Foot & Ankle International

Medial Deviation of the First Metatarsal in Incipient Hallux Valgus Deformity

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ABSTRACT

Background: **The aim of this study was to determine whether excessive medial deviation of the first metatarsal (excessive intermetatarsal angle) is present in the initial phase of hallux valgus.** ***Methods:*** **The intermetatarsal angle between the first and second metatarsals (1-2 IMA) was radiographically studied in 49 normal feet and in 49 feet with mild hallux valgus deformity.** ***Results:*** **The results demonstrated a statistically significant difference in the mean intermetatarsal angle between the two groups (8.76 degrees in normal feet; 9.98 degrees in affected feet). However, we believe that is not clinically significant. Other authors, comparing the 1-2 IMA in patients with or without more advanced hallux valgus, reported greater differences than those obtained in this study.** ***Conclusions:*** **Excessive medial deviation of the first metatarsal is not a causal factor but rather a consequence of hallux valgus deformity.**

Key Words: Etiology; First Metatarsal Deviation; Hallux Valgus

INTRODUCTION

Hallux valgus has a basic functional etiology, regardless of neurological, traumatic, iatrogenic, or degenerative causes, or external factors such as shoewear. The basic etiology usually is a biomechanical deficiency in more proximal joints, such as the subtalar or midtarsal joint.[36] However, various morphological factors are associated with the onset of the deformity. One such factor is medial deviation of the first metatarsal, which has been widely associated with hallux valgus deformity,[1,11,13,15,18,23,35,42,43] sometimes as a cause and sometimes as a consequence.

The theory that the primary cause of hallux valgus deformity is excessive medial deviation of the first metatarsal has been upheld by Truslow,[45] Jones,[16] and Bonney and Macnab.[3] Scott et al.[35] suggested that the intermetatarsal angle between the first and second metatarsals (1–2 IMA) is the best measurement for evaluating medial deviation of the first metatarsal in the transverse plane. Studies such as those of Banks et al.[1] reported low 1–2 IMA values in adolescents, indicating that excessive separation between the first and second metatarsals is secondary to the development of hallux valgus. Root et al.[31] and Michaud[27] also maintained that increased medial deviation of the first metatarsal is secondary to hallux valgus development, because this deviation occurs in advanced phases of the deformity. Piggott[30] asserted that both lateral deviation of the hallux and medial deviation of the first metatarsal increase with age. In the latter study, the high 1–2 IMA values observed in the oldest patients were not seen in younger ones. Therefore, it seems probable that the disorder is secondary to lateral displacement of the proximal phalanx of the first toe.

The aim of this study was to investigate whether excessive medial deviation of the first metatarsal is a primary etiological factor in the development of hallux valgus; that is, whether it is present at the onset of hallux valgus. The hypothesis of the study was that in the initial phase of the hallux valgus deformity, medial deviation of the first metatarsal (if it exists) is among or very similar to the normal values reported by other authors. This would suggest that the deviation increases as the deformity advances.

MATERIALS AND METHODS

The study included 76 individuals (98 feet: 51 left and 47 right), of whom 56 were women and 20 were men, with a mean age of 23.07 ± 2.64 years. The subjects were patients of the clinical foot service at the University of Seville during 2004 and 2005. To take part in the study, the patients had to meet a series of conditions: (1) be between 20 and 29 years of age, (2) never had osteoarticular surgery on the foot, (3) never had serious foot trauma, (4) did not suffer from degenerative diseases or neuromuscular imbalances,

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and (5) had no evident deformities of the forefoot (apart from hallux valgus).

Two groups were formed: one of normal feet (control group) and one of mild-hallux valgus feet. The individuals in the control group, besides meeting the aforementioned conditions, had to have a hallux valgus angle (HVA) not exceeding 15 degrees and dorsiflexion of the first metatarsophalangeal joint of more than 65 degrees. The individuals of the hallux valgus group, besides meeting the aforementioned conditions, had to have an HVA of more than 15 degrees and less than 30 degrees.

The control group comprised 49 feet (43 individuals: 12 men and 31 women, age 22.63 ± 2.38 years) of which 29 were left and 20 right. The hallux valgus group comprised 49 feet (of 33 individuals: eight men and 25 women, age 23.51 ± 2.83 years) of which 22 were left and 27 were right.

After accepting participation in the study, the patients were required to give written consent. The study was approved by the governing body of the Podiatry Clinic of Seville University before data collection was begun.

Dorsiflexion of the first metatarsophalangeal joint was measured in all feet. A dorsoplantar radiograph was obtained in each patient, with both feet together,[6] the beam centered between the navicular bones of both feet,[14] with the tube at an inclination of 15 degrees[25] and a distance of 1 m.[32,37]

Each radiograph was digitized, using a scanner able to explore images on positive film (EPSON EXPRESSION 1680 Pro®, Epson Corporation, Nagano, Japan) to create a digital image. Measurements were made on the digitized images using AutoCAD® (Autodesk, Inc., San Rafael, California) software. This software is used in Architecture and Engineering for the design of structures and buildings. Its functions include the measurement of angles, for which it was used in this study. Farber et al.[8] demonstrated that the measurement of certain angles on radiographs with a digital system is valid and improves interobserver and intraobserver reliability as compared with the use of the analogical technique of goniometer and pencil.

To check that the digitization process did not distort the real size of the radiograph, a millimeter-scale ruler was digitized, and the distance was measured between 2 centimeter and between 2 millimeter marks. The result was 10.00 and 1.00 respectively, confirming that the real size of the original image was not altered.

The HVA and the 1–2 IMA were measured in accordance with the procedure described by Coughlin et al.[7] All the measurements were made by the same observer (PVM).

To check the reliability of the measurement procedure, three feet of the control group and three of the hallux valgus group were chosen at random, and the HVA and 1–2 IMA were measured three times at weekly intervals. The intraclass coefficient of correlation was calculated using the data obtained from this group of measurements.

To decide whether to use a parametric or nonparametric contrast test for comparison of the two angles between the two study groups, the Shapiro-Wilk test was performed as a check of normality. Its result suggested that the Mann-Whitney U test was the best to compare the HVA and 1–2 IMA between the control group and the hallux valgus group. Any p value of lower than 0.05 was considered statistically significant.

Table 1: HVA and 1–2 IMA values for the subjects of both the control and hallux valgus groups

	Control group ($n = 49$)		**HV group ($n = 49$)**	
	Obtained values (degrees)	**Number of subjects**	**Obtained values (degrees)**	**Number of subjects**
HVA	4	3	16	9
	6	2	17	4
	7	2	18	5
	8	6	19	1
	9	6	20	7
	10	3	21	4
	11	9	22	4
	12	4	23	3
	13	2	24	3
	14	7	25	4
	15	5	26	3
	—		28	1
	—		29	1
IMA 1–2	4	1	4	1
	5	2	5	1
	6	2	6	3
	7	6	7	2
	8	6	8	6
	9	15	9	7
	10	12	10	8
	11	3	11	7
	12	1	12	9
	13	1	13	2
	—		15	2
	—		16	1

HVA = hallux valgus angle; IMA 1–2 = first and second intermetatarsal angle; HV = hallux valgus.

RESULTS

The values of the HVA and 1–2 IMA obtained for both the control and the hallux valgus groups are shown in Table 1.

The intraclass coefficient of correlation for the HVA and 1–2 IMA were 0.997 (IC 95%: lower limit 0.989, upper limit 1.000; $p < 0.0005$) and 0.886 (IC 95%: lower limit 0.519, upper limit 0.983; $p < 0.005$), respectively. This suggests that the reproducibility of the measurements is acceptable.[4,5]

The results of the test of normality are shown in Table 2. As the data did not follow a normal distribution, it was decided to use a nonparametric Mann-Whitney U test for independent samples.

The difference of the HVA and of the 1–2 IMA was statistically significant ($p < 0.0005$ and $p < 0.05$, respectively). The values of the mean, standard deviation, median and range are shown in Table 3 for the HVA and in Table 4 for the 1–2 IMA.

Table 2: Shapiro-Wilk test of HVA and 1–2 IMA for the control group and the hallux valgus group (to determine statistical normality)

	Shapiro-Wilk
HVA	
Control group	0.031
HV group	0.009
IMA 1–2	
Control group	0.023
HV group	0.417

HVA = hallux valgus angle;
IMA 1–2 = intermetatarsal angle between the first and second metatarsals;
HV = hallux valgus.

Table 3: Comparison of HVA between the control group and the hallux valgus group

HVA	Control group ($n = 49$) (degrees)	HV group ($n = 49$) (degrees)
Median	11	20
Range	4–15	16–29
Mean	10.53	20.59
Standard deviation	3.08	3.63
Significance (P)	0.0001	

HVA = hallux valgus angle; HV = hallux valgus.

DISCUSSION

A comparative study was undertaken of the medial deviation of the first metatarsal between a group of feet in which the hallux valgus deformity was absent and another group in which the deformity was present in the initial phase. In contrast with earlier studies on the topic,[17,26] only patients between the ages of 20 and 29 years were studied in the present work, with the hallux valgus present in a mild form, (HVA of less than 30 degrees). This excluded individuals who, while meeting the criteria of inclusion for the hallux valgus group, were beyond the third decade of life and had an HVA of 30 degrees or more. As the aim of the present work was to study a possible etiological factor of the deformity, high values of both age and HVA were excluded so that if variations in normality were detected, they were not attributed to the progression of the hallux valgus deformity.

Table 4: Comparison of 1–2 IMA between the control group and the hallux valgus group

HVA	Control group (n = 49) (degrees)	HV group (n = 49) (degrees)
Median	9	10
Range	4–13	4–16
Mean	8.76	9.98
Standard deviation	1.77	2.52
Significance (P)	0.006	

HVA = hallux valgus angle; IMA 1–2 = first and second intermetatarsal angle; HV = hallux valgus.

The results showed a statistically significant difference in the 1–2 IMA between the two groups. The authors consider that this difference, although statistically significant, was not clinically significant. That is, the mean values obtained in both the control and hallux valgus groups (8.76 degrees and 9.98 degrees, respectively) were within the range of normal values offered by most authors for this angle. Hardy and Clapham[11] assigned a range of 0 to 17 degrees. For Laporta et al.[21,22] the normal value of 1–2 IMA ranged between 0 and 14 degrees in a rectus foot type, and between 0 and 12 degrees in an adductus foot type. Tachdjian[40] considered this angle normal whenever it did not exceed 10 degrees. Steel et al.[39] offered a wider range of between 4 and 23 degrees, and stated that 90% of normal feet have a value equal to or less than 10 degrees. Palladino,[28] Valero,[46] Sanner,[34] and Martín and Pontious[24] asserted that the normal value of this angle should be between 8 and 12 degrees for rectus foot type, and between 8 and 10 degrees for adductus foot type. Scott et al.[35] obtained a normal range of 4 to 14 degrees in their study. From the classification of Mercado[26] for 1–2 IMA, the values obtained in the present study for both the control group and the hallux valgus group would be described as mild (between 8 and 10 degrees). Gentili et al.[9] and Bryant et al.[4,5] classified values between 8 and 12 degrees as normal, without differentiating between rectus or adductus foot types.

Table 5: A comparison of 1–2 IMA between control group and hallux valgus group from studies performed by various authors

Authors	Group	Sample size	Age (years)	HVA (mean ± SD)	IMA 1–2 (mean ± SD)
Hardy and Clapham[11] (1951)	Control	252 feet	16–65	15.7°	8.5°
	HV	165 feet	20–66	32°	13°
Houghton and Dickson[15] (1979)	Control	30 feet	"adults"	16.7 ± 1.3°	9.5 ± 2.2°
	HV	75 feet	23	30 ± 7.2°	13.6 ± 3.3°
Heden and Sorto[13] (1981)	Control	100 X-rays	-	12.27 ± 5.4	8.12 ± 2.2
	HV	200 X-rays	-	26.54 ± 10.36	12.21 ± 3.45
Scott et al[35] (1991)	Control	100 feet	47	13°	3°
	HV	100 feet	44	32°	13°
Tanaka et al[42] (1995)	Control	94 feet	41	9.7 ± 4.6°	9.8 ± 2.0°
	HV	177 feet	44	30.2 ± 9.3°	15 ± 3.1°
Talbot and Saltzman[41] (1997)	Control	30 patients	41	12 ± 5.1°	9.1 ± 2.0°
	HV	39 patients	42	30.2 ± 11.1°	15 ± 5.3°
Bryant et al[4] (2000)	Control	30 patients	39.8	10.3 ± 4.0°	9.4 ± 1.9°
	HV	30 patients	51.3	26.3 ± 6.3°	13 ± 3.0°
Tanaka et al[43] (2000)	Control	94 feet	-	9.7 ± 4.6°	9.8 ± 2.0°
	HV	229 feet	-	29.4 ± 9.0°	14.9 ± 3.1°
Thordarson and Krewer[44] (2002)	Control	50 feet	-	6.5°	8.8°
	HV	50 feet	-	27.9°	11.4°
Grebing and Coughlin[10] (2004)	Control	43 patients	46	10.6°	8.1°
	HV	43 patients	53	34.6°	15.4°
King and Toolan[19] (2004)	Control	15 patients	36	14 ± 4°	8 ± 2°
	HV	25 patients	48	36 ± 9°	15 ± 3°

HVA = hallux valgus angle; IMA 1–2 = first and second intermetatarsal angle; HV = hallux valgus.

Other works, in which comparisons of the 1–2 IMA in patients with and without hallux valgus formed part of the investigation, have demonstrated greater differences than those found in the present study.[4,10,11,13,15,19,35,41–44] The authors consider that such findings are the result of both the greater severity of the hallux valgus deformity and a higher mean age than in this study. These works are summarized in Table 5. The column for 1–2 IMA shows that values obtained for the difference between the two groups is greater than those obtained in the present study.

Lateral deviation of the first toe can cause medial deviation of the first metatarsal. Truslow[45] named this disorder *metatarsus primus varus* or simply a medial deviation of the first metatarsal resulting in an excessive distance between the heads of the first and second metatarsals. Because this deviation is mainly in the transverse plane, it would be more correct to speak of *metatarsus primus adductus* or *metatarsus primus adductovarus.*[29] Many authors have found a relationship between the grade of hallux valgus and the angle between the longitudinal axes of the first two metatarsals.[12,15,43] Ground reaction forces acting on the first toe during propulsion have a medial component that increasingly deviates the first metatarsal medially as the angle of deviation of the toe with respect to the longitudinal axis of the foot increases. Bojsen-Moller[2] calculated that the medial component of this force was equal to the ground reaction force acting on the deviated first toe multiplied by the tangent of the HVA. To this must be added the "bowstring" effect generated by the flexor hallucis longus and extensor hallucis longus tendons, which exert an abduction force on the hallux and consequently an adduction force on the first metatarsal, both of which increase the deformity (abduction and adduction with respect to the middle sagittal plane of the body). Sanders et al.[33] demonstrated that in feet with medial deviation of the first metatarsal, there was a correlation between the flexor moment acting on the first metatarsophalangeal joint and the increased medial deviation of the first metatarsal. Snijders et al.[38] postulated that as the HVA increases there is an exponential increase of the abductor moment in the first metatarsophalangeal joint and of the adductor moment in the first cuneometatarsal joint when the flexor muscles contract. Snijders et al.[38] described a biomechanical model by which the medial deviation of the first metatarsal increases with progression of the hallux valgus deformity, with the flexor hallucis longus playing an important role in the increase. This model was later validated by Sanders et al.[33] in patients with hallux valgus. The tendon of the flexor hallucis longus passes below the first metatarsophalangeal joint, between the two sesamoids, and through the plantar aspect of the intersesamoid ligament. In a normal foot, the vertical axis of the metatarsophalangeal joint passes directly through this tendon, such that when the muscle contracts, the direct posterior force produces plantar stabilization of the hallux and compression in the joint. In feet with hallux valgus, with the sesamoids displaced laterally, the vertical axis, around which the movement in the transverse plane is produced, falls medially to the flexor hallucis longus tendon (Figure 1). This generates a lever effect, which does not normally exist between this tendon and the vertical axis (Figure 1, double-headed arrow "A"). The combination of the force produced by contraction of the flexor hallucis longus (Figure 1, arrow "B") and that produced by friction force of the first toe with the ground (Figure 1, arrow "C") generates a vector of force posteriorly, parallel to the longitudinal axis of the deviated proximal phalanx (Figure 1, arrow "D"). To achieve a balance of forces in the transverse plane, resistance is generated on the first cuneometatarsal joint, equivalent to a vector of force equal in magnitude to that exercised by the first toe against the metatarsal, but in the opposite direction (Figure 1, arrow "E"). This pair of forces produces a counterclockwise rotational moment that tends to deviate the first metatarsal in adduction (Figure 1, striped arrow).

The distancing of the flexor hallucis longus tendon from the head of the first metatarsal has a greater effect than

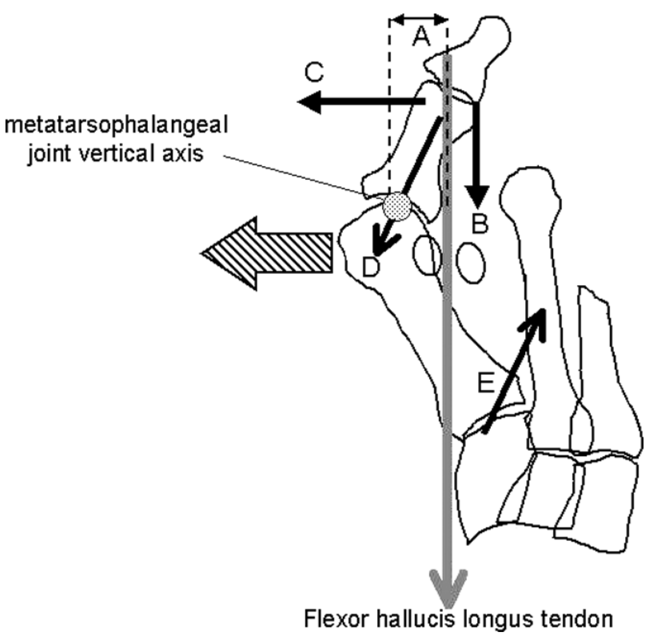

Fig. 1: Model explaining how the medial deviation of the first metatarsal is secondary to progression of the HV deformity. (Model adapted from **Snijders, CJ; Snijder, JG; Philippens, MM:** Biomechanics of hallux valgus and spread foot. Foot Ankle. **7**:26–39, 1986).

that of the extensor hallucis longus tendon.[20] The extensor hallucis longus tendon contributes to the development of hallux valgus only in advanced deformity.[29] A study by Lamur et al.[20] corroborated this and validated the model of Snijders et al.[38] Lamur et al.[20] determined the position and the lever arm of the extensor hallucis longus and flexor hallucis longus tendons in relation to abduction of the hallux and the adduction of the first metatarsal and observed that the HVA increased with increased distance of these tendons from the head of the first metatarsal. This means that the longitudinal axes of the extensor hallucis longus and flexor hallucis longus tendons are laterally dislocated with respect to the first metatarsophalangeal joint. The significance of this is that contraction of these muscles, apart from generating movement around the transverse axis (flexor-extension movement), also generates movement around the vertical axis (adduction-abduction movement), specifically producing abduction of the first toe.[29] A noteworthy result of the study of Lamur et al.[20] is that the position of the flexor hallucis longus tendon with respect to the head of the first metatarsal contributes to the increase in the hallux valgus deformity more than the position of the extensor hallucis longus tendon. They obtained a direct and statistically significant correlation between the distance of the flexor hallucis longus tendon to the head of the first metatarsal and the separation between the first two metatarsals.

A deficiency of the present study was not to have included a group of feet severely affected by hallux valgus to compare the 1–2 IMA for this group with that for the group of slightly affected hallux valgus feet. Nonetheless, comparison of the results of this study with those obtained by other authors who used more severe deformities clearly shows greater differences of the 1–2 IMA between the two groups (Table 5). Future investigations by the authors of the present study will focus on covering this deficiency.

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