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Differences in foot sensitivity and plantar pressure between young adults and elderly

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ABSTRACT

Objective: The understanding of foot sensitivity and plantar pressure contributes to the design of insoles, shoes, as well as to guide therapeutic interventions. Here we investigate differences in plantar pressure and foot sensitivity between young adults and community-dwelling elderly.
Methods: Thirty-eight participants (19 young adults and 19 elderly) underwent clinical assessment of foot sensitivity and upright standing with eyes open and closed for measurement of plantar pressure in each foot. Data were compared between feet, groups, and visual conditions.
Results: Foot sensitivity was lower in the elderly and, in contrast to young adults, differed between the foot regions (loss of sensitivity was primarily seen at the heel). Elderly shift plantar pressure to more distal foot zones, namely towards midfoot and forefoot. Asymmetries in foot sensitivity and plantar pressure were not observed. Visual condition did not influence plantar pressure distribution.
Conclusions: The forward shift in plantar pressure (away from the insensitive heel) constitutes a strategy of elderly to maintain balance.

1. Introduction

Aging is associated both with progressive degeneration of the central nervous system and impaired conduction of peripheral nerves (Anguera & Gazzaley, 2012). How this affects standing posture has been investigated in pathological conditions, such as in polyneuropathy. Insensitivity of the midfoot (3) associated with other perturbations, for example pain (Corbeil, Blouin, & Teasdale, 2004), caused greater pressure under the heel when standing. Such a shift towards loading the heel is also seen in normal adults after prolonged walking (Stolwijk, Duysens, Louwerens, & Keijsers, 2010). In contrast, the impairment of foot sensitivity, due to polyneuropathy in diabetic patients, increases forefoot loading during gait (Melai et al., 2013).

Among healthy elderly a mild degree of neuropathy is often observed as well (Perry, 2006), but it is not known how this affects plantar pressure distribution. In young adults a number of studies tried to simulate insensitivity with either cooling (Billot, Handrigan, Simoneau, Corbeil, & Teasdale, 2013), local anesthesia (Hohne, Stark, & Bruggemann, 2009) or ischemia (Mauritz & Dietz, 1980; Wang & Lin, 2008 or ischemia (Mauritz & Dietz, 1980; Wang & Lin, 2008) to identify changes in gait and posture. During gait, a significant reduction in pressure under the toes and under the heel was observed after cooling (Eils et al., 2002). Similar results could be expected during standing in normal elderly with mild sensory loss as it was shown that foot sensitivity can significantly affect plantar pressure distribution during standing immediately after foot sole cooling (Billot et al., 2013). However, extrapolation of the results to normal elderly is difficult because of the uneven distribution of the sensory loss and because acute sensory reduction may not have the same effects as a chronic reduction in foot sole sensation (Zhang & Li, 2013). In addition, monofilaments have been used to make inferences about sensitivity across the foot sole. However, they are not able to specifically identify which types of afferents may be able to contribute, and which may be deficient. The perceptual threshold from monofilament testing in relation to afferent firing indicates a significant contribution from fast adapting afferent classes at perceptual threshold, and a less than significant contribution from slowly adapting receptors (Kekoni, Hamalainen, Rautio, & Tukeva, 1989). Therefore, addressing foot sensitivity and plantar pressure in the elderly provide important clinical information even supposed these variables might not correlated between them.

Considering the already known sensorial deficits related to aging, it is important to understand how plantar pressure and foot sensitivity changes at the same stage of aging and how this

Abbreviations: MT, first metatarsal head; COP, center of pressure; PD, Parkinson disease.

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information can be helpful to manage skin injuries commonly related to exacerbated pressure under specific foot regions in the elderly. Surprisingly, while several studies consider such concepts in patients or injured people, there is few research addressing the changes in foot sensation and plantar pressure in the healthy and independent elderly. Here we examined the differences in foot sensitivity and plantar pressure between young adults and independent healthy elderly.

2. Methods

2.1. Participants

Two groups with similar height and body mass but different regarding age were formed in this research. The young adults group included 19 university students with mean (± standard-deviation) age of 24.7 ± 5.8 years, height of 1.65 ± 0.08 m, and body mass of 63.2 ± 10 kg. The elderly group had 19 community-dwelling elderly (78.6 ± 4.2 years old, height of 1.55 ± 0.05 m and body mass of 68.8 ± 9.5 kg). The elderly were regularly involved with physical and cognitive activities in a local center promoting elderly independence. All participants signed a consent form in agreement with the Helsinki Declaration and approved by the local institution. Inclusion criteria involved able-bodied gait and standing without use of orthesis or prosthesis. Exclusion criteria involved altered foot arch (excessive fallen arch as depicted by plantar pressure distribution), cerebellar diseases, cutaneous injuries in the lower limbs, and history of traumatic injury of lower extremity. Participants with diabetes, neuropathies or polyneuropathy diagnosed by a physician were excluded.

2.2. Assessment of foot sensitivity

Tactile foot sensitivity was measured in a clinical setup using a Semmes–Weinstein pressure aesthesiometer (Semmes–Weinstein Monofilaments, San Jose, USA) (Perry, 2006; Patel, 2011). The aesthesiometer comprised 6 nylon filaments of equal length, with varying diameter producing a standardized pressure to the skin (Semmes–Weinstein filaments markings 1.65–6.65 kgf) according to the calibration of the manufacturer and their recommendation for use (Holewski, Stess, Graf, & Grunfeld, 1988). The use of a reduced number of filaments to identify important functional thresholds was established by Werner and Omer (1970) and validated by Bell-Krotoski (1990). A sixth filament was added following widespread acceptance of the proposals of Birke and Sims (1986). The filaments were pressed at specific points onto the plantar surfaces of the foot: medial point of rearfoot, medial arch of the midfoot; lateral arch of the midfoot; first, third and fifth metatarsal heads; and first, third and fifth toe (Fig. 1). The order of the different sites in the foot regions tested was randomized among the subjects. Participants were supine and instructed that when the filament was placed on any of the positions mentioned above, they must report to the examiner whether and where they felt it. Tactile threshold was determined by applying thinner filaments until the subjects could no longer detect touch (Breger, 1987). The first foot evaluated was alternated between the subjects to avoid any learning effect. The average sensitivity was computed for forefoot, midfoot and rearfoot. Room temperature and time of the day for assessments were similar for all participants (Schlee, Sterzing, & Milani, 2009).

2.3. Assessment of plantar pressure

Participants were requested to stand barefoot with arms resting along the trunk and to keep looking forward with eyes open or closed. For each visual condition three trials were performed. Each trial lasted 30 s with a 30 s interval. Average plantar pressure under each foot was simultaneously sampled at 100 Hz using a pressure plate with resolution of 1.4 sensors per cm^2 (Matscan 3150E, Tekscan Inc., Boston, MA). Pressure was analyzed for different foot regions defined as forefoot, midfoot and rear foot (Burns, 2004) and normalized to the average foot pressure. Further details on definition of foot regions is presented in a recent report (da Rocha, Bratz, Gubert, de David, & Carpes, 2014).

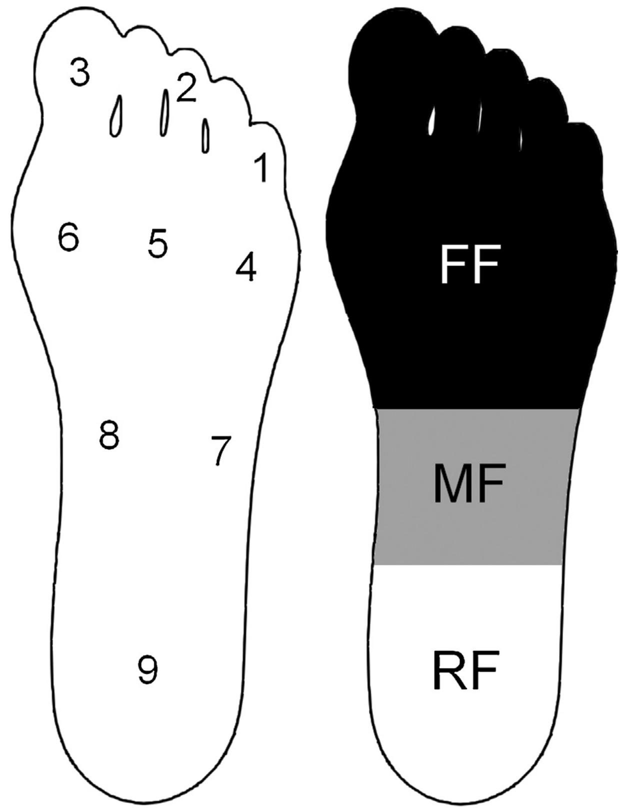

Fig. 1. Illustration of the 9 sensitivity points and foot regions considered in this study. FF, forefoot; MF, midfoot; RF, rearfoot.

2.4. Statistical analyses

Normality of data distribution was checked using Shapiro-Wilk. Foot sensitivity was compared between right and left foot for each foot region in each group using paired *t*-test. Within-groups comparisons of foot sensitivity between the foot regions were accomplished using one-way Anova with post-hoc of Bonferroni.

Effects of visual condition, group and foot region on plantar pressure were determined by an analysis of variance (2 groups × 2 legs × 3 foot regions) with Bonferroni corrections for multiple comparisons. One-way Anova with Bonferroni post-hoc was used to analyze main effects of foot region. Significance level was set at 0.05 (SPSS Inc. v. 19.0, USA).

3. Results

3.1. Foot sensitivity

Foot sensitivity was similar in the right and left foot of young and elderly regardless of foot region. Subsequent analyses considered data from right foot.

Foot sensitivity was lower in the elderly for all the foot regions compared to the young forefoot [$t_{(19)} = -6.82$; $P < 0.01$], midfoot [$t_{(19)} = -6.91$; $P < 0.01$] and rearfoot [$t_{(19)} = -7.79$; $P < 0.01$]

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