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Original Article

Comparison of plantar pressure distribution in patients with hallux valgus and healthy matched controls

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ABSTRACT

Background: Detailed information regarding differences in plantar pressure distribution between hallux valgus and healthy feet is unavailable. The purposes of the present study were to clarify the characteristics of the plantar pressure distribution in patients with hallux valgus compared with healthy matched controls and to determine whether hallux valgus leads to dysfunction of the great toe during walking.
Methods: The study consisted of 25 patients with symptomatic moderate-to-severe hallux valgus (HV group) and 13 healthy matched volunteers (C group) without hallux valgus. All patients and volunteers were women. The HV and C groups did not differ significantly in age, height, weight, and body mass index. Plantar pressure during walking was measured using F-scan. The plantar aspect of the foot was divided into eight regions. The peak pressure (Peak-P), maximum force (Max-F), contact time (Con-T), contact area (Con-A), and force time integral (FTI) were measured in each region.
Results: The Peak-P of the great toe did not differ significantly between the HV and C groups. However, all other parameters: Max-F, Con-T, Con-A, and FTI of the great toe in the HV group were significantly lower than in the C group. In the central forefoot, the Peak-P and Max-F in the HV group were significantly higher than in the C group.
Conclusion: The present study demonstrated that a moderate-to-severe hallux valgus deformity leads to dysfunction of the great toe during walking and may increase mechanical loading on the central forefoot.

1. Introduction

Hallux valgus is the most common pathologic entity of the great toe [1]. Typical symptoms include pain over the medial eminence of the first metatarsal head, metatarsalgia, and difficulty in wearing shoes [1].

A hallux valgus deformity is composed of a lateral deviation of the great toe and a medial deviation of the first metatarsal bone [2]. Consequently, the tendons of the extensor hallucis longus, flexor hallucis longus, and sesamoids are shifted laterally with the phalanx of the great toe. The resultant imbalance causes dorsiflexion and pronation of the great toe rendering its pulp non-functional. Hence, the reduction in foot pressure under the first ray may lead to insufficiency of the first ray and overload the lesser rays [3].

Earlier studies have measured foot pressure distribution to evaluate the function of feet [4–6]. Although the recent development of foot pressure measurement systems has led to a better understanding of the alteration of the function of feet in hallux valgus, reported results on foot pressure distribution in hallux valgus are inconsistent [7–11]. The potential causes of these inconsistencies include patient selection bias and use of non-matched controls. Thus, the relationship in the foot pressure distribution between hallux valgus and healthy feet is still controversial, and the alteration of the function of feet with hallux valgus compared with healthy feet remains poorly understood. No reports show the relationship in plantar pressure distribution between patients with symptomatic moderate-to-severe hallux valgus and healthy matched controls.

Our hypothesis was that the function of great toe during walking declined in patients with hallux valgus. The purposes of this study were to clarify the characteristics of the plantar pressure

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distribution in patients with hallux valgus compared with healthy matched controls and to determine whether hallux valgus leads to dysfunction of the great toe during walking.

2. Materials and methods

This study was conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). All patients and participants provided informed consent and this study was approved by our institutional review board, with the approval number, 0876.

2.1. Patients

Twenty-five patients (HV group) with symptomatic moderate-to-severe hallux valgus (hallux valgus angle $\geq 25^\circ$ and/or intermetatarsal angle $\geq 12^\circ$), who were hospitalized for hallux valgus surgery at our institution, were evaluated preoperatively. The study included 12 right feet and 13 left feet. Four patients had bilateral hallux valgus. We examined one side with symptoms. Conservative treatment, including modification of footwear, non-steroidal anti-inflammatory medication, and arch support, had failed in all patients. All patients complained of pain over the medial eminence of the first metatarsal. Of the 25 feet, 9 had painful plantar callosities at the second and/or third metatarsal heads. We excluded patients who had additional forefoot pathologies including dislocation of the lesser metatarsophalangeal (MTP) joint, hammer toe, or bunionette and those who underwent previous foot surgery or had rheumatoid arthritis, hallux rigidus, or neuropathy. Male patients were excluded because of the extremely high prevalence of hallux valgus among women and to maintain uniform background characteristics.

2.2. Controls

Thirteen healthy female volunteers (C group) were investigated as the controls. They answered a questionnaire that included past medical history as to whether they acquired an injury, had surgical treatment, or had a neurological disorder. They had no history of foot and lower-limb injury or disturbance. The author examined their feet and found no abnormalities in their feet and gaits before the study.

2.3. Demographic characteristics (Table 1)

The demographic characteristics of the C and HV groups are shown in Table 1. The groups did not differ significantly in age, height, weight, or BMI.

2.4. Clinical and radiographic evaluations

All patients with hallux valgus were evaluated clinically and radiologically and they were assessed using the Japanese Society for Surgery of the Foot hallux metatarsophalangeal-interphalangeal (JSSF) scale [12,13]. Dorsoplantar weight-bearing radiographs of the feet were obtained for patients in the HV group. The hallux valgus angle (angle between the longitudinal axes of the first metatarsal and proximal phalanx) and the intermetatarsal angle (angle between the longitudinal axes of the first and second metatarsals) were measured from the dorsoplantar weight-bearing radiograph in the HV group based on the measurement system proposed by Shima et al. [14].

Table 1
Demographic characteristics of the control and hallux valgus groups.

	C group (n = 13)	HV group (n = 25)	p Value
Age (years)	52.1 ± 6.5 (44–64)	53.0 ± 10.9 (26–68)	.363
Height (cm)	157.5 ± 4.9 (149–165.5)	158.6 ± 4.6 (150–167)	.568
Weight (kg)	54.2 ± 7.4 (45–68)	55.0 ± 7.9 (40–73)	.578
BMI (kg/m^2)	21.9 ± 2.9 (17.5–26.6)	21.8 ± 2.7 (15.4–26.8)	.987

The values are shown as the mean and standard deviation, with the range in parentheses. Statistical processing comprised the use of the Mann–Whitney *U* test, with significance level set at $p < .05$. No significant differences in age, height, weight, and body mass index were found between the C and HV groups.

2.5. Foot pressure measurement

Plantar pressure during walking was measured using the F-scan system (Tekscan, Inc., Boston, MA, USA). The F-scan was reported as a reliable system for measuring the foot pressure [15,16] and used resistance-based technology. The sensor sheet is a thin (0.18 mm), flexible, two-layer polyester sheet having inner surfaces printed with electrical circuits. The pressure applied changes the electrical resistance of the semi-conductive ink between the circuits. The insole consists of 960 individual pressure-sensing locations, providing measurements up to a maximum of 517 kPa per sensor [17,18].

Each sensor sheet was taped to the sole (Fig. 1). The sheet was not displaced when examination was performed. The sheet was connected to a cuff unit, which linked the sensor sheet to a computer using a 10-m cable. After calibration based on the manufacturer recommendations, all participants walked along an even floor at their usual speed. Recordings were made at 50 Hz for 5 s (mean, 3.3 consecutive steps [3–4 steps]), and the analysis was performed using the F-scan software (version 5.231). All participants walked a distance ranging 4–5.5 m in the 5 s of recording. These walking speeds ranging .8–1.1 m/s were defined as slow or normal walking speed [19,20].

The plantar aspect of the foot was divided into eight regions (Fig. 2). The toes were divided into three areas: the great toe (area 1), second and third toes (area 2), and fourth and fifth toes (area 3). The foot, not including the toes, was divided into three areas of the same length: the forefoot, midfoot (area 7), and hindfoot (area 8). The forefoot was further divided into three areas of the same width: the medial (area 4), central (area 5), and lateral (area 6) forefoot.

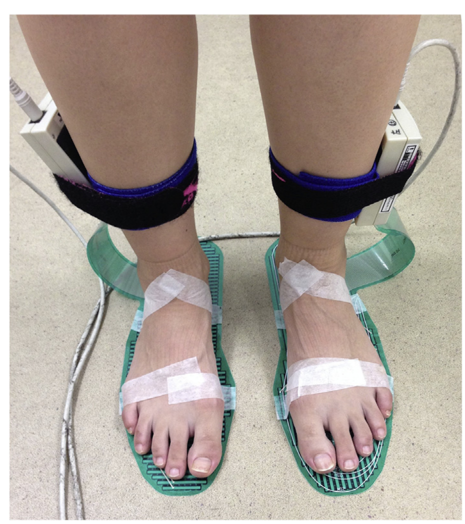

Fig. 1. Sensor placement for the foot. A sensor sheet was taped to the bare sole of all subjects. A lightweight transducer unit was strapped to their legs. A cable was used to connect the transducer to the computer. After calibration, all subjects walked along an even floor at their usual speed. Recordings were made at 50 Hz for 5 s. Data were collected from a mean of 3.3 consecutive steps (3–4 steps).

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