Gait & Posture 59 (2018) 23–27

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Original article

Characteristics of clinical measurements between biomechanical responders and non-responders to a shoe designed for knee osteoarthritis

Yongwook Kim[a], Jim Richards[b,*], Roy H. Lidtke[c], Renato Trede[d]

[a] Department of Physical Therapy, College of Medical Sciences, Jeonju University, Republic of Korea
[b] Allied Health Research Unit, University of Central Lancashire, UK
[c] Section of Rheumatology, Rush University Medical Center, Chicago IL, USA
[d] Departamento de Fisioterapia, Universidade Federal dos Vales do Jequitinhonha e Mucuri, Brazil

ARTICLE INFO

Keywords:
Knee adduction moment
Hip rotation
Knee osteoarthritis

ABSTRACT

Purpose: The purpose of this study was to investigate the characteristics of biomechanical and clinical measurements in relation to the knee adduction moment when wearing a standard shoe and a shoe design for individuals with knee osteoarthritis (Flex-OA).

Methods: Kinematic and kinetic data were collected from thirty-two healthy individuals (64 knees) using a ten camera motion analysis system and four force plates. Subjects performed 5 walking trials under the two conditions and the magnitude of individuals' biomechanical responses where explored in relation to the clinical assessment of the Foot Posture Index, hip rotation range, strength of hip rotators, and active ankle-foot motion, all of which have been described as possible compensation mechanisms in knee osteoarthritis.

Results: Significant reductions in the first peak of the knee adduction moment (KAM) during stance phase (9.3%) were recorded ($p < 0.0001$). However, despite this difference, 22 of 64 knees showed either no change or an increased KAM, indicating a non-response or negative-response to the Flex-OA shoe. Significant differences were observed between the responder and non-responder subgroups in the hip rotation range ratio ($p = 0.044$) and the hip rotators strength ratio ($p = 0.028$).

Conclusion: Significant differences were seen in clinical assessments of hip rotation range and hip rotator strength between responders and non-responders using a cut-off of 0.02 Nm/kg change in the KAM.

1. Introduction

Knee osteoarthritis (OA) is the most prevalent disease amongst individuals aged 50 years and older in South Korea, affecting approximately 12.5% [1]. Clinical characteristics of knee OA are: pain, decreased range of motion, joint instability, muscle weakness, joint stiffness, and proprioceptive loss, all of which decrease quality of life [2].

The knee adduction moment (KAM) during walking in patients with degenerative knee OA has been discussed in previous studies [3–6]. The KAM is primarily calculated by the ground reaction force and its lever arm. The KAM contributes to adduction of the knee and genu-varus deformities, which are significantly correlated with OA severity [7]. Therefore, reduction of the external KAM during walking is clinically important for treatment of OA. Biomechanical interventions such as: orthotic shoe inserts [8], knee braces [9,10], and specialized footwear [11–14] for knee OA aim to improve pain, decrease joint loading, and delay disease progression.

Over the past two decades, specialized footwear has been developed for the potential conservative management of knee OA [12]. Recently, Shakoor et al. reported that, following use of specialized mobility footwear, the Flex-OA shoe, the KAM was reduced by 18% compared to use of the participants' own shoe [14]. Although the Flex-OA shoe had a significant effect on KAM, no study has explored whether this effect is universal or whether responder and non-responder groups may exhibit differences in clinical and biomechanical measurements. Therefore, the purpose of this study was to explore differences in KAM in a healthy population when wearing a standard shoe and the Flex-OA shoe, and to investigate the characteristics of individuals' responses from biomechanical and clinical assessments.

2. Methods

2.1. Participants

This study recruited 32 healthy volunteers who consented to

* Corresponding author at: Allied Health Research Unit, University of Central Lancashire, Brook Building, Preston, Lancashire PR1 2HE, UK.
E-mail address: jrichards@uclan.ac.uk (J. Richards).

http://dx.doi.org/10.1016/j.gaitpost.2017.09.038
Received 24 April 2017; Received in revised form 16 August 2017; Accepted 28 September 2017

participate in the study and met the selection criteria. There were twenty-four males and eight females in the study population. Participants were given a detailed explanation of the study procedure and written informed consent was obtained. This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the STEMH Ethics Committee of the University of Central Lancashire (STEMH 347).

Volunteers who were able to walk freely for 10 m were recruited for this study. Volunteers who had any neurological, musculoskeletal, or cardiopulmonary problems were excluded. The mean age, height, and weight of all participants were 30.4 ± 11.5 years, 174.5 ± 9.6 cm, and 72.3 ± 12.9 kg, respectively.

2.2. Instrumentation and procedure

A Qualisys Motion Capture System (Qualisys, Gothenburg, Sweden) was used to collect three-dimensional kinematic and kinetic data from participants walking along a 10 m walkway wearing a standard shoe (control) and the Flex-OA shoe. Qualisys Track Manager software (Qualisys, Gothenburg, Sweden) was used to obtain data using ten Oqus-7 cameras (Qualisys, Gothenburg, Sweden) sampling data at 100 Hz. The camera system was synchronised with four BP400600 force platforms (AMTI, Massachusetts, USA), which were embedded in the middle of the walkway and sampled data at 500 Hz. A 750 mm calibration wand was used to calibrate the motion capture system and an L-frame reference object was used to identify the lab origin.

Changes in joint angles and moments of 32 subjects (64 healthy knees) were measured during walking when wearing the Flex-OA shoe (DJO Global, Vista, CA, USA) and a standardised shoe (Athletic footwear, DJO Global, Vista, CA, USA), which were tested in a randomised order. For the dynamic walking conditions, participants wore 52 retro reflective markers (14 mm), which were attached bilaterally onto the: pelvis, thigh, leg, and shoes over the rearfoot, midfoot and forefoot. Additional markers were placed bilaterally over the following anatomical locations: malleoli, femur epicondyles, greater trochanters, and anterior and posterior superior iliac spines. Marker clusters of four markers were affixed bilaterally on the shank and thigh according to the six-degrees-of-freedom (6DOF) model [15] (Fig. 1). Initially, a static trial was taken, which served as an anatomical calibration file. Participants were then asked to walk along a 10 m walkway in the laboratory at their self-selected walking speed. A total of 5 walking trials were collected for each shoe condition and data were obtained bilaterally. Participants were not given any walking instructions other than to walk at their self-selected speed and were allowed adequate rest if needed. In trials where participants did not make complete foot contact on the force plate, kinetic data from that trial were excluded. The mean of all gait trials of the Flex-OA shoe and the standardised shoe of all participants were 7.4 ± 2.6 trials, and 7.2 ± 1.9 trials, respectively.

Following data collection, Visual 3D motion analysis software (C-Motion, Rockville, MD, USA) was used to analyse kinematic and kinetic data using the Calibrated Anatomical System Technique with a modified oxford foot model. Kinematic data were low-pass filtered with a 4th order Butterworth filter with a cut-off frequency of 6 Hz. Kinetic data were low-pass filtered using a 4th order Butterworth filter with a cut-off frequency of 15 Hz. KAMs were calculated using inverse dynamic analysis. Fig. 2 illustrates examples of KAM during stance phase. The X-Y-Z Cardan sequence was used to define the order of rotations following the Right Hand Rule about the segment coordinate system axes. Joint kinematic and kinetic data were normalized to the gait cycle starting with initial heel contact. GRF data and joint moments were normalized for body weight.

The magnitude of individuals' responses where explored in relation to the clinical assessment of: the Foot Posture Index (FPI), passive hip rotation range, strength of hip rotators, and ankle motion, all of which have been described as possible compensation mechanisms in knee OA [16–18].

Fig. 1. Marker positions on lower limbs and pelvic during static calibration and walking trials.

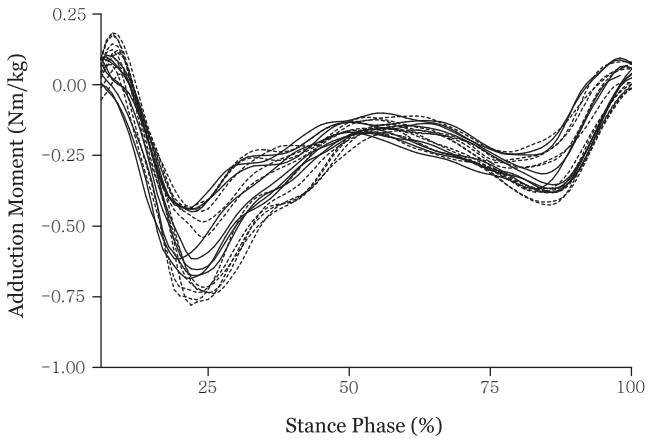

Fig. 2. Intra-individual variability of knee adduction moment during stance phase. Flex-OA shoe moment (solid line) and standardized shoe moment (dot line) from 25 repetitive trials (thin line) and their average (thick lines).

The FPI is a clinical diagnostic tool used to quantify the degree to which a foot can be considered to be in a pronated, supinated or neural position [19]. A previous study reported that the FPI exhibited good intra-observer reliability and moderate inter-observer reliability [20]. The six criteria version of the FPI was used to assess foot position on the bilateral foot. Foot position was assessed while participants stood in their relaxed standing position with double limb support, arms along each side of the side of the body, and looking straight ahead. The six-items of the FPI were: talar head palpation, supra and infra malleolar curvature, calcaneal frontal plane position, prominence in the region of the talonavicular joint, congruence of the medial longitudinal arch, and abduction/adduction of the forefoot on the rearfoot, with reference values ranging from −12 (severely supinated) to +12 (severely pronated).

A standard 12-in. plastic, round universal goniometer was used to measure passive hip rotation range of motion (ROM). For measuring hip ROM, participants were placed in the prone position on a firmly padded