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Effect of foot rotation on knee kinetics and hamstring activation in older adults with and without signs of knee osteoarthritis

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Abstract

Background. To determine the effects of changing the natural foot progression angle during gait (internal and external foot rotation) on the knee's adduction moment, lateral–medial shear force, and the ratio of medial–lateral hamstring muscle activation in those with signs of knee osteoarthritis and a matched healthy control group.

Methods. Twelve subjects with signs of knee osteoarthritis and 12 matched healthy control subjects were evaluated. A 3D gait analysis system calculated forces and moments at the knee while the subjects walked in three conditions: (1) normal foot position, (2) external foot rotation, (3) internal foot rotation. Medial and lateral hamstring EMG data was also collected simultaneously and used to calculate the medial–lateral hamstring activation ratio during the stance phase of the gait cycle. Repeated measures ANOVAs were used to compare foot rotation conditions within each group; while between group comparisons were performed in the normal rotation condition only using *t*-tests.

Findings. Those with knee osteoarthritis (OA) had an increased late stance knee adduction moment and a decreased medial–lateral hamstring activation ratio as compared to the healthy control group. Also, external foot rotation decreased the late stance knee adduction moment, lateral–medial shear force, and hamstring activation ratio. However, internal foot rotation did not increase these measures.

Interpretation. Changes in foot position during gait have the ability to alter both the external loading of the knee joint and hamstring muscle activation patterns during gait. This may have implication in helping to unload the knee's articular cartilage.

Keywords: Biomechanics; Locomotion; Adduction moment; Lateral–medial shear force; Medial–lateral hamstring muscle activation

1. Introduction

The external knee adduction moment, which can be estimated at the knee while walking, is a factor in the development and progression of knee osteoarthritis (OA) (Lynn et al., 2007; Miyazaki et al., 2002). A large knee adduction moment indicates an increased load on the knee's medial compartment, while a reduced knee adduction moment indicates an increased load on the lateral compartment (Lynn et al., 2007; Weidow et al., 2006). Hence, the gait profile associated with medial compartment OA, the most common type of knee OA (Felson, 1998), includes a large external knee adduction moment. A second knee gait measure that has been recently implicated in the development and progression of knee OA is the lateral–medial shear force (Astephen and Deluzio, 2005; Lynn et al., 2007). This is the joint reaction force calculated using inverse dynamics that acts along the joint surface to push the femur medially across the tibial plateau. In vitro studies suggest that shear stress is detrimental to cartilage health (Radin et al., 1991; Tomatsu et al., 1992) and those with medial compartment knee OA have been shown to exhibit large lateral–medial shear forces (Lynn et al., 2007). Clearly, strategies aimed at reducing the knee adduction moment and lateral–medial shear forces are warranted.

A simple strategy used by those with medial OA to reduce the associated pain is to walk with an externally

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Differences in external knee gait kinetics with foot rotation also provided some interesting results. As expected, external rotation of the foot decreased the late stance knee adduction moment in both the OA and Control population; and this agrees with the literature (Guo et al., 2007; Lynn et al., 2008). However, this peak was not different between the internal and normal foot rotation conditions for either group. This contradicts the literature as internal foot rotation has been shown to increase the knee adduction moment during late stance (Lynn et al., 2008); however, this was determined in healthy young subjects. It has been suggested that internal rotation shifts the loads more onto the knee's medial compartment (Lynn et al., 2008), which may create and uncomfortable environment for older adults and cause them to make further compensations in their gait patterns. This is supported by the fact that both the OA and control groups walked at a slower velocity with their foot internally rotated then they did in their normal foot rotation condition (Table 2). Also, the fact that the early stance knee adduction moment peak was not different between the OA and control groups in the normal foot rotation condition can be explained by the fact that the knee alignments were not different between the groups either (Table 1), as this peak is best predicted by the static alignment of the joint (Hurwitz et al., 2002).

Foot rotation had a similar effect on the lateral–medial shear force as it did for the knee adduction moment in the OA group; as the external rotation decreased the magnitude of the force in late stance as compared to the normal foot position condition, but there was no change with internal rotation. This decrease in the magnitude of the lateral–medial shear force at the knee with external foot rotation may help in taking the stress off the medial compartment articular cartilage (Lynn et al., 2007, 2008) and hence, be a mechanism that may help to explain why those who walk with the foot externally rotated have a decreased likelihood of OA progression (Chang et al., 2007). A similar pattern was present in the Control group yet there was no main effect of foot rotation in this group. The reason foot rotation did not affect the lateral–medial shear force in the control group should be examined further as it may be a function of several factors that such as muscle strength and balance, gait speed, static and dynamic knee alignment, and knee laxity in the frontal plane. It is known that shear forces are detrimental to cartilage health (Radin et al., 1991; Tomatsu et al., 1992) yet this lateral–medial shear force during gait has not been studied as extensively as the knee adduction moment to date; therefore, its role in the development and progression of knee OA is not well understood.

Differences in gait speed have an effect on both the external loading of the knee joint (Kirtley et al., 1985) and the muscle activity of the lower limb (Hof et al., 2002), although it is not clear how the differences in gait speed may have affected the results of this current work. Chiu and Wang (2007) demonstrated that increases in walking speed are associated with increased hamstring muscle activation but EMG data was only recorded from the biceps femoris (lateral hamstrings). It is unclear how differences in gait speed would affect the ratio of medial and lateral hamstrings activation.

The effect of gait speed on the frontal plane knee gait kinetics is also unclear. Studies investigating the relationship between gait speed and the peak knee adduction moment range from finding a weak/poor relationship (Kirtley et al., 1985) to a positive correlation that changes depending on the severity of OA in the population tested (Mundermann et al., 2004); yet these studies did not perform separate analyses for the early and late stance peaks. Those that did perform separate analyses for the early and late stance peaks have also presented some conflicting results (Thorp et al., 2006; Oakley, 2000). Future work should attempt to clarify this relationship and also determine the combined effects of foot rotation and changes in gait speed on external frontal plane knee gait kinetics and hamstring muscle activation. Some of the aberrant finding in this work may be due to the differences in gait speed between conditions and therefore, it is essential that this relationship be clarified.

The results of this current work suggest that the ratio of medial–lateral hamstring muscle activity may play a role in the attenuation of frontal plane loading at the knee and that the position of the foot during the stance phase of the gait cycle also has the potential to alter both the muscular and external loads applied to the knee joint. This may have implications in the development of simple, non-invasive interventions aimed at shifting the loads off of overloaded or diseased knee compartments.

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