THE EFFECTS OF MINIMAL FOOT SUPPORT BOOTS ON LOWER EXTREMITY WALKING

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UGG boots, a flat footwear with minimal medial arch support, have become one of the top footwear choices today, particularly for women. The lack of plantar foot support may cause foot injury due to over pronation in the subtalar joint. Therefore, the purpose of this study was to examine the kinematics of barefoot and minimal foot support boot walking. Ten female subjects walked on the treadmill barefoot and in MFS boots. The results showed no statistically significant difference in the kinematics of lower limb and subtalar joints between the conditions. This study suggests that MFS boots do not limit rear foot motion. It may be due to the participants in the study having low pronation ankle profiles and the short duration of MFS boot wear. Future study is warranted to examine the long term effect of wearing MFS boots with various ankle pronation profiles.

KEY WORDS: arch support, gait, kinematics, pronation, subtalar joint

INTRODUCTION: Walking is a basic fundamental method of locomotion that provides support and propulsion (Kharb, 2011). A person's walking gait, or their ability to propel forward their center of mass, can vary greatly depending on their ankle and foot movement patterns. Humans protect their ankles and feet with varying footwear, and since the ankles and feet support the rest of the body, the type of footwear chosen can greatly modify the force transmission and foot / ankle complex movements. The type and extent of foot arch support varies with footwear design, materials, and construction. Most people have normal arches, but Shercher (2008) reports 8-15% of the population have an excessive upward arch, or cavus foot, while nearly 20% of Americans have an excessive downward arch, or flat foot (Donatelli, 2000). Footwear that has flat soles and/or lack arch support may be implicated in foot injuries that in turn may affect the walking gait of the person. As discussed by Glasoe et al (1999), the medial longitudinal (ML) arch serves as the chief load-bearing structure of the foot. In other words, majority of the body's weight is put on this part of the foot when walking. Wearing shoes that do not support this ML arch can alter the walking gait, and if worn for prolonged periods, may cause foot pain. Combining foot abnormalities with flat footwear may overly challenge the foot and ankle mechanics. In recent years, at least 25% of American women own boots with flat plantar sole design and minimal arch support. However, Price (2014) indicated that flat shoes can cause detrimental effects on foot health. Stratchan (2010) further pointed out that minimal foot support (MFS) boots are designed more towards aesthetics rather than functional support. There has been extensive research on another flat shoe—the flip flop—which provide little to no arch support. Studies have confirmed that flip flops have a definite effect on gait kinetics (Shroyer, 2015). Price et. al (2014) conducted a study that found flip flops loosely secured designed altered gait parameters, particularly greater ankle dorsiflexion (13.0±2.9°) compared to barefoot (13.5±2.4°). Hestroni's (2006) study indicated that over pronation can lead to various injuries, particularly anterior knee pain. The over pronation found in flip flops may cause lower body injuries to their wearer. If flip flops are capable of affecting gait kinetics, MFS boots may have similar negative effects. Therefore, the purpose of this study was to examine the effects of MFS boots on walking gait—particularly in the lower limbs and subtalar joint.

METHODS: Ten females (age 21.3±1.2 years) with shoe sizes between 6 and 10 were recruited for participation, with Institutional Review Board Approval obtained prior. Each participant received a full briefing, signed a written consent form, and was given a chance to decline participation prior to beginning the study if they felt it necessary. All participants arrived to the Bridgewater State University Biomechanics lab and were given a chance to walk at the designated speed prior to beginning. During testing, each participant walked for one minute at the speed of 1.3 m/s on the treadmill. This speed was chosen because it closely mimics natural walking speed. Participants walked both barefoot and with the minimal foot support (MFS) boots. The particular brand test for foot support was UGG boots, and the model was the classic mini boot. Data collection was concluded in one day with a half hour in duration per participant. Five joint reflective markers were placed on the right side of the body at the glenohumeral joint, greater trochanter, lateral epicondyle of the tibia, lateral malleolus, and base of the fifth metatarsal. The three latter joints were covered by the boots. In order to locate and mark these joints as accurately as possible, manual location of joints inside the boot and careful matching outside the boot was used. This sagittal view was used to determine hip and knee joint flexion and extension as well as ankle dorsiflexion and extension. Three joint reflective markers were placed on the rear of the body at the mid-calf, Achilles tendon, and heel. Similar to the sagittal view, joints covered by the boots were located and marked by manual location inside the boot and careful placement outside the boot. This rear view was used to determine ankle eversion and inversion. This location of the rear foot joint marker placement was adapted and modified from Morley et al., (2010). Two Casio high speed cameras (Model: EX-FH25) were positioned to capture these sagittal and rear views at 120 frames/second, with both cameras in conjunction with a 650W artificial light. A two dimensional kinematic analysis was conducted for each type of footwear at zero degree incline with Ariel Performance Analysis System (APAS ^{TM}) motion software. Gait analysis of all trials was completed. The mid support phase of each of the three gait cycles was analysed, providing kinematic measures including joint angle, velocity, and acceleration. A total of 120 trials (10 participants x 3 mid supports x 2 camera views x 2 footwear) were analysed. A t-test conducted at $\alpha = 0.05$ between the two types of footwear. All statistical anaylses were conducted with SPSS software.

RESULTS: The results of this study indicate that there is no statistically significant difference between walking barefoot and walking in MFS boots in the sagittal view of the body at a zero degree incline during mid support, Table 1. No difference in the subtalar joint between the two types of footwear (barefoot: 170.8±8.5° and MFS: 174.3±4.1°) during the mid-support phase of the gait cycle was found, Table 2. This lack of statistical significance means that MFS boots do not seem to limit the rear foot motion during pronation movement as initially hypothesized. In other words, the foot does not roll inwardly when walking in MFS boots.

Table 1
Kinematic comparisons between barefoot and MFS boots during mid-support

Joint	Mean BF±SD	Mean UGG±SD	*p*
Hip (°)	170.9±5.5	169.0±6.0	.129
Knee (°)	163.1±7.1	161.3±6.1	.113
Ankle (°)	100.7±4.4	100.5±3.4	.863

**Statistical significant at p < 0.05*

Table 2
Kinematic comparisons between barefoot and MFS boots at subtalar joint during mid-support

Kinematic Measures	Mean BF±SD	Mean UGG±SD	*p*
Joint Angle (°)	170.8±8.5	174.3±4.1	.273
Velocity (m/s)	-18.6±46.0	-8.0±22.5	.494
Acceleration (m/s)	-427.4±437.2	-857.5±543.5	.591

**Statistical significant at p < 0.05*

DISCUSSION: The findings of this study were consistent with previous MFS footwear research studies in terms of ankle's dorsiflexion movement. Price et al. (2014) conducted a study on flip flops, and found ankle's maximum dorsiflexion during stance of flip flops was 13.0±2.9° compared to the barefoot condition of 13.5±2.4°, which is equivalent to 103.0±2.9° for flip flop and 103.5±2.4° for barefoot in this study. In this study, the ankle's dorsiflexion movement at mid support stance was 100.5±3.4° and 100.7±4.4° for MFS boots and barefoot conditions, respectively, and these findings are quite similar to Price's study. The slight ankle joint difference between this study and Price's study may be due to the fact that the latter examined the maximum dorsiflexion joint angle at mid support while this study evaluated the instant of entire foot contact at the mid support.

The MFS boots tested were of minimal mass (.28 kilograms each); hence, their mass should not significantly change or affect ankle's dorsiflexion movement while walking in short duration. The effects of wearing boots for a long duration of time on the ankle joint remained to be examined. The results of this study showed that there is no significant difference in short term exposure between the barefoot and MFS boot conditions in terms of ankle's eversion/pronation and inversion/supination movements. Morely et al. (2010) conducted a study to examine the ankle's eversion/pronation and inversion/supination movements between shod and barefoot running. Morley et al (2010) found that the low pronation group (3-8.9°) did not show any difference in the ankle's maximum eversion movement between barefoot and shod conditions. However, the middle pronation (9-12.9°) and high pronation (13-18°) groups showed signifcant increase in ankle's pronation movement during shod condition. Therefore, since this study did not find any difference between MFS boots and barefoot condition, a closer sub-group pronation type examination would be warranted.

There are limiations in this study. For example, three joint reflective markers were placed on the mid calf, Achilles tendon, and heel to measure the subtalar joint movement. This technique is slightly modified from Morley et al. (2010)'s study. Having the subtalar joint covered by the boots during the testing and data collection is a limiation, with potential to hinder accurate joint identification. Nonetheless, the results of the study showed consistent and similar findings on ankle's pronation/eversion movement with Morley et al (2010) and Price et al. (2014)'s studies. In this study, the ankle's pronation/eversion movement was 170.8±8.5° for barefoot and 174.3±4.1° for MFS boots. Morley et al (2010) reported the maximum ankle's eversion movement was 6.3±2.6° for barefoot and 6.7±2.1° for shod contitions, which is equivalent to the current study's 173.7±2.6° for barefoot 173.3±2.1° for shod condition. Additionally, Price (2014) reported maxmium ankle's eversion movement during stance was -4.3±2.1° for barefoot and -4.4±1.9° for shod condition, which is equivalent to the current study's 175.7±2.1° for barefoot 175.6±1.9° for shod condition. These differences may be due to different phases of foot contact examined.

Another limitation was that only new MFS boots were used. Longer term use that would involve footwear molding to foot shape were not examined in this study. Podiatric experts argue that a foot will slip around inside a flat shoe. This slipping can cause the foot to fall towards the inside of the shoe with each additional step. This may endanger the arch because of the repeated falling and inward motion. As the foot continues to follow this inward motion, the shoe will begin to mold to fit the improper slipping position and can leave the ankle with pain and future problems (Springer, 2012). This study only utilized brand new boots, with no mold or shape to the wearers foot possible. The slipping of the foot and the shaping of the boot with prolonged wear could be a very interesting area of study. Future studies could consider testing people in their personal, worn in MFS boots. Another limitattion of thise study is that only one walking speed was evaluated; that is, partipicants may have been walking at an atypical speed. Additionally, a treadmill may not replicate the way each participant would have walked on solid ground. Walking gait can change from natural walking and walking on a revolving surface. Therefore, the findings between treadmill and ground may be different.

Despite the limitations present in this study, it is still an important topic to investigate. MFS boots are an extremely popular footwear, worn by people all over the world. Research shows the importance of having supportive footwear. Additionally, research shows how flat, unsupportive footwear can cause pain and or damage to the foot, ankle, and other parts of the body (Hestroni 2006). With such popularity, it is concerning to be unaware of the potential effects these MFS boots can have on the body of the wearer. This research begun an investigation into MFS boots and their effects. Future studies are warranted to continue examining different variables, including difference phases of walking gait, different ankle pronation profiles of subjects, different walking terrain and speed, and different length of wear of the MFS boots. Research begun with this study can be expanded and built upon.

CONCLUSION: Ten healthy females participated in this study, walking at a designated speed which closely mimicked natural walking patterns in order to obtain accurate data. All participants walked on a treadmill while barefoot and while wearing the minimal foot support boots. Two dimensional kinematic analyses were conducted on the lower extremities rear and sagittal view. The results showed that the lack of significant difference found suggests that within the study's given conditions, MFS boots do not grossly limit rear foot motion in the pronation movement. Future studies are warranted to test participants with various ankle pronation profiles and to examine the long term effects of wearing UGG boots.

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