Length of the Sesamoids and Their Distance From the Metatarsophalangeal Joint Space in Feet With Incipient Hallux Limitus

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Background: We designed this study to verify whether the sesamoids of the first metatarsal head are longer than normal in feet with incipient hallux limitus, and whether feet with incipient hallux limitus are in a more proximal than normal sesamoid position.

Methods: In a sample of 183 dorsoplantar radiographs under weightbearing conditions (115 of normal feet and 68 of feet with slightly stiff hallux), measurements were made of the length of both the medial and the lateral sesamoids and of the distance between these bones to the distal edge of the first metatarsal head. These variables were compared between the normal and the hallux limitus feet. The relationship between these variables and the hallux dorsiflexion was also studied.

Results: We found significant differences between the two types of foot in the medial and lateral sesamoid lengths, but no significant difference in the distance between the sesamoids to the distal edge of the first metatarsal. A poor-to-moderate inverse correlation was found between hallux dorsiflexion and medial sesamoid length and between hallux dorsiflexion and lateral sesamoid length.

Conclusions: The length of the sesamoid bones of the first metatarsal head could be implicated in the development of the hallux limitus deformity. (J Am Podiatr Med Assoc 98(2): 123-129, 2008)

Hallux limitus is a pathology of multifactorial origin.[1-3] Its etiology can be affected by hereditary, systemic, iatrogenic, traumatic, and biomechanical factors, among others. Of the biomechanical factors, one that has occasionally been attributed an etiological role in this pathology is the length of the sesamoids and the distance between them and the distal edge of the first metatarsal head.

Durrant and Siepert[4] have stated that if the sesamoids are too elongated in the sagittal plane, their proximal aspect can cause plantar jamming by restricting the first metatarsal from plantarflexing and moving more proximally, and this may affect the adequate first metatarsophalangeal dorsiflexion. They also maintain that if the sesamoids are located too proximal to the first metatarsophalangeal joint, the sesamoids can have the same adverse effect on the function of the first ray as when they are overlong, which would also be a factor triggering the hallux limitus deformity.

At the same time, and as Camasta[1] maintains, the too-proximal position of the tibial and fibular sesamoids can be the result of a retraction or spasm of the flexor hallucis brevis muscle, which is inserted partially in these bones. Such proximal migration would be related to the hallux limitus deformity; the retraction of the flexor hallucis brevis tends to keep the proximal phalanx of the hallux in a flexed position, thereby limiting the capacity of the hallux to extend over the metatarsal head.[5] One way to know radiographically whether the soft parts that plantarly affect the base of the proximal phalanx (especially the flexor hallucis brevis) are retracted would be by observing the location of the sesamoids with respect to the metatarsophalangeal joint space.

This study is designed with the following aims: 1)

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to establish normal values of the length of the medial and lateral sesamoids; 2) to establish normal values of the location of these bones with respect to the distal edge of the first metatarsal head; and 3) to compare these values with those obtained from feet with incipient hallux limitus and to confirm or rule out that excessive length of the sesamoids or their excessively proximal position is among the possible etiologies of hallux limitus.

Materials and Methods

The sample for this study comprised 183 feet belonging to 126 subjects, 47 women and 79 men, with a mean age of 23.4 years (± SD of 2.8). These subjects were patients of the Clinical Podiatric Service at the University of Seville, Seville, Spain, during 2004, 2005, and 2006, and podiatry students who volunteered to take part in the research. After agreeing to participate in the study, each subject provided written consent. This work has been approved by the experimental ethics committee of the University of Seville.

The subjects of the sample had to fulfill the following inclusion criteria: 1) aged 20 to 29 years so that the growth physes had closed,[6-8] ruling out the possibility that any limitation of hallux dorsiflexion was from age[9]; 2) to never have undergone osteoarticular surgery of the foot; 3) to never have suffered serious trauma to the foot that might have altered its bone morphology; 4) to not suffer from degenerative osteoarticular diseases or neuromuscular imbalance; 5) to not present evident deformities of the forefoot that could affect the results of the study; and 6) to have a hallux abductus angle of 15° or less.

The sample was divided into two groups: a control group and a group of feet with hallux limitus in its initial stage. In this study, we consider hallux limitus to be incipient when there are no symptoms and hallux dorsiflexion values are between 30° and 50°. The subjects comprising the control group had to have a hallux dorsiflexion of 70° or more. The subjects with incipient hallux limitus had to have 50º or less of hallux dorsiflexion. Feet with hallux dorsiflexion values between 50° and 70° were excluded from the study. This range (50°–70°) was established to prevent confusion in those cases where values for hallux dorsiflexion were close to normality. Of the 183 feet, 115 formed the control group and 68 formed the incipient hallux limitus group.

A dorsoplantar radiograph under weightbearing conditions was taken for each individual, with both feet together. The x-ray centered between the naviculars of the two feet, with the tube inclined 15° to the vertical and at a tube-to-object distance of 1 m. A digital image of each radiograph was made with a scanner (Epson Expression 1680 Pro; Seiko Epson Corporation, Nagano, Japan) to allow the exploration of images on positive film. The radiographic measurements were taken with AutoCAD 2006 (Autodesk Inc, San Rafael, California), of proven efficacy for the task.[10-12] The following variables were studied: medial sesamoid length, lateral sesamoid length, distance between the distal end of the medial sesamoid and the distal end of the first metatarsal head, and distance between the distal end of the lateral sesamoid and the distal end of the first metatarsal head. Other measurements taken were the hallux abductus angle and the first metatarsal length. All measurements were made by the same observer (P.V.M.).

The hallux abductus angle was measured in accord with the procedure described by Coughlin et al.[13] The method of measuring the first metatarsal length was that used by Heden and Sorto[14] in 1981 (Fig. 1). This method consists of determining the distance between the distal end of the metatarsal head and the bisection of its base. The point that Heden and Sorto identify as the bisection of the metatarsal base is the point of intersection of the longitudinal axis of the metatarsal with a line connecting the proximal medial and proximal lateral ends of the metatarsal base.

The method of measuring the medial and lateral sesamoid lengths was that used by Prieskorn et al[15] in

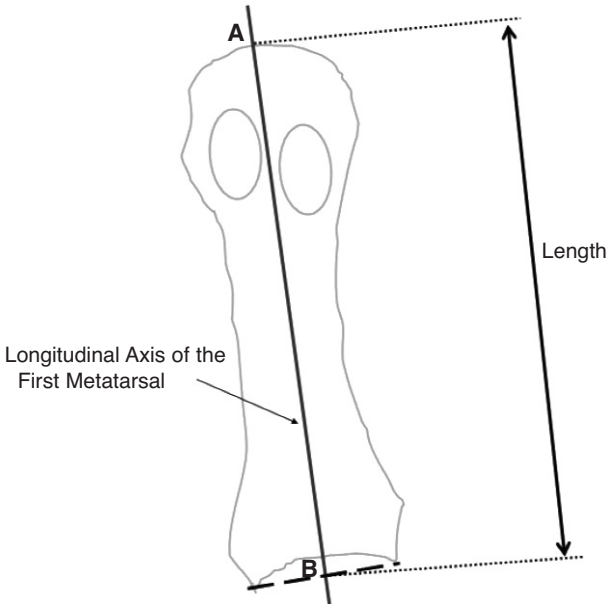

Figure 1. Measuring the first metatarsal length from the distal edge of the first metatarsal head (A) to the point of intersection of the longitudinal axis of the metatarsal (B).

1993. It consists of measuring the distance between the proximal end and the distal end of each sesamoid bone (Fig. 2).

Prieskorn et al[15] measured the distance from the distal and proximal edge of the two sesamoids to a line perpendicular to the axis of the first metatarsal and going through the point most distal from its head. This method has the drawback of involving a straight line, meaning it cannot represent the form of the joint space. Hetherington et al[16] measured the distance between the medial and lateral sesamoids to the distal edge of the first metatarsal head by calculating the distance between the most-distal point of the tibial sesamoid and the most-distal portion of the first metatarsal head on lateral radiographs. The method in this study adapts that of Hetherington et al[16] to dorsoplantar radiographs. The distance between the most-distal point of each sesamoid and the distal edge of the first metatarsal head, in a direction parallel to the axis of the first metatarsal, was measured in millimeters (Fig. 3).

To standardize the set of measurements of the sesamoid lengths and the distance from them to the distal edge of the first metatarsal head, the measurements have also been expressed as a percentage of the first metatarsal length. This procedure was similar to those used by other authors.[12, 17, 18] These variables have been denominated as "relative," to distinguish them from the absolute values.

The data were analyzed with SPSS 14.0 for Windows (SPSS Science, Chicago, Illinois). To check the reproducibility of the measurement procedure, five radiographs were chosen at random from each group, and the measurements were made on three occasions, with 1-week intervals between measurements. The data obtained from this group of measurements were used to calculate the intraclass correlation coefficient. The descriptive analysis gave the mean, SD, and 95% confidence interval for each variable. To decide whether to use parametric or nonparametric tests, the Kolmogorov-Smirnov test was performed as a check of normality. Its results suggested that the Student *t* test for independent samples—with the Levene test used for the equality of variance—was the best test for comparing the means between the control group and the group with incipient hallux limitus, because the data followed a normal distribution. Pearson correlation coefficients were calculated to assess the degree of relationship between the hallux dorsiflexion and the medial and lateral sesamoid lengths, and between the hallux dorsiflexion and the distance from the sesamoids to the distal edge of the first metatarsal head. *P* values below .05 were considered statistically significant.

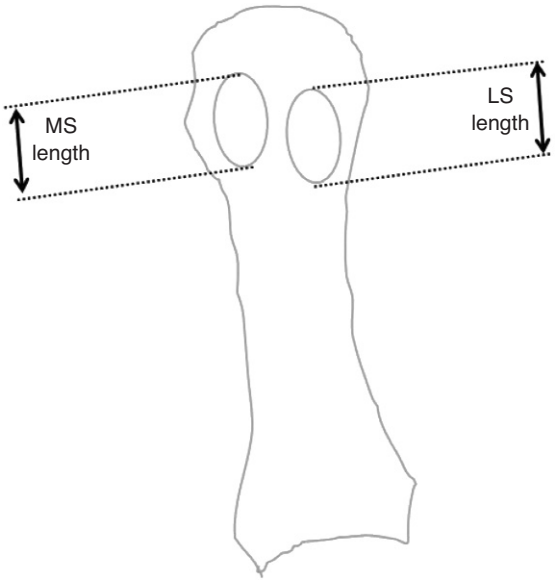

Figure 2. Measuring the medial (left) and lateral (right) sesamoid lengths. MS, medial sesamoid. LS, lateral sesamoid.

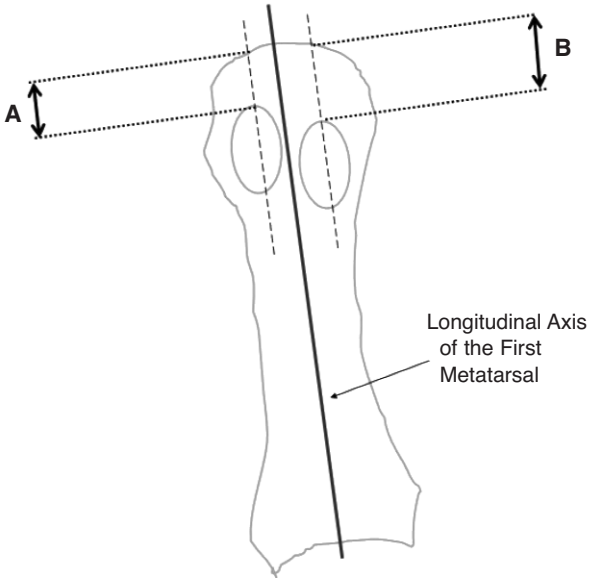

Figure 3. Measuring the distance between the medial (A) and lateral (B) sesamoid and the distal edge of the first metatarsal head. The broken lines are parallel to the longitudinal axis of the first metatarsal.

Results

The value of the intraclass correlation coefficient was greater than 0.97 for all the variables measured on the radiographs (Table 1). All these coefficients can be

Table 1. Intraclass Correlation Coefficients for the Variables Measured on the Radiographs

	Intraclass Correlation Coefficient	95% Confidence Interval
Hallux abductus angle	0.997	0.991–0.999
First metatarsal length	0.993	0.979–0.998
MS-DE1MTT distance	0.973	0.917–0.993
MS length	0.992	0.975–0.998
LS-DE1MTT distance	0.996	0.988–0.999
LS length	0.995	0.983–0.999

Abbreviations: MS, medial sesamoid; DE1MTT, distal edge of the first metatarsal; LS, lateral sesamoid.

considered very high,[19] and the reproducibility of the measurements is acceptable with the methods used.[20,21]

The control group comprised 115 feet of 78 subjects, 38 men and 40 women, with a mean age of 23.4 years (± 2.7). The incipient hallux limitus group comprised 68 feet of 48 subjects, 41 men and 7 women, with a mean age of 23.4 ± 2.8 years. In one subject, the right foot was normal and the left foot had 50° of hallux dorsiflexion.

The values from the descriptive analysis of the variables (absolute and relative values), and from the comparisons between the sesamoid variables, are shown in Table 2. Comparisons were made with the relative values of these variables. Only the medial and lateral sesamoid lengths showed significant difference between normal and hallux limitus feet (Figs. 4 and 5).

A poor-to-moderate inverse association was found between hallux dorsiflexion and medial sesamoid length ($r = -.352$; $P < .0001$), and between hallux dorsiflexion and lateral sesamoid length ($r = -.489$; $P < .0001$). Hallux dorsiflexion did not show correlation with the distance between the medial sesamoid and the distal edge of the first metatarsal head ($r = .133$, $P = .072$) or with the distance between the lateral sesamoid and the distal edge of the first metatarsal head ($r = .152$, $P = .039$).

Discussion

We conducted this study to determine radiographically whether there is a difference in the size of the sesamoids, or a difference in their position under the first metatarsal head, between normal feet and feet with incipient hallux limitus. The study investigates whether the dorsiflexion of the hallux decreases as the length of the sesamoids, or the distance between them and the articular cartilage of the first metatarsal head, increases. This study has certain limitations. We did not include more-severe cases of hallux limitus so that the results would not be affected by the degenerative changes usually found in both the first metatarsal and the sesamoids in more-serious hallux limitus or even hallux rigidus.[1]

Another possible limitation is the radiographic

Table 2. Mean Absolute and Relative Variables

	Absolute Value		Relative Value		
	Mean ± SD	95% CI	Mean ± SD	95% CI	*P*
Hallux dorsiflexion					
Control	76.7 ± 7.5	75.3–78.1	NA	NA	< .0001[a]
Hallux limitus	45.4 ± 6.5	43.8–46.9	NA	NA	< .0001[a]
Hallux abductus angle					
Control	10.0 ± 3.7	9.3–10.6	NA	NA	.21
Hallux limitus	9.2 ± 4.4	8.1–10.3	NA	NA	.21
Medial sesamoid length					
Control	11.1 ± 1.3	10.9–11.4	16.9 ± 1.9	16.6–17.3	< .0001[a]
Hallux limitus	12.9 ± 1.6	12.5–13.3	18.5 ± 2.1	17.9–18.9	< .0001[a]
Lateral sesamoid length					
Control	10.8 ± 1.2	10.6–11.1	16.5 ± 1.6	16.2–16.8	< .0001[a]
Hallux limitus	12.8 ± 1.5	12.5–13.2	18.3 ± 1.9	17.9–18.8	< .0001[a]
Medial sesamoid–DE1MTT distance					
Control	4.7 ± 1.8	4.4–5	7.2 ± 2.8	6.8–7.7	.19
Hallux limitus	4.6 ± 1.7	4.2–5.1	6.7 ± 2.5	6.1–7.3	.19
Lateral sesamoid–DE1MTT distance					
Control	6.2 ± 1.7	5.9–6.5	9.5 ± 2.7	9–10	.17
Hallux limitus	6.3 ± 1.5	5.9–6.7	8.9 ± 2.2	8.5–9.5	.17

Abbreviations: CI, confidence interval; NA, not applicable; DE1MTT, distal edge of the first metatarsal.
[a]The difference was statistically significant.

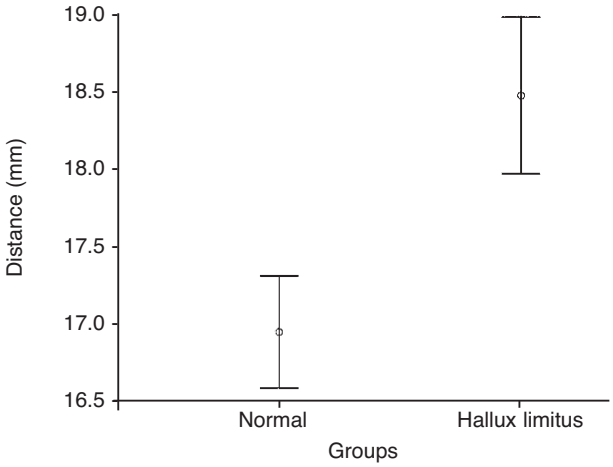

Figure 4. Mean distance between the medial sesamoid and the distal edge of the first metatarsal head (percentage of total length of first metatarsal) in normal and hallux limitus feet. Vertical lines represent 95% confidence interval.

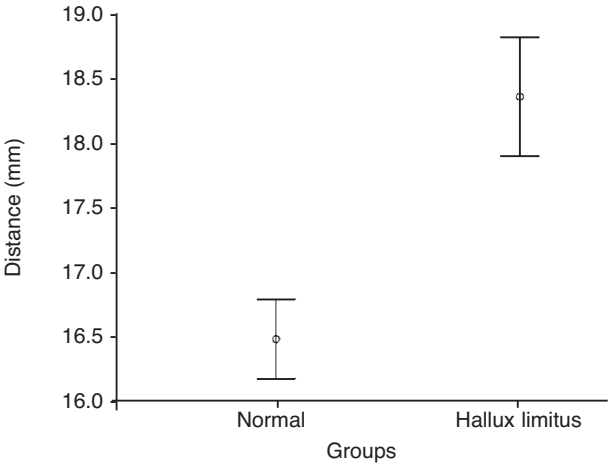

Figure 5. Mean distance between the lateral sesamoid and the distal edge of the first metatarsal head (percentage of total length of first metatarsal) in normal and hallux limitus feet. Vertical lines represent 95% confidence interval.

evaluation of the variables studied; the association between hallux limitus and the dorsiflexed first ray is widely known. In a dorsiflexed first metatarsal, the sesamoids could show a ground-projected image somewhat larger than that in a normal first metatarsal, because in the dorsiflexed first metatarsal the sesamoids would be more parallel to the ground (Fig. 6). Nonetheless, based on the results of a study carried out by Coughlin and Shurnas,[22] metatarsus primus elevatus is a secondary change that would be present in advancing grades of the deformity. Thus, this possible limitation would not affect our results.

Other studies have already demonstrated that whenever the radiography is performed with the same protocol, the differences with the real size can become nonsignificant, at least for the first metatarsodigital segment.[23] Another limitation to bear in mind is the unequal distribution of men and women in the incipient hallux limitus group when compared with the control group. To help overcome this limitation, we tested what the results would have been if the comparisons had been made with male subjects only. As can be seen in Tables 3 and 4, the results did not vary greatly.

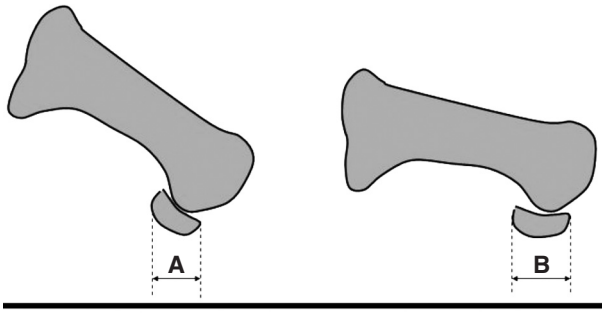

Figure 6. Projection of a sesamoid on the radiographic plate in a normal first ray (A) and in a dorsiflexed first ray (B).

Various works have studied the distance between the sesamoids and the first metatarsophalangeal joint space. Harris and Beath[24] in 1949 stated that the normal case was sesamoids located between 12.5 and 16.5 mm from the distal end of the first metatarsal. Yoshioka et al,[25] without giving specific values, stated that the tibial sesamoid is closer than the lateral sesamoid to the metatarsophalangeal joint space. Prieskorn et al[15] measured the distance between the distal end of both sesamoids to a line tangential to the distal edge of the first metatarsal, perpendicular to its longitudinal axis. They found that the mean distance for the tibial sesamoid was 4.9 mm (± 1.8), and that for the lateral was 7.6 mm (± 1.9). Hetherington et al[16] radiographically evaluated 30 subjects with no pathology of the feet and established the mean distance of the tibial sesamoid to the joint space as 5.7 mm (± 2.3). The data from our study (4.7 mm ± 1.8 for the medial sesamoid and 6.2 mm ± 1.7 for the lateral sesamoid) are closer to those of Prieskorn et al[15] and to those of Hetherington et al[16] than to those of Yoshioka et al.[25] We coincide with Yoshioka et al on the greater proximity of the medial sesamoid than of the lateral sesamoid to the metatarsophalangeal joint space.

Table 3. Relative Variable Comparison Between the Men of the Control Group and the Hallux Limitus Group

	P
Medial sesamoid length	< .0001[a]
Lateral sesamoid length	< .0001[a]
Medial sesamoid–DE1MTT distance	.84
Lateral sesamoid–DE1MTT distance	.82

Abbreviation: DE1MTT, distal edge of the first metatarsal.
[a]The difference was statistically significant.

Table 4. Correlation Between the Hallux Dorsiflexion and the Relative Variables

	Hallux Dorsiflexion	
	r	*P*
Medial sesamoid length	–0.390	< .0001
Lateral sesamoid length	–0.474	< .0001
Medial sesamoid–DE1MTT distance	0.071	.459
Lateral sesamoid–DE1MTT distance	0.073	.445

Abbreviation: DE1MTT, distal edge of the first metatarsal.

Roukis et al,[26] in a study on feet with hallux rigidus, found that the medial sesamoid joint space distance was 5.8 mm (± 1.8), and the lateral sesamoid joint space distance was 8.0 mm (± 2.0). Roukis et al concluded that there seemed to be a slight increase in proximal migration of the sesamoids, comparing the values of their study with the normal values obtained by Hetherington et al[16] and those of Prieskorn et al.[15] As far as we are aware, Roukis et al[26] are the only ones to have compared the values of this distance in normal feet and in feet with hallux rigidus. However, the normal values they report were not obtained by them but by other authors. Harris and Beath[24] give normal values much higher than those of Roukis et al,[26] so that if the comparison is made with Harris and Beath's data, the same conclusion cannot be reached.

In this work, the calculation of the distance of the sesamoids to the first metatarsophalangeal joint space was related to the length of the first metatarsal because, for example, a sesamoid located 10 mm from the joint space in a metatarsal that measures 70 mm would not have the same significance as in one that measures 60 mm. Thus, the measurement is expressed as a percentage of the length of the first metatarsal. On making the comparison between the control and incipient hallux limitus groups, no significant difference has been found for the distance from the sesamoids to the joint space. Thus, if, as noted by Camasta,[1] the too-proximal position of the sesamoids indicates a retraction or spasm of the flexor hallucis brevis, we cannot speak of such retraction in the initial phase of hallux limitus and, consequently, we cannot declare it to be a causal factor in hallux limitus.

However, we cannot affirm that such retraction is not produced in more-advanced states of the deformity. Hallux limitus is characterized by the proximal phalanx adopting a position in flexion with the first metatarsal head. This position, maintained for a long time, can lead to a retraction of the hallucal flexor musculature that, as it includes the sesamoids within its tendons, can give rise to a position more proximal than normal for these bones. To be able to make such an assertion, it would be necessary to study the distance of the sesamoids to the joint space in patients with initial-phase hallux limitus and monitor the evolution of the deformity in these same patients, observing whether this distance increases with the advance of hallux limitus.

We are unaware of any previous studies that have compared the length of the sesamoids between normal feet and feet with hallux limitus. According to our results, both the medial and the lateral sesamoids are longer in feet with hallux limitus than in normal feet. Various works have supplied data on the size of the sesamoids in normal feet. Oloff and Schulhofer[27] state that the medial sesamoid is larger and the lateral more rounded in normal feet. Yoshioka et al[25] agree, in that the medial sesamoid is larger than the lateral. Yoshioka et al found that, in normal feet, the length of the medial sesamoid is 10.6 mm, and the length of the lateral sesamoid is 10.1 mm. Aper et al[28] report the length of the lateral sesamoid only, at 13.61 mm. In our study, as in that of Yoshioka et al, the medial sesamoid is slightly longer than the lateral sesamoid.

A relationship of overlong sesamoids with the etiology of hallux limitus has already been postulated.[1, 4] An association between sesamoid hypertrophy and advanced states of hallux limitus has also been reported in the literature.[29] The increase in size of the sesamoids is attributed to the excessive traction exerted by the short retracted flexor on these bones.[29] Considering that the spasm or retraction of the short flexor has not yet been produced because the distance between the sesamoids and the joint space is normal, we think that the excessive length of the sesamoids could be related to the etiology of hallux limitus. Durrant and Siepert[4] maintain that the excessive length of the sesamoids restricts the capacity of first metatarsal plantarflexion, restricting the extension of the first metatarsophalangeal joint. The inverse relationship found between hallucal dorsiflexion and sesamoid length leads to the idea that, the longer the sesamoids, the less dorsiflexion for the hallux. Given the characteristics of the sample of this study, we think

that the increase in sesamoid length is a morphological factor that, together with other factors, could be related to the etiology of the deformity. Further research would be necessary to elucidate what effect is producing the increased length of the sesamoids in the normal mechanics of the first ray and the hallux.

Conclusion

There was no significant difference in the position of the sesamoids between the normal and hallux limitus feet in this study. That is, the sesamoids were not situated more proximally in the feet with hallux limitus than in the normal feet. However, we have found significant differences in the length of the two sesamoids upon comparing the two groups. The sesamoids of feet with hallux limitus were significantly longer than those of normal feet. Given that the individuals in the hallux limitus group were characterized by presenting the deformity in its initial phase, we think that the alteration in the length of the sesamoids could be related to the mechanism producing the hallux limitus. However, further research is necessary to determine the effects of this alteration on the normal function of the hallux.

Financial Disclosures: None reported.
Conflict of Interest: None reported.

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