Exercise Induced Biomechanical Adaptations of the Foot and Ankle

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Statement of Purpose

The purpose of this study is to examine the biomechanical adaptations of the foot and ankle due to exertional changes after running. By considering the biomechanical changes of the foot and ankle structure post exercise, there is potential to increase the effectiveness in our techniques in maintaining optimal foot position during activity.

Methodology and Hypothesis

Upon Institutional Review Board approval, a biomechanical evaluation of the foot and ankle was conducted on 34 patients unaware of the study's aim. The only inclusion criteria consisted of healthy individuals over the age of 18. At the time of the study, the researcher was unaware of the participant's level of running expertise.

The biomechanical evaluation was performed bilaterally before and after running on a treadmill, at a speed of 4.5 ± 0.5 mph for 30 minutes. The study compared pre and post-activity measurements in all three planes of motion utilizing the Root and Weed method to evaluate the exertional changes of the foot and ankle. Measurements taken are as follows: STJ inversion & eversion, RCSP, AJDF (extended & flexed), 1st Ray ROM (frontal & sagittal plane), and foot dominance.

The differences in pre and post running measurements were recorded on an excel spreadsheet. Statistical analysis utilizing a one way analysis of variance was performed to calculate p-values with at a 95% confidence interval.

The current study aims to demonstrate the 34 cases evaluated using the Root and Weed method require further evaluation to provide discernable evidence for a biomechanical change in the foot and ankle.

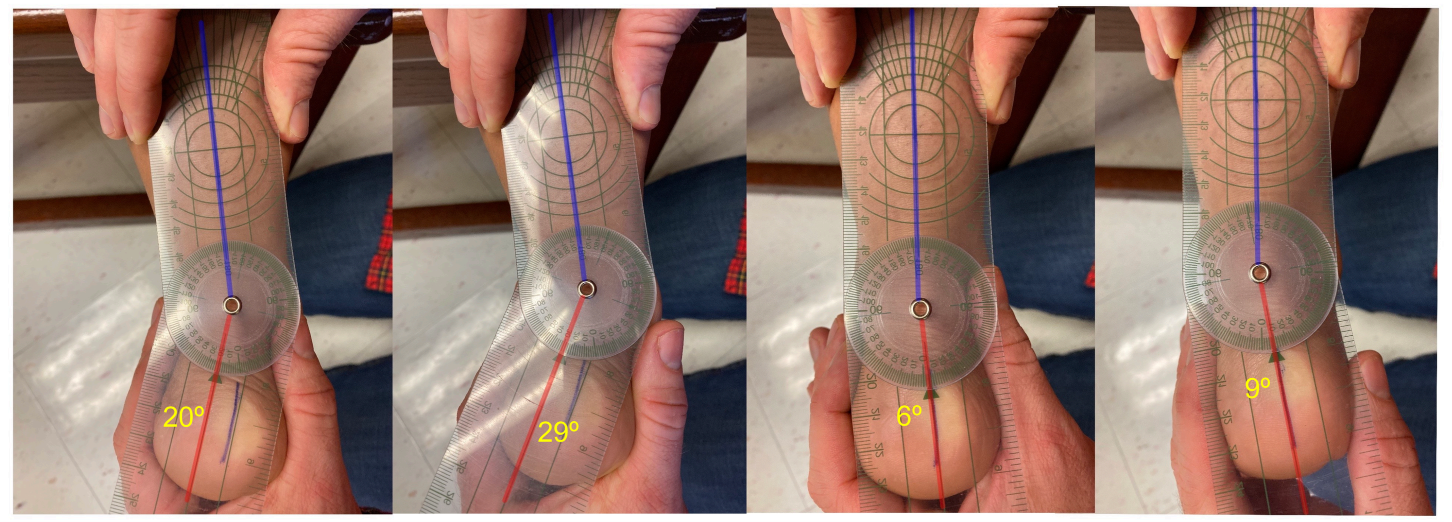

Figure 1: Pre/Post-run STJ Inversion (Left 2 images), STJ Eversion (Right 2 images)

Literature Review

Biomechanics as it relates to the field of Podiatry has been described by Merton L. Root as "a necessary basic science for the field... No specialty in the field of medicine is more intimately involved, on an everyday basis, with the clinical application of biomechanics."[7] In today's clinical practice, perhaps the most common use of biomechanics is in the evaluation and fabrication of orthotics. The evolution of biomechanical principles are built on the framework laid out by Root and colleagues over 40 years ago.[5,7]

The basic methods of fabricating a functional foot orthosis is performed by placing the foot in a neutral position, casting the foot, and attaching appropriate posts to maintain alignment, having been performed while the individual is presumably in a rested state and non-weightbearing.[6] While many methods and models have since adapted Roots theories, and even attempts to unify the prevailing theories, none have employed or considered a method that includes fatiguing the foot prior to casting or measuring. We believe this to be an unexplored paradigm, as new research has begun to show that fatigue can change the kinematics of the foot.[4]

Bravo-Aguilar et al. found that subjecting individuals to a running interval was able to change the posture of a foot from its measured pre-fatigued state, as well as changes in measured peak plantar pressures.[1] Running alters a person's biomechanics and can lead to injuries prone to active individuals. For instance, Souza found running on a treadmill has a direct correlation in the changes of person's foot strike pattern, tibial angle at loading positions, foot inclination angle, knee flexion during stance, hip extension during late stance, trunk lean, and over striding which can result in trauma to the lower extremity.[3,9] To our knowledge, no past research has sought to find fatigue induced changes of the foot and ankle in multiple planes of motion using common biomechanical measuring techniques employed by podiatrists in the clinical setting.

In addition to orthotic fabrication, biomechanical evaluations are important to evaluate a patient's range of motion post-operatively. Brorsson found with every 10 mm of surgical Achilles tendon lengthening, dorsiflexion can increase by 10 degrees.[2] Following an Achilles tendon lengthening, the tendon significantly stretches between 3 months and 12 months post-operatively. On average, the tendon elongates and additional 38 degrees during this period.[2] Abnormal Achilles tendon elongation after surgery may lead to asymmetrical weakness and gait changes. These changes have been shown to reduce the likelihood the patient will be able to return to their normal activities and increase the stresses on the lower extremity.[3] Accounting for the tendon's capacity to stretch preoperatively may reduce the postoperative complications due to overlengthening.

Results

A total of 68 limbs were enrolled. All participants were healthy individuals and able to complete the entirety of the trial. With a confidence interval of 95%, all measurements were found to be significant. The most notable changes in a comparative analysis of the participant's biomechanical evaluations were seen in eversion, resting calcaneal stance position (RCSP), and ankle joint dorsiflexion with the leg extended (AJDF-E). An average change of 46.2% (P=6.8E-06), 48.9% (P=2.0E-14), and 43.6% (P=2.2E-6) respectively were noted after running (table 1).

	Percent Change	P-Value
Inversion	14.98%	4.405E-16
Eversion	46.24%	6.585E-06
RCSP	48.94%	2.012E-14
AJDF-Flexed	26.46%	7.799E-06
AJDF-Extended	44.22%	2.233E-06
1st Ray-Saggital	30.69%	1.437E-17
1st Ray-Frontal	7.54%	4.459E-06

Table 1: Average change in range of motion after running for 30 minutes.

When evaluating the subtalar joint range of motion, 45% of the participants saw an increase in both subtalar joint eversion and inversion upon completion on the trial (Chart 1). 21% of the patient's measured inversion increased while 10% of the patient's eversion increased. No change in eversion or inversion were noted in 17% of the participants.

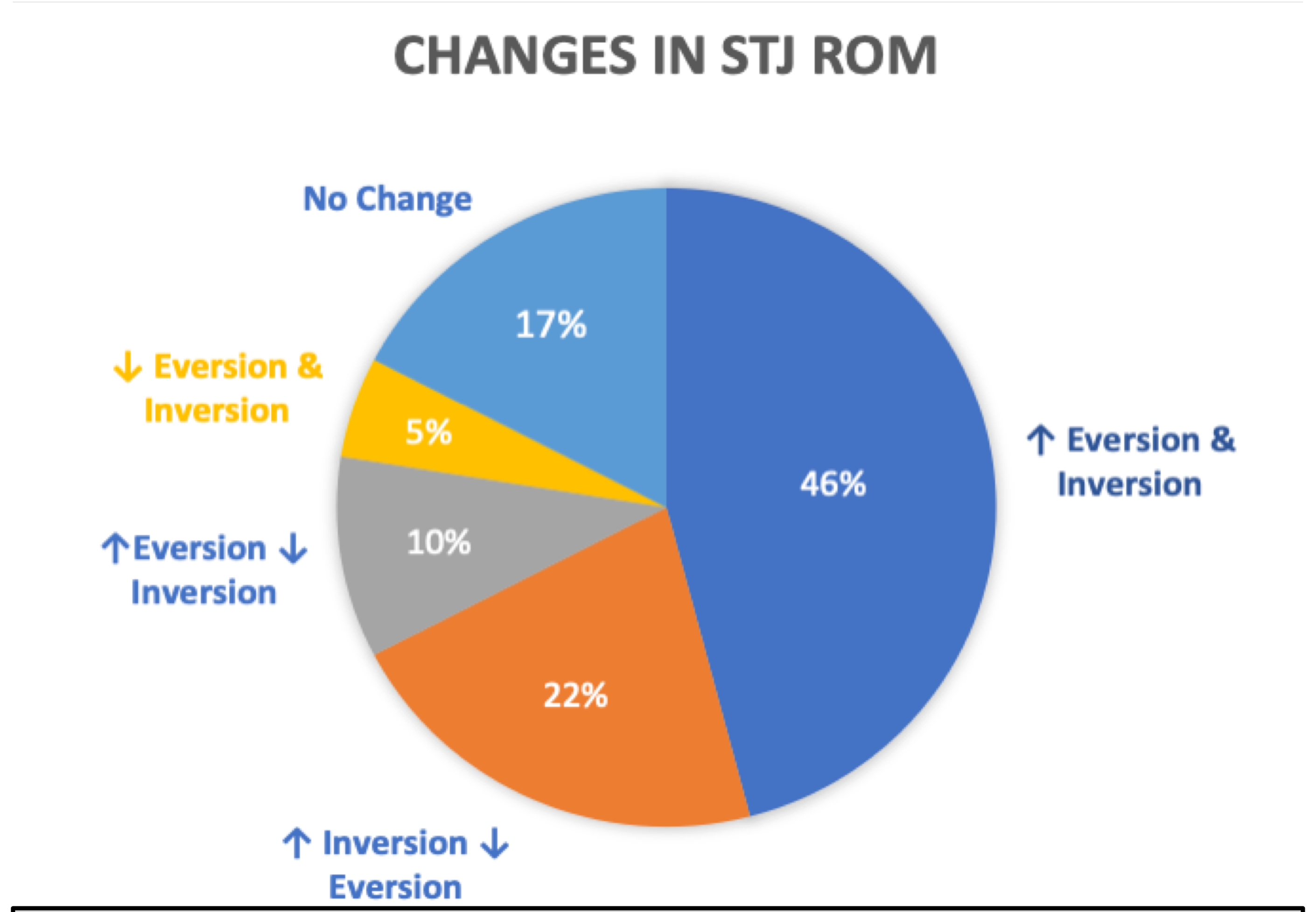

Chart 1: Average Changes in Subtalar Joint Eversion and Inversion

Analysis/Discussion

Locomotion is a multi-planar action, involving the use and activation of multiple muscle groups and joints to generate movement. Foot and ankle position stimulate specific muscle groups to perform a desired action. Likewise, positioning will trigger antagonizing muscle groups to prevent injury. The anatomical structure is constantly adapting to maintain this balance between achieving efficient movements and preventing injury. Running especially is constantly provoking the structural limitations due to exertional forces.

In our study, foot and ankle joint biomechanics show significant positional alterations after enduring exercise. Although a significant change in range of motion was noted in all joints, the most notable changes were seen in STJ eversion, RCSP, and AJDF while the leg was extended. Often etiologies of such range of motion variations are correlated with stretching, muscle fatigue, and joint elasticity. The increased exertional forces imposed on the lower extremity during running result in microfiber tears leading to the loss of integrity in LEA muscles. Compensation occurs due to the loss and/or diminished ability to sustain primary function. Ultimately, causing the foot and ankle to adapt and change anatomical position as seen in figure 2.

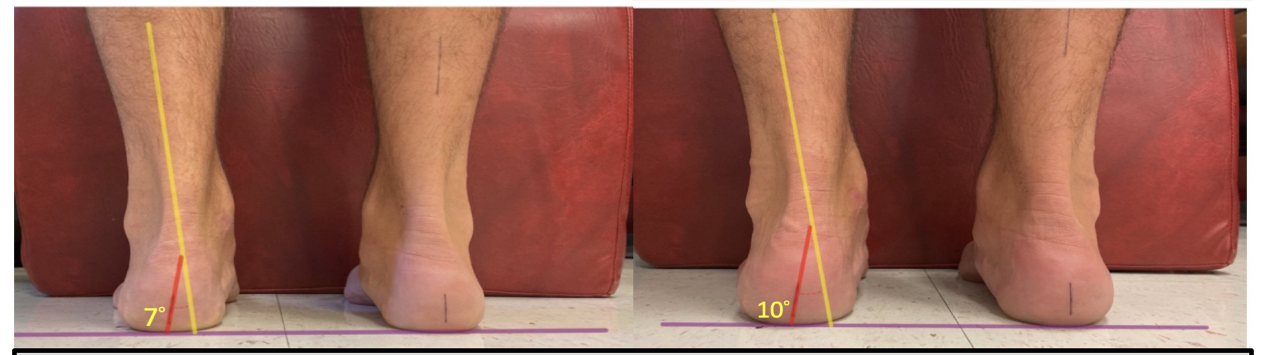

Figure 2: RCSP pre and post exercise (Left and right image respectively).

Even with significant data, the study was limited due to a largely inherent inter-observer variability when biomechanical assessments were being performed. Evaluation of exertional changes may provide physicians a more precise approach in the management of varying foot pathologies. Our study highlights the influence positional adaptations may have on how functional orthotics are prescribed, athletic footwear are purchased, runners are trained, and provide an additional evaluative modality before surgical gastrocnemius recessions are performed.

References

1. Bravo-Aguilar, María, et al. "The Influence of Running on Foot Posture and In-Shoe Plantar Pressures." Journal of the American Podiatric Medical Association, vol. 106, no. 2, Mar. 2016, pp. 109–15.
2. Brorsson, A., Carmont, M., Grävare-Silbernagel, K., Karlsson, J., Maffulli, N., and Olsson, N. The Achilles tendon resting angle as an indirect measure of Achilles tendon length following rupture, repair, and rehabilitation. Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology, Volume 2, Issue 2, 2015, Pages 49-55.
3. Davis, I., Silbernagel, K., and Willy, R. Preinjury and Postinjury Running Analysis Along With Measurements of Strength and Tendon Length in a Patient With a Surgically Repaired Achilles Tendon Rupture. Journal of Orthopaedic and Sports Physical Therapy, Volume 42, Issue 6, 2012, Pages 521-529.
4. Harradine, Paul, and Lawrence Bevan. "A Review of the Theoretical Unified Approach to Podiatric Biomechanics in Relation to Foot Orthoses Therapy." Journal of the American Podiatric Medical Association, vol. 99, no. 4, July 2009, pp. 317–25.
5. KIRBY K: Podiatric biomechanics: an integral part of evaluating and treating the athlete. Med Exerc Nutr Health 2: 196, 1993.
6. Payne, C. B. "The Past, Present, and Future of Podiatric Biomechanics." Journal of the American Podiatric Medical Association, vol. 88, no. 2, Feb. 1998, pp. 53–63.
7. ROOT ML: "Foreword," in Clinical Biomechanics of the Lower Extremities, ed by RL Valmassy, p vii, CV Mosby, St Louis, 1996.
8. ROOT ML, ORIEN WP, WEED JH: Normal and Abnormal Function of the Foot, Clinical Biomechanics Corp, Los Angeles, 1977.
9. Souza, Richard B. "An Evidence-Based Videotaped Running Biomechanics Analysis." Physical Medicine and Rehabilitation Clinics of North America, U.S. National Library of Medicine, Feb. 2016, www.ncbi.nlm.nih.gov/pmc/articles/PMC4714754/.