GROUND REACTION FORCES AND 3D KINEMATICS OF SHORT-LEG WALKING BOOTS IN GAIT

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INTRODUCTION

Short-leg walking boots have gained popularity in clinical uses [1, 2] due to several advantages over traditional casts: ease of removal for examination and cleaning, edema treatment, less expensive, and a lesser adverse effect on kinematic and kinetic gait patterns than a synthetic walking cast [1]. They are commonly used in treatment of acute and chronic injuries, and post surgical interventions [3, 4]. Limited information is available on gait biomechanics while walking in these walking boots (walker) [1]. To the knowledge of the authors, no ground reaction force (GRF) profiles of walkers were documented in the literature. Therefore, the objective of this study was to examine the ground reaction force characteristics and lower extremity three-dimensional (3D) kinematics during walking wearing two different short-leg walking boots.

METHODS

Eleven (5 females and 6 males) subjects (Age: 27.4 ± 7.8 years, Body mass: 72.0 ± 13.4 kg, Height: 1.76 ± 0.08 m) participated in the study. The subject performed five level walking trials in each of three randomized conditions: two short-leg walking boots of Gait Walker (DeRoyal Industries, Inc.) and Equalizer (Royce Medical Co.) and one pair of lab shoes. A force platform (1080 Hz, AMTI) and a 6-camera motion analysis system (120 Hz, Vicon) were used to collect GRF and 3D kinematic data simultaneously during the testing session. A pair of photocells was used to determine and monitor the preferred walking speed during testing.

Kinematic and GRF data were smoothed at 6 and 20 Hz respectively, using a fourth-order Butterworth low-pass filter. The 3D kinematic variables were computed using Visual3D software suite (C-Motion, Inc.) in conjunction with a customized computer program. A one-way repeated measures of analysis of variance (ANOVA) was used to evaluate selected GRF and kinematic variables and post hoc comparisons were conducted with an alpha level ($p < 0.05$) adjusted for multiple comparisons through a Bonferroni procedure.

RESULTS AND DISCUSSION

In addition to two normal vertical GRF peaks associated with the loading response (Max 2) and terminal stance (Max 3) in normal walking, one earlier peak (Max 1) occurs before the peak of loading response in the two walker conditions (Table 1). This peak was mostly absent in the shoe walking trials. The statistical comparisons showed no significant differences for the three peaks. Even though the first GRF peaks for the two walkers were below one body weight, it poses loading that may be detrimental to the injured foot/leg structure(s). This risen peak is related to the outsole material and the heel design of the walkers.

Table 1. Average vertical GRF peaks (N/kg).

Condition	Max1	Max2	Max3
Shoe	--	10.77 ± 0.59	10.68 ± 0.41
DeRoyal	8.91 ± 1.49	10.27 ± 0.72	10.47 ± 0.59
Royce	7.37 ± 2.74	10.72 ± 0.61	10.43 ± 0.44

--: No apparent peak observed

The ANOVA comparisons of joint kinematics suggested that the subtalar eversion range of motion (ROM) was greater for the DeRoyal compared to the no walker condition (Table 2). In addition, the hip abduction ROM for the DeRoyal and Royce walkers were significantly smaller than those for the shoes. These data suggest that both walkers restrict motions of the subtalar and hip joints in the frontal plane. Our data basically agreed with the findings of Pollo et al. [1] except for the maximum knee flexion in the earlier stance for the DeRoyal walker, which was greater than walking in the shoes. This may be related to the slight different ground reaction force profile for the condition.

CONCLUSIONS

This study showed both short-leg walking boots, DeRoyal's Intuition Gait Walker and Royce's Equalizer, were effective in minimizing motion of subtalar eversion and hip adduction. Both walkers did not increase the two peak ground reaction forces observed in normal walking in shoes. However, they did impose a small initial peak (less than one BW) in early stance phase.

REFERENCES

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Table 2. Average ROM (deg) of lower extremity joint angles.

Condition	Subtalar Eversion ROM	Knee Adduction ROM	Hip Adduction ROM
Shoe	-8.7 ± 3.3	3.3 ± 1.8	8.3 ± 2.4
DeRoyal	-1.8 ± 4.9 [1]	2.4 ± 2.5	6.1 ± 2.00 [1]
Royce	-6.6 ± 4.6	2.1 ± 2.2	6.0 ± 2.3 [1]

[1]: Significantly different from Shoe