Metatarsal Pain and Plantar Hyperkeratosis in the Forefeet of Female Professional Flamenco Dancers

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Objectives: The objectives of this study were to determine the frequency of metatarsal pain and of hyperkeratosis on the plantar forefoot in female professional flamenco dancers, and to determine whether there is a relationship between the two disorders. **Method:** Forty-four female professional flamenco dancers, with a minimum activity of 25 hrs/wk, participated in this cross-sectional study. The presence or absence of metatarsal pain while dancing was recorded, and plantar pressures were measured on a pressure platform, both barefoot and shod with the usual dance shoe. The heel height of the dance shoe was also measured. **Results:** Of the dancers, 80.7% experienced metatarsal pain while dancing, and 84.1% presented with plantar hyperkeratosis. Plantar hyperkeratosis coincided with the presence of metatarsal pain in 67.04% of the feet studied. The maximum load point in the feet when the dancers were barefoot was located 59.5% in the rearfoot and 40.5% in the forefoot; when dancers wore their specific flamenco dancing shoes, it was located 52.4% in the rearfoot and 47.6% in the forefoot. **Conclusions:** Metatarsal pain and plantar hyperkeratosis in the forefoot are common foot disorders in female flamenco dancing. The incidence of the maximum load point being located in the forefoot, and the difference between the results of the tests while shod or barefoot, are both too low to support the idea that the raised heels of flamenco shoes are a major contributing factor for these injuries. Therefore, these disorders may be caused by chronic repetitive trauma suffered during the practice of footwork dancing. *Med Probl Perform Art* 2014; 29(4):193–197.

The physical demands of professional dance have been extensively studied in the literature and are generally considered comparable to those of elite sport, including the associated risk of injury.[1–3] There have been fewer studies of flamenco dancing than of other forms of dance, but those studies also find that flamenco is a physical activity with high physiological demands.[4,5] The lower body, especially the foot, is the most likely to suffer injury in flamenco dancing.[6–8]

The aesthetics of women's flamenco dancing has two quite different parts, one corresponding to expressive movements of the upper body and the other to marked percussive movements of the legs and feet. In the former, usually following a set choreography, the flamenco dancer uses movements of her fingers, wrists, and arms, inclining and returning the trunk relative to the pelvis in both the frontal and the transversal planes.[5,9] In the latter, the legs and feet mark the rhythm of the music with rapid successive sharp strikes of different parts of the foot on the flooring. The striking gesture, or footwork step (*zapateado*), begins with knee extension, while the foot is held fixed as required to strike with the forefoot, heel, whole plantar area, or toes. On average, 240 footwork steps are performed per minute during a dance or practice.[10] The repetitive percussion of the footwork technique itself, the specific (raised-heel) shoe, and the typical dance flooring used give rise to high-impact stresses on the dancer's feet. The absorption of these impacts may cause injuries, mainly to the foot, neck, and back.[10–12] The impacts in flamenco dancing are sharper than other foot percussion dances, such as tap dancing or Irish dancing.

The foot is the first body part to receive the impact. But, unlike other dances or sports, it is shod in a high-heeled shoe which has hardly changed in the last 100 years, and whose design does not include anything to absorb impact. The flamenco dance shoe[13] has a rigid leather sole with metal tacks on the heel and toe for better sound function, and a heel height of between 4 and 7.5 cm (Fig. 1). Observational and plantar pressure studies with flamenco dance professionals have confirmed that the consistent practice of this activity at a professional level predisposes them to different foot injuries, including hallux valgus abductus, plantar hyperkeratosis, hammertoe, and onychopathies.[12,14,15]

Metatarsalgia manifests itself as a pain in the forefoot, including areas corresponding to the metatarsals and toes. It may lead to swelling and deformity in the forefoot, limiting—and even incapacitating—performance of professional activities. It is one of the most frequent reasons for consultation in podiatry, especially among athletes and women.[16] Possible causes of metatarsalgia are, on the one hand, structural deformities such as pes planus, pes cavus, abnormal subtalar joint pronation, or dorsiflexed first ray.[17] And, on the other hand, causes may relate to

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The Flamenco Andalusia Institute of the Regional Government of Andalusia (Seville, Spain) provided financial support for this study. The views expressed by the authors in this article are their own and not an official position of the institution or funder.

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acquired foot deformities due to the loss of cushioning capacity in the soft tissue, as was described previously.[18,19] These deformities may come from the individual's increasing age, certain metabolic diseases such as diabetes, or from the repetitive impacts made by the feet in the individual's physical activity.[20] If these repetitive impacts are made using a shoe heel higher than 2 cm, increased forefoot plantar pressure and compression of the soft tissue in the metatarsal area may be caused, which can lead to a clinical pattern of acute pain in that area.[21]

There have been very few studies of the causal relation between foot pain and plantar hyperkeratosis in dancers' feet and the use of specific footwear compared with the amount of research on athletes and sports footwear.[22] The aim of the present study was therefore to determine the prevalence of pain and plantar hyperkeratosis in the metatarsal area of the feet of female professional flamenco dancers. Secondarily, the relationship between the presence of metatarsal pain and the dancer's age, weight, and the heel height of the specific shoe was investigated.

METHODS

The study design was cross-sectional and observational, conducted with female professional flamenco dancers in Andalusia (Spain). The dancers either attended the Podiatry Clinic of the University of Seville, Spain, or were professionals of dance schools where they trained. Each participant was informed of the study objectives and of the method of acquiring the variables. Once they had expressed their agreement, they signed a written consent. The study was approved by the Research Ethics Committee of the University of Seville and was conducted according to the Declaration of Helsinki. The funding source had no role in the collection, analysis, and interpretation of data, in the writing of the report, or in the decision to submit the article for publication.

The inclusion criteria were: professional female flamenco dancer, adult, active dance employment at the time of the study with at least one performance weekly, and with a minimum activity of 25 hrs/wk of flamenco dancing for at least the past 12 months. The single exclusion criterion was lower limb or foot osteoarticular surgery in the past 3 years.

The participants completed a form providing their demographic information, injury history, and anthropometric data related to the practice of flamenco dancing. Forefoot pain during the execution of their professional activity was also recorded. Dancers were asked whether they suffered from pain or not. No method of rating the level of pain was used because examination of the flamenco dancers was made, in many cases, in periods when they were not dancing daily (during rest periods, for example, so that they could dedicate time to the authors of this study). The authors thought that the use of some type of pain scale would not have reflected rigorously the amount of pain perceived, so simply a yes/no variable was recorded. The heel height of their dancing shoes was measured, including the cover or layer of material that comes into contact with the floor. Subsequently, the presence of forefoot plantar hyperkeratosis and its location (under the heads of the first, second, third, fourth, or fifth metatarsals) were recorded through visual and manual examination. Static standing plantar pressures were measured using the Footchecker® platform (Footchecker Software®, version 4.0, Loran Engineering Ltd, Castel Maggiore, Italy).

FIGURE 1. Flamenco dancing shoe with a rigid-soled leather with metal tacks on the heel and toe.

The FootChecker 4.0 pressure platform is an instrument designed to determine plantar pressures, centers of gravity, and stability levels in both static and dynamic studies. However, in this investigation, we only used the static variety. This platform model has been approved in various scientific studies.[23,24] It has a total surface area of 680 × 520 mm, a thickness of 5 mm, and an active surface of 480 × 480 mm, with 2,304 sensors. The point of maximum load was also located, on either the rearfoot or forefoot. It was located with the dancer being barefoot and shod with their specific flamenco dance shoe, applying the same feet position for the barefoot and shod measurements (Figs. 2 and 3).

GlaxoSmithKline's CTM® vn 1.1 software package was used to determine the sample size. For our estimate of approximately 3,000 professional flamenco dancers worldwide,[10] an error (epsilon) of 2.2%, an initial estimate of 0.5 (50%), and a confidence level of 95%, the minimum number of participants required was 39. The final study comprised 44 dancers (88 feet).

Data analysis was performed using the SPSS 17 for Windows® software package (IBM-SPSS, Armonk, NY, USA), computing the mean and standard deviation (SD) of the quantitative variables for the descriptive analysis, and the frequency and percentage of the variables presence of metatarsal pain, presence, and location of plantar hyperkeratosis, and point of maximum load as measured by the Footchecker® static standing foot pressure platform (maximum load point on the rearfoot or forefoot, barefoot and shod). The Shapiro-Wilk test was used to check for normality in the distributions of the variables, and a con-

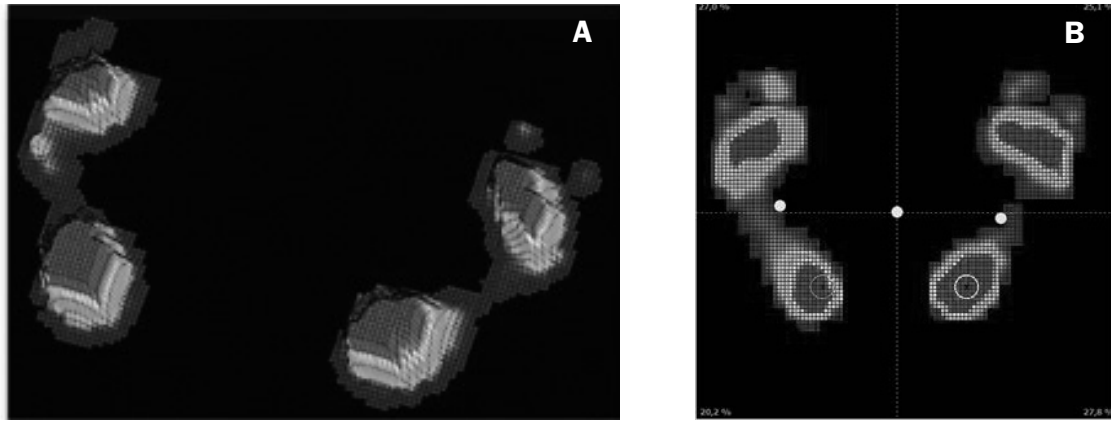

FIGURE 2. *A*, Plantar plot obtained from Footchecker platform (unshod). 3D image. ***B***, Plantar plot obtained from Footchecker platform (shod). 2D image.

tingency table and Pearson chi-squared test were used to study the potential significant correlation between the presence of pain and the presence of metatarsal plantar hyperkeratosis. The respective contingency tables were constructed and Mann-Whitney U-tests applied for the variables of age, weight, height of heel, presence of metatarsal pain, and presence of plantar hyperkeratosis. A contingency table and Wilcoxon signed-ranks test were used to check whether there was a relationship in the location of the maximum load point on the foot and the subject being barefoot and shod. Differences were considered statistically significant if the *p*-value was <0.05.

RESULTS

Eighty feet of 40 female flamenco dancers (between 18-45 yrs) were analysed (average age 26.54 ± 7.42 yrs; weight 56.22 ± 8.36 kg; and height 163.22 ± 6.12 cm). The participants spent an average of 31.42 ± 5.89 hrs/wk practicing flamenco. The mean history of professional activity was 15.06 ± 9.98 yrs (range 1–41 yrs). Heel heights ranged from 4.5 to 7 cm.

The 6-cm heel (with cover) was the most frequent (47.7% of the cases). Metatarsal pain during the practice of flamenco dancing was present in 80.7% of the dancers. Plantar hyperkeratosis was present in 84.1% of the participants. Taking into account that the same foot could present plantar hyperkeratosis in more than one location, the percentages of metatarsal heads affected were as follows: 52.3% under the first metatarsal head; 53.4% under the second metatarsal head; 43.2% under the third metatarsal head; 23.9% under the fourth metatarsal head; and 18.2% under the fifth metatarsal head (Table 1).

The results, seen in Table 2, showed that 67.04% of the feet were identified as presenting simultaneously metatarsal pain and plantar hyperkeratosis. Only 2.27% of the feet had none of these pathologies. Although 59 feet presented both metatarsal pain and plantar hyperkeratosis, 15 feet presented only hyperkeratosis without indications of pain, while 12 feet presented indications of pain without any signs of hyperkeratosis, leading us to conclude that there is insufficient evidence to support a definite relationship between these two conditions (Pearson's chi-squared statistic = 0.178; $p = 0.603$). No significant differences were found between the dancers with and without metatarsal pain in age ($p = 0.561$), weight ($p = 0.792$), or heel height ($p = 0.515$). Neither were there any significant differences between the participants with and without plantar hyperkeratosis in age ($p = 0.248$), weight ($p = 0.792$), or heel height ($p = 0.556$).

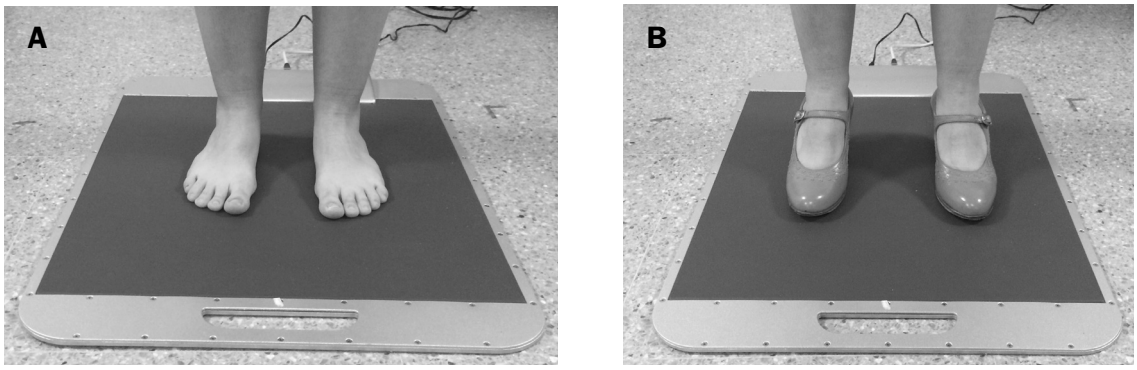

FIGURE 3. *A*, Barefoot dancer on the platform. ***B***, Shod dancer on the platform.

It should be noted that data about loading medially, laterally, or centrally in the forefoot were not recorded and that when dancers stood shod with ther dancing shoes on the platform, forefoot pressures appeared equally distributed between the medial, lateral, and central areas of the forefoot, perhaps because of the thickness and rigidness of the shoe sole between the foot and the platform. Thus, the focus of this study was concerned with forefoot versus rearfoot pressures, and not lateral versus medial problems involving foot pain.

As regards the static standing pressure measurements, 59.5% of the feet had the maximum load point located in the rearfoot, and 40.5% in the forefoot, when unshod; whereas 52.4% of the feet had the maximum load point located in the rearfoot and 47.6% in the forefoot when shod with their specific flamenco dancing shoes (Table 3). Checking whether the location of this point varied between barefoot and shod showed no significant difference ($p = 0.343$). Thus, the use of the shoes did not cause substantial change in the location of the maximum foot load point while standing.

TABLE 1. Distribution of Plantar Hyperkeratosis

Metatarsal	% (*n*)
MT 1	52.3% (*n*=46)
MT 2	53.4% (*n*=47)
MT 3	43.2% (*n*=38)
MT 4	23.9% (*n*=21)
MT 5	18.2% (*n*=16)

TABLE 2. Presence of Metatarsal Pain and Plantar Hyperkeratosis in Dancers

	% (*n*)
Metatarsal pain	13.64 % (*n*=12)
Plantar hyperkeratosis	17.05% (*n*=15)
Metatarsal pain + plantar hyperkeratosis	67.04% (*n*=59)
No pathology	2.27% (*n*=2)

TABLE 3. Distribution of Maximum Load Point

	Maximum Load Point (*n*=84)*	
	Forefoot	Rearfoot
Barefoot	40.5% (*n*=34)	59.5% (*n*=50)
Shod	47.6% (*n*=40)	52.4% (*n*=44)

* Four feet showed the same load on the forefoot and rearfoot, both barefoot and shod.

DISCUSSION

The results have shown that 80.7% of the dancers in the study experienced metatarsal pain during dance. In their study of professional and student flamenco dancers, Pedersen and Wilmerding[12] found the most frequent pathologies associated with symptoms of pain to be stress fractures and sesamoiditis. However, those authors suggested that strengthening of the foot with training helps prevent injury. They highlighted the dancing shoes' limited capacity to absorb impact since their design is specifically aimed at emphasizing sound production and rhythm. They also indicated that the use of the raised heels puts increased demand on the gastrocnemius and soleus muscles, which become shortened, leading to a lengthening and dependency of the tibialis anterior.

The measurements made with the pressure platform in the present study have shown that, as regards the specific, raised-heel, flamenco dance footwear, the area of maximum plantar pressure is very often located not in the forefoot but in the rearfoot. No statistically significant changes were found in the distribution of the point of greatest pressure with the participants barefoot and wearing raised-heel dance shoes. In both situations, the values of the plantar pressures were similar ($p = 0.343$), i.e., the use of the shoes caused no variation of the location of the maximum load point on the foot in the standing position.

It might seem controversial that the peak maximum pressure is located in the rearfoot when the dancer is wearing raised heels. In normal conditions, the routine use of high-heeled footwear leads to an anterior displacement of plantar pressures, with increased pressures in the region of the forefoot principally under the metatarsal heads, resulting in metatarsalgia.[25] Kot et al.[21] confirmed this condition in an ultrasound study of the density of the plantar metatarsal region subjected to load. In particular, they found that the soft tissue of this area reached its maximum compression with the use of high heels, and that this was associated with increased plantar pressures in this region.

In contrast, the highest plantar pressure peaks are more often located in the rearfoot in professional flamenco dancers. This is due to the fact that their raised-heel shoes are an integral part of their physical activity, and the dancers, as elite sportspersons do, adapt their body placement to make it more ergonomic during their physical activity, in this case, while dancing. These accommodations seek to balance the body, thus avoiding excessive displacement of the center of gravity. The accommodations are made in two ways, depending on the structure of the dance. On the one hand, during the footwork phases, featuring a high speed of foot strikes on the flooring, accommodation is achieved with a slight flexion of the knees and a gentle posterior pelvic tilt.[10,26] On the other, in non-footwork phases of the dance, movements are centered on the aesthetics of the arms and trunk, and balance is achieved by adopting a lumbar hyperlordosis associated with anterior pelvic tilt.[10] We think that the dancers performed this compensation instinctively during the plantar pressure test, with the result that the maximum load point was located in the rearfoot region, as has been found in other studies on flamenco dancing.[6,7]

For the above reason, we could conclude that the origins of the metatarsalgia found in the participants of this study should not be attributed to the increase in forefoot pressures, but rather to the chronic repetitive microtrauma caused by

the dance footwear's intentional lack of buffering against impact, since, as emphasized by Pedersen and Wilmerding,[12] this footwear is more oriented to producing sound than to any biomechanical or shock-absorbing function.

Those forefoot injuries, such as the fractures of the base of the second metatarsal in classical ballet reported by Davidson et al.,[27] may be due to increased forefoot pressures and/or to repetitive impact. In the case of flamenco dancing, however, and because of the compensation of both the pelvis and the knees, this cannot be the case, since there is no increase of pressure in the forefoot region. The metatarsalgia or similar processes, such as the sesamoiditis described by Pedersen and Wilmerding,[12] are more likely due to the function of the feet in producing rapid and sharp rhythmic sounds and the concomitant intentional lack of buffering against impact in the dancer's footwear. It was in this sense that Shybut et al.[11] attributed the arrest of epiphyseal growth of an adolescent flamenco dancer to repetitive trauma.

Injuries in the forefoot region, such as the fractures of the base of the second metatarsal in classical ballet,[26] may be due to increased forefoot pressures and/or to repetitive impact. However, in the case of flamenco dancing, there is no increase of pressure in the forefoot region, because of the compensation of both the pelvis and the knees.

In conclusion, the most likely cause of the metatarsalgia found in the present study, as well as other similar processes like the sesamoiditis described by Pedersen and Wilmerding,[12] is the combination of the function of the foot of producing a high volume of sharp, rapid rhythmic repetitions with the lack of buffering at the moment of the impact in the dancer's footwear.

CONCLUSIONS

Metatarsal pain during their regular physical activity was present in 80.7% of the female flamenco dancers who participated in this study, and most of them had plantar hyperkeratosis in the forefoot region. Although the heels of the footwear worn in this type of physical activity are raised, the point of maximum load was not located in the forefoot in all the cases. The authors therefore believe that the symptoms these dancers present may be related to the sound-producing function of the feet in flamenco dancing, and in particular to chronic repetitive trauma to which the dancer's feet are subjected during the practice of this activity.

The authors express our gratitude to the professional dancers who took part in the study for their generous participation.

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