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The immediate effects of foot orthoses on hip and knee kinematics and muscle activity during a functional step-up task in individuals with patellofemoral pain

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ABSTRACT

Background: Evidence shows that anti-pronating foot orthoses improve patellofemoral pain, but there is a paucity of evidence concerning mechanisms. We investigated the immediate effects of prefabricated foot orthoses on (i) hip and knee kinematics; (ii) electromyography variables of vastus medialis oblique, vastus lateralis and gluteus medius during a functional step-up task, and (iii) associated clinical measures.
Methods: Hip muscle activity and kinematics were measured during a step-up task with and without an anti-pronating foot orthoses, in people (n = 20, 9 M, 11 F) with patellofemoral pain. Additionally, we measured knee function, foot posture index, isometric hip abductor and knee extensor strength and weight-bearing ankle dorsiflexion.
Findings: Reduced hip adduction (0.82°, $P = 0.01$), knee internal rotation (0.46°, $P = 0.03$), and decreased gluteus medius peak amplitude (0.9 mV, $P = 0.043$) were observed after ground contact in the '*with orthoses*' condition. With the addition of orthoses, a more pronated foot posture correlated with earlier vastus medialis oblique onset ($r = -0.51$, $P = 0.02$) whilst higher Kujala scores correlated with earlier gluteus medius onset ($r = 0.52$, $P = 0.02$).
Interpretation: Although small in magnitude, reductions in hip adduction, knee internal rotation and gluteus medius amplitude observed immediately following orthoses application during a task that commonly aggravates symptoms, offer a potential mechanism for their effectiveness in patellofemoral pain management. Given the potential for cumulative effects of weight bearing repetitions completed with a foot orthoses, for example during repeated stair ascent, the differences are likely to be clinically meaningful.

1. Introduction

Patellofemoral pain (PFP) is one of the most common presentations in recreationally active and sporting populations (Baquie and Brukner, 1997; Taunton et al., 2002). Of 2429 injury presentations to a sports medicine clinic over a 12 month period, 668 (27.5%) cases affected the knee, with PFP reported to be the most common knee complaint (Baquie and Brukner, 1997). Furthermore, a study of 2002 running injuries over a two-year period in a sports medicine clinic, reported 331 patients (16.5%) were diagnosed with PFP (Taunton et al., 2002). PFP is commonly aggravated by stair ascent and descent, squatting, sitting for long periods and high impact activity such as running (Kujala et al., 1993). Despite its high prevalence and positive short term treatment outcomes (Collins et al., 2008; Crossley et al., 2002), 80% of individuals who complete a rehabilitation programme for PFP still report pain, and 74% report a reduction in physical activity at 5 year follow up (Stathopulu and Baildam, 2003), highlighting the need for more effective management plans to be identified. With the aetiology of PFP widely accepted to be multifactorial in nature (Powers et al., 2012), these poor long-term outcomes may represent a failure to address the specific deficits contributing to the development and persistence of PFP.

Anti-pronating foot orthoses (APFOS) are commonly prescribed to individuals with PFP, and have been reported to effectively reduce pain and improve function (Collins et al., 2008; Eng and Pierrynowski, 1993; Mills et al., 2012a). However the mechanism for their effectiveness is poorly understood (Barton et al., 2010). Tiberio (1987) proposed that excessive sub-talar joint pronation may lead to greater tibial and hip internal rotation, and consequently increased lateral tracking and loading of the patellofemoral joint (PFJ). This proposed kinematic coupling between lower limb segments has been supported by reports that greater peak rearfoot eversion is associated with greater tibial internal rotation during walking in individuals with PFP (Barton et al., 2012). It is proposed the APFOS may prevent these aberrant movement patterns and hence reduce pain associated with PFP (Tiberio, 1987).

Step negotiation was chosen to explore lower limb biomechanics in PFP populations due to higher loading forces reported within the PFJ

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during this activity (Andriacchi et al., 1980) and patients commonly reporting symptoms with stairs (Kujala et al., 1993). Contrary to previous findings that reported changes in symptomology (Eng and Pierrynowski, 1993), foot and knee (Eng and Pierrynowski, 1994) and hip (Lack et al., 2014) kinematics resulting from foot orthoses, Mills et al. (2012b) reported no significant changes to hip or knee kinematics in individuals with PFP during running with the addition of APFOS (Mills et al., 2012b). The lack of consistent findings between studies potentially highlights the multifactorial nature of the condition, differences in biomechanical response to orthoses during differing tasks, or possibly a delay in the influence of APFOS on kinematic variables in individuals with PFP.

Another proposed mechanism for foot orthoses effectiveness is altered neuromotor control. Nigg et al. (1999) proposed that an orthoses that supports a preferred movement path could minimise muscle activity and reduce fatigue by providing input through the sole (Nigg et al., 1999). Individuals with PFP have been reported to frequently possess altered neuromotor control with delayed onsets of vastus medialis oblique (VMO) (Chester et al., 2008; Lankhorst et al., 2013) and gluteus medius (GMed) (Barton et al., 2013) muscle. Despite these identified deficits and theoretical rationale for foot orthoses to address them, a paucity of research exploring the effects of orthoses on neuromotor variables exists (Mills et al., 2010). Recent studies exploring proximal neuromotor effects of APFOS have reported no immediate changes in gluteal and quadriceps muscle onsets or amplitudes during running in individuals with PFP (Mills et al., 2012b) or during a functional step-up task in asymptomatic individuals (Lack et al., 2013). However, with electromyography (EMG) changes described as being highly variable within a heterogeneous population (Mundermann et al., 2006) and PFP widely regarded as having a multifactorial aetiology (Powers et al., 2012), further work exploring the association of specific EMG changes with clinically applicable measures is clearly warranted.

The primary aim of this study was to explore the immediate effects of prefabricated foot orthoses on (i) hip and knee kinematics; and (ii) electromyography (EMG) variables of VMO, vastus lateralis (VL) and GMed. The secondary aim of this study was to identify clinical measures that may be associated with these changes.

2 . Methods

Symptomatic participants had biomechanical data collected at the knee and hip during a functional step-up task. Clinical measures were obtained prior to testing and subsequently analysed to determine any correlation with changes observed due to orthoses application.

2.1 . Participants

Twenty individuals (9 M 11 F; Table 1) were recruited to participate in the study through referral from private sports medicine clinics in greater London. A sports physician or registered physiotherapist with over 5 years clinical experience assessed all potential participants for inclusion based on; (1) age 18–40 years; (2) insidious onset of anterior knee or retropatellar pain of greater than six weeks' duration; (3) provoked by at least two of prolonged sitting or kneeling, squatting, running, hopping, or stair walking; (4) tenderness on palpation of the patella, or pain with step down or double leg squat; and (5) worst pain over the previous week of at least 30 mm on a 100 mm visual analogue scale. Exclusion criteria were; (1) concomitant injury or pain from the hip, lumbar spine, or other knee structures; (2) previous knee surgery; (3) patellofemoral instability; (4) knee joint effusion; (5) any foot condition that precluded use of foot orthoses; (5) physiotherapy or foot orthoses treatment within the previous year; and (6) use of anti-inflammatory drugs (Collins et al., 2008). Ethical approval was obtained from Queen Mary University Ethics of Research Committee and each participant provided written informed consent.

Table 1
Patient demographics and clinical measures.
Values are mean (SD) unless otherwise stated.

Measure	N = 20
Age	28.5 years (4.2)
Height	171.9 cm (7)
Weight	64.8 kg (9.7)
Kujala patellofemoral score (Median (IQR))	80 (10.75)
Orebro SCORE (Median (IQR))	63 (20.75)
Foot posture index	5.4 (3.2)
Knee straight ankle dorsiflexion	39.4° (5.8)
Knee bent ankle dorsiflexion	45° (6.6)
Hip abduction strength	26.2 kg (6.2)
Knee extension strength	30.8 kg (7.4)

2.2 . Clinical measures

2.2.1 . Kujala patellofemoral score

The Kujala patellofemoral score (KPS) is a 13-item questionnaire categorising symptoms and current knee function, such as the ability to negotiate stairs, walk, run, jump and sit for prolonged periods. Each item is weighted and a total score between 0 and 100 calculated, with higher scores representing greater levels of function (Kujala et al., 1993).

2.2.2 . Foot posture index

Methods for measuring foot posture index (FPI) have been reported previously (Lack et al., 2013). Briefly, the lead author with established excellent intra-tester reliability (ICC = 0.94) assessed static foot posture (SL). Participants were instructed to march on the spot and then stand in a comfortable position as the examiner assessed the dominant foot. A score from −12 to +12 was obtained with scores between 0 and 5 normal, 6 and 9 pronated, 10+ highly pronated, −1 and −4 supinated and −5 and −12 highly supinated.

2.2.3 . Ankle dorsiflexion range

Weight bearing, knee straight (KSAD) and knee bent (KBAD) ankle dorsiflexion range was measured using digital inclinometer methods previously described (Lack et al., 2013). The long axis of the foot was aligned with a taped line on the floor perpendicular to a wall. Participants lunged as far forward as possible whilst keeping the heel on the ground. The largest KSAD and KBAD angle of the three measures was recorded from the inclinometer (Baseline® Digital Inclinometer 12-1057; Fabrication Enterprises Inc, New York, USA) placed on the anterior tibia with the knee fully straight and maximally bent respectively.

2.2.4 . Others

Orebro musculoskeletal pain questionnaires were administered to evaluate the risk of long-term disability (Linton and Boersma, 2003), and hip abduction and knee extension maximum voluntary isometric strength were measured using a hand held dynamometer method described previously (Bohannon, 1986).

2.3 . Electromyographic recordings

Muscle activity of VMO, VL and GMed of the participant's affected leg was recorded by wireless surface electromyography (sEMG) (Telemyo 2400 T G2, Noraxon, USA). Where subjects reported bilateral symptoms, their most symptomatic leg was used. The subject's skin was prepared and pairs of Ag/AgCl surface electrodes with an intra-electrode distance of 20 mm (Tyco Healthcare, Germany) were placed over the muscles of interest according to standard SENIAM guidelines (Freriks et al., 2000). The GMed electrode was placed halfway along the line between the iliac crest and greater trochanter, orientated vertically. The VMO electrode was placed at 80% of the distance down the line between the anterior superior iliac spine (ASIS) and the medial knee joint line just anterior