LENGTH OF THE FIRST METATARSAL AND HALLUX IN HALLUX VALGUS IN INITIAL STAGE

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ABSTRACT

The aim of this study is to confirm whether the length of the first metatarsal and the length of the hallux are greater than normal in the initial phase of the hallux valgus deformity. In a sample of 152 radiographs (98 of normal feet and 54 of incipient hallux valgus feet), the length of the first metatarsal and the hallux was measured according to methods previously described. Comparisons were made between normal and hallux valgus feet, and between male and female feet. The results show significant differences between the two groups in the first metatarsal ($P < 0.0001$) and hallux ($P < 0.001$). In the male feet, these differences are more marked (when comparing the length of the hallux between the female hallux valgus feet and the female normal feet, $P > 0.05$). This indicate that in men with hallux valgus, the excess in length of the first metatarso-digital segment is greater than in women that present this deformity, at least in its initial phase. According to these results, the size of the first metatarso-digital segment could be involved in the development of the hallux valgus deformity.

INTRODUCTION

Many authors have referred in the podiatric and medical literature to an excessively long or excessively short first metatarsal as an etiology of hallux valgus. Excessive length of the first metatarsal with respect to the second has been associated to hallux valgus [9, 10, 13, 14] more often than has a short first metatarsal relative to the second

[23]. We also find authors who do not associate an alteration in the protrusion of the first metatarsal with hallux valgus [2, 3].

When a first metatarsal bone is said to be excessively long in absolute length, it does not mean that it is longer than the second, rather that the first metatarsal is longer than normal, while still shorter than the second. The association of an excessive absolute length of the first metatarsal and the deformity of hallux valgus has been reported previously [22]. However, there are also authors who state that in feet with this deformity, the first metatarsal is not longer than the second, rather it has a greater relative protrusion [14]. Paradoxically, an excessively short first metatarsal has also been attributed to the etiology of hallux valgus [23]. Also the alteration in the length of the hallux has been related with the etiology of hallux valgus, specifically an excessive length [8, 10, 18, 22].

In view of the different opinions in the literature regarding this matter, the present study was designed with the following aims: (1) to establish normal values for the lengths of the first metatarsal and hallux; (2) to confirm whether the lengths, absolute or relative, of the first metatarsal and hallux are greater than normal in the initial phase of the hallux valgus deformity, and (3) to assess the relationship between the lateral deviation of the great toe and the length of the first metatarsal and hallux.

MATERIALS AND METHODS

The subjects of the sample in this study were patients attending the Clinical Podiatric Service at the University of Seville since January 2004 to January 2006, and podiatry students who volunteered to take part in the research during the same period. After agreeing to participate in the study, each subject was asked to give written consent. This work has been approved by the Experimental Ethics Committee of the University of Seville.

The subjects participating in the study had to fulfill the following inclusion criteria: (1) to be in the third decade of life (20-29 years), so that the growth physes had closed [20]; (2) never to have undergone osteoarticular surgery of the foot; (3) never to have suffered serious traumatisms to the foot that might have altered its bone morphology; (4) not to suffer from degenerative osteoarticular diseases or neuromuscular imbalance; and (5) not to present evident deformities of the forefoot that could affect the results of the study. First, subjects were recruited and radiographed. Then, the hallux abductus angle (henceforth, HAA) and hallux dorsiflexion were measured so that they would be allocated to one of the two study groups: a control group and a group of feet with hallux valgus (henceforth, HV group). The subjects comprising the control group had to have a hallux dorsiflexion of 65º or more, and a normal HAA — that is, equal to or less than 15º [4]. The subjects of the HV group had to present an HAA greater than 15º and less than 30º. This range was established according to the mild condition of hallux valgus previously reported [11]. A total of 92 subjects (184 feet) were initially included. HAA values of 14º, 15º, and 16º were eliminated in an attempt to reduce error probability in the measuring procedure, due to the proximity of those values to the limit between normal and abnormal abduction of the hallux. Of the 152 resting feet (76 subjects), 98

formed the control group (49 subjects) and 54 the HV group (27 subjects). All the cases were bilateral.

A dorsoplantar weightbearing radiograph was taken for each individual, with both feet together, with the tube inclined 15º to the vertical and at a tube-to-object distance of one meter. A digital image of each radiograph was made using a scanner, allowing the exploration of images on positive film. The radiographic measurements were made using the AutoCAD® software (AutoCAD 2006; Autodesk Inc, San Rafael, California), of proven efficacy for this task [17]. The following variables were studied: relative protrusion of the first metatarsal, length of the first metatarsal, length of the proximal phalanx of the hallux, length of the distal phalanx of the hallux, and length of the hallux (obtained from the sum of the lengths of the proximal and distal phalanges of the hallux). Other measurements made were the HAA and the length of the second metatarsal. All measurements were made by the same observer.

All the radiographic parameters were measured in accord with previously described procedures: HAA [4], the relative first metatarsal protrusion [9] (figure 1), the lengths of the first and second metatarsals [10] (figure 2), the length of the proximal phalanx of the hallux [21] (figure 3), as well as the length of the distal phalanx [5].

To standardize the set of measurements of the length of the first metatarsal, of the proximal and distal phalanges of the hallux, and of the hallux, these measurements have also been expressed as a percentage of the total length of the second metatarsal. These variables have been denominated “relative”, to distinguish them from the absolute values.

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 intervals of a week between measurements. The data obtained from this group of measurements was used to calculate the intraclass correlation coefficient. The descriptive analysis gave the mean, standard deviation, and interval of confidence to 95% for each variable. To decide whether to use parametric or non-parametric tests, the Kolmogorov-Smirnov test was performed as a check of normality. Its result suggested that the t-Student test for independent samples was the best to use for comparing the means between the control group and the HV group, because the data followed a normal distribution. The test of Levene was used for the equality of variance. Pearson correlation coefficients were calculated to assess the degree of relationship between the HAA and length of the first metatarsal, protrusion of the first metatarsal, lengths of the proximal and distal phalanges of the hallux, and length of the hallux. P values below 0.05 were considered statistically significant. The data were analyzed using the software package SPSS 12.0 for Windows (SPSS Science, Chicago, Illinois).

RESULTS

The value of the intraclass correlation coefficient was greater than 0.95 for all the variables measured on the radiographs. All these coefficients can be considered very high, so that the reproducibility of the measurements is acceptable with the methods used.

The control group comprised 98 feet of 49 subjects, 19 men and 30 women, with a mean age of 23.44 ± 2.85 years. The HV group comprised 54 feet of 27 subjects, 11 men and 16 women, with a mean age of 23.15 ± 2.22 years.

The values from the descriptive analysis of the variables (absolute and relative values) are shown in table I. Comparisons were made using the relative values of the variables, except for first metatarsal protrusion.

When comparisons are made between control and HV groups with separated male and female feet, results change (table II). In female hallux valgus feet, the excess of length affects only the first metatarsal, not the hallux. In male hallux valgus feet, variables related to the lengths of the first metatarsal and hallux appear increased.

The values of the variables shown in table II for the male feet are different from those for the female feet. When these variables are compared between men and women, lengths of the first metatarsal and distal phalanx of the normal male feet are different from those of the normal female feet ($P < 0.01$). In the HV group, lengths of the distal phalanx and hallux of the male feet are different from those of the female feet ($P < 0.0001$). These results are shown in table III.

Poor-to-moderate association was found between HAA and first metatarsal protrusion ($r = 0.498$, $p< 0.0001$), first metatarsal length ($r = 0.443$, $p< 0.0001$), proximal phalanx length ($r = 0.383$, $p< 0.0001$) and hallux length ($r = 0.258$, $p< 0.01$). Other correlations show some interesting data: strong and significant correlation was found between first metatarsal protrusion and first metatarsal length ($r = 0. 832$, $p< 0.0001$), between

proximal phalanx and hallux lengths ($r = 0.814$, $p < 0.0001$), and between distal phalanx and hallux lengths ($r = 0.759$, $p < 0.0001$).

DISCUSSION

The authors consider that the main limitation of this work is the use of two-dimensional images to evaluate tridimensional elements. It has been tried to reduce as far as possible the risk of errors related with this aspect, following a standardized and rigorous radiological protocol. Other studies have already demonstrated that whenever the radiography is performed with the same protocol, the differences with the actual situation can become non-significant, at least with regard to the first metatarso-digital segment [6].

Different authors have associated the increased protrusion of the first metatarsal to the hallux valgus deformity [9, 10, 13, 14]. The results of this study concur. The range of normality for the protrusion of the first metatarsal is considered -2 mm to +2 mm [13, 19, 21]. Thus, according to the results of the present study, in the initial phase of the pathology of hallux valgus there is an increased protrusion of the first metatarsal (0.84 mm ± 3.02 in the control group; 3.49 mm ± 3.36 in the HV group). Moreover, we have found that the first metatarsal is not only further forward than the second in the HV group (relative protrusion), but is also longer than normal (65.48 mm ± 4.67 in the control group; 67.91 mm ± 4.41 in the HV group).

Some authors maintain that in patients with hallux valgus, the length of the proximal phalanx is greater than in patients without hallux valgus [22]. Conversely, other studies

found no direct relationship between the length of this segment and the HAA [12]. However, an excessive total length of the hallux has been related with the hallux valgus deformity on several occasions [8, 10, 18, 22]. It can also be found authors who reject the possibility that a very long hallux is related with pathologies such as hallux valgus [14]. The results of the present study show that both, the proximal phalanx of the hallux and the great toe, are longer in the hallux valgus than in the normal feet ($P < 0.0001$ and $P < 0.001$, respectively) of this sample.

When comparisons between men and women are made, it is observed that, in the case of the male feet, both the proximal and the distal phalanges are longer than normal. In the female feet only the proximal phalanx is longer than normal. The result of this is that the hallux is significantly longer than normal in the men, possibly thanks to the additional contribution of the distal phalanx. However, in women there is no excessive length of the hallux, because the distal phalanx is not different between normal and hallux valgus feet, and because the difference in the proximal phalanx is lower than in men feet.

When the protrusion of the first metatarsal, the length of the first metatarsal, the length of the proximal phalanx of the hallux, or the total length of the hallux, are separately analyzed, the differences found between the control and HV groups might be considered clinically insignificant (although they were statistically significant), as they are relatively small differences. Nevertheless, the authors think that these differences should be considered non-isolated. In fact, it has been observed a strong, and very significant association between the protrusion and length of the first metatarsal, indicating that it is very possible that when the protrusion of the first metatarsal is increased, its length is as

well. The relationship between these two variables and the length of the hallux or its proximal phalanx is lesser, but still very significant. Thus, when the increases in length of these elements are combined, the result will be a very long first metatarso-digital segment.

If the lever comprised by the first metatarsal and the hallux is over-long, the pressure received by the hallux in the push-off phase of gait [1], and the pressure from the footwear, generate the need to shorten that lever. One way to achieve this functionally is by producing segmentary deviations in the transverse plane. The deviations that must be produced in the first metatarsal and the hallux to compensate this excessive length require a joint that allows movement in the transverse plane, so that it acts as a hinge. When excessive length is combined with a rounded shape of the head of the first metatarsal — as is very frequent in the hallux valgus deformity [7, 9, 15] — the deviation takes place at the level of the metatarsophalangeal joint (figures 4 and 5). The hallux moves in abduction because under normal conditions it is already found slightly in this position [16]. If this hypothesis is accepted, the shortening of the bone following osteotomies for the surgical correction of hallux valgus could be a beneficial secondary effect of hallux valgus surgery in some cases. It needs to be made clear that this is, indeed, a hypothesis, and that there is no directly supporting evidence – the elaboration of hypotheses on the development of foot deformities on the basis of morphological or functional measurements by mean of further longitudinal studies of pathogenesis would be necessary.

It has been observed that in both the male and female feet, the protrusion of the first metatarsal, and the lengths of the first metatarsal and the proximal phalanx of the hallux,

are increased with respect to the control group. However, the values of the differences of these three variables between males and females are higher for the male feet than for the female feet. In the case of the men, the excessive length of the distal phalanx, and of the great toe, must also be added. It is possible that to arrive at the same degree of lateral deviation of the hallux, the male feet need to have a greater increase in length of the first metatarso-digital segment than do the female feet, to produce the compensation mentioned above, as women usually have a more-rounded head of the first metatarsal [7], so that the movement in the transverse plane would be produced with less difficulty — that is, with lower intensity of the forces that deviate the hallux laterally. This could be the aim of further research.

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Table I. Mean, standard deviation, and 95% confidence interval, of the absolute and relative variables.

	Absolute values		Relative values		Significance
	Mean ± SD	**95% CI**	**Mean ± SD**	**95% CI**	
Hallux dorsiflexion					
Control	75.00 ± 8.67	73.26 – 76.74	-	-	-
HV	61.71 ± 14.08	57.79 – 65.63			
HAA					
Control	8.73 ± 3.37	8.06 – 9.41	-	-	-
HV	20.50 ± 2.73	19.74 – 21.26			
1MTT protrusion					
Control	0.84 ± 3.01	0.24 – 1.45	-	-	< 0.0001*
HV	3.49 ± 3.36	2.55 – 4.43			
1MTT length					
Control	65.48 ± 4.67	64.54 – 66.41	84.27 ± 2.83	83.70 – 84.84	< 0.0001*
HV	67.91 ± 4.41	66.68 – 69.13	86.26 ± 3.00	85.42 – 87.09	
2MTT length					
Control	77.81 ± 6.47	76.51 – 79.11	-	-	-
HV	78.54 ± 5.51	77.04 – 80.04			
PFH length					
Control	32.70 ± 3.22	32.06 – 33.35	42.05 ± 2.57	41.53 – 42.57	< 0.0001*
HV	34.57 ± 2.61	33.84 – 35.30	43.92 ± 2.52	43.22 – 44.63	
DFH length					
Control	24.09 ± 2.84	23.51 – 24.66	30.94 ± 2.45	30.45 – 31.43	0.292
HV	24.75 ± 2.84	23.96 – 25.54	31.37 ± 2.31	30.73 – 32.02	
Hallux length					
Control	56.79 ± 5.53	55.69 – 57.90	72.99 ± 3.82	72.22 – 73.76	< 0.001*
HV	59.32 ± 5.10	57.90 – 60.75	75.30 ± 3.98	74.20 – 76.41	

Table II. Comparison of first metatarsal protrusion and relative variables between control and HV groups with separated male and female feet.

	MALE FEET		FEMALE FEET	
	Mean ± SD	**P**	**Mean ± SD**	**P**
1MTT protrusion				
Control	0.32 ± 4.09	< 0.01*	1.17 ± 2.07	< 0.0001*
HV	3.61 ± 4.04		3.57 ± 2.81	
1MTT length				
Control	83.23 ± 3.00	< 0.01*	84.89 ± 2.55	< 0.01*
HV	85.94 ± 3.11		86.56 ± 2.89	
PFH length				
Control	41.94 ± 2.53	< 0.0001*	42.12 ± 2.62	< 0.05*
HV	44.63 ± 1.76		43.63 ± 2.93	
DFH length				
Control	31.77 ± 2.25	< 0.05*	30.41 ± 2.45	> 0.5
HV	32.87 ± 1.67		30.28 ± 2.11	
Hallux length				
Control	73.71 ± 4.00	< 0.0001*	72.54 ± 3.67	> 0.5
HV	77.51 ± 2.64		73.69 ± 4.06	

Table III. P values from the comparison of the first metatarsal protrusion and relative variables of the male and female feet, of both the control and the HV group.

	CONTROL **Male Feet vs Female Feet** **(P values)**	**HALLUX VALGUS** **Male Feet vs Female Feet** **(P values)**
1MTT protrusion	0.178	0.971
1MTT length	0.008*	0.446
PFH length	0.731	0.159
DFH length	0.007*	< 0.0001*
Hallux length	0.140	< 0.0001*

TABLE LEGENDS

TABLE I. HAA: hallux abductus angle; 1MTT: first metatarsal; 2MTT: second metatarsal; PFH: proximal phalanx of the hallux; DFH: distal phalanx of the hallux. Hallux dorsiflexion and HAA are expressed in degrees. First metatarsal protrusion and absolute variables are expressed in millimeters. Relative variables are expressed in percentage of the second metatarsal length. * The difference was statistically significant.

TABLE II. First metatarsal protrusion is expressed in millimeters. Relative variables are expressed in percentage of the second metatarsal length.

TABLE III. * The difference was statistically significant.

Figure 1

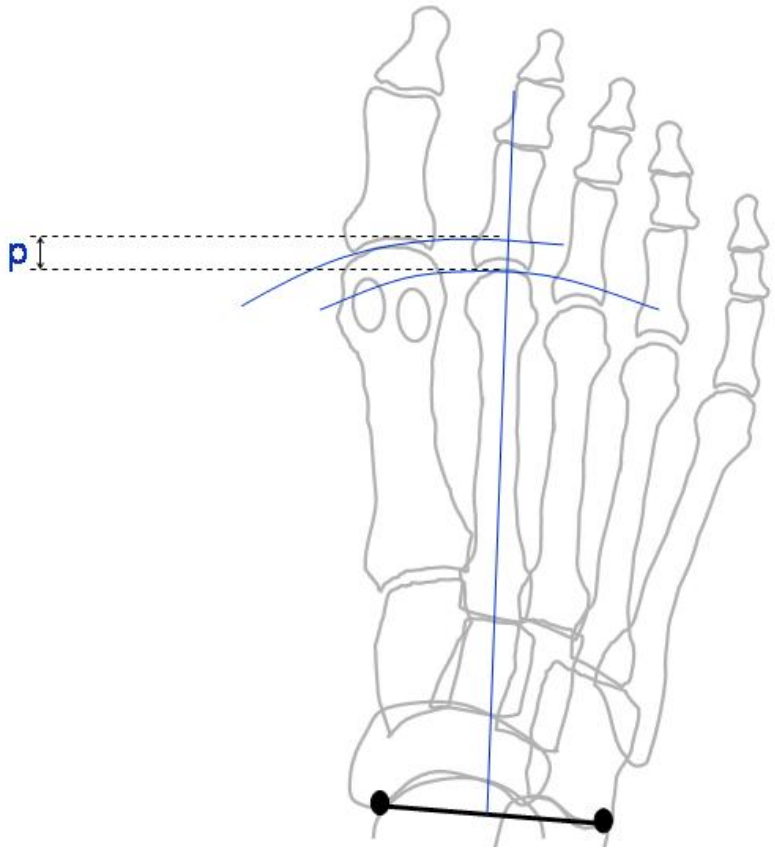

Figure 2

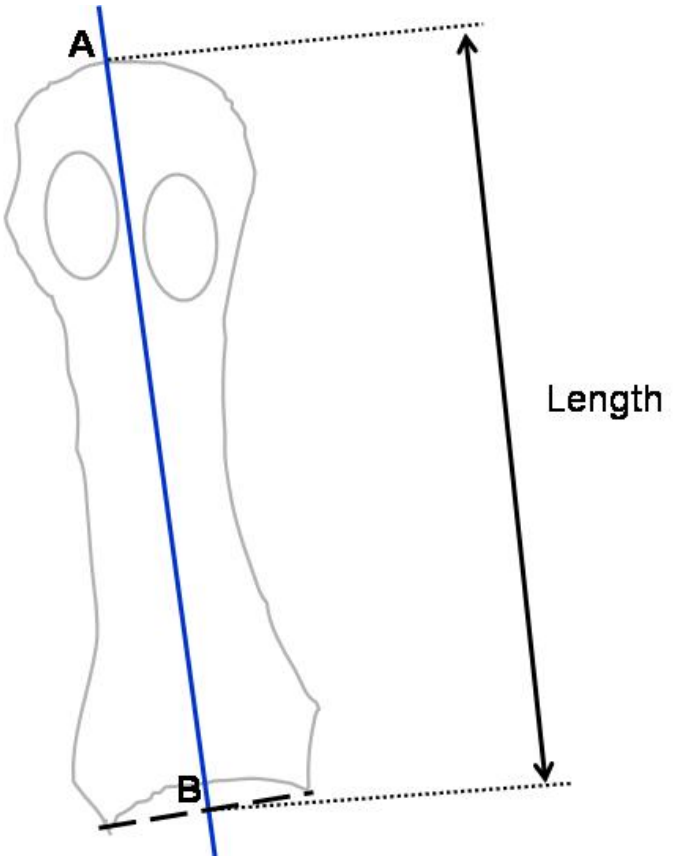

Figure 3

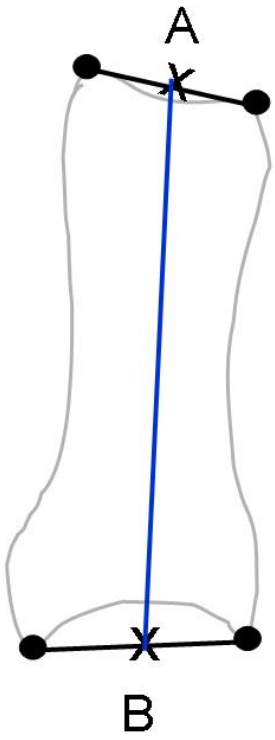

Figure 4

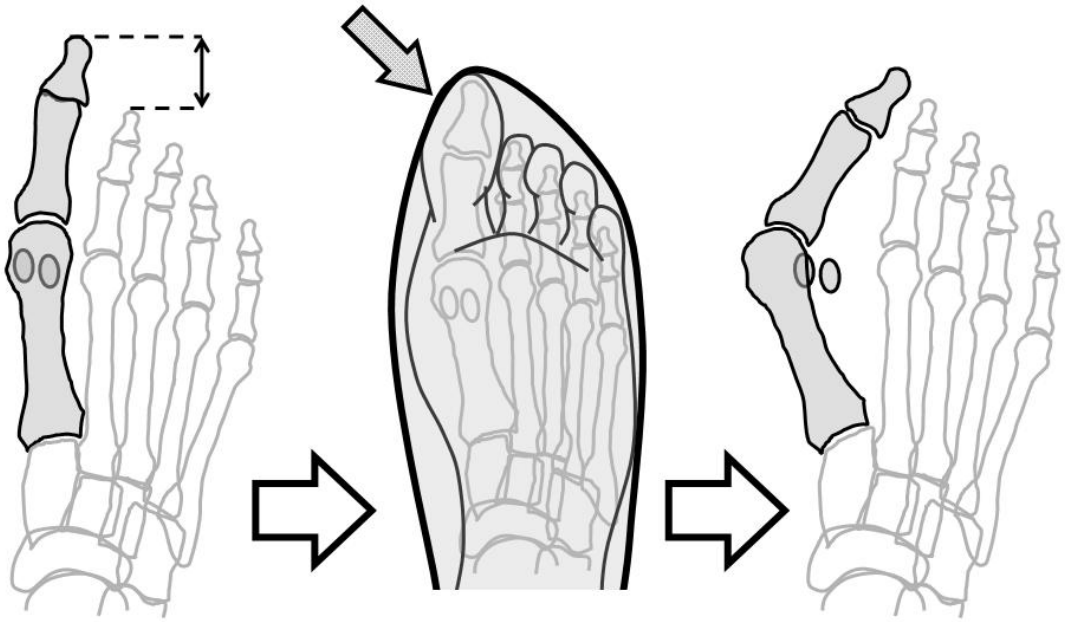

Figure 5

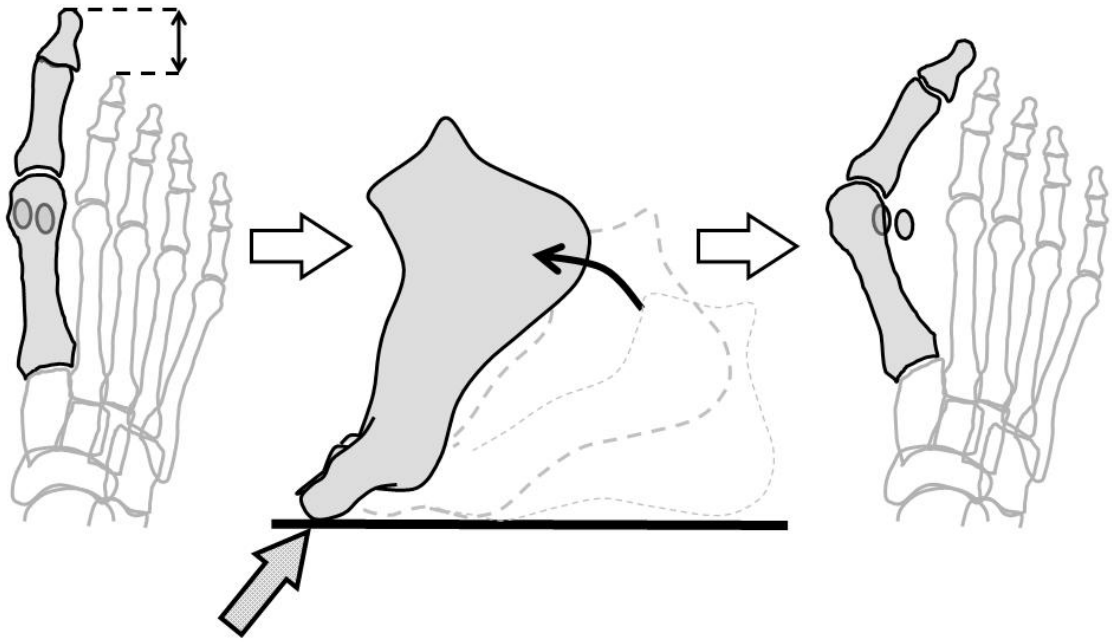

FIGURE LEGENDS

FIGURE 1. Method of measuring the relative metatarsal protrusion between the first and second metatarsals, according to Hardy and Clapham (1951). p: protrusion.

FIGURE 2. Method of measuring the length of the first and second metatarsals. A: Distal end of the first metatarsal head. B: point of intersection of the longitudinal axis of the metatarsal.

FIGURE 3. Method of measuring the length of the proximal phalanx of the hallux. A: Midpoint between the distal-medial and distal-lateral ends of the phalanx head. B: Midpoint between the proximal-medial and proximal-lateral ends of the phalanx head.

FIGURE 4. With a long first metatarso-digital segment, pressure from the fore part of the shoe trends to deviate the hallux laterally. Grey arrow: pressure from the footwear.

FIGURE 5. Pressure on the hallux in the push-off phase in gait trends to deviate the hallux laterally. Grey arrow: pressure received by the hallux in the push-off phase of gait.