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Full Length Article

High- compared to low-arched athletes exhibit smaller knee abduction moments in walking and running

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ABSTRACT

High- (HA) and low-arched athletes (LA) experience distinct injury patterns. These injuries are the result of the interaction of structure and biomechanics. A suggested mechanism of patellofemoral pain pertains to frontal plane knee moments which may be exaggerated in LA athletes. We hypothesize that LA athletes will exhibit greater peak knee abduction moments than high-arched athletes.

Methods: Twenty healthy female recreational athletes (10 HA and 10 LA) performed five over-ground barefoot walking and five barefoot running trials at a self-selected velocity while three-dimensional kinematics and ground reaction forces were recorded. Peak knee abduction moments and time-to-peak knee abduction moments were calculated using Visual 3D.

Results: High-arched athletes had smaller peak knee abduction moments compared to low-arched athletes during walking (KAM1: $p = 0.019$; KAM2: $p = 0.015$) and running ($p = 0.010$). No differences were observed in time-to-peak knee abduction moment during walking (KAM1: $p = 0.360$; KAM2: $p = 0.085$) or running ($p = 0.359$).

Conclusions: These findings demonstrate that foot type is associated with altered frontal plane knee kinetics which may contribute to patellofemoral pain. Future research should address the efficacy of clinical interventions including orthotics and rehabilitation programs in these athletes.

1. Introduction

Overuse injuries are a common occurrence in running and may include stress fractures, tendonitis and patellofemoral pain syndrome (Hamill, Bates, & Holt, 1992; Kaufman, Brodine, Shaffer, Johnson, & Cullison, 1999; Williams, McClay, & Hamill, 2001). These injuries are associated with repeated exposure of the lower extremity to loading cycles (Fukuchi & Duarte, 2008; Nigg, 1985; Radin, Yang, Riegger, Kish, & O'Connor, 1991; Radin et al., 1984). The foot is the point of skeletal interaction with the ground and therefore the point through which external forces are applied to the skeleton during locomotion. Literature has indicated that individuals with abnormal foot structure or biomechanics are at an exaggerated risk of overuse injury compared to normally aligned individuals (James, Bates, & Osternig, 1978; Kaufman et al., 1999; Williams et al., 2001). More specifically, individuals with high- (HA) and low-arched (LA) feet have a greater prevalence (Kaufman

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et al., 1999) and distinct patterns of lower extremity injury (Kaufman et al., 1999; Williams et al., 2001) compared to individuals with normal arch heights. Evidence demonstrates that HA athletes experience greater rates of injury to bony structures on the lateral aspect of the lower extremity including tibial and fifth metatarsal stress fractures (Williams et al., 2001), while LA athletes experience greater rates of soft tissue injury to the medial aspect of the lower extremity including patellar and Achilles tendinitis, and patellofemoral pain syndrome (Williams et al., 2001). These unique injury patterns represent a manifestation of altered loading patterns transmitted through the foot to more proximal structures and are evidenced by distinct kinematic and kinetic patterns in HA compared to LA individuals (Powell, Hanson, Long, & Williams, 2012; Powell, Long, Milner, & Zhang, 2011; Powell, Williams, Windsor, Butler, & Zhang, 2014; Williams, Davis, Scholz, Hamill, & Buchanan, 2004).

A common overuse knee injury readily observed in LA athletes is patellofemoral pain (Kaufman et al., 1999; Levinger & Gilleard, 2007; Murley, Menz, & Landorf, 2009; Williams et al., 2001). Patellofemoral pain (PFP) often results in reductions in physical activity and training, and has also been associated with greater risks of developing patellofemoral osteoarthritis with advancing age (Utting, Davies, & Newman, 2005). The etiology underlying PFP remains unclear, however it has been suggested that PFP is the result of increased patellofemoral stresses during lower extremity loading (Willson & Davis, 2008). A series of cohort studies comparing individuals with PFP to individuals without PFP have identified several distinct biomechanical characteristics present in individuals diagnosed with PFP. Data demonstrated that individuals with PFP have unique kinematic patterns during closed chain movements compared to healthy controls including greater hip internal rotation and hip adduction angles (Noehren, Barrance, Pohl, & Davis, 2012; Noehren, Pohl, Sanchez, Cunningham, & Lattermann, 2012; Willson & Davis, 2008). Moreover, it has been shown that individuals with PFP exhibit unique knee abduction moments (KAMs) compared to healthy controls during running (Stefanyshyn, Stergiou, Lun, Meeuwisse, & Worobets, 2006) and landing (Myer et al., 2010). Though PFP is the result of three-dimensional multi-joint biomechanical patterns, sufficient evidence suggests that frontal plane knee biomechanics are a significant contributor to PFP.

Though these distinct kinematic and kinetic patterns may contribute to the development of PFP in individuals that are regularly active, there is evidence that rehabilitation and training programs may reduce PFP. Earl and Hoch (2010) reported that a training program designed to improve core and hip strength was efficacious in reducing the symptoms associated with PFP as well as altering lower extremity biomechanics during running. Specifically, the training intervention was associated with increases in isometric hip abduction and external rotation strength while peak KAMs during running were reduced. A second study investigating a hip strengthening intervention in PFP revealed that during running, increases in hip abduction and external rotation were associated with reduced rearfoot inversion moments and KAMs (Snyder, Earl, O'Connor, & Ebersole, 2009).

These studies demonstrate that PFP is the result of an interaction between external loading patterns and intrinsic neuromuscular control strategies. Evidence has demonstrated that a critical factor in the development and treatment of PFP is the magnitude of KAMs. As the foot remains the point of contact with the external forces from the ground during locomotion, the role of foot structure and function in the development of excessive KAMs during locomotion must be considered as a potential contributor to the development of PFP. Therefore, the purpose of this study was to compare knee abduction moments in HA compared to LA athletes during walking and running movements. It was hypothesized that HA athletes would exhibit significantly smaller KAMs than low-arched athletes during walking and running tasks due to the mobile nature and exaggerated eversion present in LA athletes during running.

2. Methods

2.1. Participants

Seventy-three females were screened for inclusion in this study. Twenty female recreational athletes (10 HA and 10 LA) were identified and recruited to participate in this study. Participation in this study was limited to female athletes due to the greater incidence and prevalence of PFP in female compared to male athletes. All potential participants were active in university club sports at the time of testing and participated in training or competition at a moderate or high level of intensity at least three days per week for a duration of at least 90 min per session. Potential participants had their arch height index (AHI) measured as the vertical height of the dorsum at half of the total foot length divided by the truncated foot length (Williams & McClay, 2000). All foot measurements were recorded using the Arch Height Index Measurement System (AHIMS) which has been shown to be a valid and reliable measurement system for characterizing the structure of the foot (Butler, Hillstrom, Song, Richards, & Davis, 2008). Participants were included and assigned to HA or LA groups based on AHI measurements. The HA group was characterized by AHI values greater than 0.377 while the LA group was defined as having AHI values less than 0.290. These AHI values correspond to 1.5 standard deviations above and below a mean of 604 feet previously reported in the literature (Zhang, Powell, Keefer, King, & Hamill, 2007) and represent the top and bottom 10% of the population. These values are also similar to previously reported AHIs in the literature (Butler et al., 2008; Williams & McClay, 2000). The experimental protocol was approved by the University Institutional Review Board and all subjects signed informed consent prior to study participation. Participant anthropometrics were collected including height, mass and age (Table 1).