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Ankle work and dynamic joint stiffness in high- compared to low-arched athletes during a barefoot running task

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ABSTRACT

High- (HA) and low-arched (LA) athletes have an exaggerated risk of injury. Ankle joint stiffness is a potential underlying mechanism for the greater rate of injury within these two functionally different groups. An alternative candidate mechanism of injury in HA and LA athletes pertains to the efficacy of the foot as a rigid lever during propulsion. The purpose of this study was to quantify the differences in ankle dynamic joint stiffness, and ankle braking work and ankle propulsive work during stance phase of running.

Methods: Ten HA and ten LA athletes performed five barefoot running trials while ground reaction forces and three-dimensional kinematics were recorded. Ankle dynamic joint stiffness was calculated as the slope of the ankle joint moment–ankle joint angle plot during load attenuation. Ankle braking and propulsive work values were calculated for the stance phase.

Results: HA athletes had significantly greater ankle dynamic joint stiffness and significantly smaller ankle net and propulsive work than LA athletes.

Conclusions: These data demonstrate that HA and LA athletes exhibit unique biomechanical patterns during running. These patterns may be related to lower extremity injury.

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1. Introduction

Mal-alignment and aberrant mechanics of the foot and ankle have been implicated as contributing factors to lower extremity injury (Kaufman, Brodine, Shaffer, Johnson, & Cullison, 1999; Williams, McClay, & Hamill, 2001). It has been demonstrated that individuals with high- or low-arched feet have a greater incidence of lower extremity injury than individuals with a normal arch (Kaufman et al., 1999). Further, it has been shown that high- and low-arched athletes exhibit divergent overuse injury patterns with high-arched athletes experiencing a greater number of bony injuries to the lateral aspect of the lower extremity while low-arched individuals experience a greater number of soft tissue injuries to the medial aspect of the lower extremity (Williams et al., 2001).

These unique injury patterns have been attributed to the role of the foot in load attenuation and the altered transmission of force through the lower extremity kinetic chain (Kaufman et al., 1999; Powell, Hanson, Long, & Williams, 2012a; Powell, Long, Milner, & Zhang, 2011; Powell, Long, Milner, & Zhang, 2012b; Williams, Davis, Scholz, Hamill, & Buchanan, 2004; Williams et al., 2001; Williams et al., 2004). It has been demonstrated that high-arched feet are typically rigid and exhibit greater stiffness while low-arched feet are typically mobile and exhibit less stiffness compared to normal feet (Zifchock, Davis, Hillstrom, & Song, 2006). Previous research has also reported significantly greater knee joint stiffness in high- compared to low-arched athletes during a level running task (Williams et al., 2004). It has been suggested that exaggerated or insufficient stiffness throughout the lower extremity predispose an individual to injury (Butler, Crowell, & Davis, 2003; Williams et al., 2004; Williams, McClay, Hamill, & Buchanan, 2001). Though the roles of foot structure and joint stiffness in lower extremity injury have been established, no previous study has investigated differences in ankle joint stiffness, specifically during the period believed to be most responsible for overuse injury, load attenuation.

Currently research hypotheses have identified aberrant patterns of lower extremity loading in response to load attenuation as a potential mechanism for overuse injury to the lower extremity. An alternative hypothesis pertains to the role and efficacy of the foot as a functional lever during the propulsive portion of the stance phase. Research has demonstrated that lower extremity joint work values are significantly greater during the propulsive compared to braking phases of walking (DeVita, Helseth, & Hortobagyi, 2007) and running (Heiderscheit, Chumanov, Michalski, Wille, & Ryan, 2011). Moreover, in running, the greatest differences in lower extremity joint work values, when comparing the braking and propulsive phases of stance, have been observed at the ankle joint (Heiderscheit et al., 2011). Specifically, the magnitude of positive ankle work in propulsion was two- to threefold greater than negative ankle work in braking when athletes ran at different step frequencies. It is possible that the low-arched, mobile foot is a less effective lever for the application of muscle force to the ground and requires greater muscle work to achieve similar mechanical output compared to the normal or high-arched foot. Further, it can be postulated that the interaction of the low-arched, mobile foot with increased muscle work could potentially underlie soft tissue overuse injury in low-arched athletes, particularly during the propulsive portion of the stance phase. However, no previous research study has quantified the differences in ankle joint work between high- and low-arched athletes. If significant differences in ankle dynamic joint stiffness and work values are present in the braking compared to propulsive phases of running stance, greater insight may be gained into the mechanisms underlying the unique injury patterns experienced by these two functionally different groups.

Therefore, the purpose of this study is to investigate the differences in dynamic joint stiffness and joint work of the ankle during the total stance phase as well as the braking and propulsive portions of the stance phase during running. It was hypothesized that high- compared to low-arched athletes would exhibit significantly greater ankle dynamic joint stiffness values and significantly smaller ankle work values throughout the stance phase.