The Pedobarographic Assessment and Investigation of Quality of Life in Individuals With and Without Hallux Valgus*

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Abstract

Aim: Hallux valgus (HV) is a complex three-dimensional deformity characterised by medial deviation of the first metatarsal and lateral deviation and pronation of the first metatarsophalangeal joint (MTF). This deformity of the foot directly affects the distribution of plantar pressure due to misalignment of the bones of the foot. Considering this information, the primary aim of this study was to analyze the changes in plantar pressure between individuals with and without hallux valgus.

Method: The study included 60 feet with HV and 60 feet without HV. All assessments were performed by the same physiotherapist using a pedobarography device for Hallux Valgus Angle (HVA), SF-36 Short Form and plantar pressure assessments. Statistical software IBM Statistical Package for Social Sciences Version 22.0 (SPSS Inc., Chicago, IL, USA) was used. Continuous variables are presented as mean ± standard deviation, while qualitative variables are expressed as number and percentage (%). The independent variable (IV) was analysed using Student's t-test with a statistical significance of $p \leq 0.05$ for all measurements in both directions.

Results: In the study, a significant decrease was observed in all sub-parameters of quality of life among individuals with HV compared to individuals without HV ($p < 0.05$). Individuals with HV showed a significant decrease in plantar pressure under the hallux and first metatarsal head but a significant increase in plantar pressure under the second and third metatarsal heads, second and third toes, and fourth and fifth toes compared to individuals without this condition ($p = .001$).

Conclusion: It is thought that the decrease in plantar pressure on the hallux in individuals with hallux valgus is due to pain and inflammation in the affected area. Therefore, it was observed that the plantar pressure on the lateral side of the foot increased depending on the affected area. In addition, it was found that the decrease in the quality of life of individuals with hallux valgus was associated with pain, inflammation and changes in the plantar pressure of the hallux.

Keywords: Hallux valgus, pedobarography, plantar pressure, quality of life.

Özgün Araştırma Makalesi (Original Research Article)
Geliş / Received: 14.05.2024 & **Kabul / Accepted:** 11.11.2024
DOI: https://doi.org/10.38079/igusabder.1484121

* This study has been derived from the master's thesis titled "Investigation of pedobarographic evaluation and quality of life in individuals with and without hallux valgus" which was accepted in 2023 at Istanbul Gelisim University, Institute of Graduate Studies, Department of Physiotherapy and Rehabilitation and prepared by Görkem AÇAR under the consultancy of Asst. Prof. Adem AKTÜRK ; The plantar pressure pilot data of my master's thesis were presented as an oral presentation at the 9th National Hitit Student Congress on 26-30/04/2023 by the thesis owner, Görkem AÇAR, under the consultancy of Asst. Prof. Adem AKTÜRK.

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ETHICAL STATEMENT: Ethics committee approval was obtained from the Istanbul Gelisim University Non-Interventional Ethics Committee with protocol number 2023-03-91 date: 08.03.2024, and the study was conducted under the principles of the Declaration of Helsinki.

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Halluks Valgusu Olan ve Olmayan Bireylerde Pedobarografik Değerlendirme ve Yaşam Kalitesinin İncelenmesi

Öz

Amaç: Halluks valgus (HV), birinci metatarsal medial deviasyonu ile birlikte birinci metatarsofalangeal eklemin (MTF) lateral deviasyonu ve pronasyonu ile belirgin üç boyutlu kompleks bir deformitedir. Ayaktaki bu deformite, ayak kemiklerinin yanlış hizalanması nedeniyle plantar basınç dağılımını doğrudan etkilemektedir. Bu bilgiler göz önüne alınarak, bu çalışmanın birincil amacı halluks valgusu olan ve olmayan bireyler arasında plantar basınçtaki değişiklikleri analiz etmektir.

Yöntem: Çalışmaya 60 HV'li ayak ve 60 HV'li olmayan ayak dahil edilmiştir. Tüm değerlendirmeler aynı fizyoterapist tarafından Halluks Valgus Açısı (HVA), SF-36 Kısa Formu ve plantar basınç değerlendirmeleri için pedobarografi cihazı ile yapılmıştır. İstatistiksel yazılım IBM Statistical Package for Social Sciences Version 22.0 (SPSS Inc., Chicago, IL, ABD) kullanılmıştır. Sürekli değişkenler ortalama ± standart sapma olarak sunulurken, nitel değişkenler sayı ve yüzde (%) olarak ifade edilmiştir. Bağımsız değişken (IV), her iki yöndeki tüm ölçümler için p ≤ 0,05 istatistiksel anlamlılık ile Student's t-testi kullanılarak analiz edilmiştir.

Bulgular: Çalışmada, HV'li bireyler arasında HV'li olmayan bireylere kıyasla yaşam kalitesinin tüm alt parametrelerinde anlamlı bir düşüş gözlemlenmiştir (p <0,05). HV'li bireyler halluks ve birinci metatars başı altındaki plantar basınçta belirgin bir azalma gösterirken, ikinci ve üçüncü metatars başları, ikinci ve üçüncü ayak parmakları ile dördüncü ve beşinci ayak parmakları altındaki plantar basınçta bu rahatsızlığı olmayan bireylere kıyasla belirgin bir artış göstermiştir (p = ,001).

Sonuç: Halluks valguslu bireylerde halluks üzerindeki plantar basıncın azalmasının etkilenen bölgedeki ağrı ve enflamasyona bağlı olduğu düşünülmektedir. Bundan dolayı etkilenen bölgeye bağlı olarak ayağın lateralinde plantar basıncının artışına neden olduğu görülmüştür. Ayrıca, halluks valguslu bireylerin yaşam kalitesindeki düşüşün ağrı, enflamasyon ve halluksun plantar basınçtaki değişikliklerle bağlantılı olduğunu bulunmuştur.

Anahtar Sözcükler: Halluks valgus, pedobarografi, plantar basınç, yaşam kalitesi.

Introduction

Hallux valgus (HV) is a multifaceted deformity marked by the lateral deviation and pronation of the hallux's first metatarsophalangeal joint (MTF) and medial deviation of the first metatarsal[1]. Structural abnormalities arise from the imbalance between the abductor and adductor muscles, resulting in issues like pain and dysfunction. This imbalance is recognized as one of the primary contributors to the development of HV deformity[2,3]. It often causes pain, dysfunction, and changes in the joint mechanics in the forefoot[1,4]. The prevalence of hallux valgus is 23% in individuals aged 18-64, while it is 35.7% in individuals aged 65 and above[4]. The incidence of hallux valgus is higher in females compared to males, and it has been found that the bilateral occurrence rate of hallux valgus in individuals with this deformity is 87%[5].

The hallux valgus angle (HVA) is determined by drawing a line along the long axis of the proximal phalanx and another line along the first metatarsal. A normal angular value falls below 15°, while an angle ranging between 20° and 40° indicates moderate hallux valgus. If the HVA is 40° and above, it is classified as severe hallux valgus. The intermetatarsal angle (IMA) should be less than 9°. An angle of 10°-15° is considered mild, 15°-19° is considered moderate, and angles above 20° are classified as severe[6].

Symptoms of HV include pain, inflammation, swelling, changes in joint mechanics, and excessive sensitivity. As hallux valgus progresses, the adductor muscles become a force that increases deformity, while the abductor muscles become insufficient. As the big toe

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moves laterally, the first metatarsal shifts medially. In response to this deformity, the movement of the flexor hallucis longus muscle changes from a plantar direction to a lateral direction, altering the joint moment from the sagittal plane to the transverse plane. This situation leads to various problems[7]. The increase and chronicization of the HVA result in cosmetic concerns, limitations in daily activities, pain, inflammation, and biomechanical problems in the foot[1,2]. As the deformity progresses, the abductor muscles slide toward the plantar and lateral surfaces, becoming even more ineffective. Over time, the abductors that shift towards the plantar surface start working in a direction that increases deformity and pushes the hallux towards pronation. The flexor and extensor tendons also lose their tension angle and start working like adductors. In advanced deformities, the soft tissues on the lateral side of the hallux shorten, while the amount of soft tissue on the medial side of the joint increases[8]. Hallux valgus is generally evaluated using parameters such as HVA, IMA, distal dorsal articular angle (DMAA), and radiological assessments. Pedobarographic measurements demonstrate varying plantar pressure in individuals with HV, leading to plantar changes in other regions of the foot as well[9].

Pedobarography is one of the most common methods to evaluate the interaction between the foot and the supporting surface during bipedal posture or walking. It provides valuable information about the vertical components of ground reaction forces. Plantar pressure in humans is defined as the pressure applied to the soles when the feet come into contact with the ground surface. Plantar pressure distribution in the foot is considered a reliable biomechanical parameter for investigating and diagnosing various foot disorders[10].

The measurement of the HVA was utilized to determine the degree of deformity. The pedobarographic assessment was implemented to evaluate plantar pressure changes in individuals with and without HV. The Turkish version of the SF-36 was used to assess the daily life impacts of individuals with and without HV. Pain levels of individuals with HVA were assessed using the Numeric Pain Rating Scale. Especially due to foot deformities, the plantar pressure changes of the foot become significant when creating therapy programs and daily life activities. We compared the plantar pressure changes of individuals with HV to those with healthy feet. We investigated the variations in plantar pressure changes of the feet and, consequently, the alterations in daily life activities.

Material and Methods

Ethics

Ethical approval was obtained from the Institutional Review Board of Istanbul Gelisim University, Non-Interventional Ethics Committee (date: 08.03.2024; protocol number: 2023-03-91. Furthermore, this study adhered to the principles outlined in the Declaration of Helsinki. All participants provided informed consent, and written informed consent was obtained from each participant. The assessments were carried out in person by a physiotherapist, and they were conducted only once.

The evaluations for this study were taken at Diagenics R&D Technology Health Import and Export Limited Company between 20.03.2023 and 20.04.2023.

Participants

The inclusion criteria for the study comprised individuals aged 18 years or older who voluntarily consented to participate and had a hallux valgus angle (HVA) of 15° or higher. Conversely, the exclusion criteria encompassed individuals who underwent surgery in the foot-ankle region within the previous 6 months, those with neurological or psychiatric disorders, significant lower extremity disabilities, inflammatory diseases, as well as individuals with pes planus and pes cavus deformities.

Assessments

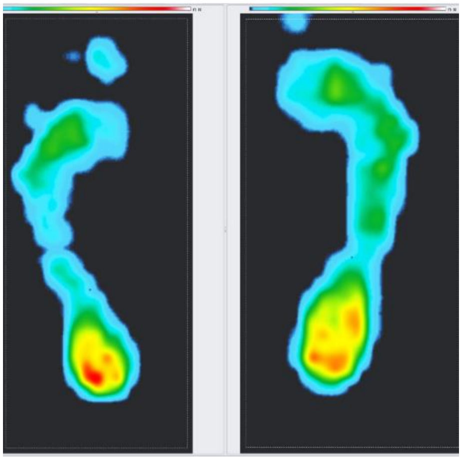
Sociodemographic Data Form: The questionnaire comprised the following information regarding the individuals: gender, age, height (cm), weight (kg), body mass index (BMI), and the presence of hallux valgus deformity.

Hallux Valgus Angle (HVA): The hallux valgus angle was assessed using a goniometer. The pivot point of the goniometer was positioned at the medial projection of the metatarsophalangeal joint. At the same time, the stationary arm was aligned parallel to the medial aspect of the first metatarsal (Figure 1). The movable arm was then placed parallel to the medial aspect of the first proximal phalanx, and the recorded narrow-angle represented the angular severity of the deformity[11].

Pedobarography: The plantar pressures were measured statically in a bipedal position. The plantar pressure data were evaluated statically using the AS Foot Scan (Analysis System, Istanbul, Turkey) device. The device has a sensor area of 400mm x 400mm, 2288 sensors (1.4 sensors/cm^2), and a data rate of up to 200 to 400Hz. The delay rate is <3%. The pedobarography device divides the foot into 8 parts: great toe (Hallux), second and third toes (digits 2-3), fourth and fifth toes (digits 4-5), metatarsal 1 (MT 1), metatarsals 2-3 (MT 2-3), metatarsals 4-5 (MT 4-5), midfoot, and rearfoot (Figure 1,2). The emed software generated the peak pressure (kPa).

Figure 1. Goniometric measurement of hallux valgus angle

Figure 2. Pedobarography static analysis plantar pressure



SF-36 Quality of Life Scale: The SF-36 Turkish version is a self-assessment scale that assesses eight distinct health parameters. These parameters include physical function, social function, role limitations due to physical and emotional factors, mental health, energy level, and overall health perception. The scale comprises 36 items aimed at evaluating these health parameters in a clear and straightforward manner[12].

Numeric Pain Rating Scale (NPRS): Individuals with hallux valgus were evaluated using the Numeric Pain Rating Scale (NPRS) to quantify their pain levels. This scale enables individuals to self-assess their pain on a scale ranging from 0 to 10, where 0 signifies the absence of pain and 10 denotes excruciating pain[13].

Statistical Analysis

The normal distribution of measurements obtained from the groups was assessed using the Kolmogorov-Smirnov test and analyzed utilizing the independent-samples t-test for intergroup comparisons. Statistical analysis was conducted using Statistical Package for the Social Sciences (SPSS v 22.0). The significance level was defined as alpha <0.05.

The research sample size was determined using the G*Power 3.1.9.7 program. Sample size calculation was performed for the independent-sample t-test. Based on the calculation, with an effect size of 0.50 ($d = 0.50$), alpha error set at 0.05, and a power of 80%, a sample size of 51 was determined for each group. Considering the potential for data loss, the sample size for each group was increased by 15%, resulting in a planned inclusion of 60 feet per group, totaling 120 feet[14,15].

Results

The study was completed with 60 feet affected by HV and 60 feet without HV. Individuals with HV had a mean age of 34.1±9.7 years, while those without HV had a mean age of 27.1±5.5 years. The sociodemographic forms of individuals are given in Table 1. Among the participants with hallux valgus, 22 were female, and 13 were male, while among those without HV, 20 were male, and 11 were female. Among individuals with HV, 32 had it on their right foot, and 28 had it on their left foot. The HVA was measured using a goniometer with equal weight to both feet in a bipedal position, resulting in an angle of 20±3.4° for feet with HV.

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Table 1. The demographic characteristics of the individuals

Parameters	Groups	Mean ± SD	p
Age (years)	**Non - HV**	27.1±5.5	<0.005
	HV	34.1±9.7	
Height (cm)	**Non - HV**	171.7±8.8	0.219
	HV	169.5±10.2	
Kilogram (kg)	**Non - HV**	69.4±10.9	0.213
	HV	72.6±16.5	
Body Mass Index (BMI)	**Non - HV**	23.4±2.4	<0.005
	HV	25.0±3.7	

In terms of plantar pressure changes measured by a pedobarography device, the hallux plantar pressure was 33.1±37.3 kPa in feet with HV and 89.7±57.1 kPa in feet without HV, indicating a significant decrease in plantar pressure in feet with HV (p<0.001). The plantar pressure of the second and third toes was 60.0±36.0 kPa in feet with HV and 29.3±27.7 kPa in feet without HV, demonstrating a significant increase in plantar pressure in feet with HV (p<0.001). Similarly, the plantar pressure of the fourth and fifth toes was 25.3±20.3 kPa in feet with HV and 9.3±10.3 kPa in feet without HV, showing a significant increase in plantar pressure in feet with HV (p<0.001). The plantar pressure of the first metatarsal head was 27.1±27.2 kPa in feet with HV and 65.4±39.3 kPa in feet without HV, indicating a significant increase in plantar pressure in feet without HV (p<0.001). Moreover, the plantar pressure of the second and third metatarsal heads was 67.5±31.4 kPa in feet with HV and 26.1±27.4 kPa in feet without HV, revealing a significant increase in plantar pressure in feet with HV (p<0.001). However, the plantar pressure of the fourth and fifth metatarsal heads showed no significant difference between feet with HV and those without HV (19.3±17.1 kPa vs. 14.3±18.2 kPa, p=0.124). Furthermore, in the plantar pressure measurements of the midfoot region, there was no significant difference between feet with HV and those without HV (13.8±7.1 kPa vs. 14.2±7.7 kPa, p=0.753). Similarly, in the plantar pressure measurement of the rearfoot region, there was no significant difference between feet with HV and those without HV (19.2±9.3 kPa vs. 21.4±8.7 kPa, p=0.191). The results of plantar pressure are provided in Table 2.

Table 2. The results of plantar pressure

Foot Region	Groups	Mean ± SD	p
Hallux	**Non - HV**	89.7±57.1	<0.005
	HV	33.1±37.3	
Digit 2-3	**Non - HV**	29.3±27.2	<0.005
	HV	60.0±36.0	
Digit 4-5	**Non - HV**	9.3±10.3	<0.005
	HV	25.3±20.3	
MT 1	**Non - HV**	65.4±39.3	<0.005
	HV	27.1±27.2	

MT 2-3	**Non - HV**	26.1±27.4	<0.005
	HV	67.5±31.4	
MT 4-5	**Non - HV**	14.3±18.2	0.124
	HV	19.3±17.1	
Midfoot	**Non - HV**	14.2±7.7	0.753
	HV	13.8±7.1	
Rearfoot	**Non - HV**	21.4±8.7	0.191
	HV	19.2±9.3	

Digits 2/3: Second and third toes; Digits 4/5: Fourth and fifth toes; MT 1: Metatarsal 1; MT 2/3: Metatarsal 2/3; MT 4/5: Metatarsal 4/5; SD: Standard Deviation

In the subparameters of the SF-36 Turkish version, the physical function parameter was 81.5±21.7 in individuals with HV and 97.5±7.2 in those without HV, revealing a significant difference between the two groups (p<0.001). Similarly, the physical role limitation parameter was 70.4±31.7 in individuals with HV and 87.5±23.2 in those without HV, indicating a significant difference (p<0.001). Likewise, the emotional role limitation parameter was 75.0±31.8 in individuals with HV and 81.1±29.7 in those without HV, showing a significant difference (p<0.001). Furthermore, the energy/vitality parameter was 65.8±13.1 in individuals with HV and 74.6±19.3 in those without HV, indicating a significant difference (p=0.004). Additionally, the mental health parameter was 65.4±21.2 in individuals with HV and 72.7±15.2 in those without HV, showing a significant difference (p=0.005).

Table 3. SF-36 short form health-related quality of life and its subparameters

Variables	Sub-Dimensions	Groups	Mean ± SD	p
SF-36	**Physical Function**	**Non - HV**	97,5±7,2	<0.005
		HV	81,5±21,7	
	Physical Role Difficulty	**Non - HV**	87,5±23,2	<0.005
		HV	70,4±31,7	
	Emotional Role Difficulty	**Non - HV**	81,1±29,7	<0.005
		HV	75,0±31,08	
	Energy/Vivacity	**Non - HV**	74,6±19,3	<0.005
		HV	65,8±13,1	
	Mental Health	**Non - HV**	72,7±15,2	<0.005
		HV	65,4±12,2	
	Social Functioning	**Non - HV**	87,5±20,8	<0.005
		HV	75,6±18,0	
	Pain	**Non - HV**	86,9±12,3	<0.005
		HV	76,3±16,6	
	General Health Perception	**Non - HV**	83,3±11,7	<0.005
		HV	71,2±15,4	

The social functioning parameter was 75.6±18.0 in individuals with HV and 87.5±20.8 in those without HV, indicating a significant difference ($p<0.001$). Moreover, the pain parameter was 76.3±16.6 in individuals with HV and 86.9±12.3 in those without HV, showing a significant difference ($p<0.001$). Similarly, the general health perception parameter was 71.2±15.4 in individuals with HV and 83.3±11.7 in those without HV, indicating a significant difference ($p<0.001$). The results of all subparameters of the SF-36 Turkish version are presented in Table 3. The Numeric Pain Rating Scale (NPRS) yielded a score of 3.3±2.9 for feet with hallux valgus.

Discussion

The main hypothesis of this study posits that individuals with hallux valgus (HV) demonstrate differences in plantar pressure distribution and quality of life compared to those without HV. Our findings support this hypothesis, revealing that feet affected by HV showed a decrease in plantar pressure in the hallux and first metatarsal head, coupled with an increase in plantar pressure in the second and third toes, as well as the second and third metatarsal heads, in comparison to feet without HV. Furthermore, individuals with HV experienced a significant decline in their overall quality of life compared to those unaffected by the condition.

HV is more commonly observed in females than males, and its prevalence increases with age[16]. In our study, the proportion of females with HV feet was higher than males. There was a significant association between gender and the groups. Furthermore, individuals with HV were significantly older than those without the condition. HV deformity is more frequently observed in females than males, with some studies reporting ratios of 2:1 and even 15:1[16,17]. The prevalence of HV deformity generally increases in the 3rd and 5th decades of life[18].

HV deformity is linked to alterations in plantar pressure. In our study, feet affected by HV exhibited a reduction in plantar pressure in the hallux and first metatarsal head, alongside an elevation in plantar pressure in the second and third metatarsal heads, second and third toes, and fourth and fifth toes, compared to feet without HV.

In one study, researchers compared the plantar pressures of 36 individuals with HV to 30 healthy feet. The findings revealed a significant increase in plantar pressure at the second and third metatarsal heads and fourth and fifth toes, alongside a significant decrease in plantar pressure at the hallux compared to healthy feet[19]. In another study conducted by Ulrich Koller et al., 61 feet with HV were examined. The results indicated a negative correlation between HVA and plantar pressures of the toes, maximum force of the hallux, and contact time of the toes. Conversely, a positive correlation was observed between contact area, maximum force, and plantar pressure[20].

Another study examined the plantar pressures of 39 females with HV and 55 women without HV. They found a relationship between toe flexor strength and HVA. During walking, a significant decrease in plantar pressures was found in the 2nd-5th toes and 2nd-4th metatarsal heads, with an increase in plantar pressure on the lateral side of the foot[21]. In a study by Galica et al., biomechanical data from a total of 3205 individuals and 6393 feet were examined. HV feet showed a decrease in plantar pressure at the hallux and an increase in plantar pressure at the other toes[22].

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Iliou et al. discovered a notable rise in plantar pressure at the second metatarsal among individuals with hallux valgus[23]. In another study involving 73 individuals with HV and 81 individuals without HV, it was identified that there was a significant reduction in plantar pressure at the hallux in feet afflicted by hallux valgus[24]. In a study involving 66 feet with HV and 60 feet without HV, plantar pressure was assessed both dynamically and statically. However, no significant differences in plantar pressure were observed between feet with HV and healthy feet[25]. In research by Hida et al., comprising 25 females with HV and 13 females without HV, no significant disparity was found in plantar pressure of the hallux between individuals with and without HV. Nevertheless, a notable increase in plantar pressure at the 2nd-3rd metatarsal heads was noted in individuals with HV[26]. However, in another investigation involving 79 females with moderate HV and 98 females with healthy feet, both groups exhibited a significant rise in plantar pressure at the 2nd metatarsal head. Additionally, females with HV significantly increased plantar pressure at the hallux. Moreover, HV-affected feet reported higher pain levels at the 1st metatarsal heads than those without HV. In a study by Bryant et al., which included 44 feet with HV and 36 feet without HV, an elevation in plantar pressure at the hallux in feet with HV was observed[27,28]. Lastly, another study encompassing 36 feet with HV and 18 healthy feet found no increase in pressure under the 2nd and 3rd metatarsal heads in individuals with HV during the evaluation of plantar pressure[29].

Based on the literature review of studies measuring plantar pressure, it is generally concluded that there is a decrease in plantar pressure at the hallux in individuals with hallux valgus (HV). Additionally, a significant increase in plantar pressure at the 2nd and 3rd metatarsal heads and the 4th and 5th toes has been observed compared to healthy feet. However, it is important to note that there is no definitive consensus in the literature regarding the effects of HV on plantar pressure.

In this study, individuals with hallux valgus (HV) exhibited a decrease in plantar pressure in the hallux and first metatarsal (MT 1), accompanied by an increase in plantar pressure in MT 2-3, digits 2-3, and digits 4-5. This increase in plantar pressure can be attributed to the lateral shift and pronation of the first metatarsophalangeal (MTF) joint. Consequently, the displacement of the joint leads to reduced plantar pressure on the hallux and a redistribution of the foot's weight-bearing center towards other regions. Additionally, the pain experienced in the hallux of individuals with HV significantly contributes to decreased plantar pressure on the hallux. This pain may also influence the increase in plantar pressure observed in the MT 2-3 regions. Furthermore, the transfer of load from the sesamoid bones located in the deviated hallux towards MT 2-3 is believed to increase plantar pressure compared to feet without HV. The increase in plantar pressure in the digit 2-3 and digit 4-5 areas, due to the decrease in the lever arm of the rocker bar of the hallux during the push-off phase in the gait cycle and its redirection towards digit 2-3 and digit 4-5, is also thought to increase plantar pressure during the static stance phase.

Individuals with HV may experience a negative impact on their quality of life[30]. This can be attributed to pain and inflammation associated with the HV deformity. In our research, feet with HV were found to have significantly lower scores in all subscales of the SF-36 Turkish version compared to feet without HV.

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In a study by Palomo-Lopez et al., it was revealed that individuals with hallux valgus (HV) experienced a negative impact on their daily life activities. Moreover, as the severity of the deformity increased, the impairment of daily life activities also escalated[31]. Another study conducted in Japan, which involved individuals with a hallux valgus angle (HVA) greater than 20°, found that all subdomains and summary scores of the SF-36 questionnaire were significantly lower compared to healthy feet[32]. Similarly, an additional study reported that eight subdomains of the SF-36 were significantly affected in individuals with HV compared to those without the condition[33]. In Spain, a study utilizing the SF-36 questionnaire revealed a decrease in quality of life, an increase in foot pain, and limitations in functionality among individuals with HV[34]. Finally, a study conducted in the United Kingdom in 2021 concluded that the quality of life of individuals with HV was significantly reduced compared to the general population[35].

The decrease in quality of life is believed to be due to the presence of foot pain in individuals with HV, which significantly affects the subdomain of physical functioning in the SF-36. Additionally, it was observed that individuals with HV were affected by the appearance of their feet, resulting in a decrease in the subdomain of general health perception. Furthermore, our study's almost equal distribution of the female and male population ensured a balanced outcome.

Conclusion

Feet with HV exhibited a decrease in plantar pressure in the hallux and first metatarsal head compared to feet without HV. Additionally, plantar pressure was increased in the second and third toes, fourth and fifth toes, and second and third metatarsal heads compared to feet without HV. According to the SF-36, individuals with hallux valgus demonstrated a decrease in all subparameters. However, no significant differences between emotional role functioning and pain groups were found.

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