Gait & Posture 64 (2018) 101–107

Contents lists available at ScienceDirect

Gait & Posture

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

Full length article

Biomechanical approach in facilitating long-distance walking of elderly people using footwear modifications

Mustafa Mohamed Osman Elhadi[a,1], Christina Zong-Hao Ma[a,b,1], Wing Kai Lam[c], Winson Chiu-Chun Lee[d,*]

[a] Department of Biomedical Engineering, The Hong Kong Polytechnic University, Hong Kong Special Administrative Region, 999077, China
[b] Rehabilitation Engineering Research Institute, China Rehabilitation Research Center, Beijing, 100068, China
[c] Li Ning Sports Science Research Center, Li Ning (China) Sports Goods, Co. Ltd., Beijing, 101111, China
[d] School of Mechanical, Materials, Mechatronic and Biomedical Engineering, University of Wollongong, Wollongong, 2500, Australia

ARTICLE INFO

Keywords:
Insoles
Gait
Older adults
Long-distance walking
Physical activity
Fatigue

ABSTRACT

Background: Long-distance walking is a convenient way for prompting physical activity of elderly people. However, walking ability declines with aging.

Research question: This study assessed if silicone insoles with heel lifts (named here the prescribed insoles) could facilitate long-distance walking of older adults.

Methods: Fifteen adults aged over 65, who did not have obvious lower-limb problems, walked on a treadmill for totally 60 min in two separate walking sessions: 1) with the prescribed insoles, and 2) with original insoles of the standardized shoes. Gait tests using force plates and a motion analysis system, and subjective evaluation using visual analog and Borg's CR10 scales were conducted at different time points of the treadmill walking.

Results: Objective gait anaylsis showed that without using the prescribed insoles, there were significant reductions ($p < 0.05$) in stance time, vertical ground reaction force, ankle dorsiflexion angle and ankle power generation of the dominant leg after the 60-minute treadmill walk. Such significant reductions were not observed in the same group of subjects upon using the prescribed insoles. Meanwhile, significant improvements in subjective perception of physical exertion, pain and fatigue were observed.

Significance: Heel lifts and silicone insoles are generally used to relieve plantar pain and reduce strain of plantar flexors in patients. This study showed they might also be solutions to facilitate long-distance walking of older adults, an approach which could prompt their physical activity.

1. Introduction

Improving health and preventing disease in the elderly population are among the top priorities in health-care policy of many governments. Evidence suggests that regular physical activity can reduce fall-related injuries [1], cognitive declination [2] and mortality rates [3] among older adults. Long-distance walking is a safe and convenient way of exercise for older people [4], which can easily be integrated into their daily routine [1]. Walking for over an hour per day was found to be able to reduce the risk of mortality [3] and disability [5] of the elders. However, walking ability clearly declines with advancing age [6]. A meta-analysis of 42 studies indicated that adults aged over 65 walked only an average of about 3000 steps per day [7], less than a total 30 min of walking per day.

Muscle weakening and fatigue could be the major reasons for the difficulty faced by the healthy elders walking long distances. Over the age of 60, muscle strength decreases by an average of 3% per year [8]. In addition, older people have even greater relative force loss than young adults and slower return to resting levels, after the muscles become fatigued [9]. Plantarflexors were found to be more susceptible to fatigue than other lower-limb muscles [10]. Fatigued plantarflexors could lower the abilities of shock absorption and motion generation [10], which potentially affect the ability of long-distance walking.

Discomfort and pain at the plantar surface of the foot could also account for the lack of walking among elderly people. The pain may not occur at the beginning of the day, but it may be perceived after some walking [11]. This could be explained by the hysteresis of the soft tissue at the plantar foot reducing its stiffness upon repeated loading [12]. A previous study suggested that after a long-distance walk the gait of the young adults changed to reduce loading at the forefoot which could be

* Corresponding author.
E-mail address: ccwlee@uow.edu.au (W.C.-C. Lee).
[1] These two authors contributed equally to this work.

https://doi.org/10.1016/j.gaitpost.2018.05.032
Received 7 September 2017; Received in revised form 9 April 2018; Accepted 28 May 2018
0966-6362/

a response of avoiding pain and discomfort [13]. There is a lack of studies investigating the changes in level of pain at the lower-limb upon long-distance walking of older people. However, it was documented that older people have lower shock absorption ability of the soft tissue at the plantar foot [14], potentially bringing them more susceptible to foot pain upon repeated loading at the feet.

Modifying the forces applied to the lower limbs might address the biomechanical problems. Traditionally, orthopedic insoles are used to treat patients with foot pain. Silicone insoles were found effective in relieving foot pain in patients [15], inducing a significant reduction in peak plantar pressure [16] and soft tissue strain [17]. In addition, a wedge lifting the heel has been used to reduce the stretching of plantarflexors during lomoction, reducing further strain and fatigue [18]. Advantages of heel lifting in amputee population included a reduction in power generation of plantarflexors and a facilitation to walk longer distances [19]. Footwear modification has been used with success to treat a variety of foot problems [15–18]. However, little attempt has been made to use such approach to facilitate long-distance walking of older people.

This study examined whether modification of shoe inserts, with the use of a full-length silicone insole and a heel lift, could facilitate long distance walking of the elderly. Gait tests measuring spatial–temporal, kinetic and kinematic parameters as well as evaluation of perceived level of physical exertion, fatigue and pain were conducted in the same group of older adults who walk for one hour with and without the shoe inserts modifications. It was hypothesized that such footwear modifications reduced pain and fatigue, producing noticeable improvements in perceived exertion and gait patterns of older people walking long distances.

2. Methods

2.1. Subjects

A convenience sample of 15 elderly subjects (age > 65 years) participated in this study. Subjects should be aged over 65, living in a community-based setting, and capable of ambulation without any walking aids. They should not have a history of fall in the past year, cardiovascular or pulmonary diseases, diabetes, cancer, uncontrolled hypertension. They should not have any lower-limb pain or deformities that affect walking, as assessed by a certified orthotist following standard procedures specified in [20]. Their passive ankle range of motion was not smaller than the reported average values among older people presented in a previous study (dorsiflexion 8 degrees and plantarflexion 35 degrees) [21]. This study was approved by the university's Human Subject Ethic Sub-committee, with all methods performed in accordance with its relevant guidelines and regulations. This study was registered in the Chinese Clinical Trial Registry (clinical trial registration numbers: ChiCTR-IPB-15006530).

2.2. Design of the prescribed insoles

The prescribed insoles were incorporated with two features 1) a 3-mm thick full-length silicone gel insoles (Jing Jian Da, Beijing, China) and 2) a 20-mm Ethylene Vinyl Acetate (EVA) (40 Shore A hardness) heel lift. The silicone gel insoles were trimmed to fit the subjects' shoes size. The full-length insole and the heel lift were adhered together and inserted in the shoes after removing the original insole.

2.3. Experimental design

Each subject participated in two walking sessions, which were conducted on separate days (4–7 days apart depending on the availability of the subjects). The subjects wore the prescribed insoles on both feet in one walking session. In another walking session, they wore the original insoles provided by the shoes. In both walking sessions, standardized running shoes (NIKE Air Pegasus, Beaverton, OR, USA) were used. Each subject was fitted the shoes without looking at the insoles by the experimenters. The order of the two sessions for each subject was randomized by computer-generated random numbers of one and two denoting the two possible orders.

In each walking session, subjects were asked to walk on a treadmill without holding the handrails for two consecutive walking trials of 30 min. The duration between the two walking trials was controlled as less than 3 min. Subjects were allowed to change the speed of the treadmill in order to walk comfortably. They could stop the treadmill walking at any time they requested. Gait tests and assessment of subjective perception were conducted three times in each walking session: 1) before the treadmill walking (baseline), 2) after the 1 st 30 min and 3) after the 2nd 30 min of treadmill walking trails. Subjects walked in self-selected comfortable speed in both treadmill walking and gait analysis, to eliminate the artificial alteration of gait patterns [22].

2.4. Evaluation of perceived level of exertion, fatigue and pain

Subjects were asked to rate their level of lower-limb fatigue and pain by putting a mark on a 100 mm line in the Visual Analogue Scale (VAS) (Fig. 1), which had a long history of use in medical outcome studies investigating pain and fatigue [20]. The 100 mm line in the scale had two ends, denoting extremes of possible answers. The lower-limb fatigue and pain scores were calculated based on the distance of the marking from the right end.

In addition, they were asked to rate the degree of physical exertion by providing a score (allowing decimals in any numbers) based on a Borg CR10 scale (Table1). Borg scale is widely used as a valid measure to assess perceived intensity of physical activity, and is considered to be the most sensitive scale for general fatigue compared to other subjective scales [23].

2.5. Gait tests

Gait tests were conducted over-ground along a straight 8-meter walkway. Motion capturing was conducted using an eight-camera system (Oxford Metrics Limited, West Way, Oxford, UK) sampling at 200 Hz and synchronized with two force platforms (Advanced Mechanical Technology, Inc., Watertown, US) sampling at 1000 Hz, which were placed midway on a straight 8-m walkway. Reflective markers were placed on the subjects' left and right lower limbs over the anterior/ posterior superior iliac spine, iliac crest, mid-thigh, med-shank, greater trochanter, medial/lateral femoral condyles, lateral and medial malleoli, heel and dorsum of the foot [24]. Each trial was considered to be successful only if the whole foot fell in full contact within the force platform. At least five successful gait trials were collected for each participant.

Spatial temporal, kinetic and kinematic gait data were analyzed using Plug-in gait in Vicon. Ground reaction forces in the anterior (GRFx) and vertical (GRFz) directions were analyzed and walking

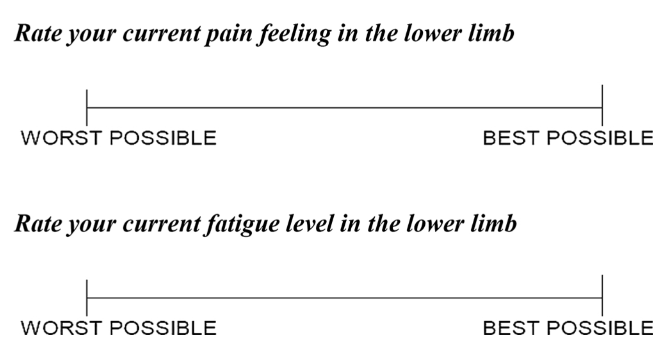

Fig. 1. Visual Analogue Scale (schematic) assessing perceived level of pain and fatigue.