

Original Article

Plantar Hyperkeratotic Patterns in Older Patients

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SUMMARY

Background: Plantar hyperkeratotic lesions are very common among the older population. Very little has been documented on the frequency or distribution of such lesions. The aim of this study is to analyse the location of plantar hyperkeratoses in a group of the older population, defining the patterns of the most significant manifestations thereof and analysing the correlation between them and different contributing factors.

Methods: It is a descriptive correlational study conducted on 850 participants who attended the Bellvitge Podiatry Hospital in Barcelona province, Spain, in 2015. Hallux valgus, lesser toe deformities and hyperkeratoses were documented on a topographical map of the foot. The existence of plantar hyperkeratoses was correlated with different variables from the medical record of each participant.

Results: Of the 850 participants, 529 (62%) presented with hyperkeratotic lesions. In all, 87 hyperkeratotic patterns were documented, the most common of which were the medial side of the first metatarsophalangeal joint (MTPJ) (8.7%), the medial side of the first MTPJ plus the medial side of the first interphalangeal joint (IPJ) (8.5%) and the medial side of the first IPJ (7.7%). In addition, the hyperkeratoses were associated with hallux valgus ($p < 0.01$) and with lesser deformities of the second ($p < 0.04$), third ($p < 0.04$) and fourth ($p < 0.05$) toes.

Conclusions: The most common hyperkeratotic patterns were found on the first radius, corresponding to 36% of total lesions. In addition, hyperkeratotic lesions appear to be associated with the presence of hallux valgus and with lesser deformities of the second, third and fourth toes.

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1. Introduction

Hyperkeratosis is defined as a thickening of the stratum corneum of the epidermis caused by hypertrophy or hyperplasia of its cells.¹ This increase fundamentally affects the keratinocytes or corneocytes, which are the most numerous cells of the outermost layer of the epidermis.² In addition, their production may lead to the onset of various cutaneous alterations, which can have a significant impact on the patient's quality of life.³

Plantar hyperkeratotic lesions are one of the most prevalent foot problems among the older population, affecting 30–65% of people aged over 65 years.^{4,5} Incidence is greater among this group because, with age, the skin undergoes several changes that cause alterations in the functions of the integumentary system. These

changes entail a thinning of the stratum corneum, a decline in sebaceous gland secretion, a reduction in the skin's fat and water content, a loss of subcutaneous adipose tissue and of connective tissue, and a decline in the quantity of collagen,⁶ thus contributing to the formation of hyperkeratoses. In addition, dryness of the skin may contribute to the formation of fissures, which is directly related to the proliferation of fungal and bacterial infections.⁷

Various authors have conducted studies on plantar hyperkeratoses, but only five of those studies have documented the prevalence and distribution thereof^{7–11} (Table 1). Just one of those studies focused exclusively on the distribution of hyperkeratoses of the forefoot,⁸ whereas the others performed an analysis of the metatarsal heads.

Although the number of existing studies is small, knowledge of the topographical location of plantar hyperkeratoses is fundamental when it comes to creating footwear, orthotics and ergonomic supports to prevent and minimise their onset, thereby reducing the high cost of treating them on the one hand, and improving the patient's quality of life on the other.

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Table 1
Prevalence and distribution of plantar hyperkeratotic lesions. MTPJ: Metatarsophalangeal joint. IPJ: Interphalangeal joint.

	n	Characteristics	Mean age (years)	Most common lesions			Country	Year
Spink et al ⁸	181	Older people	77.2 ± 4.9	1st MTPJ (12%)	1st MTPJ + IPJ (12%)	1st MTPJ (12%)	Australia	2009
Menz et al ⁹	151	Older people	77.6 ± 6.9	1st MTPJ (53%)	2nd MTPJ (44%)	1st IPJ (43%)	Australia	2007
Springett et al ¹⁰	328	Caucasians, non-smokers	Not given	2nd MTPJ (35.9%)	1st MTPJ (26.9%)	5th MTPJ (13.4%)	UK	2003
Grouios et al ¹¹	91	Male runners	29.6	2nd MTPJ (31.9%)	1st MTPJ (23.2%)	5th MTPJ (12.6%)	Greece	2005
Merriman et al ⁷	145		Not given	2nd, 3rd, 4th MTPJ (14%)	2nd MTPJ (10%)	1st, 5th MTPJ (8%)	UK	1983

The aim of this study is, therefore, to analyse the location of plantar hyperkeratoses in a group of the older population, defining the patterns of the most significant manifestations thereof and analysing the correlation between them and different contributing factors.

2. Material and methods

Firstly, the sample size was calculated on the basis of total population aged over 65 years ($n = 53,181$ inhabitants) registered as resident in the city of Barcelona, Spain. To that end, data published by the Spanish National Statistics Institute (INI, as abbreviated in Spanish) on 31 December 2014 were taken into consideration. For a confidence interval of 95% and a confidence level of 3.5, a sample size of 773 people was obtained. A further 10% of subjects were added to this size to prevent any accidental sample losses. In total, 850 participants were ultimately analysed. All of the participants took part voluntarily in the study. The sample characteristics are shown in Table 2. All of the participants were recruited by the Chiropody Service of the University of Barcelona's Podiatry Hospital, Spain. The inclusion criteria for taking part in the study were that participants had to be older than 65 years and have attended the Hospital's Chiropody Service in 2015. Participants were excluded from the study if they had undergone any type of surgery on a lower limb in the past 18 months; were suffering from Parkinson's disease, neurological disorders or plantar verrucas; were unable to fill in questionnaires; had undergone lamination of the hyperkeratoses in the past six weeks (performed by a podiatrist or by themselves); had had any pathologies that cause hyperkeratosis (tinea pedis, eczema or psoriasis); were unable to walk without help or were amputees. None of the participants received any payment in cash or in kind for taking part in the study, and all the participants signed an informed consent form. Local Ethical Committee approval was received from University of Barcelona and written consent was obtained from all participants.

Before commencing the study and after signing an informed consent form, the participants were each given a questionnaire that they had to complete, stating their gender and age, and whether or not they suffered from diabetes mellitus type 2 and/or were smokers. The grade of hallux valgus was assessed using the Manchester scale.¹² Based on standardised photographs of the foot, this instrument defines four grades of hallux valgus: none, mild, moderate and severe. A high correlation was found between the Manchester scale and the hallux valgus angle measurement using

Table 2
Characteristics of the study sample. SD: Standard deviation. CI: Confidence interval.

n = (850)	Mean (SD)	CI 95%
Age	76.2 (6.18)	75.66–76.74
Height	1.57 (0.18)	1.42–1.72
Weight	67.7 (11.83)	66.67–68.73
Body mass index	27.36 (5.07)	26.92–27.8
Shoe size	38.86 (4.23)	38.43–39.17

conventional radiology (Spearman's $\rho = 0.73$, $P < 0.01$).¹³ Deformities of the toe and hyperkeratoses were documented on a topographical map of the foot. Lesser toe deformities were definite as alterations in normal anatomy that create an imbalance between the intrinsic and extrinsic muscles, include mallet toe, hammer toe, claw toe, curly toe, and crossover toe.¹⁴ The margin between normal skin and hyperkeratotic skin was clinically assessed on the basis of the location of the transition zone between normal pink skin and the yellowish hyperkeratotic plaque. The diameter of the lesions was measured using a ruler (millimetre precision), and the repeatability of this measurement proved to be high ($p < 0.01$).¹⁰

2.1. Statistical analysis

Creative Research Systems software (Petaluma, United States of America) was used to calculate the sample size. A descriptive analysis of the results was then performed, presenting the mean and standard deviation as centralisation and dispersion statistics, respectively. After that, associations and comparisons between the participants with and without hyperkeratotic lesions were determined using chi-square coefficients and odds ratios (for the dichotomous variables). Differences were considered statistically significant when they reached values of $p \leq 0.05$. All the data were analysed using SPSS (version 20.0).

3. Results

Of the 850 participants recruited into the study, 569 were women (67%) and 281 were men (33%). The mean age was 75.96 ± 4.8 years (mean \pm standard deviation), 286 participants presented hallux valgus (34%) and 172 had lesser toe deformities (20%). Eighty-seven participants stated that they suffered from diabetes mellitus type 2 (10%), 53 were smokers (6%) and 135 presented with obesity (BMI > 30) (16%). In addition, 529 participants (62%) suffered from at least one hyperkeratotic lesion. All of the participants completed the study (Table 3).

3.1. Hyperkeratotic patterns

Of the 1700 feet analysed, 985 (58%) presented with hyperkeratotic lesions. In all, 87 different hyperkeratotic patterns were recorded, of which 10 of the most common patterns (representing 49% of total lesions) were selected for this study (Fig. 1).

3.2. Diameter

Regarding the diameter of the hyperkeratoses, 43.4% were between 0.1 and 1 cm, 31.8% between 1.1 and 2 cm, 20% between 2.1 and 3 cm and 4.8% between 2.1 and 3 cm.

3.3. Correlations of the hyperkeratoses

From the different variables analysed, hallux valgus was associated with the presence of plantar hyperkeratoses ($X^2 = 27.13$,

Table 3
 Characteristics of the participants with and without hyperkeratosis. SD: Standard deviation. HV: Hallux valgus. LTD: Lesser toe deformities.

N (850)	Without hyperkeratosis (n = 321)	With hyperkeratosis (n = 529)	Total
Age (SD)	75.9 (4.2)	76.81 (4.7)	75.96 (4.8)
Men (%)	142 (64)	139 (26)	281 (33)
Women (%)	179 (36)	390 (74)	569 (66)
BMI > 30 (%)	45 (14)	90 (17)	135 (16)
Diabetes type 2 (%)	29 (9)	58 (11)	87 (10)
Smoker (%)	22 (7)	31 (6)	53 (6)
Hallux valgus (%)	48 (15)	238 (45)	286 (34)
Moderate/Severe HV Right foot	25 (8)	132 (25)	157 (18)
Moderate/Severe HV Left foot	22 (7)	106 (26)	128 (15)
Lesser toe deformities (%)	45 (14)	127 (24)	172 (20)
LTD Right foot	25 (8)	69 (13)	94 (11)
LTD Left foot	27 (8)	74 (14)	101 (12)

$p < 0.01$, OR = 4.48), and moderate and severe hallux valgus was associated with lesions on the medial side of the first MTPJ (HK pattern A) ($X^2 = 26.62$, $p < 0.02$, OR = 5.73) and with lesions on the medial side of the first IPJ (HK pattern C) ($X^2 = 24.29$, $p < 0.04$, OR = 5.223). Regarding lesser toe deformities, an association was found between hyperkeratoses under the MTPJ and lesser deformities of the second toe ($X^2 = 5.02$, $p < 0.04$, OR = 3.51), of the third toe ($X^2 = 4.91$, $p < 0.04$, OR = 3.16) and of the fourth toe ($X^2 = 4.71$, $p < 0.05$, OR = 2.87).

In contrast, no significant correlations were found between the presence of plantar hyperkeratoses and the presence of diabetes ($p = 0.53$), BMI > 30 ($p = 0.42$), smoking ($p = 0.71$) and gender ($p = 0.57$). Women were the most affected, with 74% of total lesions.

4. Discussion

The aim of this study was to assess the prevalence and distribution of plantar hyperkeratoses of the forefoot in subjects older than 65 years. In our study, 62% of the subjects presented with at least one hyperkeratotic lesion. This percentage is high in comparison to those reported in other studies conducted on younger people, in which prevalence rates of 30%⁸ and 29%¹⁰ were found, and it is consistent with those reported in various studies conducted on older people, in which prevalence rates of 52%¹³ and 57%¹⁵ were found. These differences may be due in part to differences in age between the study samples analysed, as the mean age of the participants in our study was higher. Another contributing factor might be, that in this study, the enrolled participant were those attending in the Chiropody Service, which could create a selection bias. Several studies have found that, as people age, there is a considerable loss of thickness and flexibility of the fat pad due to a reduction in collagen and the disappearance of elastin.¹⁶ In addition, there is gradual aplasia of the sweat glands accompanied by certain clinical manifestations such as dryness, an increase in roughness of the skin, a reduction in the thickness of adipose tissue, and a loss and hypertrophy of the melanocytes, which will lead to an alteration of the blood vessels.¹⁷ Such cutaneous ageing will

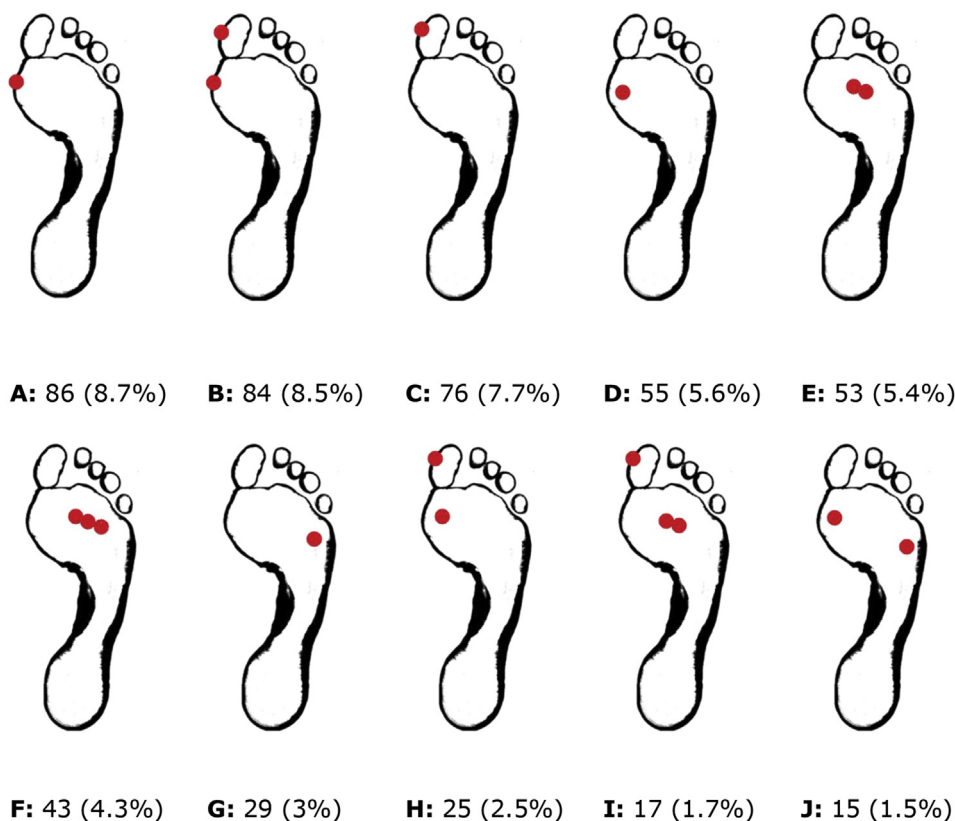


Fig. 1. Different hyperkeratotic lesion patterns: n = number of participants, (%) = total percentage. A: Medial side of the first metatarsophalangeal joint (MTPJ). B: Medial side of the first MTPJ plus medial side of the first interphalangeal joint (IPJ). C: Medial side of the first IPJ. D: Plantar side of the first MTPJ. E: Plantar side of the second and third MTPJ. F: Plantar side of the second, third and fourth MTPJ. G: Plantar side of the fifth MTPJ. H: Plantar side of the first MTPJ plus medial side of the first IPJ. I: Plantar side of the second and third MTPJ plus medial side of the first IPJ. J: Plantar side of the first and fifth MTPJ.

translate into increased fragility and decreased effectiveness of the skin when it comes to acting as a protective barrier. This results from a reduction in its elasticity, an increase in dryness and paleness, an alteration of thermoregulation, and an inflammatory response. All of the above will contribute to the onset of fissures, ulcers and superinfections, an increase in pain threshold and less resistance to minor injuries, which will make blood vessels more prone to rupture and healing slower and irregular.⁷ In addition, aging has been related to an increase in the prevalence of certain foot deformities such as hallux valgus and to lesser toe deformities, which may alter plantar pressure patterns.^{4,5}

The most common hyperkeratotic patterns were lesions on the medial side of the first MTPJ (8.7%), the medial side of the first MTPJ plus the medial side of the first IPJ (8.5%) and the medial side of the first IPJ (7.7%). All together, they account for 34% of total lesions. These results are consistent with those obtained by Spink et al.⁸ Age appears to be associated with an increase in the prevalence of foot deformities, which will cause an alteration of plantar pressure patterns and the onset of certain deformities such as hallux valgus, which will contribute to the formation of localised hyperkeratoses.

Regarding the diameter of the lesions, most of them were between 0.1 and 1.0 cm (43.4%), while the remainder were between 1.1 and 2 cm (31.8%), 2.1–3 cm (20%), and 3.1–4 cm (4.8%). These results are consistent with other studies and suggest that smaller diameter lesions are the most common.^{10,11}

In our study, 34% of the participants presented with hallux valgus, which is consistent with other studies that state prevalence rates of 12–56% in the population aged over 65 years. Those studies found that the prevalence of hallux valgus increases with age^{4,18} and is one of the most common podiatric complications among older women.¹⁹

In addition, the presence of hallux valgus has been associated with the onset of hyperkeratosis on the metatarsal heads. This may be due to the fact that, with the onset of hallux valgus, the propulsive function of the foot alters because of the modification of the lever arm and the motion axis, which will cause lateral displacement from the centre of plantar pressure and an increase in the level of load that will be applied on the metatarsal heads.^{20,21}

Moreover, the presence of moderate/severe hallux valgus was associated with hyperkeratotic patterns A and C. These results are similar to those obtained by Spink et al.,⁸ which, to our knowledge, is the only previous study in which lesions of this type had been assessed. In addition, it appears that subjects with hallux valgus are more likely to have lesser toe deformities, and those with such deformities are more likely to have plantar hyperkeratoses and toe lesions.¹⁴ The association between plantar hyperkeratoses and hallux valgus is consistent with other studies²⁰ and suggests that the altered propulsive function of the hallux associated with the condition produces an increase in loads on the metatarsal heads.²¹

Regarding lesser toe deformities, a prevalence rate of 20% was found, which is similar to the one found in other studies. Claw toe and hammertoe are the most common deformities, and the latter is considered to be a more advanced stage of the former.²²

In addition, it has been suggested that individuals who present with claw toe or hammertoe may show signs of exaggerated postural sway due to the foot's reduced area of contact with the ground,²³ which will cause an increase in local plantar pressure and in microtrauma, thus facilitating the formation of hyperkeratosis. Bus et al.²⁴ found that participants with lesser toe deformities had higher plantar pressure peaks on the metatarsal heads, which led them to suggest that the distal displacement of the fat pad that occurs with age is a primary mechanism of compensation that tries to minimise the effects of increased plantar pressure and of toe deformities.²⁵ Similar results were also found by Menz et al.²⁰

No relationship between the presence of diabetes and hyperkeratosis was found ($p = 0.49$). The prevalence of hyperkeratosis in participants with diabetes is the same as that in the normal population. However, the onset of alterations of this type in participants with neuropathy or ischaemia may potentially be the start of more serious problems. In the case of diabetics, it has also been found that hyperkeratosis is associated with an increased risk of ulceration.^{26,27}

The presence of a higher body mass index was not associated with any hyperkeratotic pattern ($p = 0.61$). It has been shown that body weight is a fundamental factor that has an impact on plantar pressure in older people,²⁸ especially under the metatarsal heads and when walking.²⁹ In this respect, it seems that weight plays an important but not exclusive role when it comes to determining the magnitude of the load under the foot.³⁰

In our study, the lack of relationship found between plantar lesions and body weight indicates that its influence may be multifactorial and possibly related to other factors such as soft tissue thickness, skin hydration and vascular status. Future studies analysing the multifactorial relationship using mathematical models are therefore necessary.

Smoking has been associated with the onset of pain in limbs and to poor mobility.³¹ Smoking causes vasoconstriction and a reduction in the blood's capacity to transport oxygen and in blood supply to peripheral tissues, which may contribute to the onset of atrophy of subcutaneous tissue, degradation of connective tissue, a reduction of the fat pad and an increase in pressure on the metatarsal heads. In our study, no type of relationship was found between smoking and the onset of hyperkeratosis ($p = 0.26$).

Regarding gender, our study found that women were the most affected (74%), which is consistent with other studies.^{5,14,15} The underlying mechanism seems to be related to a higher prevalence of toe deformities (predominantly hallux valgus) and the use of high-heeled and narrow-pointed footwear. It has recently been shown that women are more likely than men to use unsuitable footwear, and that there is a direct relationship between the presence of plantar hyperkeratoses and an increase in pressure on the metatarsal heads.¹³

5. Conclusions

The results of this study suggest the existence of 87 different hyperkeratotic patterns, of which 10 are more prominent. The most common ones are those affecting the first radius. Smaller diameter lesions are the most prevalent (43.4% had a diameter between 0.1 and 1 cm). In addition, hyperkeratotic lesions appear to be associated with the presence of hallux valgus and with lesser deformities of the second, third and fourth toes. No significant correlations were found between plantar hyperkeratoses and smoking or BMI.

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