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An immediate effect of custom-made ankle foot orthoses on postural stability in older adults

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ABSTRACT

Background: Foot and ankle problems are highly prevalent fall risks in the elderly. Ankle foot orthoses designed to stabilize the foot and ankles have been studied within specific patient groups, but their efficacy with a less restrictive elderly population is unknown. This study investigated if custom-made ankle foot orthoses improve postural stability in older adults.

Methods: Thirty ambulatory older adults averaged 73 (standard deviation = 6.5) years completed Romberg's balance (eyes-open/eyes-closed), functional reach, and Timed Up and Go tests while wearing validated kinematic sensors. Each test was completed in standardized shoes with and without bilateral orthoses. Additionally, barefoot trials were conducted for the Romberg's and functional reach tests.

Findings: Compared to the barefoot and 'shoes alone' conditions, the orthoses reduced center of mass sway on average by 49.0% ($P = 0.087$) and 40.7% ($P = 0.005$) during eyes-open balance trials. The reduction was amplified during the eyes-closed trials with average reductions of 65.9% ($P = 0.000$) and 47.8% ($P = 0.004$), compared to barefoot and 'shoes alone' conditions. The orthoses did not limit functional reach distance nor timed-up and go completion times. However, the medial-lateral postural coordination while reaching was improved significantly with orthoses compared to barefoot (14.3%; $P = 0.030$) and 'shoes alone' (13.5%; $P = 0.039$) conditions.

Interpretation: Ankle foot orthoses reduced postural sway and improved lower extremity coordination in the elderly participants without limiting their ability to perform a standard activity of daily living. Additional studies are required to determine if these benefits are retained and subsequently translate into fewer falls.

1. Introduction

Falls are a major health concern for the rapidly growing older adult population (above 65 years of age). Estimates of the proportion of elderly that fall each year have ranged from 22.1% to almost 40% (Hausdorff et al., 2001; Shumway-Cook et al., 2009). Miller et al. found that 8.3% of seniors treated for a fall at an emergency department, returned for treatment of a secondary fall within 6 months of the initial fall (Miller et al., 2009). The cost of treating a fall requiring any medical care averages $4100 for Medicare patients (Shumway-Cook et al., 2009). Falls by older adults treated in an emergency department are reported to average $11,408 in costs and increase to $29,363 if hospitalization is required (Woolcott et al., 2012).

While falls are often multifactoral in cause and subsequently their prevention will require interprofessional interventions, podiatry is one area of medicine that has recently been increasing its efforts to better understand and prevent falls (Najafi et al., 2013a). Prospective research has shown foot and ankle problems which are highly prevalent in older adults (Dunn et al., 2004), increase the risk of falls (Menz et al., 2006a). This relationship has implications for quality of life and occurrence of depression (Downton and Andrews, 1991; Quach et al., 2013). The contribution of footwear to falls has in part been demonstrated by work that showed an association between indoor falls of older adults and lack of shoe use indoors, suggesting that shoes may help prevent falls (Menz et al., 2006b). Previous research has shown that a multifaceted podiatric intervention utilizing home based foot and ankle exercises, assistance with the purchase of safe footwear, and provision of prefabricated foot orthoses can reduce the rate of falls in older people with disabling foot pain (Spink et al., 2011).

Foot problems, loss of proprioception and decreases in ankle strength and range of motion associated with aging have been tied to deteriorations in balance and increased fall risk (Anon, 2011b; Bok et al., 2013). Ankle foot orthoses (AFO) are intended to keep the foot and ankle in optimal positions and are commonly prescribed with the intent of improving gait and balance. Previous work with non-pathologic samples has suggested that AFO can facilitate proprioception via stimulation of cutaneous mechanoreceptors (Feuerbach et al., 1994)

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and mitigate the impact of fatigued ankle muscles upon stability (Vuillerme and Pinsault, 2007). In the case of peripheral neuropathy patients, AFO reduced gait variability while walking on uneven surfaces by stabilizing the ankle (Richardson et al., 2004; Son et al., 2010). In 2006, there were 75,240 AFO prescribed under Medicare alone (HCPCS/Alpha-Numeric, 2008). While there is a large volume of studies that have shown the benefits of AFO for individuals that have suffered a stroke, multiple sclerosis, Charcot, or non-progressive brain lesions (Geboers et al., 2002; Menotti et al., 2014; Tyson and Kent, 2009), research involving a less restrictive sample of the older adult population is lacking (Hijmans et al., 2007).

Although a direct objective predictor of fall risk has not been discovered yet, several studies have determined a strong association between poor postural balance and increased risk of falling. Abnormal postural sway measured by the range of sway, for example, has been introduced as a significant independent predictor of recurrent falls (Maki et al., 1994; Thapa et al., 1996), or as a distinguishable factor among fallers and non-fallers (Lajoie and Gallagher, 2004; Maki et al., 1994).

Therefore if an AFO were able to improve postural stability while avoiding limiting the ankle range of motion, it may subsequently reduce fall risk in the general older adult population. Hence, the purpose of this investigation was to determine the immediate effect of a custom-made flexible AFO on balance and functional reach distance in a less restrictive sample of older adults than has been utilized in previous AFO research. We hypothesize that an open gauntlet style custom made AFO could improve postural stability. Secondarily, we hypothesize that such an AFO might influence ankle function in the anterior posterior direction as well as tasks of daily living. To validate the later hypothesis, we examined the immediate impact of AFO on forward reach distance, a common household activity, as well as timed-up and go (TUG) completion times as a surrogate of motor function performance during activities of daily living.

2. Methods

2.1. Participants

Thirty participants were recruited over a six-month period (Table 1) by flyers, word of mouth and from an outpatient podiatry clinic in North Chicago, IL. Inclusion criterion included being aged 65 years or older and the ability to walk 20 m without an assistive device. Individuals with hemiplegia and with excessive lymphedema or edema that would prohibit appropriate fit of the AFO were excluded. All potential participants read and signed a local institutional review board approved consent form prior to completing any study procedures.

Table 1
Subjects' demographics.

Number of participants	N = 30
Age (years)	73 (6.5)
BMI (kg/m^2)	30 (5.2)
Gender	Female: n = 23; 76.7% Male: n = 7; 23.3%
Diabetes mellitus	n = 14; 46.7%
Diabetes mellitus with peripheral neuropathy	n = 13; 43.3% Average VPT left foot = 51.9 (23.2) Average VPT right foot = 53.3 (27.2)
Geriatric Depression Scale	Average score: 2.59 (3.21) No depression: n = 24; 80.0% Mild depression: n = 4; 13.3% Server depression: n = 2; 6.7%
Fall Efficacy Scale International	Average score: 30.6 (8.5) No concern for fall: n = 4; 13.3% Moderate concern for fall: n = 7; 23.3% High concern for fall: n = 19; 63.3%
Self reported history of one or more falls in the past 12 months	No fall: n = 14; 46.7% One fall: n = 10; 33.3% Multiple falls: n = 6; 20.0%

2.2. Procedures

During the initial visit, eligibility was confirmed and shoe size was measured for requisition of standardized athletic shoes (OrthoFeet, Northvale, NJ, USA). The participants were casted with their feet on a contoured footboard and knees at 90° in order to produce the custom-made AFO (Moore Balance Brace, Langer Biomechanics, Ronkonkoma, NY, USA) which had flexible, open ankle posterior leaf style gauntlet design which is intended to allow ankle stabilization without inhibiting sagittal plane motion. The participants reported previous history of falls in the past one year and completed a fear of falling questionnaire, Fall Efficacy Scale International (FES-I) (Delbaere et al., 2010; Yardley et al., 2005). Based on the FES-I scores, the participants were further classified as having low (16–19), moderate (20–27), or high (FES-I score ≥28) concern for falling (Delbaere et al., 2010). The Geriatric Depression Scale (GDS-15) (Almeida and Almeida, 1999; de Craen et al., 2003) was also administered with GDS-15 score of 5 or greater selected as cutoff for the identification of signs of moderate or severe depression (Marc et al., 2008). Finally, subject demography characteristics (e.g. age, gender, height, and weight) and medical history (e.g. presence of diabetes) were collected. Peripheral neuropathy (loss of plantar sensation) was assessed via vibration perception threshold score (VPT) as described by Young (Young et al., 1993) for the participants who were diabetic as the prevalence of peripheral neuropathy is approximately 35% in this population (Gregg et al., 2004). The presence of moderate to severe neuropathy was determined by VPT score ≥25 V, whereas those with a VPT <25 V were classified as having only mild or no neuropathy. With the participants in a seated position with their eyes closed, VPT was assessed by asking the participants to identify when they perceived vibratory sensation on the great toe using a biothesiometer (Xilas Medical, San Antonio, TX, USA). VPT scores were recorded as continuous variables within a range of 1–100 V. The highest value obtained at the right and left great toe was used for analysis (Armstrong et al., 1998).

The second and final visit was completed once the custom-made AFO had been manufactured. Subjects had no experience using the AFO prior to this visit. Each of the AFO had a custom-made footplate and arch support with flexibility for plantar/dorsi flexion as shown in Fig. 1a. The AFO was placed inside the shoe (Fig. 1b) and the participants slid their feet into the shoe. The appropriate fit was determined after each patient walked approximately 30 ft and the shoe size, straps and laces were adjusted by the researcher. Balance and functional reach (FR) bilateral assessments were conducted in three conditions: 'barefoot', standardized shoes ('shoe alone'), and with AFO in standardized shoes ('shoe + AFO'). TUG tests were limited to the 'shoe alone' and 'shoe + AFO' conditions. With the exception of barefoot assessments, all assessments were performed while the subjects wore knee high athletic socks and the standardized shoes. To prevent any learning or practice bias, the order of 'shoe alone' and 'shoe + AFO' conditions was randomized for each subject.

2.3. Assessment protocols

2.3.1. Balance assessment

Each participant performed six 30-second trials (two for each footwear condition during eyes-open and eyes-closed) standing upright (bipedal) with their arms crossed, feet positioned close to each other without being in contact. During eyes-open trials, the participants were instructed to keep their eyes open and focused straight ahead with no visual target being specified. During eyes-closed condition, the participants were instructed to close their eyes while standing till any instruction was heard from the examiner. Talking was not allowed during the assessments. The order of footwear conditions was randomized across subjects, however, within each condition eyes open trials were administered first and then eyes closed trials followed. One of