Gait & Posture 39 (2014) 86–90

Contents lists available at SciVerse ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Kinematic analysis of postural reactions to a posterior translation in rocker bottom shoes in younger and older adults

Dorothy R. Kimel-Scott, Elisha N. Gulledge, Ryan E. Bolena, Bruce C. Albright *

Department of Physical Therapy, College of Allied Health Sciences, East Carolina University, Greenville, NC 27858, United States

ARTICLE INFO

Article history:
Received 10 July 2012
Received in revised form 31 May 2013
Accepted 3 June 2013

Keywords:
Rocker bottom shoes
Posture control
Stability

ABSTRACT

Shoes with rocker bottom soles are utilized by persons with diabetic peripheral neuropathy to reduce plantar pressures during gait. The risk of falls increases with age and is compounded by diabetic neuropathy. The purpose of this study was to analyze how rocker bottom shoes affect posture control of older adults (50–75 years old) and younger adults (20–35 years old) in response to posterior slide perturbations. The postural response to a posterior platform translation was normalized among subjects by applying the below threshold stepping velocity (BTSV) for each subject. The BTSV was the fastest velocity of platform translation that did not cause a stepping response while wearing the rocker bottom shoes. Joint excursion, time to first response, response time, and variability of mean peak joint angles were analyzed at the ankle, knee, hip, trunk, and head in the sagittal plane. The statistical analysis was a 2-factor mixed repeated measures design to determine interactions between and within shoe types and age groups. While wearing rocker bottom shoes, both age groups exhibited increased joint excursion, differences in time to initial response, and longer response time. The older group demonstrated decreased joint excursion and increased time to initial response compared to the younger group, as well as a significantly slower mean BTSV. These findings support the conclusion that in healthy older adults and in populations at risk for falls, the use of rocker bottom or other unstable shoes may increase the potential of falls when confronted with a standing perturbation such as a forceful slip or trip.

1. Introduction

Over one-third of adults over the age of 65 fall each year and of these falls, approximately 10% result in a major injury including fractures, serious soft tissue injury, or traumatic brain injury [1–3]. Most falls in older adults are due to unexpected perturbations such as a slip or trip [4,5]. Previous reports on the causes of postural instability in older adults have shown that performance is significantly influenced by quadriceps strength [6], base of support [7], timing of joint movements [8], and variability of joint excursion [9]. In response to a standing perturbation, older adults demonstrate a higher maximum joint excursion [10] along with increased variability [9]. Older adults also exhibit longer time to peak force during voluntary stepping [8], age related differences in timing and sequence of body segment reorientation [11], and delays in joint movements after perturbations [9,10]. Additionally, older adults cannot tolerate as strong a perturbation as young adults without losing stability [12].

Older adults' impairments in postural control can be further complicated by significant medical conditions such as diabetes. Diabetes affects 20% of those age 65–75 and 40% of those older than 80 [13,14]. Persons with diabetic peripheral neuropathy have reduced somatosensation of the feet which not only increases the risk of developing pressure ulcers but also increases the risk of falls due to impaired balance and postural control responses [13]. To reduce the incidence of pressure ulcers, specialized footwear was designed to offload high plantar pressure areas such as the metatarsal heads [15,16]. Forefoot rocker bottom soles are a standard feature of off-loading footwear [16] and have been shown to reduce peak plantar pressures by 30% in medial and central forefoot and toe regions compared to controls [17].

While the rocker bottom shoe design decreases localized plantar pressures, the curved sole effectively reduces the size of the base of support and increases instability during stance [18]. As a consequence to their effect on postural control, shoes with rocker bottom soles are referred to as unstable shoes. During quiet stance, unstable shoes initially increase postural sway in healthy adults and women over the age of 50 [19,20]. In response to a posterior slide translation, young adults wearing rocker bottom shoes have significantly larger sway amplitudes and sway variances compared to control shoes, however little is known about the effect of rocker

* Corresponding author. Tel.: +1 252 744 6231; fax: +1 252 744 6240.
E-mail address: abrightb@ecu.edu (B.C. Albright).

0966-6362/$ – see front matter
http://dx.doi.org/10.1016/j.gaitpost.2013.06.002

bottom shoes on the older adult population [18]. No studies have explored differences in joint excursion, joint timing, and variability while wearing rocker bottom shoes in response to a posterior perturbation. While little is known about the effect of rocker bottom shoes on the postural stability of older adults, it is well established that differences in balance reactions during perturbations between older and younger adults are more pronounced on smaller support surfaces [9].

The purpose of this study was to analyze how rocker bottom shoes affect posture control of older and younger adults in response to posterior slide perturbations. It was hypothesized that older adults' postural response to posterior perturbation would include greater joint excursion, increased time to first response, increased response time, and increased variability compared to younger adults and that these differences would be more pronounced while wearing rocker bottom shoes.

2. Methods

2.1. Subjects

Fifteen young adults age 20–35 years old (12 females, 3 males) with a mean age of 25.4 ± 3.1 and fourteen older adults age 50–75 years old (9 females, 5 males) with a mean age of 62.8 ± 7.1 participated in this study. Exclusion criteria included neurological impairments, a lower extremity orthopedic deformity, or an injury that required surgery within 6 months of their participation. Subjects had to fit comfortably in either a women's size 7 or 8 or a men's size 11 canvas tennis shoe. This project was approved by and was in compliance with the University and Medical Center Institutional Review Board for the utilization of human subjects in research.

2.2. Equipment

Subjects wore two types of shoes for testing. Shoes were canvas with rubber soles and of the same style and brand in all sizes. All shoes were modified by the addition of a 5/8th-in. thick crepe sole material to the outsole, shaped to conform to the shoes' perimeter. Shoe soles were modified to represent either a control shoe (CS) or a mild rocker bottom shoe (RB) (Fig. 1). In the control shoe the crepe material was full thickness throughout the length of the shoe. In the RB shoe the crepe sole was full thickness from the heel to apex and gently rounded to zero thickness at the toe. The rocker apex was positioned posterior to the ball of the shoe and within 60–65% of shoe length [21]. The heel edge was also slightly rounded. A certified orthotist designed and fabricated all shoe modifications. The experimental shoes of this study were used in a previous report [18].

A dynamic dual force plate (NeuroCom International, Oregon, USA) was programmed to present a posterior surface translation for a distance of 17.5 cm and an anterior surface translation for a distance of 7.5 cm. Kinematic data were collected during all trials using an eight-camera Qualysis Motion Analysis System (Glastenbury, CT) sampled at 240 Hz.

Fig. 1. Photo of the control shoe (A) and rocker bottom shoe (B).

2.3. Data collection

2.3.1. Below threshold stepping velocity (BTSV)

The below threshold stepping velocity (BTSV) was determined for each subject and used to normalize the maximal non-stepping postural response. The BTSV was defined for both posterior and anterior translations as the fastest platform velocity that did not result in a compensating stepping response. Posterior and anterior translations were randomly administered with decreasing velocity until the participant did not step in three consecutive trials. The BTSV was found for every participant in both directions while wearing the rocker bottom shoes and was used for kinematic data collection trials. The trials to determine BTSV were conducted at least 24 h prior to the kinematic data collection.

2.3.2. Kinematic data collection

Thirty retroreflective markers were attached to the subjects' right lower extremity, pelvis, trunk, and head. Anatomical markers were placed on the first and fifth metatarsal heads, medial and lateral malleoli, medial and lateral femoral condyles, greater trochanters, and acromions. Tracking markers were placed on the left and right head above ear; forehead; sternum; T1; T10; iliac crests; L5–S1 vertebral junction; proximal, distal, and lateral calcaneus (attached to shoe); and an array of 4 markers was placed on the right thigh and lower leg segments. Subjects stood on the force plate with feet in a predetermined position [22] with arms across chest, looking forward at an eye level target and were told to maintain balance without stepping. Data were collected for three platform horizontal perturbations in both posterior and anterior directions for each shoe type. Platform velocities were set to individual BTSV's and motion data were captured 2 s before and 5 s after the onset of the each perturbation. Shoe selection and the order of posterior and anterior perturbations were randomized for each subject. The randomized order of anterior and posterior perturbations was used to minimize anticipatory postural responses.

2.4. Kinematic variables

Marker data were processed using Visual3D (C-Motion, Germantown, MD.) to obtain sagittal plane kinematic variables at the ankle, knee, hip, trunk, and head. Kinematic data were not normalized to the static neutral trial. As such, zero degrees in the sagittal plane corresponded to a vertical posture of the hip and knee and the foot at a right angle to the leg. For each angle, excursion, time to initial response, response time, and variability were determined for each subject. The perturbation of the force plate caused an initial passive movement in one direction followed by an active response in the opposite direction. The initial response and the initiation of recovery were defined as distinct points in time when the angle of the joint was reversed (Fig. 2). Motion that occurred prior to the initial response was considered passive and caused by the force place. This was followed by an active response until the initiation of recovery when the body actively returned to neutral stance. Joint excursion was determined as the difference between the joint angles at initial response and initiation of recovery. The time to initial response was defined as the time between the initial movement of the platform to the initial response. Response time was defined as the time between the initial response to the initiation of recovery (Fig. 2). Two separate measures of variability were calculated for each participant. The