Title: **Comparison of Gait Kinetics in High Heels vs. Barefoot**

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Introduction:

The biomechanical effect of varying footwear in athletes is a well-researched field, but there is a lack of research regarding a common footwear in the workplace and social scene: the high heeled shoe. The American Podiatric Medical Association (APMA) conducted a survey reporting that in 2014, 49% of women wear high heels, even though 71% of those heel wearer complain that wearing heels is painful (Titchenal MR, et al. 2015). As individuals are wearing high heeled shoes as a regular occurrence, clinicians must be weary of a possible correlation with musculoskeletal impairments. Previous research on high heels has demonstrated altered gait mechanics - which contributed to increased risk of muscle strains - as well as increased knee joint forces and shortened plantar flexors (Cronin NJ, 2014).

The purpose of this study was to compare gait mechanics, including vertical ground reaction forces as well as joint angles at the hip, knee, and ankle, while ambulating barefoot versus in high heels, in order to assess the effects and clinical implications.

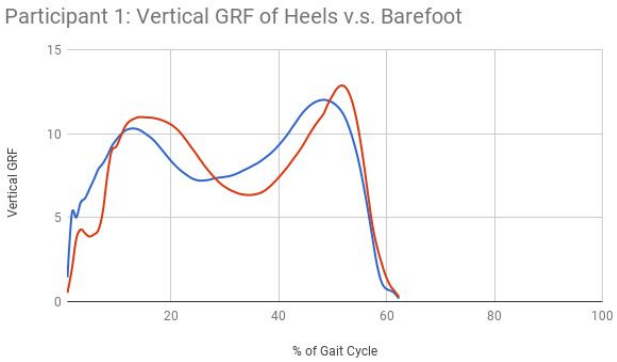
Methods:

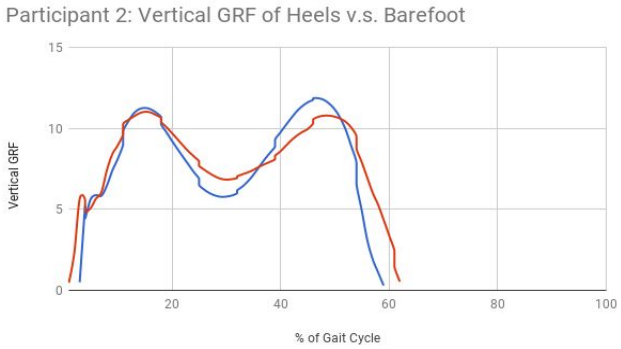
This study used a quasi-experimental crossover design in which two subjects performed three barefoot and three heeled trials each. Each subject walked at a self-selected speed over a level surface with a force platform embedded in the walkway. Vertical ground reaction force, hip angles, knee angles, and ankle angles were captured using a Vicon motion capture system. Markers were placed on each subject at the ASIS, PSIS, mid-femur, knee joint, mid-tibia, heel, and base of first metatarsal. Data was synthesized and interpreted using Microsoft Excel.

Results:

Results included many discrepancies between participant data. Participant one (P1) completed barefoot and heeled trials at the same velocity, while participant two (P2) demonstrated a longer gait cycle in heel trials than barefoot trials. In looking at joint angles, both participants demonstrated increased plantarflexion throughout a majority of the gait cycle. While P1 remained in plantarflexion throughout the gait cycle, P2 exhibited more neutral ankle angles during late stance and early swing (max plantarflexion barefoot P1=20.3±1.7°, P2=11.3±1.8°; in heels P1=36.6±0.4°, P2=22.9±.7°). During heel trials, P1 demonstrated less knee flexion in early stance on average (max barefoot=35.7±1.0°, heels=30.6±1.6°) and more in mid swing (max barefoot=56.9±.6°, heels=61.8±1.7°), as well as knee hyperextension in late stance which was not seen in barefoot trials. P2 demonstrated decreased peak knee flexion (max barefoot=63.6±.3º, heels=54.7±1.7º), however maintained greater flexion throughout stance phase, never reaching full knee extension in heels. Hip angles were inconclusive.

Peak vertical ground reaction forces increased in participant one, with less variation in participant two as compared to barefoot trials. More distinctive impact peaks were noted on the graphs for both participants during heel trials.





Discussion:

Ultimately, our results highlight the biomechanical differences seen based on comfort in heels. Participant one demonstrated more frequent heel-wearing, whereas participant two demonstrated the joint force and angle changes that may occur in an individual who is unfamiliar with the motor plan necessary to walk in heels.

The increase in impact seen in the vertical ground reaction force component, in addition to the rigidity of the footwear at the ankle not allowing for absorption of force, supports the evidence of increased knee joint forces. The difference in force transmission patterns noted in both participants would be less efficient for an infrequent heel-wearer who is accustomed to ambulating barefoot.

Conclusion/Clinical Implications:

The main observation seen in this study was an increase in plantar flexion, which would cause poor body mechanics for both frequent and infrequent heel wearers. Decreased efficiency in a gait cycle could lead to an increased risk of muscle strain and/or injury. Frequent heel wearers are predisposed to

knee OA due to an increase in force transmitted up the chain (Titchenal MR, et al. 2015). In addition, gastrocnemius/soleus tightness are common in heel wearers, evidenced by the plantarflexion angles throughout the gait cycle (Titchenal MR, et al 2015). In clinical settings, the physical therapist's history should include the patient's footwear and frequency of each type. This will help guide treatment and patient education for activity modification.

References

1. Titchenal MR, Asay JL, Favre J, et al. Effects of high heel wear and increased weight on the knee during walking. *J Orthop Res.* 2015;33: 405-411.
2. Franklin S, Grey MJ, Henegan N, et al. Barefoot vs common footwear: a systematic review of kinematic, kinetic and muscle activity differences during walking. *Gait and Posture.* 2015;42: 230-239
3. Cronin, NJ. The effects of high heeled shoes on female gait: a review. *J Electromyogr Kinesiol.* 2014;24: 258-263.