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The influence of monocular vision on the plantar pressure distribution

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ABSTRACT

Background: Although the influence of monocular vision to upper limb biomechanics has been well documented, data about lower extremity biomechanics are limited. The objective of the present study was to demonstrate pedobarographic differences between both feet of the individuals with monocular vision in static and dynamic conditions.

Methods: Pedobarographic analysis of twenty-four participants with monocular vision was performed. Relative static pressure load (%) and dynamic peak plantar pressure (N/cm^2), force (N) distributions and contact area percentages (%) were recorded under both low vision and normal vision side foot.

Findings: The results showed that relative static pressure loads did not differ between low vision and normal vision foot. Under midfoot of low vision side, a significant increment was found in peak plantar pressures (2.42 (SD 1.09) N/cm^2) and forces (136.77 (SD 64.96) N) compared to normal vision side foot (1.87 (SD 0.96) N/cm^2; 106.94 (SD 65.03) N). No difference in contact area percentages was detected.

Interpretation: These results indicate that there are differences in plantar pressure measurements between feet of individuals with monocular vision. These pedobarographic differences reported here appear to support the assumption that individuals with monocular vision have adaptive gait strategies such as, decreased walking speed, limited ankle motion and postural compensations.

1. Introduction

Gait is a complex function of the human body involving; proprioceptive, visual musculoskeletal, vestibular, and neurological systems. Binocular vision is one of the cues that help to perceive in three dimensions. The visual information is two-dimensional when it falls on the retina. Seeing with two eyes provides stereoscopic information from the environment such as, the height of obstacles and the edges of surfaces. Therefore, it is not surprising that people with monocular occlusion or blur are at a higher risk of falls and related injuries (Close et al., 1999; Felson et al., 1989).

From a kinematic point of view, there are a number of studies concerning locomotion in individuals with vision loss. These studies indicated a compensation mechanism including a reduced walking speed and step length (Hollands and Marple-Horvat, 1996; Moe-Nilssen et al., 2006; Patla et al., 2004; Reynolds and Day, 2005), additional backward leaning of the trunk (Courtine and Schieppati, 2003; Hallemans et al., 2010) and, limited ankle plantar flexion (Buckley et al., 2008; Hallemans et al., 2009, 2010) in blindfolded subjects. Authors have reported similar adaptations with a lesser extent, under blurred conditions. Studies on gait adaptations in people with total vision loss suggested that walking in a more cautious pattern might be necessary to maintain the dynamic postural balance for the people with vision loss.

A considerable amount of literature has been published on the contribution of monocular vision on upper limb kinematics. These studies have demonstrated the negative impact of monocular occlusion on prehension, which is mostly evident in the terminal reach and grasping. In these studies, participants made more online adjustments, showed longer periods of deceleration and increased grip aperture, under monocular viewing conditions (Marotta et al., 1998; Mon-Williams and Dijkerman, 1999; Servos and Goodale, 1998). In contrast to upper limbs, there is much less information about the effects of monocular vision on lower limb motion. Previous studies have suggested that the elimination of binocular vision might result in an increased toe clearance when stepping over an obstacle (Buckley et al., 2010; Chapman et al., 2012; Patla et al., 2002).

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Pedobarography assesses the interactions between the foot and supporting surface. Dynamic assessment of plantar pressure gives data during dynamic activities, while static pedobarography can analyze the plantar pressure distribution in upright standing position (Orlin and McPoil, 2000). Studies on the biomechanics of gait and postural control in those who have monocular vision can help us to understand the impact of visual system on locomotion. Dynamic plantar pressure distribution and forces are hereby used as an outcome parameter characterizing the adjustment of gait. In another point of view, the present study is also valuable to improve our knowledge about the gait pattern of individuals with monocular vision. This information will guide us to identify problems faced by these people, during gait.

The aim of the present study is to provide pedobarographic data from both feet of the individuals with monocular vision during standing and walking, in order to compare differences in loading patterns between two sides. We hypothesize that considering the adaptive strategies induced by monocular vision loss in gait kinematics, individuals with this impairment present peculiar plantar loading patterns. Such information may then be discussed in the light of the earlier findings regarding the kinematics of foot functionality in people with vision loss, especially in terms of creating safe and comfortable environment for this population.

2. Methods

A cross-sectional design was used in this study. Thirty-three participants who met following criteria were selected among the patients attending the Outpatient Clinics of Ophthalmology, to constitute the study sample: being younger than 65 years of age and having a best corrected visual acuity of 1.0 in the Snellen chart in one eye and best corrected visual acuity of 0.05 or less in the fellow eye. Exclusion criteria were a history of ocular trauma or surgery and chronic eye disorder in the fellow eye. Eyedrop users, individuals with orthopedic disorders of lower limbs, a history of orthopedic surgery, patients who had neurological disorders involving lower limbs, were excluded from the study. The study protocol was approved by the local research ethics committee (Protocol No. 2014/338). The informed consent of each participant was obtained. Demographic characteristics of the patients were recorded at baseline. Thirty-three individuals completed the pedobarographic analysis and data obtained from 24 individuals (4 females, 20 males) were found to be eligible to be included in the study. The causes of monocular vision were amblyopia in 5 participants, cataract in 4 participants, microphthalmia in 1 participant, optic atrophy in 2 participants, optic glioma in 1 participant, retinal detachment in 4 participants, retinal vein occlusion in 1 participant, central retinal artery occlusion in 1 participant, trauma in 4 participants and macular degeneration in 1 participant.

2.1. Pedobarographic assessment

For the static measurement, participants were asked to stand barefoot on a capacitive pressure distribution platform (RSscan International, Olen, Belgium) with the arms at the side. The platform composed of 4096 sensors arranged in an active sensor area of 488 mm by 325 mm, and connected to a personal computer. When the patient had a comfortable position, they were instructed to look at a constant point on the wall, which is 2 m. away. All measurements were performed twice. The pressure distribution was assessed in four quadrants; right forefoot (RFF), right rear foot (RHF), left forefoot (LFF), left rear foot (LHF). The relative pressure load percentages (%) of these four quadrants were recorded.

Same platform was used for the dynamic pedobarographic assessment which was 0.5 m. long and embedded in a 3 m. walkway. The device measured the dynamic foot loading with a frequency of 300 Hz. Patients were asked to walk barefoot with their normal steps at a customary walking speed. The patient took at least three steps before and after the platform. For the detailed analysis of plantar foot loading foot prints subdivided into ten anatomical zones by the footscan® software mask: hallux (T1), toe 2 to toe 5 (T2–T5), metatarsal 1 (M1), metatarsal 2 (M2), metatarsal 3 (M3), metatarsal 4 (M4), metatarsal 5 (M5), midfoot (MF), medial heel (HM), and lateral heel (HL). Maximum forces (N) and peak pressures (N/cm^2) were recorded for these regions. In addition, contact area percentages (%) were recorded for three regions of the foot; the forefoot, midfoot and rear foot. Measurements were repeated twice for either limb and the parameters of low-vision (LV) side and normal-vision (NV) side were collected for statistical analysis.

2.2. Statistical analysis

Each average value of the two measurements was taken as the final score and included in the analysis. The Kolmogorov–Smirnov test was used to assess the normality of numeric variables. For the numeric variables that were normally distributed, comparison between two groups was made by independent samples t test and descriptive statistics are presented as mean (SD). For the numeric variables that were not normally distributed, comparison between two groups was made by Mann–Whitney U test and descriptive statistics are presented as median (25–75 percentiles). To analyze the categorical data, a chi-square test was used and descriptive statistics are presented as frequency (%). The p values below 0.05 were considered statistically significant.

3. Results

The demographic and clinical features of the study population are shown in Table 1. Static pedobarographic results revealed a similar plantar pressure distribution under both feet. In dynamic testing results, the LV side displayed a significantly greater pressure under the mid-foot area compared with the NV side (Fig. 1). There was also a relatively high pressure under the fifth metatarsal area of the LV side, although the difference between two sides was not statistically significant. In accordance with the pressure distribution, forces under the toes 2 to 5 and the mid-foot area were significantly higher on the LV side (Fig. 2). Contact surface percentages did not differ between the two feet ($p > 0.05$). The differences in the results of pedobarographic measurements between the LV side and NV side are highlighted in Table 2.

4. Discussion

The present study investigated whether or not a monocular vision might disturb the static and dynamic plantar loading patterns. As expected, differences were found between the pedobarographic distributions on LV and the NV side. These findings indicated that a reduced visual field influenced the dynamic, but not the static plantar loading patterns in individuals with monocular vision. The most important clinically relevant finding was the relative peak pressure and force increments under the midfoot during walking in the LV side foot in comparison to the foot on the NV side.

Dynamic pedobarographic assessments revealed a general increased peak pressure and maximum force under the LV side foot. This result may be explained by the compensation of the visual field loss with head rotation or by the trunk inclination to the affected side, in order to see the environment at that side. The results of the kinematic studies of the upper limbs have shown that, when the head movement was restrained, participants made more online adjustments during grasping

Table 1
Demographic and clinical features of the study population.

Gender (F/M)	4/20
Age (years) (SD)	41.7 (15.05)
Duration of the vision loss (months) (percentiles)	220.5 (36–429)
Side of vision loss (R/L)	10/14