THE EFFECT OF MOTION CONTROL SHOES ON LOWER LIMB MECHANICS IN FEMALE RUNNERS WITH PATELLOFEMORAL PAIN

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Patellofemoral pain (PFP) is the most common complaint affecting runners and is understood to be a multifactorial condition. Excessive pronation of the subtalar joint has been associated with almost all maladies of the lower limb throughout the sports medicine literature however biomechanical research linking excessive subtalar joint pronation and patellofemoral pain is scarce. This study set out to ascertain the role of foot eversion on skeletal alignment and PFPS. Secondary to this, the effectiveness of Motion Control shoes to carry out their primary function was also investigated. A second type of neutral running shoe, ASICS Nimbus, was used as the control comparison. The results of this study found that Motion Control running shoes reduced leg adduction and thigh external rotation ($p>0.01$), thereby resulting in the adoption of a more neutral lower limb skeletal alignment. The neutral shoe (Nimbus) induced no change to leg or thigh mechanics over the adaptation period.

KEY WORDS: shoes, motion control, patellofemoral pain, knee injury

INTRODUCTION: The promotion of physical activity as vital to increased fitness and longevity sparked an explosion of fitness related activities in the 1970s (McClay, 2000). This increased interest in exercise has prevailed into the twenty-first century with 62.4% (9.2 million) of the Australian population participating in sport and physical activities in 2001 (Australian Bureau of Statistics, 2001). Running has emerged as an exercise of choice, primarily due to the numerous benefits associated with this activity, including increases to cardiovascular, musculoskeletal and mental health (Stergiou, Bates & James, 1999).
A major threat to the exercise and health movement is the associated risk of sports related injuries. Running results in repetitive stress on the body and is frequently associated with overuse musculoskeletal injuries. In fact, injury prevalence between 20% and 70% has been documented. Knee overuse injuries are well recognised within the medical community as the most frequently injured anatomical site (Taunton et al., 2002). Of the three joints comprising the knee, the patellofemoral joint is recognised as a particular site of pain and dysfunction. In a review of the epidemiological literature McClay (2000) investigated running and related injuries and found that PFP syndrome was the most common complaint affecting runners. Females are also twice as likely to suffer from PFP as males (Reischl et al., 1999; Taunton et al., 2002). It is a common clinical assumption that specialised shoe features can assist in the control of excessive pronation and reduce knee pain associated with the abnormal torsional movements of the thigh and lower leg (Novacheck, 1999). However, there is little quantitative evidence to substantiate these claims. Research specifically examining the claims of shoe manufacturers regarding the effects of shoes on lower extremity alignment is therefore necessary. The primary aim of this study was to investigate the effect of anti pronation features in motion control shoes and their effect on femoral and tibial motion in female runners with PFP.

METHODS: Female runners symptomatic for PFP as diagnosed by a Sports Physican, aged between 18 and 39 years of age, with a history of chronic pain from a minimum of 2 years running experience were eligible for inclusion in this study. Two-dimensional assessment of rear-foot motion allowed the exclusion of participants who did not demonstrate greater than 10° of rear-foot eversion (Stergiou et al., 1999). Subjects using orthotics and with a history of knee surgery or any other knee pathology (such as ligament, cartilage, or meniscal damage) were excluded from participation in the study. Subsequently, 16 females aged 26 years (± 7 years) with an average height and body mass of 170 cm (± 6 cm) and 62 kg (± 7 kg), respectively, met the inclusion criteria. The participants were matched on level of rear-foot eversion, and randomly divided into treatment and control groups. Subjects were blinded to the purpose of the construction features of the shoe they received. The control group received a neutral pair of running shoes - ASICS Nimbus IV. The Motion Control, or treatment group, received Motion Control shoes whose construction features are designed to control excessive rear-foot eversion – ASICS Koji.

A Vicon 612 data station with twelve camera's operating at 250 Hz, combined with a Kistler force plate sampling at 2000Hz were used to collect data. Thirty-three 15 mm retro-reflective markers were placed on the torso, pelvis and lower limbs. The marker placement, coordinate system determination and joint centre calculation allowed for 3D segmental motion to be calculated. The study design consisted of an initial testing session (*Current* condition), which required subjects to run in their personal running shoes at 3.8 ± 0.2 m.s^{-1}. Subjects were not aware that force platforms lay beneath a carpeted walkway. Five successful force platform strikes were collected from each leg with adequate rest provided between trials. This process was immediately repeated with subjects wearing either the treatment or control shoes (*New* condition). All subjects then completed an eight-week training program in the intervention shoe which required a minimum of three running sessions per week. Running diaries and pain charts were completed by all subjects throughout the training period. At the completion of training period subject's returned for a final analysis in the new shoes (*Post* condition). Marker coordinate data were filtered using a Woltring quintic spline routine (Woltring, 1986) with a mean squared error of 20. Kinematic and kinetic data was determined using a customised biomechanical model and data was temporally normalised in MATLAB to 101 data points to allow for between subject comparisons. Statistical analysis of the data was conducted in SPSS using multiple one-way analyses of variance for relevant dependant variables.

RESULTS AND DISCUSSION:

As no significant kinematic between session differences were observed in the Nimbus shoe (control group; Table 1) only the Motion Control group data are discussed.

Table 1 Nimbus shoe group kinematic variables.

Variable	Current	New	Post
Ankle (shoe) Eversion	8.2 *(6.7)*	7.8 *(7.2)*	7.2 *(5.8)*
Leg Internal Rotation	19.1 *(4.9)*	19.2 *(4.2)*	20.0 *(3.7)*
Thigh Internal Rotation	4.8 *(7.5)*	4.4 *(7.8)*	8.5 *(5.4)*
Thigh adduction	15.1 *(4.1)*	15.5 *(4.5)*	15.0 *(4.1)*
Leg adduction	5.3 *(4.6)*	4.7 *(4.2)*	5.7 *(3.0)*

Ankle (shoe) eversion: The introduction of Motion Control shoes was hypothesised to immediately reduce peak ankle eversion. No significant differences were observed in this variable between the *Current* to *New* testing conditions (Table 2). Further, no significant difference was observed in ankle eversion results following the eight-week adaptation period *(New-Post)*. This finding is somewhat inconsistent with the functional design features of the Motion Control shoe, however the measure of ankle eversion itself cannot be used to infer actual foot movement. This is due to markers being placed directly on the shoe which may not accurately represent foot movement inside the shoe (Stacoff et al., 2001).

Leg internal rotation: The existence of a coupled relationship between the foot and lower leg in normal populations has been quantified by numerous authors (Reischl et al., 1999; Bellchamber & Van Den Bogert, 2000; Nester, 2000). Motion Control running shoes were hypothesised to reduce excessive internal leg rotations clinically associated with PFP. No significant difference or consistent trend for altered leg internal rotation was found between the three testing sessions (*Current*, *New & Post;* Table 2). This finding is consistent with the ankle (shoe) eversion results.

Table 2 Motion control shoe group kinematic variables.

Variable	Current	New	Post
Ankle (shoe) Eversion	9.5 *(4.6)*	9.6 *(5.0)*	11.7 *(5.9)*
Leg Internal Rotation	19.6 *(4.2)*	19.0 *(4.1)*	17.6 *(4.5)*
Thigh Internal Rotation	9.7 *(5.6)*	9.8 *(5.2)*	11.4 *(8.4)*
Thigh adduction	15.1 *(3.8)*	15.3 *(3.8)*	16.4 *(5.7)*
Leg adduction	6.0 *(4.6)*	6.2 *(4.7)*	6.9 *(4.2)*

Thigh internal rotation: Although the interrelationship between the tibia and the femur is yet to be quantified in PFP sufferers it was hypothesised that a reduction in peak internal rotation of the leg would be coupled with a reduction in peak internal rotation of the thigh following Motion Control shoe intervention. No significant difference was observed between conditions on analysis of the peak thigh internal rotation results due to the large within group standard deviations, however this results is consistent with the leg internal rotation findings. Conversely, Motion Control shoe intervention (*New*) resulted in reduced thigh external rotation from the *Current* shoe condition by approximately 5° across the entire stance phase (Figure 1).

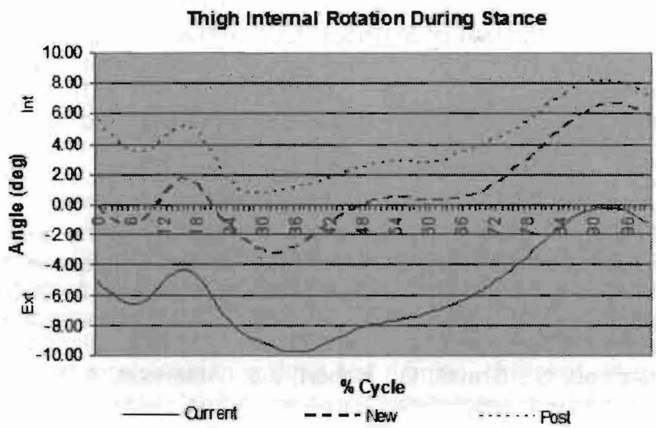

Figure 1 Motion Control shoe group stance phase thigh rotation.

This trend continued into the *Post* condition such that, the Motion Control group displayed internal thigh rotation throughout the entire stance phase (Figure 1).

Leg adduction: Excessive Q angles are frequently associated with PFP development (Woodall and Welsh, 1999). It was therefore hypothesised that subjects would initially present in a position of excessive knee valgus (leg abduction) which would be reduced by the introduction of Motion Control shoes. That is, the introduction of Motion Control shoes would facilitate leg adduction resulting in reduced knee valgus. Surprisingly, the results found no significant differences for peak leg adduction between the three testing conditions (Table2). Furthermore, contrary to the frequently assumed relationship between excessive knee valgus (leg abduction) and PFP syndrome, the runners in this study initially presented in a position of leg adduction (knee varus). Following the introduction of Motion Control shoes a more neutral frontal plane knee alignment was adopted.

Thigh adduction: It is generally accepted that PFP sufferers employ compensatory gait strategies to avoid symptom aggravation (Nadeau et al., 1997). However, the nature of the compensatory strategies adopted by PFP pain sufferers in the frontal plane has not been elucidated. In contrast with the findings of McClay Davis et al. (2003) who reported increased thigh adduction in female runners with PFP, no between session thigh adduction differences were found in this sample (Table 2).

Altered thigh and lower leg coupling It is only when the frontal and transverse plane results are combined that the effect of the Motion Control shoes may be interpreted. The introduction of Motion Control shoes resulted in decreased leg adduction (knee varus), which was coupled with a decrease in thigh external rotation. The implications for the PFP sufferer who initially presents with increased leg adduction (knee varus) and increased thigh external rotation is that the patella will not sit effectively in the patellofemoral groove which has been associated with PFP development (Juhn, 2003). Bringing the limb back to a more neutral alignment will inevitably assist the patella to follow a more congruent path.

CONCLUSION: The results suggested that female PFP runners with excessive rearfoot eversion in this study displayed slight leg adduction (knee varus) not leg abduction (knee valgus), which is in contrast to the commonly held clinical assumptions regarding PFP and limb alignment. The Motion Control running shoes reduced both leg adduction and thigh external rotation, thereby resulting in the adoption of a more neutral lower limb skeletal alignment. These altered mechanics were related to significant reductions in perceived PFP and were more pronounced following an eight-week shoe adaptation period. The neutral shoe (Nimbus) induced no change to leg or thigh mechanics over the adaptation period.

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