10]. Studies have been focusing on reducing the external knee adduction moment to reduce joint loading and slow osteoarthritis progression [11]. However, the external knee flexion moment has been associated with total medial compartment load, suggesting that investigating both flexion and adduction moments are relevant for knee osteoarthritis [12]. The relationship between these knee moments and structural disease progression is important because, in the absence of a cure, interventions usually aim to reduce joint loads related only to the knee adduction moment [13]. Furthermore, flexion moment are substantially influenced by OA-related knee joint pain [14] and can change in response to an intervention [15]. Therefore, it is necessary to explore

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Fig. 1. Custom-made valgus knee brace (a), custom-made full-length lateral wedge orthoses (b) and pre-fabricated shoe (c).

novel methods to reduce pain and improve function in osteoarthritis patients.

Other kinetic variables such as ground reaction forces (GRF), vertical loading rate, impulses and free moments are relevant to describe mechanical changes related to osteoarthritis. It has been demonstrated that both medial and vertical GRF increase in knee osteoarthritis patients [16]. Furthermore, higher vertical loading rate shortly after initial contact may contribute to the development and progression of knee osteoarthritis [17]. Free moment is also associated with torsional forces on the lower limb during walking. Therefore, investigating the influence of valgus bracing and/or lateral wedges beyond measuring external knee adduction moments is relevant to describe the effectiveness of such devices in changing gait mechanics in osteoarthritis patients.

Moyer et al. proposed the simultaneous use of lateral wedges and knee brace as alternative osteoarthritis treatment [18]. The authors found that this combination lead to greater reductions in the knee adduction moment during walking when compared to the sole use of knee braces or lateral wedges. However, this study does not provide data regarding knee loading in the sagittal plane (knee flexion moment), or other kinetic variables (three-dimensional GRF, loading rate, etc.). Therefore, the aim of this study was to determine the effects of using valgus knee braces and lateral foot orthotics, in isolation and combined, on walking kinetics of osteoarthritis patients. It was hypothesized that combining valgus knee brace and lateral wedge would induce greater reductions in peak ground reaction forces, vertical loading rates, impulses in all axes, free moments and external adduction and flexion knee moments during walking when compared to the sole use of knee brace or lateral wedge.

2. Methods

2.1. Participants

Twenty-four male patients (age: 62.1 ± 2.0 years; mass: 71.6 ± 6.2 kg; height: 169.4 ± 8.6 cm) with varus alignment, symptomatic medial compartment knee osteoarthritis in both lower limbs participated in this study. Medial compartment knee osteoarthritis severity was confirmed by clinical criteria from the American College of Rheumatology. Lower limb dominance was determined by the "kicking test" [19]. Inclusion criteria were: 1) varus alignment Q angle < 6° and medial knee epicondyles distance between 6 and 10 cm in upright relaxed standing posture; 2) greater joint space width on the medial side compared with the lateral and 3) pain localized to the medial side of the tibiofemoral joint. The Research Ethics Board of the University of Mohaghegh Ardabili (p/15/32/9/5146–08/03/2016) approved this protocol, and patients provided written informed consent before participation. A prior statistical power analysis program (G*power) revealed that 14 patients were needed for a statistical power of 0.80 at a partial η^2 of 0.199 with an alpha level of 0.05.

2.2. Experimental design

In a single session, four different gait conditions were tested: (1) control condition (no valgus knee brace or lateral wedge) (CC), (2) lateral wedge condition (LWC), (3) knee brace condition (KBC), and (4) both lateral wedge and knee brace condition (LWKBC). The order of testing conditions was randomized for each participant. Randomisation was performed when the participant came in the laboratory. The experimenter was blind for devices/tests order. For each condition, patients were asked to walk at their preferred speed on an 18-m walkway containing two force platforms embedded on the floor. Patients were asked to step on one of these platforms with the dominant leg in every trial, until three correct trials were recorded. A 2-min rest period was provided between test conditions. Patients filled out a visual analog pain scale after each condition.

2.3. Valgus knee brace

Patients used a custom-made valgus knee brace with a point pressure system in medial side to produce a valgus torque (Fig. 1A). The brace was adjusted using straps to set a valgus angle between 4° and 7°. The valgus knee brace did not limit the knee flexion-extension during walking.

2.4. Lateral wedge

Patients used custom-made lateral wedge orthoses made of Lunalastik (NORA-Freudenberg GmbH, Weinheim, Germany) with shore firmness = 60 (Fig. 1B). Firstly, an expert orthopedist fitted five types of prefabricated orthoses (4, 6, 8, 10 and 12 mm lateral height) to each patient during walking. The maximum tolerated wedge height was defined, and a comfortable foot orthotics was designed for each patient. All patients wore the same prefabricated shoes during walking (GEL-Venture 5 (4E)/T5P0N.9099, Asics, Japan, Fig. 1C).

2.5. Motion capture

A 6-camera optical motion capture system (100 Hz sampling rate,