THE MEDIAL DEVIATION OF THE FIRST METATARSAL IN THE INCIPIENT HALLUX VALGUS DEFORMITY

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ABSTRACT

The intermetatarsal angle between metatarsals I and II (IMA 1-2) has been radiographicaly studied in 49 normal feet and in 49 feet with a mild hallux valgus (HV) deformity. The aim of the study is to know whether an excessive medial deviation of the first metatarsal with respect to II (IMA 1-2 over normal values reported by some authors) is present in the initial phase of HV.

The results demonstrate that the difference in the mean intermetatarsal angle between the two groups is statistically significant (8.76º in normal feet; 9.98º in affected feet). However, the authors think it is not clinically significant.

Other authors, comparing the IMA 1-2 in patients with more advanced HV and without HV, report greater differences than those obtained in this study,.

The authors conclude that the excessive medial deviation of the first metatarsal is not a causal factor, but a consequence, in the HV deformity.

INTRODUCTION

Hallux valgus (subsequently, HV) has a basic functional etiology, regardless of neurological, traumatic, iatrogenic, and degenerative causes, or external factors such as footwear. The basic etiology is usually a biomechanical deficiency in more-proximal joints, such as the subtalar and/or midtarsal joint (Seibel 1994). However, various morphological factors are associated with the onset of the deformity. One such factor is the medial deviation of the first metatarsal, which has been widely associated with the HV deformity (Hardy and Clapham 1951, Hardy and Clapham 1952, Lundberg and Sulja 1972, Houghton and Dickson 1979, Heden and Sorto 1981, Kilmartin et al. 1991, Scott et al. 1991, Banks et al. 1994, Tanaka et al. 1995, Tanaka et al. 2000), sometimes as a cause, and sometimes as a consequence.

The theory that the primary causal factor in the HV deformity is an excessive medial deviation of the first metatarsal is specifically upheld by authors such as Truslow (1925), Jones (1948), and Bonney and Macnab (1952). Scott et al (1991) suggested that the intermetatarsal angle between the first and second metatarsals (subsequently, IMA 1-2) is the best measurement for evaluating medial deviation of the first metatarsal in the transverse plane. Studies such as those of Banks et al (1994) report low values of IMA 1-2 in adolescents, indicating that excessive separation between first and second metatarsals is secondary to the development of HV. Root et al (1977) and Michaud (1996) also maintain that increased medial deviation of the first metatarsal is secondary to HV development, as it occurs in advanced phases of the deformity. Piggott (1960) asserts that both lateral deviation of the first toe and medial deviation of the first metatarsal increase with age. In the latter study, the high values of IMA 1-2 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 the present work is to investigate whether an excessive medial deviation of the first metatarsal is a primary etiological factor in the development of HV — that is, whether it is present at the onset of HV. The hypothesis of the study is that in the initial phase of the HV deformity, the medial deviation of the first metatarsal (if 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.

PATIENTS AND METHODS

The study has included 76 individuals (98 feet studied: 51 left and 47 right), of whom 56 were women and 20 men, with a mean age of 23.07 ± 2.64 years. The subjects were patients attending the Clinical Podiatric Service at the University of Seville in 2004 and 2005. To take part in the study, the subjects had to meet a series of conditions: be between 20 and 29 years of age, never have undergone osteoarticular surgery on the foot, never have suffered serious foot traumatisms, not suffer from degenerative diseases or neuromuscular imbalances, and not present evident deformities of the forefoot (apart from HV).

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

The control group comprised 49 feet (of 43 individuals: 12 men and 31 women, age 22.63 ± 2.38 years), of which 29 were left and 20 right. The HV group comprised 49 feet (of 33 individuals: 8 men and 25 women, age 23.51 ± 2.83 years).

After accepting participation in the study, the subject was required to give written consent. Then the dorsiflexion of the first metatarsophalangeal joint was measured. A dorsoplantar X-ray was made in each subject, with both feet together (Bryant 2001), the beam centred between the navicular bones of both feet (Horsfield 1991), with the tube at an inclination of 15º (McCrea et al. 1977) and a distance of 1 metre (Smith et al. 1984, Saltzman et al. 1994).

Each X-ray was digitised, using a scanner able to explore images on positive film (EPSON EXPRESSION 1680 Pro®) to create a digital image. Measurements were made on the digitised X-rays using AutoCAD® 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 (2005) have demonstrated that the measurement of certain angles on X-rays, using a digital system, is wholly valid, and improves inter- and intra-observer reliability as compared with the use of the analogical technique of goniometer and pencil.

To check that the digitisation process did not distort the real size of the X-ray, a millimetre-scale rule was digitised, and the distance was measured between two centimetre marks, and between two millimetre ones. 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 IMA 1-2 were measured in accord with the procedure described by Coughlin et al (2002). All the measurements were made by the same observer (PVM).

To check the reliability of the measurement procedure, 3 feet of the control group and 3 of the HV group were chosen at random, and the HVA and IMA 1-2 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 non-parametric 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 is the best to use for comparing the HVA and IMA 1-2 between the control group and the HV group. Any value of P lower than 0.05 was considered statistically significant.

RESULTS

The values of the HVA and IMA 1-2 obtained for both the control and the HV groups are shown in table I.

The intraclass coefficient of correlation for the HVA and IMA 1-2 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 (Bryant et al. 2000).

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

The difference of the HVA and of the IMA 1-2 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 III for the HVA, and in Table IV for the IMA 1-2.

DISCUSSION

A comparative study has been made of the medial deviation of the first metatarsal between a group of feet in which the HV deformity was absent and another group in which the deformity was present in the initial phase. In contrast with earlier studies on the topic, only subjects aged between 20 and 29 years are studied in the present work, with the disorder present in a mild form — that is, with an HVA of less than 30º (Kelikian 1965, Mercado 1995). This excludes individuals who, while meeting the criteria of inclusion for the HV group, are beyond the third decade of life, and have an HVA equal to or greater than 30º. As the aim of the present work is to study a possible etiological factor of the deformity, high values of both age and HVA are excluded, so that if variations in normality are detected, they are not attributed to the progression of the HV deformity.

The results show a statistically significant difference in IMA 1-2 between the two groups. The authors consider that this difference, although statistically significant, is not clinically significant. That is, the mean values obtained in both the control and HV groups (8.76º and 9.98º, respectively) are within the range of normal values offered by most authors for this angle. Hardy and Clapham (1951) assign a range of 0º to 17º. For Laporta et al (1974, 1994) the normal value of IMA 1-2 ranges between 0º and 14º in a rectus foot type, and between 0º and 12º in an adductus foot type. Tachdjian (1985) considers this angle normal whenever it does not exceed 10º. Steel et al (1980) offer a wider range, of between 4º and 23º, and state that 90% of normal feet have a value equal to or less than 10º. Palladino (1991), Valero (1992), Sanner (2003), and Martín and Pontious (2004) assert that the normal value of this angle should be between 8º and 12º for rectus foot type, and between 8º and 10º for adductus foot type. Scott et al (1991) obtained a normality range of 4º to 14º in their study. From the classification of Mercado (1995) for IMA 1-2, the values obtained in the present study for both the control group and the HV group would be described as mild (between 8º and 10º). Gentili et al (1996), and Bryant et al (2000) classify values between 8º and 12º as normal, without differentiating between rectus or adductus foot type.

Other works, in which comparison of IMA 1-2 in patients with and without HV has formed part of the investigation, have demonstrated greater differences than those found in the present study. The authors consider that such findings are the result of both the greater severity of the HV deformity and a higher mean age than in this study. These works are summarised in Table V. The column for IMA 1-2 shows that value obtained for the difference between the two groups is greater than that obtained in the present work.

Lateral deviation of the first toe can cause medial deviation of the first metatarsal. Truslow (1925) denominated this disorder *metatarsus primus varus* — that is, 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 adducto varus* (Phillips 1994). Many authors have found a relationship between the grade of HV and the angle between the longitudinal axes of the first two metatarsals (Hardy and Clapham 1952, Houghton and Dickson 1979, Tanaka et al. 2000). The 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 (1979) 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 develop an abductory force of the first toe and an adductory one of metatarsal I which increase with the deformity (abduction and adduction with respect to the middle sagital plane of the body). Sanders et al (1992) 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 (1986) postulated that as HVA increases, there is an exponential increase of the abductor moment in the first metatarsophalangeal joint and of the adductor moment in the first cuneo-metatarsal joint when the flexor muscles contract.

Snijders et al (1986) described a biomechanical model by which the medial deviation of the first metatarsal increases with progression of the HV deformity, with the flexor hallucis longus playing an important role in the increase. This model was later validated by Sanders et al (1992) in patients with HV. The tendon of the flexor hallucis longus passes below the first metatarsophalangeal joint, between the two sesamoids, 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 stabilisation of the hallux and compression in the joint. In HV feet, 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 (double-headed arrow “A”). The combination of the force produced by contraction of the flexor hallucis longus (arrow “C”) and that produced by friction force of the first toe with the ground (arrow “B”) generates a vector of force posteriorly, parallel to the longitudinal axis of the deviated proximal phalanx (arrow “D”). To achieve a balance of forces in the transverse plane, a resistance is generated in the first cuneo-metatarsal 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 (arrow “E”). This pair of forces produces an anti-clockwise rotational moment that tends to deviate the first metatarsal in adduction (striped arrow).

The distancing of the flexor hallucis longus tendon from the head of the first metatarsal has a greater effect than that of the extensor hallucis longus tendon (Lamur et al. 1996). The extensor hallucis longus contributes to the development of HV only when this is very advanced (Phillips 1994). A study carried out by Lamur et al (1996) corroborates this, and also validates the model of Snijders et al (1986). Lamur et al (1996) determined the position and the lever arm of the extensor hallucis longus and flexor hallucis longus tendons in relation to the abduction of the hallux and the adduction of the first metatarsal, and observed that the HVA increased with distance of these tendons to 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 (flexo-extension movement), will also generate movement around the vertical axis (adduction-abduction movement), specifically producing an abduction of the first toe (Phillips 1994). A noteworthy result of the study of Lamur et al (1996) 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 HV deformity more than does 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 metatarsal I and the separation between the first two metatarsals.

A deficiency of the present study is not to have included a group of feet severely affected by HV to compare the IMA 1-2 for this group with that for the group of slightly affected HV 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 IMA 1-2 between the two groups (table V). Future investigations by the authors of the present study will focus on covering this deficiency.

In accordance with the foregoing, the authors of this work concur with the theory relating medial deviation of the first metatarsal in the HV deformity with severe deformities developing over many years. Our justification is the results of this study, which demonstrate that in the initial phase of the HV deformity, the medial deviation of the first metatarsal is among, or very similar to, the normal values. Thus, we do not consider this disorder a causal factor of HV deformity, rather a consequence.

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Table I.

HVA and IMA 1-2 values for the subjects of both the control and HV 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

Table II.

Shapiro-Wilk test of HVA and IMA 1-2 for the control group and the HV group

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

Table III.

Comparison of HVA between the control group and the HV 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)	0.000	

Table IV.

Comparison of IMA 1-2 between the control group and the HV 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	

Table V.

A comparison of IMA 1-2 between control group and HV group from studies performed by various authors.

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

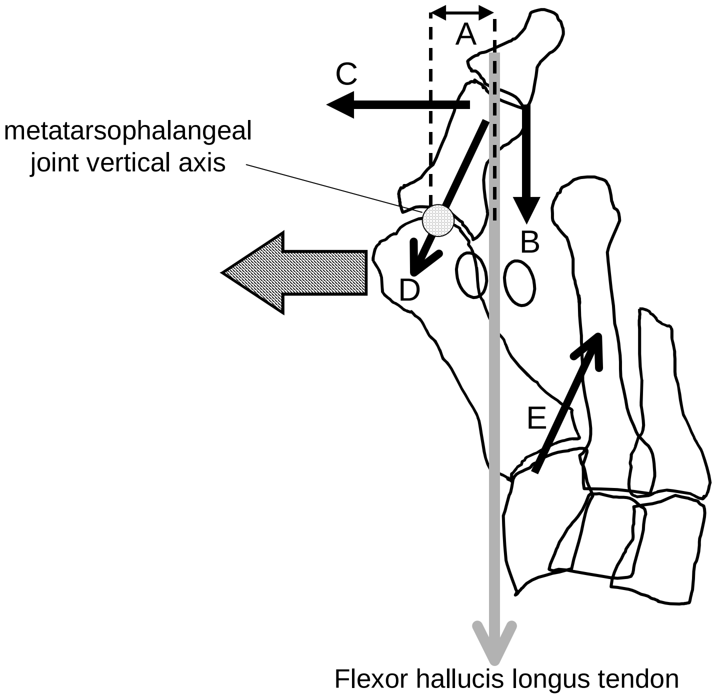

Figure 1.

Model explaining how the medial deviation of metatarsal I 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* 1986; 7: 26-39.