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Comfort and midfoot mobility rather than orthosis hardness or contouring influence their immediate effects on lower limb function in patients with anterior knee pain

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ABSTRACT

Background: Despite evidence for use of foot orthoses in the treatment of anterior knee pain, there is a paucity of research into their mechanisms of action. This study (i) determined the immediate lower limb kinematics and muscle activity adaptations, and (ii) evaluated the effect of individual's comfort and foot mobility.
Methods: Forty individuals diagnosed with anterior knee pain were measured for lower limb kinematics and electromyographic activity (via surface electrodes) while they jogged in three prefabricated contoured orthoses (hard, medium and soft) and a soft-flat orthosis. Subjects ranked orthoses in order of comfort.
Findings: Soft orthoses were more comfortable. No immediate adaptations in kinematics and electromyographic activity were observed when orthoses were added to shoes. There were few effects of perceived comfort and foot mobility, one being a significant interaction in frontal plane hip motion (Pillai's $V=0.089$, $P=0.031$) with the least comfortable orthosis producing the greatest relative adduction in those with mobile feet (0.54° (standard deviation 0.87)). Other main effects were a significant increase in vastus lateralis activity when wearing the least comfortable orthosis (6.94%, $P=0.007$) and a delay in offset of medial gastrocnemius in individuals with less mobile feet (1.51%, $P=0.045$).
Interpretation: It is becoming apparent that it is important to use more comfortable foot orthoses in a condition like anterior knee pain, where there is an associated increased hip adduction and vastus lateralis activity with least comfortable orthoses. Future research is needed to determine adaptations after ongoing wearing of orthoses.

1. Introduction

There is an increasing body of evidence supporting the use of in-shoe foot orthoses in the treatment of anterior knee pain (AKP) (Collins et al., 2008; Eng and Pierrynowski, 1994). Despite this emergent evidence of efficacy, there is a paucity of research into the mechanism by which orthoses exert their effect. A recent systematic review suggests that the neuromotor effect of orthoses may be dependent on the injury history of the individual (Mills et al., 2010a). Asymptomatic individuals demonstrate increases in amplitude of electromyographic activity of tibialis anterior, peroneus longus, biceps femoris and quadriceps muscles (Mundermann et al., 2006; Murley and Bird, 2006), whereas individuals with a range of lower limb injuries show a reduction in biceps femoris activity (Nawoczenski and Ludewig, 1999).

Clinically, the prescription of orthoses is often based on re-aligning the lower limb skeleton. This principal is the topic of some conjecture as several investigations have noted no systematic difference between rearfoot and tibial kinematic variables in individuals with low and high-arches wearing both custom-moulded and pre-fabricated orthoses (Nawoczenski et al., 1995; Zifchock and Davis, 2008). In individuals diagnosed with AKP, Eng and Pierrynowski (1993) reported soft orthoses produced kinematic changes of the knee and ankle during different phases of walking and running gait. However, point estimates of effect were small and the clinical relevance of such changes questionable.

Nigg et al. (1999) suggested this traditional notion of skeletal re-alignment is questionable and highlighted the importance of comfort. Accordingly, an orthosis perceived as comfortable will reduce muscle activity, and consequently fatigue, by supporting the preferred movement path (Nigg et al., 1999). Orthosis comfort is a complex issue, which has been suggested as a prognostic indicator of orthosis success (Hennig et al., 1996; Jordan et al., 1997; Miller et al., 2000; Mundermann et al., 2002; Nigg et al., 1999). Perhaps more simply, it has also been observed that if an orthosis is not comfortable, individuals desist wearing them (Finestone et al., 2004; Pawelka et al., 1997).

Commonly observed features of AKP are a disruption in coordination of the vastii muscles as well as strength deficits of hip abductors and external rotators (Cichanowski et al., 2007; Coqueiro et al., 2005; Robinson and Nee, 2007; Van Tiggelen et al., 2009). The dearth of research into the neuromotor adaptation to orthoses in this population is, therefore, surprising due to their advocated use (Barton et al.,

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2010b; Gross and Foxworth, 2003; Neptune et al., 2000) and as jogging gait is frequently reported as an aggravating activity (Barton et al., 2010a; Collins et al., 2008; Crossley et al., 2002; Fagan and Delahunt, 2008; Robinson and Nee, 2007). Therefore the first aim of this study was to determine whether orthoses, regardless of comfort level, produce immediate changes in electromyography (EMG) and kinematics of the lower limb compared with the shoe. As comfort and foot function have been identified as important considerations in the prescription of orthoses, the second aim was to establish whether perceived comfort of orthoses and foot mobility influence the magnitude of acute EMG and kinematic adaptations.

2. Methods

We addressed the aims of the study by measuring the immediate effects of a range of orthoses on changes in EMG and kinematics of the lower limb in patients with AKP, with follow up analyses of the immediate influence of comfort perception and foot mobility.

2.1. Participants

Participants were recruited for a randomised controlled clinical trial through local advertisement on notice boards, newsletters and websites and upon screening had to meet the following criteria to be included in the study: (1) age 18 to 40 years; (2) anterior or retropatellar knee pain of a non-traumatic origin with a duration of longer than 6 weeks; (3) aggravated by at least 2 of the following activities: running, hopping, hill or stair walking, prolonged sitting or kneeling, or squatting; and (4) pain on palpation of the patellar facet or double leg squat. Exclusion criteria were (1) concomitant pain or injury in the hip, pelvis or lumbar spine; (2) damage to any knee structures or indications of patella tendinopathy; (3) chronic patella instability (4) knee effusion; (5) any foot conditions that would preclude the use of orthoses; (6) the use of physiotherapy treatment for knee pain or foot orthoses in the previous 3 years; or (7) any previous lower limb surgery (Collins et al., 2008; Crossley et al., 2002). Forty people met these criteria and were recruited for the study (Table 1). The study was approved by the Medical Research Ethics Committee of the University of Queensland. Prior to enrolment, subjects were familiarised with the protocol and written informed consent was obtained.

2.2. Orthoses

All participants were fitted with prefabricated orthoses constructed of ethylene-vinyl acetate (EVA) with fabric covering (Vasyli International, Labrador). Three orthoses exhibited the same contouring (manufacturer's specification) but were of different hardness (Supplemental data 1): hard (Shore A 75°); medium (Shore A 60°) and; soft (Shore A 52°). A fourth orthosis featured identical Shore A value to the soft orthosis but was of uniform thickness (3 mm) along its length (i.e. flat). Subjects were blinded to the difference between the orthoses.

Table 1
Means (SD) of participants. Groups defined by foot mobility.

	Mobile (>10.96 mm)	Less mobile (<10.96 mm)
n	27	13
n of women (%)	19 (70)	10 (77)
Age (years)	28.67 (6.13)	31.15 (4.41)
Height (cm)	169.58 (14.94)	171.2 (8.41)
Weight (kg)	71.03 (11.97)	71.15 (11.22)
Jogging speed (km/h)	8.11 (1.67)	8.31 (2.10)

2.3. Electromyography

We measured EMG activity from 8 muscles of the symptomatic leg. In instances where individuals reported bilateral knee pain, measures were taken from the patient's chosen worse knee. Circular pre-gelled bipolar silver/silver chloride surface electrodes were used to measure activity from tibialis anterior (TA), soleus (SOL), medial gastrocnemius (MG), rectus femoris (RF), vastus lateralis and medialis obliquus (VL, VMO), bicep femoris (BF) and gluteus medius (GM). Electrodes had a 10 mm diameter contact area and fixed inter-electrode distance of 20 mm (Viasys NeuroCare Inc, San Diego, USA). Skin preparation was conducted in accordance with SENIAM guidelines (Hermens et al., 2000) and electrode placement was referenced to recommendations of previous literature (Chapman et al., 2006; Hermens et al., 2000; Perotto, 1994) and innervation zones reported by Rainoldi et al.(2004) (Supplementary Data 2). A ground electrode (3M HealthCare, Pymble City, Australia) was placed on the proximal tibial shaft. Data was sampled at 3000 Hz and band-pass filtered between 10 and 1000 Hz.

2.4. Kinematic data

Three dimensional motion analysis of the ankle, knee, hip and pelvis was conducted using a 14 camera VICON system (Oxford Metrics, Oxford, UK) capturing at a sampling rate of 250 Hz. Retroflective markers, 14 mm in diameter, were placed on both lower limbs according to the Plug In Gait model (Oxford Metrics, Oxford, UK) which was used to determine kinematic data. Joint rotations were referenced to a standing position.

2.5. Classification of foot mobility

In a recently published paper, Vicenzino et al. (2010) reported a change of midfoot width from weight bearing to non-weight bearing to be one of four predictors, and the only foot posture measure of those included in the analysis, that could identify individuals with AKP who would benefit from the use of orthoses. Therefore, participants were classified on their midfoot mobility measured with a foot assessment platform using a previously described protocol (McPoil et al., 2009). Twenty-seven participants demonstrated greater than 10.96 mm change in midfoot width and were considered to have a more mobile midfoot (McPoil et al., 2009; Vicenzino et al., 2010) (Table 1).

2.6. Protocol

Participants jogged on a treadmill in 3-minute intervals alternating between their usual jogging shoe and their shoe with an orthosis inserted, until all orthoses has been trialled (8 intervals). Prior to commencement all shoes were inspected for wear (KM) such as torn uppers, damage to the outer sole. No instances of excessive wear were found and all participants reported their shoes were purchased within the last 9 months. Participants were requested to self-select a jogging speed that would not provoke their pain and could remain constant throughout the protocol. There was no restriction placed on the time between intervals. The order of presentation of the orthoses to subjects was randomised between subjects. Importantly, the orthoses were inserted into shoes out of the subjects' visual field in order to maintain blinding.

After all the orthoses had been worn, participants were asked to rank the orthoses in order of most comfortable to least comfortable (i.e., 1 = most comfortable, 4 = least comfortable). As participant were blinded to the actual orthosis that they were wearing during any jog, the participants nominated the number of the trial. A ranking scale was chosen as this has been shown to be the most reliable