**Effects of Shoe Outsole Design and Incline on Walking Biomechanics**

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**ABSTRACT**

The purpose of the study was to examine the effects of incline at foot contact of treadmill walking between rounded outsole (ROS) and traditional outsole (TOS) shoes. **METHODS**

Twelve participants, 7 males (75.1±3.9 kg, 173.6±3.8 cm, 22.6±3.5 yrs) and 5 females (56.5±4.1 kg, 158.3±4.3 cm, 25.4±4.1 yrs) granted written consent and preferred walking speed was determined. An accelerometer (480 Hz) was attached to the distal leg to measure maximum leg impact (MLI) and an electromyograph (102 Hz) was placed on the back to measure sagittal lumbar motion (SLM). Sagittal video capture (60 Hz) included thigh inclination (TI), knee angle (KA), and ankle angle (AA) (30). Participants walked on a treadmill in one of four randomized conditions: 1) ROS 0% (mass 540.5±93.8 g, apex height 4.3±0.2 cm) 2) TOS 0% (mass 304.6±64.3 g) 3) ROS 5% (mass 556.4±15.3 g) 4) TOS 5% (mass 286.6±35.1 g). Participants walked at 10% greater than preferred pace. Data were obtained for five consecutive right foot contacts for each condition. A 2 (shoe) x 2 (incline) mixed model ANOVA was conducted (p<0.05) across all variables with post hoc paired t-tests used when appropriate. **RESULTS**

ANOVA revealed significant differences in MLI for incline (p=0.04) with a reduction in MLI for 5% (0.69±0.25 g) vs 0% (0.82±0.23 g) in ROS (p=0.008). Significant differences were observed in SLM between inclines (p=0.047) with an increase in SLM for 5% (12.2±6.5 g) vs 0% (10.1±5.4 g) in ROS (p=0.001). AA was not significantly different for incline in TOS (p=0.284). There were no significant differences in MLI, TI, KA, AA or SLM between shoes at either incline. **Discussion:** The mass and design differences did not elicit changes in parameters between shoe conditions. It was anticipated that there would be a change in kinematics between incline conditions, yet KA did not change significantly from walking at 0% to 5% incline, suggesting individuals relied on back, thigh, and ankle adaptations to walk at a 5% incline. **CONCLUSION**

The mass and design differences did not elicit changes in parameters between shoe conditions. It was anticipated that there would be a change in kinematics between incline conditions, yet KA did not change significantly from walking at 0% to 5% incline, suggesting individuals relied on increased back, thigh, and ankle motion adaptations to decrease MLI at a 5% incline.

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**INTRODUCTION**

A rounded outsole shoe (ROS) is specifically designed with a fuller under the sole so that when the mass of the body is over it, the foot is forced to roll anteriorly. Traditional ROS studies have included analyses on bipedal stance1 single leg standing2, muscle activity during treadmill walking,3 kinetics during over ground walking4, and kinematics after a 6-week accommodation period.5 Presently, there is no research comparing a ROS and a TOS at 0% and 5% incline. The significance of this study is to expand the current body of literature relative to the biomechanical/functional understanding of a ROS. This study provides empirical data that will lend insight to kinetic and impact characteristics between a TOS and ROS at foot contact while walking on 0% and 5% incline.

**METHODS**

Participants:

- Twelve participants, 7 males (75.13±3.94 kg, 173.60±3.63 cm, 22.86±3.53 yrs) and 5 females (56.54±4.13 kg, 158.26±4.51 cm, 25.40±11.10 yrs)

Instrumentation:

- Leg accelerometer (PCB Piezotronics; Depew, NY) was attached on the distal tibia shaft (480 Hz)
- Electromyograph (Biometrics Ltd.; Ladysmith, VA) was attached to the lumbar spine (480 Hz)
- Video camera (Basler Scout Model sc6450–120gm; Exton, PA) to collect motion in the sagittal plane (60 Hz)

Procedures:

- Preferred walking speed was determined
- Accelerometer, electromyograph, and four reflective markers (lateral distal third of the femur, lateral knee joint center, lateral malleolus, and dorsal tip of shoe) were attached to participants
- Randomized conditions
- Data were obtained for 15 seconds after walking at self selected speed + 1.5 minutes

Data Reduction:

- Butterworth low pass filter, cut off frequency 6Hz was used to filter all data (Labview 8.6, National Instruments; Austin, TX)

- Maximum leg impact (MLI; g’s), sagittal lumbar motion (SLM; °), thigh inclination (TI; °), knee angle (KA; °), and ankle angle (AA; °) were extracted from the average of five consecutive right foot contacts for each condition

- Statistical Analysis

  - Dependent variables: MLI, SLM, TI, KA, and AA
  - A 2 (shoe) x 2 (incline) mixed model ANOVA was conducted (p=0.05). Post hoc paired t-tests were performed for significant within-subject main effects

**RESULTS**

There was no shoe main effect at 0% or 5% incline for any of the dependent variables. There was a significant difference in SLM, TI, AA, and MLI between inclines. There was no interaction.

**DISCUSSION**

Known differences between walking on an incline and 0% grade are as treadmill gradient increases, hip flexion and ankle dorsiflexion at foot contact increase. Furthermore, no differences in knee flexion among 0%, 5%, 10% and 15% treadmill gradients have been found. The current results are in agreement with previous studies for TI (TOS and ROS), KA (TOS and ROS), and AA (ROS only). Currently, it is accepted that by using an adaptation of greater knee flexion, impact forces can be better attenuated during weight bearing activities. However, MLI decreased from 0% to 5% for ROS without a significant difference in knee flexion between incline conditions. This suggests that possibly the strategy for reducing MLI at a 5% incline while wearing ROS is due to adaptations of increased hip flexion, ankle dorsiflexion and trunk flexion rather than knee flexion.

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**REFERENCES**


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Figure 1. Lateral view of ROS (top left), medial view of ROS (bottom left), lateral view of TOS (top right), and medial view of TOS (bottom right).

Figure 2. Footwear across incline conditions: SLM (top left), TI (top middle), KA (top right), AA (bottom left), and MLI (bottom right).