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The effect of anti-pronation foot orthoses on hip and knee kinematics and muscle activity during a functional step-up task in healthy individuals: A laboratory study

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ABSTRACT

Background: Greater frontal and transverse plane hip and knee motion, and delayed gluteus medius and vastus medialis oblique activation have frequently been identified in patellofemoral pain syndrome populations, whilst prefabricated anti-pronation foot orthoses have been reported to reduce symptoms. The aim of the study was to evaluate the effects of such orthoses on hip and knee kinematics, gluteal and vasti muscle activity, kinematic and electromyographic interactions alongside correlations with specific clinical measures.
Methods: Eighteen asymptomatic individuals (11 male 7 female) had measures taken of static foot posture and ankle range of motion. Hip muscle activity and kinematics were measured using electromyography and an active motion capture system during a step-up task. Order of testing with or without orthoses was determined using a coin toss.
Findings: Between condition paired t-tests indicated significantly reduced peak hip adduction angles (1.56°, $P < 0.05$) and significantly reduced knee internal rotation (1.3°, $P < 0.05$) in the orthoses condition. Reduced ankle dorsiflexion range of motion correlated with a reduction in hip adduction following the orthoses intervention ($r = 0.59$, $P = 0.013$).
Interpretation: The effects of prefabricated orthoses may be partially explained by kinematic alterations that occur proximal to the foot in the kinetic chain. These clinically and biomechanically relevant effects appear more evident in those with reduced underlying ankle motion. Further research is indicated using a symptomatic population to explore the clinical relevance of these observations.

1. Background

Patellofemoral pain (PFP) is a prevalent complaint within physically active populations (Baquie and Brukner, 1997; Taunton et al., 2002) and is reported to be one of the most common injuries of the lower extremity (Baquie and Brukner, 1997; Taunton et al., 2002). Among 2002 patients presenting to a sports medicine clinic with running related injuries, 842 (42.1%) reported knee pain with 331 (46%) being diagnosed with PFP (Taunton et al., 2002). Although the anatomical source of pain is uncertain (Powers et al., 2012), the aetiology of PFP is considered to be multifactorial, with numerous risk factors identified (Heino Brechter and Powers, 2002; Powers et al., 2012).

Consensus among clinicians and researchers is that PFP can develop as a result of altered or elevated lateral patellofemoral joint (PFJ) loading with distal, proximal and local biomechanical factors thought to contribute (Powers et al., 2012). Distally, it has been proposed that excessive sub-talar joint pronation (Tiberio, 1987) might result in greater tibial segment and hip joint internal rotation (Fig. 2). External tibiofemoral joint rotation, necessary to extend the knee and align the foot in the direction of travel, consequently results in increased lateral loading of the PFJ. This proposed kinematic coupling between lower limb segments was recently supported by reports that greater peak rearfoot eversion was associated with greater tibial internal rotation in individuals with PFP (Barton et al., 2012). Additionally, imposed constraint of ankle dorsiflexion range has been reported to result in decreased knee flexion angles during squatting activities (Macrum et al., 2012) identified prospectively as a risk factor for developing PFP (Boling et al., 2009).

A growing body of research has explored neuromuscular and biomechanical variables at the hip in individuals with PFP (Aminaka et al., 2011; Nakagawa et al., 2012; Willson et al., 2011), reporting evidence of delayed GMed onset (Aminaka et al., 2011; Nakagawa et al., 2012) and increased hip adduction angles (Willson et al., 2011) during functional tasks. With favourable outcomes reported following a proximal strengthening intervention in PFP (Fukuda et al., 2012), further research exploring the effects at the hip of other commonly used interventions for managing PFP is clearly warranted.

Locally, neuromotor patterns of the quadriceps muscles have been proposed to contribute to altered lateral PFJ loading through the delay of vastus medialis oblique (VMO) compared to vastus lateralis (VL) (Fig. 1) (Coqueiro et al., 2005). A recent systematic review identified a

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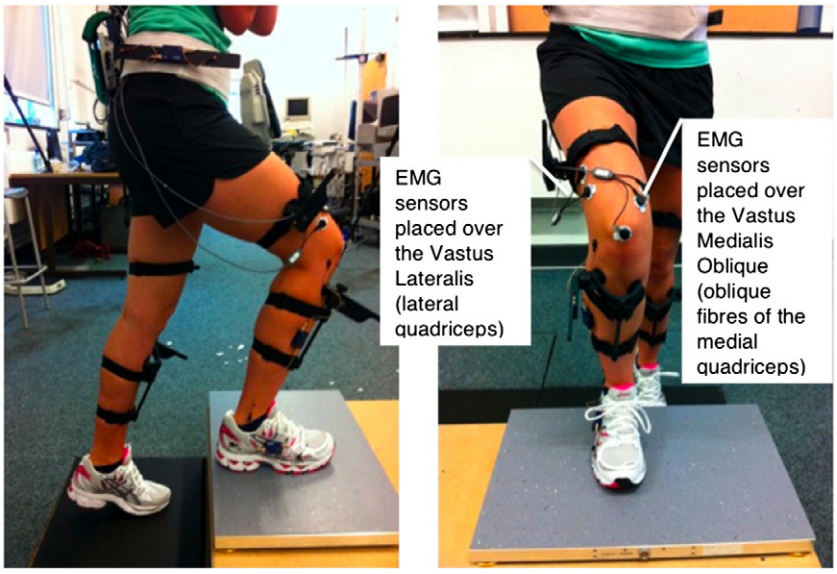

Fig. 1. Demonstrating the CODA motion and electromyography (EMG) set up during completion of the step up task.

trend of delayed VMO activation in individuals with PFP, although a substantial degree of heterogeneity across pooled studies and participants within studies was identified (Chester et al., 2008).

Physiotherapy intervention including patellofemoral joint (PFJ) mobilisation, patella taping, quadriceps strengthening and education remains the gold standard management of PFP management (Collins et al., 2008; Crossley et al., 2002). However, Level 1 evidence also exists to support the use of anti-pronation foot orthoses (APFOS) as an adjunct to hasten recovery (Collins et al., 2008). Specifically, Collins et al. (2008) randomised controlled trial reported significantly greater global improvement on a five point Likert scale at six weeks in a group of PFP individuals receiving prefabricated APFOS compared to a control group. However, the mechanism for this effectiveness is poorly understood, due to a paucity of research evaluating biomechanical effects of APFOS in individuals with PFP (Mills et al., 2010). Eng and Pierrynowski's (Eng and Pierrynowski, 1994) study remains the only published paper exploring the effects of APFOS on lower limb kinematics, demonstrating a significant reduction in both frontal and transverse plane movements at the foot and knee. However, no attempt was made to evaluate effects proximal to the knee.

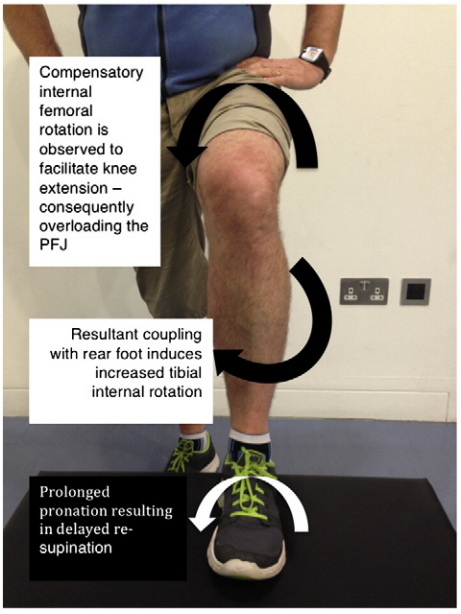

Fig. 2. Diagrammatic representation of the hypothesised kinematic coupling within the lower limb.

Limited literature evaluating the effects of APFOS on muscle activation at the hip also exists. Hertel et al. (Hertel et al., 2005) studied healthy adults during a single-leg squat and lateral step down tasks in neutral, medial and lateral posted orthoses and reported significantly increased EMG amplitude within both the VMO and gluteus medius (GMed) muscles for all conditions compared with no orthoses. However, without kinematic data, conclusions about the relevance of this to the control of lower limb alignment cannot be made.

The aim of this study was to improve understanding of the effects of APFOS on relevant hip and knee muscle activity and kinematics in normal subjects, as a precursor to identify the possible role of APFOS in the management of PFP populations. The hypotheses of this study were that: (i) APFOS would result in earlier onset of GMed and VMO, and a relatively delayed onset of VL, and a reduction in the peak frontal and transverse plane kinematics at the hip and knee during a functional step up task, (ii) foot posture index (FPI) scores indicating greater pronation and reduced ankle dorsiflexion range would influence kinematic coupling within the lower limb such that correlations with these biomechanical changes will be observed.

2. Method

2.1. Participants

A convenience sample of eighteen physically active, asymptomatic individuals (M 11 F 7; Mean (SD); age = 29.2 (3.7) years; height = 174.8 (7.2) cm; weight = 72.5 (11.8) kg) was recruited to participate in the study in response to advertisements within the university campi. Ethical approval was obtained from the Queen Mary University Ethics Committee and each participant provided written informed consent. Participants were required to have no history of lower extremity injury or knee pain in the last 12 months, and to be free of lower back pain or other neuro-musculoskeletal deficits potentially affecting stair ascent ability.

3. Procedure

3.1. Foot posture index

Static foot posture was assessed by the lead author, having previously tested over 30 individuals clinically, and deemed proficient using the six