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Potential interaction of experimental knee pain and laterally wedged insoles for knee off-loading during walking

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ABSTRACT

Background: Laterally wedged insoles are one of the gait modifications potentially slowing down progression of medial knee osteoarthritis. Clinical studies have, however, found large individual differences in the biomechanical effect and an insufficient pain reduction. To clarify if and how pain mediates mechanical changes during gait the current study investigated how acute experimental knee pain changes the mechanical effect of laterally wedged insoles in healthy subjects during walking.

Methods: 3D gait analysis was carried out for twelve healthy individuals. The study followed a cross-over design and data were collected with both a neutral and a 10-degree laterally wedged insole with experimental pain induced by hypertonic and isotonic saline injections into the infrapatellar fat pad. Peak knee adduction moment was the primary outcome. A repeated ANOVA (analysis of variance) was used to evaluate the relationship between the factors wedge, condition and test number.

Findings: Wedges significantly reduced peak knee adduction moment but experimental knee pain did only marginally affect its magnitude in either condition. While frontal plane mechanics were relatively unaffected by pain, the sagittal plane knee extension moment increased with laterally wedging ($P = 0.008$), whereas late knee flexion moment was reduced by experimental knee pain ($P = 0.04$).

Interpretation: The effect of laterally wedged insoles in attenuating knee adduction moment during walking is independent of experimental knee pain. The present study provides evidence that subjects with experimental knee pain reduce knee loading by reducing extension moment, whereas lateral wedges have the opposite effect and increase the extension moment.

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1. Introduction

Knee osteoarthritis (OA) is one of the most common chronic joint diseases worldwide with the medial compartment more frequently affected than the lateral (Felson, 2006). The disease progression of knee OA is marked by muscle weakness, joint deformities, instability, inflammation, joint effusion and pain as the cardinal symptom indicating a tremendous impact on quality of life (Felson, 2006). Initiation, progression and successful treatment of OA have often been centered on aspects of mechanical loading (Wilson et al., 2013). Cross-sectional studies have shown a relationship between the external knee adduction moment (KAM) and medial knee joint loads (Baliunas et al., 2002; Miyazaki et al., 2002; Thorp et al., 2007) although a high individual variability has been observed across otherwise homogenous groups of patients (Kutzner et al., 2011). Peak knee adduction moment has been associated with the presence, severity (Mundermann et al., 2004) and rate of progression (Miyazaki et al., 2002) of medial knee OA while only a few longitudinal studies have provided a strong link of knee adduction moment and OA initiation (Bennell et al., 2011b; Miyazaki et al., 2002).

A consistent observation is that peak adduction moments are increased in medial knee OA patients compared with asymptomatic subjects and radiographic disease severity influences the difference between patients and asymptomatic subjects (Astephen et al., 2008; Baliunas et al., 2002; Mundermann et al., 2004). Nevertheless, in patient groups with less severe knee OA, i.e., with a Kellgren–Lawrence (K–L) score ≤ 2, lower (Henriksen et al., 2010) or similar peak knee adduction moments have been observed when compared to healthy control subjects (Mundermann et al., 2004; Mundermann et al., 2005). Munderman et al. and Fregly et al. suggested the importance of considering both frontal and sagittal plane kinetics to better understand the gait alterations observed in OA (Fregly et al., 2007; Mundermann et al., 2005). Several studies have shown that pain relief or induced pain may change knee loading during walking (Briem et al., 2009; Henriksen et al., 2006, 2010; Hurwitz et al., 2000; Schnitzer et al., 1993) indicating that pain may trigger a protective mechanism by a

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reduction of medial knee loading. It is, however, not fully understood if and how pain may best be controlled to slow down disease progression (Hurwitz et al., 2000).

Laterally wedged insoles are one of the common treatment strategies that have been shown to reduce knee adduction moment in healthy subjects and in patients with knee OA (Kakihana et al., 2005b; Kean et al., 2013; Kerrigan et al., 2002; Mølgaard and Kersting, 2011). However, the promising biomechanical effects of laterally wedged insoles have not been found to slow down disease progression or reduce pain in patients with knee osteoarthritis (Bennell et al., 2011a). It is therefore required to further investigate the interaction of pain and mechanical interventions such as lateral wedges. Experimental techniques to induce localized pain in healthy subjects have therefore been suggested as a model for simulation of OA related gait alterations (Henriksen et al., 2010). The infrapatellar fat pad has a high proportion of nociceptive afferents (Bohnsack et al., 2005) and stimulation of this structure induces anteromedial knee pain with alterations in sensory-motor control comparable to what is seen in clinical anterior knee pain (Hodges et al., 2009). Thus this pain model has been suggested to simulate a pain distribution similar to that of knee OA patients (Henriksen et al., 2010).

The aim of the present study was to assess if acute experimental knee pain alters the mechanical effect of laterally wedged insoles in healthy subjects during walking. It was hypothesized that laterally wedged insoles reduce knee adduction moment and that this reduction is further increased by experimental knee pain during walking.

2. Methods

2.1. Participants

Twelve healthy individuals with no current knee pain or history of trauma or knee surgery were included. Eight men and four women with an average age of 31.9 years (range: 22–50), height of 1.75 m (range: 1.57–1.96); body mass index (BMI): 24.0 (range: 20.2–28.6). None of the included subjects suffered from neurological, psychological, or cardiovascular diseases or had any pain during the week prior to participating. All participated after giving oral and written consent. The study was conducted in accordance with the Declaration of Helsinki and approved by the local ethical committee (N20080066).

2.2. Protocol

The study was designed as a cross-over study with each subject tested on two days separated by at least one week. During each test day, six series of walking trials were performed alternating between neutral and wedged shoes and the initial conditions randomized in a balanced design (Fig. 1). A neutral running shoe (Nike Air Pegasus) was used both with and without a full length 10-degree laterally wedged insole (Rehband, Technogel® — Pes Velour). Subjects were tested at a self-selected and controlled pace on a 10-meter walkway and at least five walking trials per series were recorded. Series 1 and 2 served as control before unilateral injections of either hypertonic (painful) or isotonic (control) saline provided before each of the series 3 to 6. Only one type of saline was injected on each test day. Prior to each walking trial, subjects were asked to rate their knee pain on a numeric rating scale from 0 to 10. The subjects continued to perform the walking trials at constant walking speeds until the pain had vanished. The order of the saline type was selected using a wedge-stratified randomization technique, allowing equal numbers of neutral and laterally wedged insoles starting with isotonic and hypertonic saline, respectively (Fig. 1). Series were separated by a 10-min break after pain had vanished, during which the subjects rested on a chair and changed inserts.

2.3. Experimental knee pain

Sterile hypertonic saline (5.8%, 0.25 ml) was injected into the right infrapatellar fat pad, medial to the patella tendon and proximal to the joint line. The injection was directed at 45° in a superolateral direction (Hodges et al., 2009). Isotonic saline (0.9%, 0.25 ml) was injected as a control. Immediately before each walking trial the pain intensity was verbally rated by the participant on an 11-point numerical rating scale (NRS) where 0 indicated 'no pain' and 10 was equal to 'worst pain possible' (Bellamy et al., 1997).

2.4. Gait analysis

Participants' height, bodyweight, and Foot Posture Index (FPI-6) (Redmond et al., 2006) as well as self-reported weekly hours of moderate to high activity (e.g., brisk walking, sport, transport cycling, physical work, cleaning or gardening) (Pedersen and Andersen, 2011) level were recorded prior to gait analysis.

Participants walked along the walkway at a self-selected pace measured by two photoelectric cells. Self-selected walking velocity was practiced until a comfortable speed was maintained within ±5%. Requirements were to obtain the walking speed without adjusting step length, and to maintain the required walking speed while crossing the force platform incorporated in the walkway. Trials not meeting these criteria were excluded from the analysis. Kinematic data were collected at 120 Hz using an 8-camera system (Qualisys Oqus 300, Gothenburg, Sweden) and ground reaction forces were recorded at 1200 Hz from two AMTI force platforms (AMTI OR6-5, Advanced Mechanical Technologies, Inc., MA, USA). Motion and force recordings were synchronized. Joint centers of the lower right limb were defined using 19-mm retroreflective markers placed bilaterally over the iliac crests,

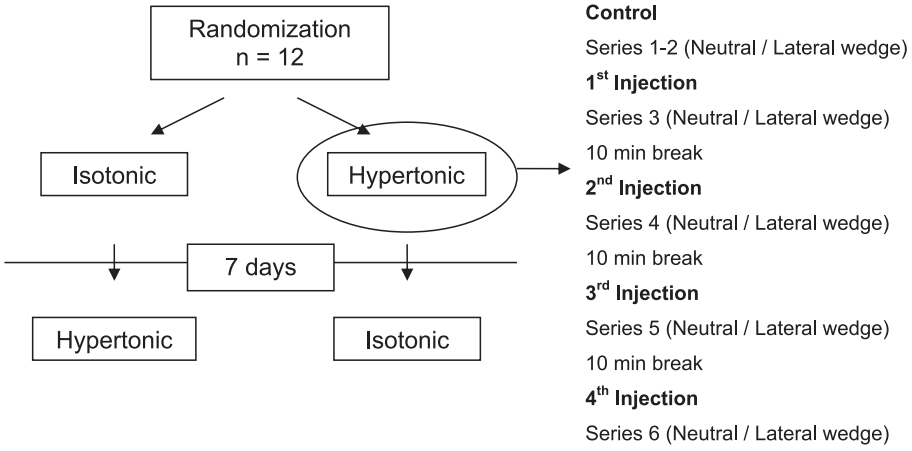

Fig. 1. Study design.

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