Effect of Foot Rotation during Running on Knee Moments and Lateral-medial Shear Force

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Introduction

Approximately 10%-20% of Americans run for recreational purposes on a regular basis (6). Currently, there are running races which have over 40,000 people participating (27) while in 1960, marathon races struggled to get 1,000 participants (6), which serves as a statement of illustration for the growth of running as a recreational sport. The health benefits of running continue to draw in new runners, but the increasing incidence of injuries leaves some runners and aspiring runners questioning the sport. The knee joint is the most common site for a running related injury (21). Osteoarthritis (OA) is a commonly occurring pathology in older adults with 10% of people over 55 experiencing symptomatic knee OA, while there are signs of radiographic knee OA in 70% of people over the age of 65 (17). This high prevalence of knee OA is thought to be due to improper loading of the knee over many years (18). Since approximately 17% of male runners and 6% of female runners are over the age of 56, it stands to reason that a good portion of the running community is at risk for OA.

It has been hypothesized that OA is caused by abnormal loading of the knee joint which contributes to wearing down of the articular cartilage and the development of OA (13). Two biomechanical measures which have been associated with cartilage loading in the knee are the knee adduction moment (16, 23) and the lateral-medial shear force (LMF) created during locomotion (2, 11). The knee adduction moment (KAM) is created during locomotion when the vertical ground reaction force (VGRF) vector is positioned medial to the knee's axis of rotation in the frontal plane and has been prospectively linked to the development of knee OA (12, 22).

The KAM directly affects the loading of the medial and lateral compartments of the knee (23) and the magnitude of this moment is able to predict the magnitude of cartilage loss (16).

Subjects with medial knee OA are known to have higher KAM than normal controls (16, 20). Medial knee OA groups have shown increased KAMs during late-stance of gait (12) and also tend to externally rotate their foot during gait in an attempt to unload the diseased compartment (24). It has been shown that foot rotation can alter the KAM during late-stance while the foot is fully in contact with the ground (1, 7, 9, 22). External rotation of the foot has been shown to reduce the KAM which may reduce the load on the medial tibiofemoral compartment and could be helpful in the prevention and/or management of medial compartment knee OA (22). Research has shown a similar relationship with foot rotation and lateral-medial shear force. This research illustrates importance of the KAM and its variability with changing foot angles during movement on the loading of the knee joint as it relates to the development of knee OA; however, the effect of foot rotations on the KAM has not been examined during running. Therefore the purpose of this current study was to examine the effect of foot rotation on the knee moments and shear forces in healthy recreational runners.

Methods

Twenty subjects (22.3±3.9 yrs, 1.77±0.10 m, 68.59±10.36 kg, 13 males, 7 females) volunteered for this study. Requirements for participation included being between the ages of 18 and 35 (4, 5, 8), having no history of lower limb trauma/injuries (25, 26), have been running a minimum of 10 miles per week (15, 26) for the last six months, and were able to hold a pace of 3.35m/s for 30 minutes (15, 25).

Participants came into the biomechanics lab for a one-time visit and all procedures for collection of data on human subjects were reviewed and approved by the Institutional Review Board of California State University Fullerton. The subjects completed five trials in two conditions (normal foot pattern and external rotation of foot). The subjects ran along a 20m pathway and struck a force plate at approximately 15m with their dominant leg at a consistent pace of 3.35m/s ± 5% (3, 19, 24), so that speed could not be an impact factor in the results. Trials were eliminated if subjects altered their stride to strike the force plate. Kinematic and kinetic data were collected using a 9-camera Qualisys Oqus 300 motion capture system (Gothenburg, Sweden) at 240Hz and an AMTI force plate (AMTI, Inc., Watertown, MA, USA) at 1200Hz, respectively. Visual 3-D software (C-Motion Inc., Rockville, MD, USA) was used for processing of data while knee moments, shear forces, and VGRF were calculated and statistically compared using a repeated measures (1x2) ANOVA.

Results

Repeated measures ANOVAs performed on the two conditions revealed significant differences between the NORM condition and the EXT condition for the KAM (Table 1). The EXT condition significantly decreased the average values for the KAM, resulting in an average reduction of 6% (Table 1). All subjects had peak knee moments in the frontal plane that were external adduction moments. The LMF proved to be significantly different between the NORM and the EXT. As with the KAM, the EXT saw reductions in LMF from the NORM values of 7.7% (Table 1). Additionally, the VGRF values were significantly lower during the EXT condition than the NORM , reducing by over 3% and going below 250% of BW.

Discussion

The purpose of this research was to examine the effect of different foot rotation conditions on the KAM and LMF. The KAM was shown to decrease significantly during the EXT condition compared to the NORM condition, which aligned with our hypotheses. This coincides with the past research regarding foot rotation during gait (12, 13, 22), stair climbing (7), and golf (14). The research of Lynn et al (2008) and Teichtahl et al (2006) both showed reductions in the KAM while subjects externally rotated their feet during walking trials (13, 22). It has been suggested that utilizing this external rotation intervention may decrease the moment values and shift some of the knee loading onto the lateral compartment of the knee, which may in turn slow the medial knee OA progression (13). Additionally, it was suggested that this intervention may also help prevent medial knee OA (22). All three of these motions (walking, stair climbing, and golf) have direct application to this research in that they all displayed reductions in the KAM during an EXT condition; however, it is important to note that the magnitudes of the moments were much higher during running than during these other movements. Running showed average values of 1.33 Nm/kg and 1.25 Nm/kg in the NORM and EXT conditions while the largest KAM measured during gait, stair climbing, and golf was 0.63Nm/kg (7, 13, 14).

During the EXT condition the LMF displayed similar results to the KAM, showing a 7.7% reduction in average peak values. This is consistent with research examining external rotation during walking. Average peak magnitudes of LMF were increased by approximately 300% over those reported by Lynn et al during walking (13). Since running has values substantially larger than walking, these factors may be exponentially more important for people with OA who wish to continue to run but desire to do so without the detrimental cartilage wear to

their knees. Given that a population with medial knee OA already has knee injury issues, it becomes exponentially more important to minimize the impact of the LMF as it is already known to be more detrimental than pure compressive loading so as not to increase the impact of the current knee injuries/pathologies.

Additionally, the reductions in the VGRF values during the EXT condition signify increased benefits of the movement. High VGRF values have been linked to reductions in injury rates (10), which given the potential population targeted for use of this intervention, is crucial. The idea is that the people who would benefit from this are people with knee OA, who already have an injury and would desire to minimize the overall risks so as to reduce any negative consequences, and therefore allow them to continue running in a healthy manner for as long as possible.

Conclusion

The practical applications of this research contribute to the idea that external rotation of the foot will decrease the KAM, LMF, and VGRF which may help unload the medial compartment of the knee and slow the progression of medial knee OA. This research warrants an additional test group of a population with medial knee OA to ensure that the same results are achieved. It is known that subjects with medial knee OA are known to have higher KAM than normal controls (16, 20), making it exponentially more important to reduce these values as they are increasingly detrimental to the population who has knee OA.

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Table 1: Results

	EXT	NORM
Foot Rotation (°)‡*	14.31 (4.91)[a]	0.00 (0.00)[b]
KAM (Nm/kg) ‡	1.25 (0.38)[a]	1.33 (0.44)[b]
LMF (N/kg) ‡	4.06 (1.03)[a]	4.40 (1.14)[b]
VGRF (x BW) ‡	2.48 (0.20)[a]	2.56 (0.20)[b]

Note: Different superscript letters = a difference between conditions ($p<0.05$)
‡ = significant main effect for this variable ($p<0.05$)
* The Foot Rotation is in relative values with the normal foot position set to 0 degrees for each participant