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A Randomized Comparison of the Biomechanical Effect of Two Commercially Available Rocker Bottom Shoes to a Conventional Athletic Shoe During Walking in Healthy Individuals

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ABSTRACT

Rocker bottom shoes have recently gained considerable popularity, likely in part because of the many purported benefits, including reducing joint loading and toning muscles. Scientific inquiry about these benefits has not kept pace with the increased usage of this shoe type. A fundamental premise of rocker bottom shoes is that they transform hard, flat, level surfaces into more uneven ones. Published studies have described a variety of such shoes—all having a somewhat rounded bottom and a cut heel region or a cut forefoot region, or both (double rocker). Despite the fundamentally similar shoe geometries, the reported effects of rocker bottom shoes on gait biomechanics have varied considerably. Ten healthy subjects agreed to participate in the present study and were given appropriately sized Masai Barefoot Technology (St. Louis, MO), Skechers™ (Manhattan Beach, CA), and New Balance (Boston, MA) conventional walking shoes. After a 12-day accommodation period, the subjects walked wearing each shoe while 3-dimensional motion and force data were collected in the gait laboratory. The key findings included (1) increased trunk flexion, decreased ankle plantarflexion range, and reduced plantarflexion moment in the early stance; (2) increased ankle dorsiflexion and knee flexor moment in the midstance; (3) decreased peak ankle plantarflexion in the late stance; and (4) decreased ankle plantarflexion and decreased hip flexor and knee extensor moments in the pre-swing and into swing phase. The walking speed was unconstrained and was maintained across all shoe types. A biomechanical explanation is suggested for the observed changes. Suggestions for cautions are provided for using rocker bottom shoes in patients with neuromuscular insufficiency.
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Shoes are an important tool that assist walking by protecting the foot and facilitating varying walking capabilities (1). Different types of shoes have been created to enhance lower extremity movement. Recently, rocker bottom shoes have come into the spotlight and have been purported to be more natural, improve balance, promote musculoskeletal benefits (increased muscle activity and toning), reduce joint loading and pain (2), and even promote recovery from fatigue after running a marathon (3). The shoe from Masai Barefoot Technology (MBT; St. Louis, MO) is one such shoe that was designed to specifically reduce joint load/stress on the knee and hip joints (1). The MBT shoe has a rounded soft sole in the anteroposterior direction under the heel area, providing an unstable base of support. A fundamental principle of the shoe is to transform flat, hard, artificial surfaces into uneven surfaces, emulating the gait of our barefoot ancestors (4). Skechers™ (Skechers, Manhattan Beach, CA) has also produced a rocker bottom shoe that was purported to help tone leg muscles during every day walking activities (5)—a claim that has since been retracted (6). The claims about how such shoes might affect musculoskeletal performance are numerous; however, scientific information has not kept pace with the development of these shoe types and their purported effects. More importantly, the existing data have not reached a clear conclusion regarding the basic effects of rocker bottom shoes on walking performance.

Reports of the effect of rocker shoes on the temporospatial parameters of walking have varied considerably. The walking velocity has been commonly reported; however, the effect is not consistent. Some evidence has suggested that subjects walk slower when wearing the MBT shoe than when wearing regular shoes (1,4,7), although others have reported no differences in the velocity (8–10). However,

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none of these were specifically for the MBT but for a similarly constructed double rocker shoe. The cadence has similarly been widely reported with mixed results. Myers et al (8) and Li and Hong (11) found increases, although others found no changes (1,9,10,12). The double support time has been reported to be reduced by some investigators (9,10,13) and not influenced by rocker bottom shoes by others (1,12). The stride length was found to decrease in 1 study (11) but was not affected in others (1,8,12).

Several studies have asserted that rocker bottom shoes affected the movement patterns in the ankle joint more than in the hip and knee joints (1,14); most other kinematic parameters have not shown consistent results throughout a wide array of studies (1,9,12,14). Peterson et al (9) reported increased plantarflexion at the initial contact, and Romkes et al (4) and others (11,15) reported increased dorsiflexion early. Myers et al (8) and Long et al (12) reported reduced dorsiflexion in midstance in 40 healthy adults using prescription negative heel rocker bottom shoes. In contrast, Peterson et al (9) found increased plantarflexion in midstance. Peterson et al (9) found decreased plantarflexion during push off, as have others (1,11). However, Myers et al (8) and Long et al (12) reported greater plantarflexion at toe-off. Still others have reported reduced dorsiflexion for the entire stance phase (6). This same group of studies also reported decreased knee extension (1,4,8) or increased knee flexion (9) at the initial contact and increased flexion during loading (1,4,8). Some have reported increased late stance flexion (2), some reduced late stance knee flexion (9), and still others have reported that rocker shoes have relatively little to no influence on knee joint kinematics (10,15). At the hip, evidence has shown a less flexed or more extended pattern during some (4,16) or all (8,11) of the gait cycle, decreased extension in late stance (1,4), and no effect (10).

The effect of rocker bottom shoes on kinetic variables has also been explored—with similar inconclusiveness. An increased plantarflexion moment has been reported by some early in the gait cycle (1,8,17); however, others have reported reduced peak positive ankle joint powers during early midstance and decreased plantarflexion moment and power generation at push off (1,8,18). At the knee, a generally (1) or partially (8) increased knee extensor moment profile, along with reduced flexion moments (19,20), have been reported. At the hip, decreased peak hip flexion moments (1,21), along with increased hip extensor moments and decreased hip power generated in the late stance into the swing phase (8) have been reported (1).

Although the breadth of studies on rocker bottom shoes is somewhat encouraging, the overall body of work is still quite small, sufficiently diverse in method and focus, and has not yet provided much clarity on the basic mechanism by which rocker shoes influence the gait pattern in either healthy able people or persons with disability. The most commonly available rocker bottom shoes putatively have nearly the same or at least highly a similar structure and design and, thus, should also engender similar biomechanical consequences. The seemingly disparate results provided in the reported studies to date are somewhat surprising. Further information and analysis are needed to formulate more definitive conclusions and a better understanding of the mechanisms that result in the observed changes.

The present study was undertaken to better understand the kinematics and kinetics during walking with rocker bottom shoes versus conventional athletic footwear. Our own preliminary findings from the data collected for an earlier study (22) showed a trend toward decreased early ankle plantarflexion and again during the late stance/push-off phase. A reduction in ankle dorsiflexion moment and power absorption during loading was seen. The decreased pretibial muscle activity observed during loading was consistent with these kinetic findings. A trend was seen toward decreased power generation in the terminal stance/preswing, and this was corroborated by decreased plantar flexor muscle activity in midstance. The other more general trend observed was a reduction in various joint moments and powers from midstance through preswing. No specific joint and phase trends were consistent across all subjects, other than a general reduction in magnitude. Together, these findings suggest the gait wearing rocker bottom shoes might actually be more efficient, because the subjects were able to maintain walking speed while seemingly reducing the magnitude of the kinetics that produce that performance. How this was accomplished was, however, unclear. These findings formed the basis for the a priori predictions for the present study. A careful analysis would likely help to elucidate the biomechanical consequences of rocker bottom shoes and unify some of the existing body of data. The a priori hypotheses were generated from previous work by others (4,10,11,15) and from our own pilot data from 3 normal subjects (22). We hypothesized reduced plantarflexion both during the loading phase and during the push off and generally reduced magnitudes in sagittal joint moments when wearing the rocker bottom shoes.

Materials and Methods

Subject Recruitment

Ten healthy normal adult subjects were chosen from a convenience sample of volunteers who had agreed to participate. The inclusion criteria for participation were no orthopedic, neurologic, or other conditions that affect the ability to walk; equal strength on the basis of manual muscle testing and range of motion of the left and right ankle, knee, and hip flexion and extension muscles; age >26 years; and no foot-related injuries in the previous 6 months or that currently affect the ability to walk within the normal range of age- and velocity-matched laboratory data.

Intervention and Data Collection

The subjects were provided with 2 pairs of rocker bottom shoes (MBT and Skechers™ ShapeUps) and a pair of regular walking shoes (New Balance, Boston, MA; Fig. 1). The shoes were appropriately sized to each subjects' feet. The subjects were given the shoes 12 days before testing and were instructed to use each for ≥4 days for 4 hours every day to ensure an adequate fit, comfort, and accommodation. They stopped using the test shoes and returned to using their regular walking shoes 3 days before the gait study. Interventions were provided and data collected from the subjects from August to November 2011. One of us (A.E.) participated in the provision of the intervention (shoes) and data collection.

After the accommodation period described, the subjects returned to the laboratory for the walking performance data collection. Anthropometric measurements were taken. Three-dimensional motion data were captured during walking using an active marker system (Coda CX1; Charnwood Dynamics Ltd., Rothley, United Kingdom) consisting of 3 sensors and the placement of miniature infrared lights on the subjects' legs. The markers were placed bilaterally on the fifth metatarsal head, lateral malleolus, heel, anatomic knee center, mid-tibia, mid-femur, and pelvis, and unilaterally on the posterior aspect of the trunk in accordance with the standard manufacturer's biomechanical model use in our laboratory. Further details on the setup and data acquisition have been previously reported (23).

The subjects were provided with the shoes in a random order and were instructed to practice walking in each shoe until comfortable. Test conditions were determined by a random number generator within the Matlab programming environment (The Mathworks, Natick, MA). Specifically, a randomization list was determined at the outset of the study. The random number seed itself was reset by a random number to generate a random sequence of random numbers. Then, 20 numbers were generated (2 for each intended study subject), assigning each subject a shoe type to wear first and second during testing. The subjects then walked in each type of shoe on a 12-m instrumented walkway until 10 runs of clean ground reaction force data were obtained from 4 force platforms (FP60120; Bertec Corp., Columbus OH), and the motion capture data were simultaneously recorded.

Statistical Analysis

Up to 5 runs of clean marker and force plate data were identified for each subject in each shoe type. A single experienced laboratory staff member performed the data screening for initial validity and subsequently processed the data through the default (manufacturer provided; CodaMA; Charnwood Dynamics, Ltd.) biomechanical model. This resulted in computation of the joint angles and moments. The sagittal joint angles and moments were the primary outcomes of interest in the present analysis. These trials were time normalized in 1% intervals for the entire gait cycle. These data were subsequently passed on to research assistants (including 1 of us, S.P., who was not blinded to the intervention), who performed the intermediary data analysis on trends in the data. The individual subject trial velocity was computed as the linear displacement of the

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