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Age-related differences in women's foot shape

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ABSTRACT

Purpose: Describe age-related differences in women's foot shape using a wide range of measurements and ages.
Study design: Cross-sectional, observational study.
Main outcome measurements: Six foot-shape measurements of each foot: foot lengths, ball widths, ball circumferences, low instep circumferences, high instep circumferences, and heel instep circumference.
Results: 168 women from 20 to over 80 years of age, divided into seven age categories, were included. Older women had significantly greater foot-shape measurements, even after adjusting for Body Mass Index. Ball widths increased 3.1–4.0 mm per decade, ball circumferences 5.6–7.4 mm per decade, high instep circumferences 0.4–4.8 mm per decade, and heel instep circumferences 1.8–1.9 mm per decade. Ball widths, ball circumferences, and left high instep circumference plateaued in the 70–75 years-of-age category, and decreased in the oldest age category. For low instep circumference, age did not prevail significantly over Body Mass Index. Foot length was not associated with age.
Conclusion: This study described women's progressive foot-shape changes with age. The findings provide a better understanding of foot-shape changes, mainly found in the forefoot. It demonstrates that for a good fit, shoe design for older adults and for younger adults should differ.

1. Introduction

Foot pain is present in 20–30% of older adults, displaying a higher prevalence in females than in males [1–4], and in 10–14% of young people aged between 12 and 19 years [5,6]. Some structural conditions are related to foot pain. Such is the case for plantar fasciitis, hallux valgus, toe deformities, metatarsalgia, calluses and corns, bunions, and ingrowing toenails [1,7,8]. These structural conditions may result from friction, repetitive stress in forefoot or heel, toe adaptations to shoe shape, pressure spots on toes, and/or changes in plantar pressure distribution due to wearing an ill-fitting shoe [9–12].

Evidence has shown that individuals with foot pain and foot-morphology problems wore inadequate shoes, and that these were mainly women. The main reason demonstrated for this situation was the use of too small and narrow footwear in relation to foot size [9,12–14]. In the case of women, the use of high heels was an additional source of foot pain, even later in life [2]. Because off-the-shelf shoes may be based on an "average" foot shape for adult people, the possible effects of age on foot shape may not be taken into consideration in the design of shoes. As a result, incorrect shoe designs may be used, which, in turn, lead to a poor fit and consequent foot pain.

A few studies have investigated the potential age-related changes in foot shape. One study analyzed the differences in foot structure and function between young adults and older adults [15]. In so doing, they demonstrated that older feet are flatter than younger feet. This finding was also supported by another study, one based on the assumption that a better understanding of foot morphology would improve shoe fit [16]. Through their anthropometric study of the foot, they showed that foot circumference was markedly larger in the older group. These two studies have shown differences in foot shape between young and older adults, or young adults, adults and older adults; presenting a limited evidence on the progressive evolution of feet. Another study examined changes, as a result of ageing, in the size and shape of the foot [17]. Their findings indicated that older Japanese individuals had wider feet than younger groups. Nevertheless, that study only compares a

Abbreviations: FL, foot length; BW, ball width; BC, ball circumference; LI, low instep circumference; HI, high instep circumference; HIC, heel instep circumference.

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Table 1
Description of localization of foot-shape measurements of participants.

Measurement		Location	Device
FL	Foot Length	Distance from the horizontal line situated at the top of the first toe to the back end point of the calcaneal bone in a straight line	Brannock device
BW	Ball Width	Space between MTP-I and MTP-V joints	Sliding caliper
BC	Ball Circumference	Circumference at the level of MTP-I and MTP-V joints	Tape measure around the feet
LI	Low-Instep Circumference	Circumference at a proximal level of the heads of MT-I and MT-V bones	
HI	High-Instep Circumference	Circumference at the level of navicular and base of MT-V bones	
HIC	Heel Instep Circumference	Circumference at the front of the subtalar joint and the posterior end-point of calcaneus bone	

MTP-I, 1st metatarsal-phalanx; MTP-5, 5th metatarsal-phalanx; MT-I, 1st metatarsal; MT-V, 5th metatarsal.

limited number of measurements among age categories. As a result, an overall description of the genuine process of ageing in feet is lacking.

In response to the limitations found in the literature, the aim of this study was to describe women's foot-shape evolution using a wide range of foot measurements and age categories. In particular, our hypothesis is that a woman's foot shape is continuously changing throughout all stages of adulthood. To test this, several foot-shape measurements were taken from different age categories, with gaps between the age groups in order to highlight the changes among contiguous groups.

2. Methods

2.1. Study design and setting

This is a cross-sectional, observational study that took place between October 2013 and March 2014 at the University Medical Center Groningen (UMCG), the Netherlands. Participants were recruited through advertising material in supermarkets, public places, homes for older people, and local newspapers. The measurement process was conducted once and lasted 45 min. Participants were allowed to rest between measurements, if they needed to. The study is part of a larger project, "The effect of age on foot structure, foot complaints, plantar pressure, and center of pressure in adult women," and has the approval of the Medical Ethical Committee of the UMCG (Number: 2013-225). The project was conducted according to the principles of the Declaration of Helsinki (October 2000) and in accordance with the Medical Research Involving Human Subjects Act (WMO).

2.2. Participants

In the current study, women from the age of 20 until over 80, from the north of the Netherlands, took part. They were divided into categories with gaps of five years between them, so that differences among the groups could be highlighted. Subjects were included if they: (1) were Caucasian women, (2) fitted into one of the age categories, and (3) presented a self-reported ability to walk at least ten meters without any walking aid. Contrarily, participants were excluded if they: (1) reported medical conditions that had a major influence on gait (Parkinson's disease or stroke); (2) had undergone a lower limb amputation; and/or (3) currently used orthopedic footwear (the use of insoles was accepted, however). All participants signed the informed consent form.

2.3. Measurements

2.3.1. Procedure

Before the actual assessment, the participants met with the measurer. In these meetings the eligibility of the participants was determined, the measuring procedures were explained, signed informed consents were collected, and participants were given the opportunity to ask questions. Throughout the whole measuring process, participants were barefoot and instructed to maintain a standing position. First, height and weight were measured using a fixed tape on the wall and an analogue weight scale. Then, trained testers took foot-shape measurements as recommended by the orthopedic shoe technicians in the Orthopedic Instrument Manufacturer (OIM) protocol. According to this protocol, measurements were manually taken using a tape, a sliding caliper, and the Brannock device (The Brannock Device®, Liverpool, NY, USA). The tape in the Brannock Device was replaced with a millimeter scale for this study. Both the sliding caliper and tape measure were placed close to the foot over the points marked for foot-shape measurements; under no circumstances were they ever stretched.

2.3.2. Foot marking and measurement

Before proceeding to take the measurements, predefined locations were marked with a pen on the skin of the foot. These markers were at the level of 1st metatarsal-phalangeal (MTP-I) and 5th metatarsal-phalangeal (MTP-V) joints, proximal base of the heads of 1st metatarsal (MT-I) and 5th metatarsal (MT-V) bones, navicular bone, base of MT-V bone, front of the subtalar joint (bending point between foot and lower leg), and posterior end point of the calcaneus bone. Once the markers were set, the foot-shape measurements were taken (Table 1). One tester took all the measurements for the same subject, beginning with the right foot and followed by the left.

A graphic description of foot markers and foot-shape measurements is shown in Fig. 1.

2.4. Power calculation

On the basis of the data from a pilot study with four different age categories, a pooled Standard Deviation (SD) of 1.53, giving an effect size of 0.296, was assumed. With α defined as 0.05, power as 0.8, and using seven age categories, a sample size of 168 participants needed for multiple regression analysis was calculated.

2.5. Statistical analysis

Analyses were performed using SPSS software version 22.0 (IBM Corp., NY, USA). For details on the participant's physical (height, weight, and Body Mass Index [BMI]) and foot- shape characteristics, a descriptive statistical analysis was undertaken. To determine the predictive significance of age on foot-shape differences, a series of simple as well as multiple linear regression models were analyzed. Foot-shape measurements (FL, BW, BC, LI, HI, and HIC) were the outcome variables, and the age of the women was the predictor. In the multiple linear regression analyses, the squared term of age was added as a predictor to ascertain a possible plateau effect. Furthermore, the participant's BMI association with age and foot shape was examined using the Spearman's rho correlation in order to establish a possible confounding effect. All variables were included as continuous variables. The predictors and the confounder were entered