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Original Article

Relationship between forefoot structure, including the transverse arch, and forefoot pain in patients with hallux valgus

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Abstract. [Purpose] Hallux valgus occurs in the forefoot where the transverse arch is located and may be a factor involved in forefoot pain. The relationship between forefoot pain and forefoot structure is unknown. This study aimed to analyze the relationship between forefoot pain and the transverse arch in patients with hallux valgus. [Participants and Methods] In this study, 122 (197 feet) adult females (46 to 86 years old) with hallux valgus were studied. By using questionnaires, the females were divided into two groups depending on whether or not they had forefoot pain (a group with forefoot pain [P group] and a group without forefoot pain [NP group]). The hallux valgus angle was measured using a goniometer, and the transverse arch was measured using a weight-bearing plantar ultrasonography imaging device. The transverse arch measurements included the transverse arch height and length. [Results] Only the transverse arch length, even after adjustment, was significantly greater in the P group. No significant difference was found between the hallux valgus angle and the transverse arch height. [Conclusion] The greater transverse arch length in the P group was possibly due to the collapsing transverse arch support muscles. Increased width probably caused inadequate impact absorption which in turn led to forefoot pain.

Key words: Hallux valgus, transverse arch, forefoot pain

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INTRODUCTION

The feet are the only parts of the human body connected to the ground, and they play an important role in motility. Foot deformity is an important problem that affects daily life. Among foot deformities, hallux valgus (HV) has plagued many people. HV is a deformity characterized by abnormal angulation, rotation, and lateral deviation of the great toe at the first metatarsophalangeal joint[1)]. The prevalence of HV is higher in people aged more than 65 years (35.7%) than in those aged 18–65 years (23%); it is also higher in females (30%) than in males (13%)[2)]. In a Japanese study, the prevalence of HV for individuals aged over 65 years was 11.6% for males and 41.1% for females[3)]. HV is a very common foot deformity in elderly females. It is a progressive disease that impairs the aesthetic appearance of the foot and significantly limits the patient's daily activities if not treated. In addition to the limitations of pain and physical function, the severity of deformation may have psychological effects[4, 5)]. Pain especially affects most domains of quality of life (QOL), primarily physical and emotional functioning. Pain is not synonymous with poor QOL and constitutes only one important factor in determining QOL[6)]. However, QOL and pain are closely related. A previous study reported that the increasing HV angle and pathomechanical changes in the rear foot are correlated, resulting in increasing pain, thus, decreasing functional status and quality of life[7)]. In other previous studies, many intrinsic and extrinsic factors related to HV were investigated[8, 9)]. Many studies about pain in HV focus on changes in pain due to surgical and conservative interventions[10)]. However, HV patients do not necessarily

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experience pain. Nevertheless, we did not find studies related to forefoot pain with HV and foot structure.

There are three arches (medial-lateral arch, lateral longitudinal arch, and transverse arch (TA)) in the foot. The arches play a functionally important role by supporting weight during running and walking and by absorbing the impact of the body[11, 12]. The TA is an arch formed by the five metatarsal bones in the frontal plane on the foot, and it is present in the forefoot region. HV is also present in the forefoot region; thus TA is directly involved in HV. Until now, few studies on TA have been done. However, in recent years the importance of TA has been reported in some studies. Findings include that forefoot bones may be related to superior sprint performance[13], and that foot pain occurs most frequently in the forefoot[14, 15]. However, the relationship between forefoot pain and forefoot structure, including the role of TA in HV patients is unknown. In addition, HV patients do not necessarily feel pain, and the reason for the appearance of pain has not been elucidated.

TA and gait have not been well investigated. It has been reported that TA spreads due to weight bearing placed on the forefoot during gait[16, 17]. Therefore, in adding the morphologic change measurements of TA during weight bearing to the static measurements of TA, the TA becomes more efficiently understood during human activities[18]. Currently, various devices are used for measuring the foot structure at the loading position. Ultrasound (US) imaging is useful in measuring foot structure and has the advantages of noninvasiveness, low cost, and high portability compared with other imaging techniques, such as computed tomography (CT) and magnetic resonance imaging (MRI)[19]. Therefore, in this study, we used US imaging and measured the forefoot structure in standing and sitting positions. Understanding the relationship between forefoot structure and forefoot pain is useful for the prevention and treatment of pain. In this study, we investigated the relationship between forefoot pain and the TA in HV.

PARTICIPANTS AND METHODS

Through e-mails and advertising in public information magazines, we recruited participants in Kyoto, Japan. We provided a verbal explanation of the aims and protocols of this study of this study and targeted 281 females who provided consent. A total of 122 adult females with HV (15°<)[20] participated in this study. This study specifically focused on feet (n=197). Exclusion criteria included were those with no HV and those with a history of fracture, dislocation, and surgery on the lower limbs. As a result, 88 females (age, 69.8 ± 9.4 years; body mass index (BMI), 21.5 ± 3.1) participated in this study, and measurements of their feet were obtained (n=144). We obtained signed consent forms from each participant that was included in this study. The current study was in accordance with current local guidelines and the Declaration of Helsinki, and it was approved by the Ethical Committee for Human Experiments (R0450-1) of Kyoto University.

A questionnaire was used to obtain demographic data, including height and age, as well as to record forefoot pain. Participants indicated whether or not forefoot pain was present in daily life by answering “Yes” or “No” when illustrations of forefoot parts were shown to them. Items measured were weight, foot length (FL), hallux valgus angle (HVA), and TA structure. Body weight was measured using a scale. Foot length was measured using a caliper.

The protocol for measuring HVA is described by Kilmartin[21]. HVA is the angle between the first metatarsal axis and the proximal phalanx axis. We measured HVA with a goniometer. At that time, the participants were standing. Test-retest reliability of two measurements of HVA with a 1-week interval was excellent (intra-class correlation coefficient=0.965) in a sample of 28 feet[22].

Transverse arch height (TAH) was evaluated using a weight-bearing plantar ultrasound-imaging device[23] and a US diagnostic device (Noblus, Hitachi Aloka Medical, Tokyo, Japan). One forefoot was placed on a solid gel block for US evaluation, and the other foot was placed on a digital weight scale to adjust the weight-bearing rate of each foot. In this study, images were taken when patients were bearing 50% of their weight (standing) and 10% of their weight (sitting). To ensure a consistent method of loading for all patients, patients were instructed to shift body weight to the forefoot as much as possible. Images were obtained using a B-mode US with a frequency of 9.0 MHz during weight bearing. US images were obtained at positions where four points were visible (i.e., each of the lowest points of the epiphysis of the medial sesamoid bone [MS], the lateral sesamoid bone [LS], the second metatarsal bone [2MT] and the fifth metatarsal head [5MTH]). The images were transferred to a computer and analyzed using ImageJ software (National Institutes of Health). We calculated the length of the line perpendicular (LP) to the line passing through both the MS and 5MTH as well as the length between MS and 5MTH (MS5M). Transverse arch length (TAL) was defined as the percentage (MS5M /FL×100). TAH was defined as the percentage (LP/FL×100). With this correction, the measurement items were normalized.

For statistical analysis, the pain group (P group) and the no pain group (NP group) were divided. After conducting a Shapiro-Wilk test, the differences in the aforementioned factors between the two groups were compared using the Mann-Whitney’s U test. In addition, logistic regression analysis was conducted to examine whether the TA was independently associated with forefoot pain after adjusting for other factors. The results are reported as odd ratios (OR) with 95% confidence intervals (CI). All statistical analyses were performed using JMP® 13 (SAS Institute Inc., Cary, NC, USA), with significance being assumed when $p<0.05$.

RESULTS

Eighty-eight (n=144 feet) participants meeting the criteria were targeted and no measurement items were missing. The average age was 70 (range, 46–86) years.

Table 1. Physical characteristics of participants

	NP group (n=104)	P group (n=40)	p value
Age (years)	70.4 ± 8.9	69.7 ± 9.7	0.822
Hight (cm)	154.4 ± 5.9	153.8 ± 6.6	0.851
Weight (kg)	51.3 ± 8.2	50.7 ± 7.1	0.874
Body mass index (kg/m^2)	21.5 ± 3.1	21.4 ± 2.5	0.996

Mean ± SD. SD: Standard Deviation.

Table 2. Mann- Whitney U test analysis of groups

		NP group (n=104)	P group (n=40)	p value
Hallux valgus angle (°)		24.3 ± 8.9 (21)	28.4 ± 12.7 (24)	0.079
TAL (%)	Sitting	30.0 ± 1.8 (29.8)	31.0 ± 2.2 (30.7)	0.022*
	Standing	30.7 ± 1.9 (30.6)	31.8 ± 2.5 (31.5)	0.030*
TAH (%)	Sitting	6.0 ± 3.5 (5.2)	6.5 ± 3.8 (6.4)	0.393
	Standing	5.9 ± 3.5 (5.6)	6.0 ± 3.6 (5.8)	0.918

Mean ± SD (Median), *p<0.05.
TAL: MS5 M /FL×100; TAH: LP/FL×100; TAL: transverse arch length; TAH: transverse arch height; MS5M: length between MS and 5MTH; FL: foot length; LP: length of line perpendicular.

Table 3. Logistic regression analysis

				Unadjusted odds	Adjusted odds
		NP group	P group	(95% CI)	(95% CI) [b]
TAL (%)	Sitting	104 (72.2) [a]	40 (27.8) [a]	0.78 (0.64 to 0.95)*	0.75 (0.60–0.94)*
	Standing			0.79 (0.66 to 0.94)*	0.79 (0.64–0.96)*

[a]Values are the number (percentage). [b]Adjusted for age (years), BMI, and HV angle.
CI: Confidence Interval, *p<0.05.

There were 40 feet (28%) in the P group and 104 feet (72%) in the NP group. The demographic data are shown in Table 1. Table 2 presents the results of the Mann-Whitney U test. TAL was greater in the P group tan in the NP group when patients were in the sitting position (NP group: 30.0 ± 1.8; P group: 31.0 ± 2.2; p=0.022). TAL was also greater in the P group when patients were standing (NP group: 30.7 ± 1.9; P group: 31.8 ± 2.5; p=0.030). There was no significant difference in the other measurements.

Table 3 shows the results of the logistic regression analysis. Despite adjustments for age, BMI, and HVA, TAL was independently associated with forefoot pain when in the sitting position (OR: 0.75; 95% CI: 0.60–0.94; p<0.05). Likewise, TAL was independently associated with forefoot pain when in the standing position (OR: 0.79; 95% CI: 0.64–0.96; p<0.05).

DISCUSSION

This study showed that TAL was significantly greater in the P group than in the NP group. In addition, TAL was relevant even after adjusting for age, BMI, and HVA. There was no significant difference about HVA and TAH.

One of the reasons for the large TAL in the P group may be the weakening of the muscle forming the TA. The transverse head adductor halluces muscle supports the TA. However, this muscle is very weak, and if it collapses, the foot width widens[24]. Previous studies showed that the foot arch has a role in shock absorption during walking[11, 12], but its role is insufficient if the muscles forming the arch structure are weakened. Therefore, in groups that experience pain, there is a possibility that shock absorption by the transverse head adductor halluces muscle during walking cannot be sufficiently performed; thus mechanical stress accumulates, leading to pain. Conversely, there is a possibility that muscle weakness due to a decrease in activity because of pain may have occurred. Since there is no difference in TAL between the sitting and standing positions, there is a possibility that the ligament is loose. However, as this study is a cross-sectional study, the causal relationship responsible for no change in TAL between sitting and standing is unknown.

Another possible cause for a large TAL in the P group is shoe mismatch. A large TAL is synonymous with large foot width. If it is the same foot length, the wider foot width will increase the friction even if the same shoes are worn. Wearing shoes substantially narrower than the foot was associated with corns on the toes, HV deformity, and foot pain[25]. As a result, the friction between the shoe and the inside or outside of the head of the first and 5th metatarsal may become large, and pain may occur.

There were some limitations to this study. First, this was a cross-sectional study of only females of a high age group, and causal relationship was not clear. Second, we did not actually evaluate the muscles and ligaments. Finally, a survey of forefoot pain was carried out with a questionnaire that did not scrutinize the place of pain, strength, frequency, and the appearance of movement reported.

In conclusion, we investigated the relationship between the TA and forefoot pain in HV patients. As a result, we found that a greater TAL was associated with forefoot pain. Despite some limitations, we believe that our study highlights the importance of focusing on the TA structure in HV patients. Interestingly, the results show that TAL and not HVA is associated with pain. When considering HV pain, the TAL, as well as the severity of HVA, is considered important. However, considering the limits of current research, further studies should be conducted to determine the role of TA. Because TA is not widely recognized, future research can clarify its importance.

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Conflict of interest

Authors declare no conflicts of interest associated with this manuscript.

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