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Digital formula is conditioned by deformities and footwear characteristics in older people. A comparison between general population and population with psychiatric disorders

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SUMMARY

Forefoot morphology is determined by toe length. It is hereditary and unlikely to change during a person's lifetime, although certain factors may lead to modifications. This study examines whether extrinsic factors such as footwear or deformities are associated with changes in the morphology of the forefoot and its pathologies. A study was made of the forefoot morphology, deformities and footwear of 331 participants divided into two populations: a control group (168 participants) and a population of people living in an institution (163 participants with psychiatric disorders). The results show that although Egyptian foot is the most common morphology in both populations, square foot was more prevalent among the women in the control population than among the women in the institution group. In addition, the type of footwear used by the women in the control population was mostly high-heeled constrictive street footwear, compared to the non-constrictive home footwear worn by the women in the institution population, p-value < 0.001. A high prevalence of square feet was observed in the control group women with hallux valgus (HV), p-value 0.008. A relationship was detected between the presence of HV and its prevalence in participants with square foot, concurrent with the use of constrictive footwear and mostly affecting women. The combination of HV and constrictive footwear could explain the high prevalence of the square foot morphology. These footwear characteristics can be considered risk factors in the alteration of the digital formula and aggravation of the deformity suffered in older women.

Key words: Footwear – Hallux valgus – Digital formula – Foot deformities – Psychiatric foot

INTRODUCTION

Foot morphology is important for foot functionali-

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ty, because a shorter or longer length of any of the metatarsals or phalanges can lead to the appearance of certain pathologies (Glasoe and Coughlin, 2006). The digital formula is obtained by measuring the length of the bone elements of the toes.

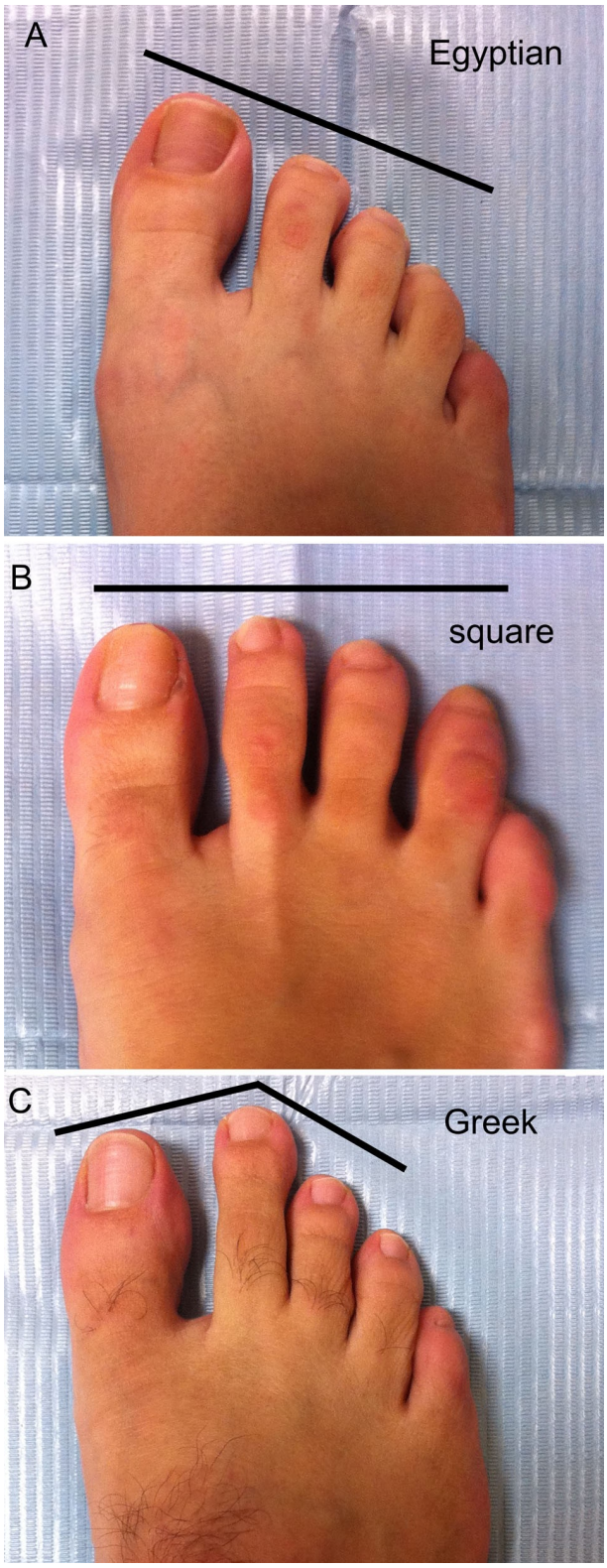

Fig 1. Digital formula. Photographs showing the three different digital formulas. **A**) Egyptian, **B**) Square, **C**) Greek.

The literature includes three forefoot morphologies: Egyptian foot, square foot and Greek foot (Viladot Pericé, 2001). An Egyptian foot is one where the first toe is longer than the others (Fig. 1A), a square foot has first and second toes of equal length (Fig. 1B), and in a Greek foot the second toe is the longest (Fig 1C) (Ridola et al., 2001).

Although the percentages of forefoot morphologies vary between studies, the literature indicates that the Egyptian foot is the most prevalent, followed by the square foot and the Greek foot. It has been demonstrated that the Greek foot is more prone to suffer claw or hammer toes (Zwart Milego, 2004; Massó Ortigosa, 2010). Egyptian foot seems to be the most susceptible to certain pathologies, such as hallux valgus (HV) (Domjanic et al., 2013) and metatarsophalangeal arthritis such as hallux rigidus (Zwart Milego, 2004; Montes Castillo, 2007), as there is more overload with footwear. A square foot usually suffers fewer toe deformities, because this morphology is normally better suited to standard footwear and therefore is less prone to alterations (Massó Ortigosa, 2010).

Studies have been conducted on digital formula prevalence in the general population, children, and specific population groups such as young women and athletes (Viladot Pericé, 2001; Domjanic et al., 2013; Pita-Fernández et al., 2014; Alagnide et al., 2016). However, we found no studies that have analyzed digital formula prevalence in populations with intellectual disabilities and/or psychiatric disorders or examined the factors that can alter digital formula. The objective of this study is to examine and compare forefoot morphology between an institutionalized population with psychiatric disorders or intellectual disabilities and a control population, and to determine the possible influence of extrinsic factors.

MATERIALS AND METHODS

A cross-sectional, descriptive study was designed, with a convenience sample. The study was approved by the Bioethics Committee of the University of Extremadura (Spain) and the Centro Sociosanitario de Plasencia, the residential care center where part of the study was conducted.

The total number of participants was 331. The control group comprised 168 participants who attended the Podomer foot clinic: 92 women and 76 men, with an average age of 65.8 years±12.19. The inclusion criteria were: be autonomous; not have any intellectual disabilities or diagnosed psychiatric disorder; not have been permanently hospitalized and have worn the same type of footwear for the previous ten years. The institution group comprised 163 participants from the residential care center in Plasencia: 72 women and 91 men, with an average age of 68.5 years±10.68. The inclusion criteria were: to have a diagnosed intellec-

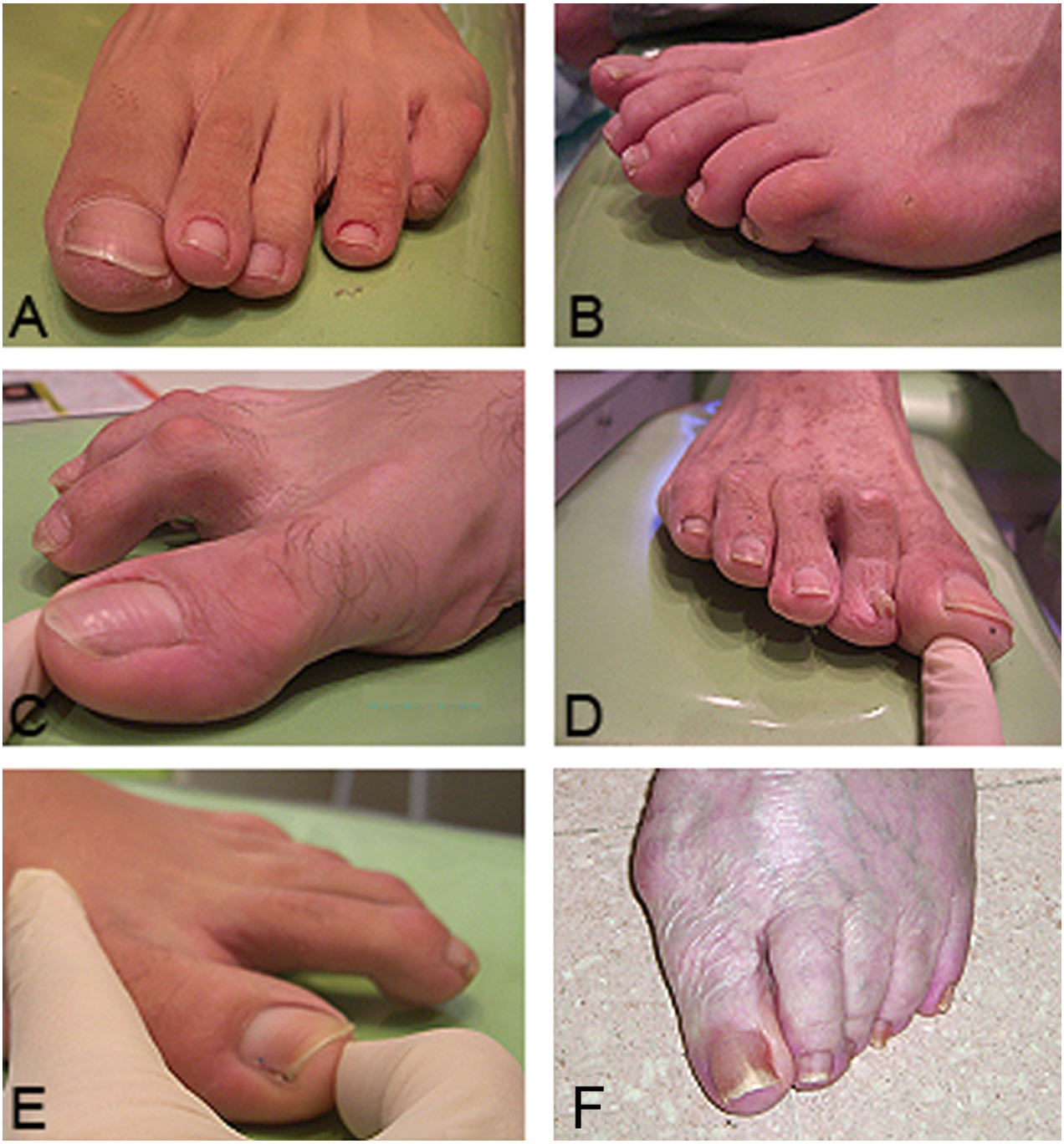

Fig 2. Digital deformities. Photographs of feet with digital deformities. **A**) Tailor's bunion. **B**) Claw toes. **C**) Hammertoes. **D**) Gooseneck toe. **E**) Mallet toes. **F**) Hallux valgus.

tual disability (disorders starting in childhood or adolescence) and/or a chronic psychiatric disorder and to have been living in the residential center for more than ten years, as this would provide information about the type of footwear normally worn during that time. All participants were required to have the same digital formula in both feet and not to have been diagnosed with rheumatic disease.

Participants (or the caretakers of non-autonomous participants) indicated the style of shoes they had worn most frequently in the last ten years. From this we distinguished between two types: street footwear (walking shoes, oxford shoes, moccasins, high/medium heeled shoes, court shoes, athletic/running shoes) and home footwear (slippers) (Barton, et al., 2009; Silvester et al., 2010).

For the analysis of footwear characteristics, we followed the studies of Menz and Sherrington (2000), Barton (2009) and Álvarez-Calderón (2009), collecting information about the toe box and heel that may have influenced the presence of forefoot deformities. If the shoe had a narrow and/or low toe box for the size of the participant's foot,

or a heel higher than 3 cm, it was considered constrictive footwear; otherwise it was classified as non-constrictive.

The digital formula was measured using the medial axis of the foot as a reference. Three types of forefoot morphology were obtained: Egyptian foot, square foot and Greek foot (Fig. 1). Toe deformities were analyzed by visualization of the forefoot in the frontal, lateral and dorsal plane. The following deformities were observed: HV, claw toes, mallet toes, overlapping toes (supraductus or infraductus), gooseneck toe, hammertoes and tailor's bunion (Fig. 2). All measurements were made by the same podiatrist, who had more than ten years of experience.

In all cases it was noted whether participants were taking psychopharmacological medication, defined as antiepileptics, anxiolytics, sedative-hypnotics, antipsychotics and antidepressants.

The data were treated statistically using the SPSS 19.0 software. To analyze the qualitative variables, the Chi-square test and Fisher's statistical test were applied. For all the statistical tests a significance level of 5% was established.

RESULTS

The data obtained show that the most prevalent forefoot morphology in both populations is Egyptian foot, followed by square foot and Greek foot. However, a significant high prevalence of square foot was observed in the control population, p-value 0.034 (Table 1).

Analysis of the data by sex showed that the control group women presented almost twice the prevalence of square foot than the women in the institution population, p-value 0.006, whereas among the men no significant differences were found for the three morphologies. Greek foot was slightly more prevalent in the institution group than in the control group (p-value 0.088) and significantly more prevalent in the women, p-value 0.046 (Table 1).

Table 1. Forefoot morphology in each population in total and by sex. The data show the percentages of forefoot morphologies in both populations. Egyptian foot is the most prevalent and square foot is the most frequent among women in the control population

Total/ Forefoot type	CP	IP	Chi-square	Fisher's Stat
Egyptian	51.2%	55.2%	**0.044***	0.463
Square	37.5%	26.4%		**0.034***
Greek	11.3%	18.4%		0.088
Men/Forefoot type	**CP**	**IP**	**0.767**	**Fisher's Stat**
Egyptian	60.5%	54.9%		0.530
Square	22.4%	25.3%		0.718
Greek	17.1%	19.8%		0.694
Women/Forefoot type	**CP**	**IP**	**0.007***	**Fisher's Stat**
Egyptian	43.5%	55.6%		0.157
Square	50.0%	27.8%		**0.006***
Greek	06.5%	16.7%		**0.046***

CP: Control population, IP: Institution population, %: percentage, *: Statistical significance.

Table 2. Hallux valgus (HV) prevalence in each population in total and by sex. Equal percentages of the HV prevalence in the populations studied and a significantly higher HV prevalence among men in the institution population

Population	Sex	%HV	Fisher's Stat/ Population	Fisher's Stat/ sex
CP	**Woman**	69,6	0.615	0.054
	Men	53,9	**0.006***	
	Total	62.5	0.131	
IP	**Woman**	65.3		0.227
	Men	74.5		
	Total	70.6		

HV: Hallux valgus, PC: Control population, IP: Institution population, %: percentage *: Statistical significance.

The prevalence of deforming pathologies is similar in both populations: 86.9% in the control population and 87.7% in the institution population, p-value 0.822. The pathology with the highest prevalence in the two populations is hallux valgus (HV): 62.5% in CP and 70.6% in IP, p-value 0.131. Analysis of pathologies by sex and population shows that the prevalence of HV among the women is similar, p-value 0.615, whereas in the men it is higher in the institution group, p-value 0.006 (Table 2). None of the pathologies observed showed significant differences between populations (data not shown).

Analysis of forefoot morphology by the presence of HV in each population shows that control group participants with HV have the same proportion of Egyptian foot as square foot, whereas Egyptian foot was more prevalent in the institution group, p-value 0.058. Analysis by sex shows that the control group women with HV present more square foot than the women that do not present HV, p-value 0.008. The other participants (IP women and men and CP men) have a higher proportion of Egyptian foot and this does not depend on the presence of HV, regardless of the group, p-values 0.088, 0.285 and 0.730, respectively (Table 3).

Because of the difference between the forefoot morphologies observed and the presence of HV among the women in the two populations, it was necessary to analyze whether a different factor, such as footwear, had influenced the results. In the control population, 98.8% used street footwear and only 1.2% used home footwear. However, in the institution group, only 46% used street footwear,

Table 3. Forefoot type in each population and hallux valgus (HV) by sex. The data show that the percentages of HV prevalence between populations and forefoot type are similar and Egyptian foot presents more HV than the other types in the control population. The women in the control population show a significant prevalence of HV.

Population/ Sex	Pathology	% Egyptian foot	% Square foot	% Greek foot	Chi-square/ HV	Chi-square/ sex	Chi-square/ population
CP	HV	43.8	43.8	12.4	**0.044***		0.058
	No HV	63.5	27.0	09.5			
IP	HV	53.0	28.7	18.3	0.568		
	No HV	60.4	20.8	18.8			
CP Women	HV	32.8	59.4	07.8	**0.008***	**0.000***	**0.029***
	No HV	67.9	28.6	03.6			
IP Women	HV	55.3	34.0	10.6	0.088	0.183	
	No HV	56.0	16.0	28.0			
CP Men	HV	61.0	19.5	19.5	0.730		0.624
	No HV	60.0	25.7	14.3			
IP Men	HV	51.5	25.0	23.5	0.285		
	No HV	65.2	26.1	08.7			

CP: Control population, IP: Institution population, %: percentage, *: Statistical significance, W/M: Women versus Men

Table 4. Footwear types and characteristics in each population in total and by sex. The data show significant differences between populations by footwear types and characteristics in total and by sex.

Population	Sex	% Street Footwear	%Home Footwear	Fisher´s Stat/ population	Fisher´s Stat/ sex
CP	**Men**	100.0	00.0	**0.000***	0.502
	Women	97.8	02.2	**0.000***	
	Total	98.8	01.2	**0.000***	
IP	**Men**	61.5	38.5		**0.000***
	Women	26.4	73.6		
	Total	46.0	54.0		
Population	**Sex**	**% Constrictive**	**%Non- Constrictive**	**Fisher´s Stat / population**	**Fisher´s Stat/Sex**
CP	**Men**	78.9	21.1	**0,008***	**0.000***
	Women	96.7	03.3	**0,000***	
	Total	88.7	11.3	**0.000***	
IP	**Men**	59.3	40.7		**0.000***
	Women	27.8	72.2		
	Total	45.4	54.6		

CP: Control Population, IP: Institution population, %: percentage, *: Statistical significance.

compared to 54% who used home footwear, p-value <0.001. In terms of footwear characteristics, the control population wears constrictive footwear more (almost twice the value) than the institution population, p-value <0.001 (Table 4).

Analysis of footwear data by sex also revealed significant differences. Most control group women said they had habitually used street footwear in the last ten years and only 2.2% said they wore home footwear. However, in the case of the women in the institution group, the percentages were inverted, as the most commonly used footwear was home footwear (73.6%), with only 26.4% saying they had worn street footwear, p-value < 0.001. Data by sex for constrictive footwear show that this type of footwear is more than three times more prevalent among the women in the control population, p-value <0.001 (Table 4).

None of the control group men said they had used home footwear in the last ten years, meaning all of them had used street footwear (100%). However, the men in the institution population alternate between both types, wearing street footwear more often, p-value <0.001. The men in both groups wear constrictive footwear more often, but the percentages are higher in the control group, p-value 0.008 (Table 4).

Another factor studied was the use of psychopharmalogical medication. No significant differences were found in the prevalence of HV in rela-

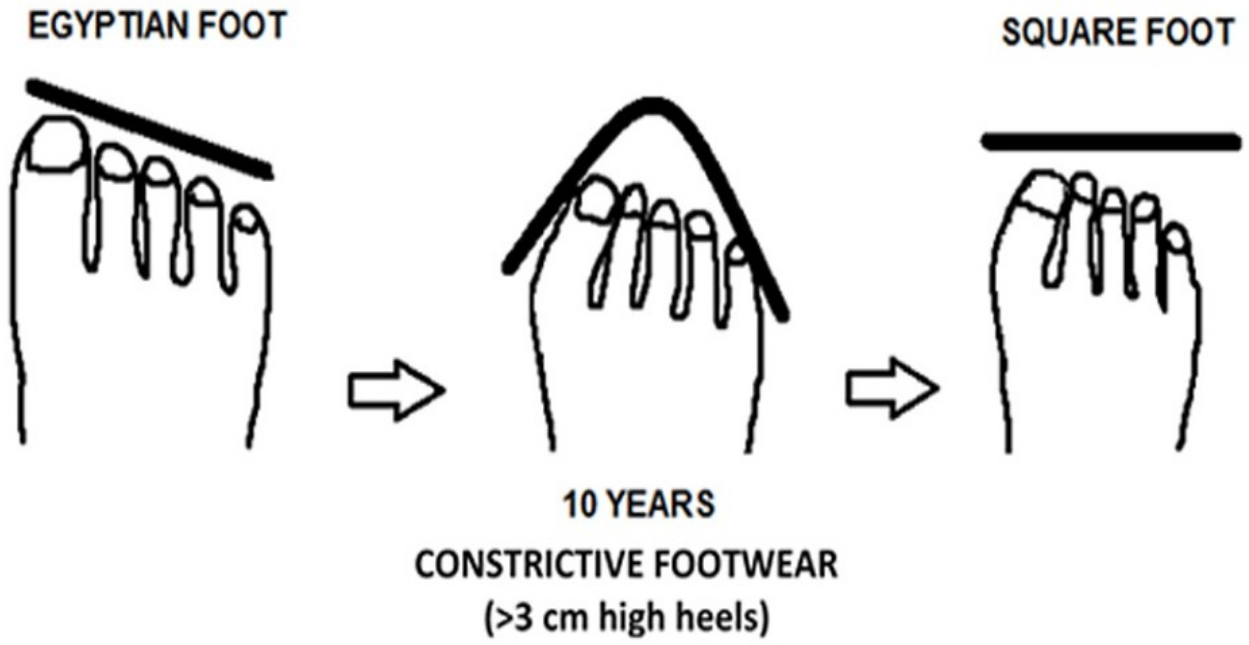

Fig 3. Deformation of the forefoot. The diagram suggests the possible cause of the change in forefoot morphology due to the use of constrictive footwear.

tion to medication (p-value 0.418) or forefoot morphology, p-value 0.605 (data not shown).

Therefore, in reference to the footwear used, the results showed that in the control population both men and women use the same type of footwear (street shoes), p-value 0.502, which is also constrictive, p-value <0.001. However, in the institution population there are significant differences, which show that the men use street shoes and constrictive shoes more frequently, whereas the women in this population use domestic and non-constrictive shoes more frequently, all p-values <0.001 (Table 4).

DISCUSSION

The forefoot morphology results obtained concur with the studies by Alagnide et al (2016), whereas other authors found that the second most frequent morphology was Greek foot (Pita-Fernández et al., 2014) and some reported equal percentages of square foot and Greek foot (Ridola et al., 2001). This indicates that various factors may influence the ratios of foot morphologies depending on the type of population studied.

The control population shows high percentages of square foot. After determining whether this was related to sex, it was found that women have a higher percentage of square foot. This information has not been mentioned previously in the literature.

Chinese women who subjected their feet to constantly applied specific pressures were able to alter their foot morphology considerably (Berg, 1995; Howard and Pillenger, 2010; Gu et al., 2013). Young women showed variations in the morphology of the whole foot after constantly wearing high-heeled shoes (Domjanic et al., 2013). A recent study showed that age and footwear characteristics could influence foot pain and the presence of HV in older women (Menz et al., 2016).

The use of tight footwear with high heels may have influenced the forefoot morphology of the control group women, explaining the high percentages of square foot. The results show how the use of footwear with a narrow toe box and high heel for at least ten years by the control group women, who chose this type of shoe for fashion and design reasons (Naidoo et al., 2011), could have been influencing the alteration of the digital formula by diverting the first toe and shortening it in such a way that an Egyptian foot changes to a square foot (Fig. 3). This would explain the high prevalence of the square foot morphology observed in the women in this population.

In addition, when comparing these data with the data for the women in the institution population, it was noted that because these women are not influenced by fashion, they have a preference for comfort and their caretakers and/or guardians choose comfortable rather than tight footwear for them. This means that their digital formula would not change even though they suffer from deforming pathologies.

The presence of HV is high in both populations, but this may be because all the participants are older people and, as previously mentioned, age and sex are influencing factors (Menz et al., 2011; Pita-Fernández et al., 2014). Other internal factors affect the quality and structure of joint cartilage or phalange, shortening the toes, e.g., arthritis produces changes in the cartilage and can even re-

duce it as a result of degenerative processes (Orozco et al., 2007; García et al., 2011). These processes are more frequent in women and older people, but none of the participants in this study suffered from rheumatic disease. Nevertheless, we cannot completely discard the possibility that osteoarthritis may also be a factor involve in the changes observed.

Without taking forefoot morphology into account, HV prevalence among the women is similar in both populations, but among the men it is significantly higher in the institution group. In this case no differences were found in relation to digital formula, although a slightly higher prevalence of square foot was observed in the men at the institution group. This could be because although they use constrictive footwear, like the women, the toe box is slightly more anatomical and they do not wear high heels. However, the relation between HV and the square digital formula is significant, but only among the women in the control population. This supports the statement that the digital formula of the control group women is altered by their footwear. It could be also the cause of the HV observed, although the deformity may have been present before the use of constrictive footwear, which merely favored the greater deviation of the first toe. The men in both populations and the women in the institution population show percentages that are not influenced by footwear and their data indicate higher percentages of HV, concurring with earlier studies (Montes Castillo, 2007; Domjanic et al., 2013).

The relation between HV and square foot was therefore detected only when a separate analysis was made of the control group women who had consciously chosen to wear constrictive, high-heeled footwear that influences the alteration of their digital formula.

The transverse design of this study does not determine direct causality and therefore it is not possible to make conclusions about the origin of the foot disorders, although associated risk factors can be suggested. There is a direct relation between the high percentage of square foot in the women with HV and the use of constrictive footwear that could be altering their digital formula. Therefore, the data strongly suggest the possibility that these women are consciously causing a change from Egyptian foot to square foot when they have HV and use constrictive footwear with a narrow toe box and high heels (as shown in Figure 1). These footwear characteristics can be considered risk factors in the alteration of the digital formula and aggravation of the deformity suffered.

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