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Correlation between the foot pressure index and the prevalence of plantar hyperkeratosis

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ABSTRACT

Background: Plantar hyperkeratosis (HK) is a very prevalent foot lesion formed due to an alteration in the keratinisation process, thereby increasing keratynocites and accumulating multiple layers of the stratum corneum that leads to plantar pain. As foot shape and plantar pressures is related with their appearance, the aim of this study is to examine how foot posture and plantar pressure influence the appearance of this keratopathy.
Material and methods: On a sample of 400 subjects (201 men and 199 women), the plantar pressures were evaluated by the Footscan® platform in 10 zones. The clinical exploration consisted in the valuation of the Foot Posture Index (FPI), and the assessment of the appeerance (and location) or not of plantar calluses or hyperkeratosis.
Results: 6.3% of the feet presented a highly supinated FPI, 15.5% were supinated, 57.3% corresponded to neutral, 17.3% were pronated and 3.8% were highly pronated. The participants with HK on the hallux, on the 1st, 2nd, 3rd or 5th MTH or on the lateral heel had a significantly higher pressure index ($p < 0.001$), ranging from 24.3 to 44% higher than those with no such alteration. Of the highly pronated feet, 66.7% presented HK in the hallux, while 32.3% of the supinated feet and 60% of the highly supinated feet presented it beneath the first MTH.
Conclusion: Foot posture influences the appearance of HK, though its association with plantar pressures. The participants with HK presented a mean foot pressure that was 32.3% higher than in those with no such condition. These values can be considered predictive for the appearance of HK and should be indicative of the need for preventive treatment.

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Ethical responsibilities

The studies involving human participants were previously reviewed and approved by the Research Ethics Committee of the University of Extremadura (ID: 05/2011). All participants gave prior written informed consent to take part in this study.

1. Introduction

Plantar hyperkeratosis (HK), one of the most prevalent foot lesions [1], affects 30–65% of people aged over 65 years, especially those with systemic pathologies such as rheumatoid arthritis [2] or diabetes [3]. It is produced by an alteration in the keratinisation process [4–7] which increases the thickness of the stratum corneum, in response to excessive pressure or friction on the skin. In most cases, this effect arises from the use of inappropriate footwear [3] or is caused by a biomechanical alteration [4–9], but it can also be triggered by sports activities [4,5]. Other risk factors include subtalar protonation [9] associated with the presence of hallux abductus valgus [1,2,10], flat feet [3] and minor deformities of the second, third and fourth toes [1]. In addition, some

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studies refer to problems such as inadequate hygiene [5], the loss of elasticity or of plantar pad [5,11], the impact of friction from seamed hosiery [12], prolonged standing [8,11,13], excess weight [5,11] or aging.

HK is most frequently located in the first radius, in the medial zone of the first metatarsophalangeal joint and/or the medial zone of the hallux [1,13]. This condition can make walking difficult and heighten the risk of falls, especially in the elderly [14,15], thus decreasing their quality of life [16,17]. Moreover, it has been associated with elevated plantar pressure, but to date the only studies conducted in this regard have focused on data for elderly or diabetic patients [10,18,19]. Although excessive pressure may play an important role in the development of HK among persons who are otherwise healthy, the pathological plantar pressure threshold at which this skin lesion may appear and the type of stride making a person more vulnerable to the condition have yet to be established. In view of these considerations, the aim of this study is to examine how foot posture and plantar pressure influence the appearance of this keratopathy.

2. Material and methods

2.1. Participants

This study was carried out at a podiatric clinic of the Universidad de Extremadura in the city of Plasencia (Spain). Participants were selected by non-random sampling, in accordance with standard recommendations for the communication of observational studies, known as Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [20]. A total sample size of 400 subjects was considered, and statistical significance was assumed at $p < 0.05$. The following inclusion criteria were applied: the patient should be aged 18–65 years, with asymptomatic, symmetric feet (similar foot posture, footprint, shape and morphology) and no joint deformities. The exclusion criteria were: (a) degenerative bone or joint disease; (b) lower limb surgery; (c) prior serious foot injury provoking morphological alterations; (d) obvious leg length discrepancy; (e) loss of balance; (f) painful cutaneous condition such as helomata or plantar warts; (g) inability to step correctly and in good coordination on the pressure platform during measurement. The study was approved by the university's Human Research Committee (ID: 05/2011), and informed written consent was obtained from all participants.

2.2. Procedure

A clinician with more than eight years' experience in the treatment of foot pathologies recorded the anthropometric variables (age, sex and body mass index), screened for the inclusion and exclusion criteria and obtained the necessary study data as follows:

A. Location of HK: With the subject lying on an examination table, the foot was inspected and the presence or absence of HK in the following areas was noted on a data collection sheet: hallux, other toes, 1st to 5th metatarsal heads (MTHs), midfoot, medial heel and lateral heel.

B. FPI measurement: Foot pressure was measured with the subject standing in a relaxed position on both feet, with their arms relaxed at their side, looking straight ahead, holding this position for about 2 min. Because the FPI has good intra-observer reliability but only moderate inter-observer reliability [21,22], all measurements were taken by the same examiner. The FPI criteria evaluated were talar head palpation, supra and infra-malleolar curvature, calcaneal frontal plane position, prominence in the region of the talonavicular joint, congruence of the medial longitudinal arch, and abduction/adduction of the forefoot on the rearfoot. Each criterion was scored on a scale of −2, −1, 0, +1 or +2. The FPI cutoff points to define the type of foot were; a) Highly supinated −12 to −5, b) Supinated - 4 to −1, c) Neutral 0 to 5, d) Pronated 6 to 9 and e) Highly pronated 10 to 12.

C. Plantar pressure measurement: In this study, the measuring system used was the FootScan® platform, with dimensions 40 × 50 × 2 cm, with 4096 sensors (4 sensors per cm^2) and operating at 150 Hz. This instrument is known to be reliable, with high intra-class correlation coefficients, and has been validated for the assessment of plantar pressure distribution [23]. The platform was recalibrated prior to each data collection. In use, the platform was placed at the centre of a carpet about 8 m in length and the same thickness as the platform. The data corresponding to the second step were taken for analysis, since this protocol has been shown to be the most reliable and repeatable. The subjects were instructed to stand at 1.5 m from the carpet, and then to take their first step on the carpet and the second on the platform, and to walk about 4 m. The capture of the step data was repeated as many times as necessary to obtain five valid measurements. The platform's software automatically divides the foot into ten masked zones – medial and lateral heel, midfoot, first to fifth MTHs, hallux and lesser toes. The maximum pressures were normalised (obtaining so the pressure index) to the subject's weight using the following: maximum pressure under each zone/weight × 100. This formula obtained a value that can be defined as the relative load of each zone with respect to the total pressure, and is expressed as a percentage. In order to maintain the independence of the data for the statistical analyses, the data considered were those only of the left foot, using the mean values of the five measurements. This method produced representative and reliable data.

2.3. Statistical methods

Descriptive analyses (mean range) and the Mann-Whitney Wilcoxon *U* test for independent samples were performed to analyse the differences in the pressure index between areas with and without HK. The prevalence of HK, according to the type of foot, in men and women separately, was determined by means of contingency tables and the chi-square (χ^2) test. All statistical tests were conducted assuming a level of significance of 0.05, and the data were analysed using IBM SPSS 19 software.

3. Results

The sample consisted of 400 participants (201 men and 199 women) with non-pathological feet. The mean age of the sample was 29 ± 10.7 years (range 18–65 years), mean height 169.3 ± 9.2 cm (range 149–196 cm), mean weight 68.3 ± 14 kg (range 43–130 kg) and mean BMI 23.7 ± 3.5 kg/m^2 (range17.1–37 kg/m^2). The anthropometric data, by sex, are listed in Table 1.

Of the 400 feet analysed, 25 presented a highly supinated FPI (6.3%), 62 were supinated (15.5%), 229 corresponded to a neutral FPI (57.3%), 69 were pronated (17.3%) and 15 were highly pronated (3.8%). The Chi-Square test showed no significant differences between the distribution of foot types by sex (Table 2, $p = 0.143$). The participants with HK on the hallux, on the 1st, 2nd, 3rd or 5th MTH or on the lateral heel had a significantly higher pressure index (Table 3). Specifically, the feet with HK in these areas presented an average pressure index range 24.3–44% higher than those with no such alteration. The mean difference was

Table 1
Anthropometric data.

Variable	Total (n = 400)	Men (n = 201)	Women (n = 199)
	Mean ± SE Range	Mean ± SE Range	Mean ± SE Range
Age (years)	29 ± 10.7 (18–65)	32.10 ± 11.3 (18–65)	25.9 ± 9.1 (18–57)
Height (cm)	169.3 ± 9.2 (149–196)	175.1 ± 7.9 (149–196)	163.4 ± 6.2 (149–186)
Weight (Kg)	68.3 ± 14 (43–130)	76.7 ± 13 (50–130)	59.9 ± 9.1 (43–100)
BMI (Kg/m^2)	23.7 ± 3.5 (17.1–37)	24.9 ± 3.3 (17.1–37)	22.3 ± 3.3 (17.1–35.8)

Table 2
Distribution among FPI groups by gender.

Group	Men (n = 201)	Women (n = 199)	*p*
↑Supinated	18 (9%)	7 (3.5%)	0.143
Supinated	34 (16.9%)	28 (14.1%)	
Neutral	111 (55.2%)	118 (59.3%)	
Pronated	30 (14.9%)	39 (19.6%)	
↑ Pronated	8 (4%)	7 (3.5%)	

Table 3
Foot pressure index (PI) in participants with and without hyperkeratosis.

	No HK	With HK	*p*	Percentage increase of PI
	Pressure Index Mean range			
Hallux	187.2	232.7	**<0.001**	**24.3%**
1st MTH	187.8	236.10	**<0.001**	**25.7%**
2nd MTH	180.1	246.4	**<0.001**	**36.8%**
3rd MTH	189.2	250.3	**<0.001**	**32.2%**
5th MTH	176.7	254.6	**<0.001**	**44%**
Lateral heel	193.9	253.2	**0.001**	**30.5%**

HK, Hyperkeratosis; PI, Pressure index; MTH, Metatarsal head.
Mann-Whitney Wilcoxon *U* test.

32.3% (Table 3).

Of the highly pronated feet, 66.7% presented HK in the hallux, while 32.3% of the supinated feet and 60% of the highly supinated feet presented it beneath the first MTH. Both groups of supinated feet also presented a higher prevalence of HK in the third and fifth MTHs and in the lateral heel (p = 0.039, 0.010 and 0.017 respectively, Table 4). The images at the top of Table 4 summarizes the pattern of the HK location in each type of foot based on the FPI.

The female participants presented more HK than the men in the second, third, fourth and fifth MTHs and in the medial and lateral heel (Table 5). In the second and third MTHs, 43.7% and 27.6% of the women presented HK, compared to 17.9% and 9.5% of the men, respectively (p < 0.001 in both cases).

4. Discussion

The development of HK is a response by the skin to external pressure or friction, which generally coincides with the location of a bony prominence. Our study results show that supinated and highly supinated feet are most subject to HK in general, but especially in the first and/or fifth MTH. Highly pronated feet are only associated with the appearance of HK in the hallux (Table 4).

Table 4
Presence of hyperkeratosis (%) by foot group.

Type of foot	Localitation of hyperkeratosis				
					
↑Supinated **n = 25**	28.0%	**60.0%**	22.0%	36.0%	16.0%
Supinated **n = 62**	33.9%	**32.3%**	29.0%	**46.8%**	22.6%
Neutral **n = 229**	26.2%	24.5%	19.2%	**29.7%**	9.2%
Pronated **n = 69**	**27.5%**	15.9%	13.0%	18.8%	5.8%
↑Pronated **n = 15**	**66.7%**	20.0%	0.0%	20.0%	6.7%
p value	**0.018**	**<0.001**	**0.039**	**0.010**	**0.017**

↑, Highly; HK, Hyperkeratosis; MTH, Metatarsal head.
Chi-square test (χ^2).

Table 5
Prevalence of hyperkeratosis, by sex.

Location		Men	Women	*p*
HK Hallux	YES	29.9%	28.6%	0.791
	NO	70.1%	71.4%	
HK Lesser toes	YES	1.5%	4.0%	0.122
	NO	98.5%	96.0%	
HK 1st MTH	YES	25.4%	27.1%	0.689
	NO	74.6%	72.9%	
HK 2nd MTH	YES	17.9%	**43.7%**	**<0.001**
	NO	82.1%	56.3%	
HK 3rd MTH	YES	9.5%	**27.6%**	**<0.001**
	NO	90.5%	72.4%	
HK 4th MTH	YES	9.0%	**18.1%**	**0.008**
	NO	91.0%	81.9%	
HK 5th MTH	YES	23.4%	**37.7%**	**0.002**
	NO	76.6%	62.3%	
HK Midfoot	YES	0.0%	0.5%	0.498
	NO	100.0%	99.5%	
HK Medial heel	YES	4.0%	**13.1%**	**0.001**
	NO	96.0%	86.9%	
HK Lateral heel	YES	7.5%	**14.6%**	**0.023**
	NO	92.5%	85.4%	

HK, Hyperkeratosis; MTH, Metatarsal head.
Chi-square test (χ^2).

Some evidence of characteristic plantar pressure patterns has been identified with specific foot postures. Thus, persons with pes planus (flat feet) usually present higher values for pressure, force and contact area in the medial arch, the central forefoot and the hallux, while those with pes cavus receive greater pressure on the heel and lateral forefoot, and less pressure, force and contact area on the midfoot and hallux [24,25]. However, studies in this regard do not always use the same technique to measure foot posture, or standardised protocols for the analysis of plantar pressure [24,25].

Our data for the distribution of hyperkeratoses according to foot type and the relationship between HK and plantar pressure strengthen the theory that elevated plantar pressures are an important risk factor for the appearance of keratopathies in the foot. Nevertheless, other factors may also be involved. For example, the differences found regarding plantar pressure in supinated feet suggest that HK may be related to factors such as footwear or sports activities [26].

In supinated and highly supinated feet, the centre of pressure is displaced laterally, causing loads to shift towards the outer edge of the foot and consequently increasing pressure beneath the fifth MTH [27]. This delays the support of the medial area of the forefoot during the propulsive period, abruptly transferring the load towards the first MTH, possibly causing microtrauma and accelerating the process of keratinisation. Other morphological factors associated with supinated feet, such as plantarflexion of the first metatarsal [28], may also influence the formation of HK.

Pooter et al. [29] reported that foot pressure in persons with HK was up to 25% higher than in a control group. Similarly, Menz et al. [10] found that persons with HK on the hallux had a pressure index 12.3% greater than those in a control group. In our study, pressure index in participants with HK was 22.4–44% higher than in the control group.

Despite the widespread belief that the removal of HK reduces underlying plantar pressure, neither Pitei et al. [30], Pooter and Pooter [29] nor Menz et al. [10] observed any differences in plantar pressure peaks after removing HK, althoug these studies don't looked at the foot position. This suggests that there exists a positive feedback between hyperpressure and the appearance of HK, since it appears in areas of high pressure, but once formed can act as a foreign body and contribute to increasing the plantar pressure peak. At present, however, the threshold values that separate pathological pressure from normal levels and that could lead to the appearance of HK remain unknown. In our

study, the participants with keratopathies presented a pressure index value that was 32.3% higher than in those with no HK. Thus, in podiatry visits or screenings, the finding of increased pressure values could indicate the need for treatment to prevent the appearance of associated skin lesions. As HK is a precursor to a foot ulcer, where 82% of patients with diabetes are preceded by HK we have therefore a reason to start with preventative approaches [31,32].

Our study results show that women present a higher prevalence of HK than men, both in the forefoot and in the heel (Table 5). This seems not been related with differences in the frequencies of foot position, as seen in Table 3. This difference between the sexes has been noted in previous studies [6], and is an evident fact in daily clinical practice. In men, HKs are most frequently located in the medial forefoot (hallux and first MTH) and lateral forefoot (fifth MTH), while in women they are located in the central zone (second and 3rd MTHs) and under the fifth MTH. These data are similar to those reported by Pooter et al. [29], who observed a greater quantity of calluses in the first and fifth MTHs in men and in the second MTH in women. In our study, the fourth MTH presented the lowest prevalence of HK, which is consistent with other studies in this regard. Due to its anatomical structure, the central zone of the forefoot supports the highest pressure of all the foot groups [33]. This fact, together with the greater foot pressure experienced by women in general [34], and the use of less physiological footwear, may explain the greater presence of HK among females [35].

The present study is subject to certain limitations, and the results we present should be considered with caution. Although the study sample was large, it contained a high proportion of participants with neutral feet. In subsequent work in this area, it would be useful to analyse a balanced sample of all foot types in order to obtain reliable, representative values in terms of plantar pressure. Also, other factors as footwear and sports activities that could be important alternative causes of HK was not controlled in this study. Another question is the cross-sectional nature of our study design. This enabled us to determine the situation at a given time. However, long-term follow-up would reveal the evolution of the participants' HK status, pressure patterns and any future symptoms.

5. Conclusions

Foot posture directly influences the appearance of HK, through its association with plantar pressures. In our study, the participants with HK presented a mean foot pressure that was 32.3% higher than in those with no such condition. Therefore, the values obtained in our study can be considered predictive for the appearance of HK. From this we conclude that exploratory baropodometric analyses revealing plantar pressure values exceeding 32.3% should be indicative of the need for preventive treatment in order to avoid potential subsequent wounds.

Declaration of competing interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We further confirm that any aspect of the work covered in this manuscript that has involved either experimental animals or human patients has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). He is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by the Corresponding Author and which has been configured to accept email from.

References

[1] Caleb Araguas García C, Corbi Soler F. Plantar hyperkeratotic patterns in older patients 2017;11(4):239–43.

[2] Mochizuki T, Yano K, Ikari K, Hiroshima R1, Ishibashi M, Okazaki K. Relationship of callosities of the forefoot with foot deformity, Health Assessment Questionnaire Disability Index, and joint damage score in patients with rheumatoid arthritis. Mod Rheumatol 2020;30(2):287–92. https://doi.org/10.1080/14397595.2019.1589921.

[3] Kase R, Amemiya A, Okonogi R, Yamakawa H, Sugawara H, Tanaka YL, Komiyama M, Mori T. Examination of the effect of suitable size of shoes under the second metatarsal head and width of shoes under the fifth metatarsal head for the prevention of callus formation in healthy young women. Sensors 2018;18(10):3269. https://doi.org/10.3390/s18103269.

[4] Dense B. Freeman. Corns and calluses resulting from mechanical hyperkeratosis. Am Fam Physician 2002;65(11):2277–80.

[5] Grouios G. Corns and calluses in athletes' feet. A cause for concern. Foot 2004;14:175–84.

[6] Springett KP, Whiting MF, Marriott C. Epidemiology of plantar forefoot corns and callus, and the influence of dominant side. Foot 2003;13:5–7.

[7] Kim SH, Choi HI, Choi YJ, Lee YS, Sohn KC, Kim CD. Callus formation is associated with hyperproliferation and incomplete differentiation of keratinocytes, and increased expression of adhesion molecules. Br J Dermatol 2010;163:495–501.

[8] Singh D, Bentley G, Trevino SG. Fortnigthtly review: callosities, corns, and calluses. Br Med J 1996;312:1403–6.

[9] Bevans JS, Bowker P. Foot structure and function; aetiological risk factors for callus formation in diabetic and non-diabetic subjets. Foot 1999;9:120–7.

[10] Menz HB, Zammit GV, Munteanu SE. Plantar pressures are higher under callused regions of the foot in older people. Clin Exp Dermatol 2007;32(4):375–80.

[11] McCanick AM. A study examining the occurrence of corns and calluses in males and females. Saint Martin's University Biology Journal 2006;1:265–72.

[12] Mann RA, Duvries HL. Intractable plantar keratosis. Orthop Clin N Am 1973;4:67–73.

[13] Spink MJ, Menz HB, Lord SR. Distribution and correlates of plantar hyperkeratotic lesions in older people. J Foot Ankle Res 2009;2:8.

[14] Niu J, Zheng Y, Liu H, Chen X, Ran L. Stumbling prediction based on plantar pressure distribution. Work 2019;64(4):705–12. https://doi.org/10.3233/WOR-193032.

[15] Song Z, Ou J, Shu L, Hu G, Wu S, Xu X, Chen Z. Fall risk assessment for the elderly based on weak foot features of wearable plantar pressure. IEEE Trans Neural Syst Rehabil Eng 2022;30:1060–70. https://doi.org/10.1109/TNSRE.2022.3167473.

[16] Jalali M, Mojgani P, Saeedi H, Azadinia F, Niksolat M, Ghorbani F. The relationship between common foot problems with falls and quality of life in older people. Int J Older People Nurs 2021;16(6):e12402. https://doi.org/10.1111/opn.12402.

[17] Demir B, Erden I, Ucak H, Demir S, Cicek D, Ozturk S. Quality of life in patients with calluses. Int J Dermatol 2016;55(1):e47–9. https://doi.org/10.1111/ijd.12996.

[18] Qiu Xuan, Tian De-Hu, Han Chang-Ling, Chen Wei, Wang Zhan-Jian, Mu Zhen-Yun, Liu Kuan-Zhi. Plantar pressure changes and correlating risk factors in Chinese patients with Type 2 Diabetes: preliminary 2-year results of a prospective study. Chinese Med J 2015;128(24):3283–91. https://doi.org/10.4103/0366-6999.171394.

[19] Murray HJ, Young MJ, Hollis S, Boulton AJ. The association between callus formation, high pressures and neuropathy in diabetic foot ulceration. Diabet Med 1996;13(11):979–82. https://doi.org/10.1002/(SICI)1096-9136(199611)13:11<979:AID.DIA267>3.0.CO;2-A.

[20] Vandenbroucke JP, von Elm E, Altman DG, et al. Strengthening the reporting of observational studies in Epidemiology (STROBE): explanation and elaboration. Int J Surg 2014;12(12):1500–24. https://doi.org/10.1016/j.ijsu.2014.07.014.

[21] Redmond AC, Crane YZ, Menz HB. Normative values for the foot posture index. J Foot Ankle Res 2008;1(1):6.

[22] Redmond AC, Crosbie J, Ouvrier RA. Development and validation of a novel rating system for scoring standing foot posture: the Foot Posture Index. Clin Biomech 2006 Jan;21(1):89–98. https://doi.org/10.1016/j.clinbiomech.2005.08.002.

[23] Xu C, Wen XX, Huang LY, Shang L, Cheng XX, Yan YB, Lei W. Normal foot loading parameters and repeatability of the Footscan® platform system. J Foot Ankle Res 2017 Jul 17;10:30. https://doi.org/10.1186/s13047-017-0209-2.

[24] Buldt AK, Allan JJ, Landorf KB, Menz HB. The relationship between foot posture and plantar pressure during walking in adults: a systematic review. Gait Posture 2018;62:56–67. https://doi.org/10.1016/j.gaitpost.2018.02.026.

[25] Buldt AK, Forghany S, Landorf KB, Levinger P, Murley GS, Menz HB. Foot posture is associated with plantar pressure during gait: a comparison of normal, planus and

cavus feet. Gait Posture 2018;62:235–40. https://doi.org/10.1016/j.gaitpost.2018.03.005.
[26] [Risk factors associated to musculoskeletal pathologies in athletes with cavus foot through baropodometric studies], Orozco-Villaseñor SL, Mayagoitia-Vázquez JJ, Miguel-Andrés I, De la Cruz-Alvarado KD, Villanueva-Salas R. Acta Ortop Mex 2021;35(4):317–21.
[27] Fernández-Seguín LM, Diaz Mancha JA, Sánchez Rodríguez R, Escamilla Martínez E, Gómez Martín B, Ramos Ortega J. Comparison of plantar pressures and contact area between normal and cavus foot. Gait Posture 2014;39(2):789–92. https://doi.org/10.1016/j.gaitpost.2013.10.018.
[28] Schwend RM, Drenan JC. Cavus foot deformity in children. J Am Acad Orthop Surg 2003;11:201–11.
[29] Potter J, Potter MJ. Effect of callus removal on peak plantar pressures. Foot 2000;10:23–6.
[30] Pitei DL, Foster A, Edmonds M. The effect of regular callus removal on foot pressures. J Foot Ankle Surg 1999;38(4):251–5. https://doi.org/10.1016/s1067-2516(99)80066-0. discussion 306.
[31] Sage RA. Outpatient care and morbidity reduction in diabetic foot ulcers associated with chronic pressure callus. J Am Podiatr Med Assoc 2001;91:275–9.
[32] Murray HJ. The association between callus formation, high pressures and neuropathy in diabetic foot ulceration. Diabet Med 1996;13:979–82.
[33] Sánchez-Rodríguez R, Martínez-Nova A, Escamilla-Martínez E, Pedrera-Zamorano JD. Can the Foot Posture Index or their individual criteria predict dynamic plantar pressures? Gait Posture 2012;36(3):591–5. https://doi.org/10.1016/j.gaitpost.2012.05.024.
[34] Sánchez Rodríguez R, Martínez Nova A, Escamilla Martínez E, Gómez Martín B, Martínez Quintana R, Pedrera Zamorano JD. The foot posture index: anthropometric determinants and influence of sex. J Am Podiatr Med Assoc 2013;103(5):400–4. https://doi.org/10.7547/1030400.
[35] Nyska M, McCabe C, Linge K, Klenerman L. Plantar foot pressures during treadmill walking with high-heel and low-heel shoes. Foot Ankle Int 1996 Nov;17(11):662–6. https://doi.org/10.1177/107110079601701103.