Hallux Abductus Interphalangeus in Normal Feet, Early-Stage Hallux Limitus, and Hallux Valgus

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Background: Excessive deviation of the distal phalanx in abduction frequently occurs in advanced stages of hallux rigidus but not in hallux valgus. Therefore, theoretically there should be no significant differences in the hallux interphalangeal angle (HIPA) between individuals with normal feet, those with hallux valgus, and those with mild hallux limitus. The objective of the present study was thus to determine if significant differences in HIPA exist in the early stages of hallux valgus or hallux limitus deformities.

Methods: The hallux interphalangeal angle was measured in three groups of participants: a control group with normal feet (45 participants), a hallux valgus group (49 participants), and a hallux limitus group (48 participants). Both of the pathologies were at an early stage. A dorsoplantar radiograph under weightbearing conditions was taken for each individual, and measurements (HIPA and hallux abductus angle [HAA]) were taken using AutoCAD (Autodesk Inc, San Rafael, California) software. Intergroup comparisons of HIPA, and correlations between HIPA, HAA, and hallux dorsiflexion were calculated.

Results: The comparisons revealed no significant differences in the values of HIPA between any of the groups (15.2 ± 5.9 degrees in the control group, 15.5 ± 3.9 degrees in the hallux valgus group, and 16.15 ± 4.3 in the hallux limitus group; P = 0.634). The Pearson correlation coefficients in particular showed no correlation between hallux dorsiflexion, HAA, and HIPA.

Conclusions: For the study participants, there were similar deviations of the distal phalanx of the hallux with respect to the proximal phalanx in normal feet and in feet with the early stages of the hallux limitus and hallux valgus deformities. (J Am Podiatr Med Assoc 104(2): 169-173, 2014)

Hallux abductus interphalangeus (HAI) is an alteration involving a lateral deviation of the distal phalanx of the hallux with respect to the proximal. The first literature report was of two patients in 1935.1 Unlike hallux valgus, this condition is commonly present at birth.2 Cases of HAI acquired for various reasons have been reported,3,4 and it has also been associated with certain congenital chromosomal abnormalities.5 Apart from the friction produced by the medial prominence of the hallux, the deviation may be related to more serious symptoms, especially in patients with at-risk foot.6

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that if the first metatarsophalangeal joint is stable in the transverse plane, the lateral forces that tend to divert the hallux (eg, shoe pressure, muscle action) will encounter greater resistance to lateral deviation in the metatarsophalangeal joint, resulting in interphalangeal joint involvement in the deviation, with an increase in HIPA.\textsuperscript{11} If, however, the metatarsophalangeal joint is unstable in the transverse plane, these forces will be at a mechanical advantage to produce the deviation in this joint instead.\textsuperscript{2}

Although a hallux deviation becomes more apparent with increasing severity of hallux valgus or hallux limitus, it is unknown whether the deviation of the distal phalanx is present in the initial phases of these deformities. If the deviation of the distal phalanx in abduction occurs only at very advanced stages of these pathologies, theoretically the difference in HIPA between individuals with hallux valgus and those with (mild to moderate) hallux limitus, and even between the latter and individuals with normal feet, would not be significant.

The objective of the present study was, therefore, to determine whether there are significant differences in HIPA in the early stages of hallux valgus or hallux limitus. Failure to find any such differences would lend support to the aforementioned theory that HAI is aggravated with the evolution of hallux limitus/rigidus but not with that of hallux valgus. Therefore, the null hypothesis was that, at least for the participants in the study, there would be no significant difference in HIPA between normal feet, hallux valgus feet, and hallux limitus feet (these last two groups both being restricted to early-stage deformities).

Materials and Methods

The sample for this study comprised 142 participants (55 women, 87 men), with a mean age of 23.6 ± 2.8 years. The participants were patients attending the Orthopaedic Service of the Clinical Podiatry Area of the University of Seville (Spain) who satisfied the criteria for inclusion and gave their written informed consent to voluntarily participate in the study. The study was approved by the Experimental Ethics Committee of the University of Seville.

The minimum sample size necessary to contrast the means was calculated with the formula $n = \frac{2 \times (Z_{\alpha} + Z_{\beta})^2 \times S^2}{d^2}$. For an error $\alpha$ of 0.05, a power of 95%, an SD of about 5.5 obtained from pilot studies of normal feet, and considering as relevant a difference between groups greater than or equal to 4 degrees, each group would have to consist of at least 40 participants approximately. We finally included 45 to 50 participants per group to allow for possible losses.

The study participants were assigned to three groups: one of individuals with hallux valgus, one of individuals with hallux limitus, and the other of individuals without these pathologies (control group). The patients who served as the control group were attending the Orthopaedic Service for elimination of calluses or treatment of nail disorders.

The inclusion criteria were: to be in the third decade of life (20–29 years old), so that the growth physes had closed\textsuperscript{15-17}; to never have undergone osteoarticular surgery of the foot; to never have had serious foot trauma that might have altered the bone morphology; to not have degenerative osteoarticular diseases or neuromuscular imbalance; and to not present evident deformities of the forefoot that could affect the results of the study. The individuals comprising the control group had to have a hallux dorsiflexion of 70 degrees or more, and a normal hallux abductus angle (HAA), ie, with a value of at most 15 degrees.\textsuperscript{18} Those in the hallux valgus group had to have an HAA greater than 15 and less than 30 degrees, corresponding to mild hallux valgus.\textsuperscript{19} Those in the hallux limitus group had to have 50 degrees or less of hallux dorsiflexion. Feet with hallux dorsiflexion values in the range of 50 to 70 degrees were excluded from the study so as to avoid possible confusion in cases in which the hallux dorsiflexion was close to normality.\textsuperscript{20,21} The resulting groups were the following: control group of 45 participants (17 women, 28 men; age 23.7 ± 2.7 years); hallux valgus group of 49 participants (30 women, 19 men; age 23.4 ± 2.8 years); and hallux limitus group of 48 participants (8 women, 40 men; age 23.8 ± 2.8 years).

A dorsoplantar radiograph under weightbearing conditions was taken for each individual with the feet together, the X-ray centred between the naviculars of the two feet, and the tube inclined 15 degrees to the vertical and at a tube-to-object distance of 1 M. A digital image of each radiograph was made and scanned, allowing the exploration of the positive film images. Radiographic measurements were made using the AutoCAD software package (Autodesk Inc, San Rafael, California) of proven efficacy for this task.\textsuperscript{20,22,23} The HAA and HIPA were measured on each radiograph, with all measurements made by the same observer (P.V.M.).

The HAA was measured in accordance with the procedure described by Coughlin et al.\textsuperscript{18} For the HIPA measurement, due to the small size and often irregular shape of the distal phalanx diaphysis, its longitudinal axis was drawn according to the method proposed by Coughlin and Shurnas,\textsuperscript{11} in which the distal-most point of the distal phalanx is joined to the middle point of the articular surface.
Hallux dorsiflexion was determined as described by Buell et al.\textsuperscript{24} except that the neutral position of the first metatarsophalangeal joint was taken to be that in which the hallux is in a relaxed position relative to the first metatarsal.

The data were analyzed using the software package SPSS for Windows (SPSS Science, Chicago, Illinois). To check the reproducibility of the measurement procedure, three radiographs were chosen at random from each group, and the measurements were made on three occasions separated by 1 week. The data obtained from this group of measurements were used to calculate the intraclass correlation coefficient (3,1). A descriptive analysis was performed to give the mean, SD, and 95\% confidence interval (CI) for each variable. The Shapiro-Wilk normality test was applied to decide whether to use parametric or nonparametric tests. The results allowed us to make comparisons using a one-way ANOVA. When the differences were significant, multiple comparisons were performed by means of the Bonferroni post-hoc test. Pearson’s correlation coefficients were calculated to examine the relationships between the first metatarsophalangeal joint dorsiflexion, HAA, and HIPA. \(P\)-values of less than 0.05 were considered statistically significant.

Results

The intraclass correlation coefficients for HAA and HIPA were 0.997 (95\% CI: 0.991–0.999; \(P < 0.001\)) and 0.965 (95\% CI: 0.892–0.992; \(P < 0.001\)), respectively. This is indicative of acceptable reproducibility of the measurements.\textsuperscript{10}

Table 1 lists the values of HAA and HIPA obtained for the three groups. The one-way ANOVA with Bonferroni correction showed the HIPA to present no significant differences between any of the three groups (\(F = 0.457, df = 2; P = 0.634\)). In the correlation analysis, the Pearson’s correlation coefficient between hallux dorsiflexion, HAA, and HIPA showed no statistical associations (Table 2). Therefore, these results indicate that, for the sample of this study, the value of the HIPA was similar in normal feet, in feet with early-stage hallux valgus, and in feet with early-stage hallux limitus.

Discussion

The results of this study allowed the null hypothesis to be accepted because there were no significant differences in HIPA between the three groups. Previous authors have suggested that the degree of lateral deviation of the distal phalanx relative to the proximal phalanx at the hallux may be different in feet with hallux valgus versus feet with hallux limitus/rigidus.\textsuperscript{2,10-14} These authors maintain that the greater the lateral deviation of the proximal phalanx from the first metatarsal, the smaller the lateral deviation of the distal phalanx from the proximal phalanx, and vice versa (Fig. 2). The explanation seems to be the stability of the first metatarsophalangeal joint in the transverse plane. If the joint is relatively stable in the transverse plane due to, for example, a squarer morphology of the joint, any retrograde effects of ground reaction force acting on the hallux during late midstance and propulsion, which tends to abduct the hallux toward the second digit during the propulsive phase of gait, will encounter greater resistance to transverse plane motion at the first metatarsophalangeal joint. As a result, the transverse plane rotational forces would then instead produce transverse plane motion and deviation at the interphalangeal joint, thereby increasing the HIPA.\textsuperscript{11} If, however, the first metatarsophalangeal joint is relatively unstable in the transverse plane, for example, due to a more rounded morphology of the joint, there is a mechanical advantage for any forces that tend to abduct the hallux toward the second digit to produce deviation at the first metatarsophalangeal joint, instead of at the interphalangeal joint.\textsuperscript{12} According to some authors, footwear pressure on the medial aspect of the distal phalanx also contributes to this deviation, since barefoot popu-
lations seem to have the distal phalanx more aligned with the proximal phalanx than do shod populations.\textsuperscript{25,26}

The fact that the combination of the first metatarsal and the hallux is longer than normal in hallux valgus and hallux limitus,\textsuperscript{20,27} might enhance the effect of footwear in producing these deviations. A foot with a longer first metatarsal and hallux will likely have increased shoe pressure on the distal hallux during weightbearing activities, which may cause increased transverse plane rotational forces at the first metatarsophalangeal and/or hallux interphalangeal joint. The joint with the least transverse plane rotational stability will likely show the most transverse plane deviation over time.

In the hallux limitus case, if the metatarsophalangeal joint had a more square and stable morphology, there would likely be less rotational motion within the transverse plane because of its increased rotational stability within the transverse plane.\textsuperscript{28,29} This lack of transverse plane rotation of the first metatarsophalangeal joint could lead to excessive compression forces within the first metatarsophalangeal joint when the ground reaction forces plantar to the hallux are high.\textsuperscript{20} Conversely, when excess length of the first metatarsal and hallux is combined with a rounded shape of the first metatarsal head, it would seem likely that transverse plane deviation would occur at the first metatarsophalangeal joint. In hallux valgus, the excessive length of the first metatarsodigital segment is reduced by a lateral deviation of the great toe and a medial deviation of the first metatarsal.

In the present study, we compared feet with hallux valgus, feet with hallux limitus, and normal feet and found no significant differences in HIPA between the three. The authors believe that these results may have occurred because the hallux valgus and hallux limitus pathologies of the participants in the study were in their early stages, so that there had as yet been little or no change in the transverse plane deviation of the distal phalanx relative to the proximal phalanx. Of course, our research also supports the hypothesis that hallux valgus and hallux limitus deformities have no mechanical effects on the production of transverse plane deformities at the hallux interphalangeal joint. Further research will need to be performed in hallux valgus and hallux deformities of different stages of development in order to better determine whether these deformities have a mechanical effect in the production of increased transverse plane angulation deformities of the hallux interphalangeal joint.

**Conclusions**

The deviation of the hallux distal phalanx with respect to the proximal was similar in normal feet and feet with early stages of hallux limitus or hallux valgus deformities. The present results showed that the highest value of HIPA corresponds to the hallux limitus group, although there was no significant difference between groups, or correlation between HIPA and HAA.

| Table 2. Hallux Dorsiflexion (DF), Hallux Abductus Angle (HAA), and Hallux Interphalangeus Angle (HIPA) Values for the Three Groups Included in the Study |
|----------------|----------------|----------------|
| Hallux DF | Control Group | 74.8 ± 6.7 (72.8–76.7) | Hallux Valgus Group | 64.1 ± 12.1 (60.5–67.7) | Hallux Limitus Group | 48.2 ± 6.2 (46.4–50.0) |
| HAA | 9.5 ± 4.1 (8.3–10.7) | 19.3 ± 3.0 (18.4–20.2) | 9.1 ± 4.7 (7.7–10.4) |
| HIPA | 15.2 ± 5.9 (13.4–15.2) | 15.5 ± 3.9 (14.3–16.6) | 16.15 ± 4.3 (14.8–17.3) |

Data are presented as mean ± SD (95% confidence interval).

| Table 2. Pearson's Correlation Coefficient and Statistical Significance for the Relationship Between Hallux Dorsiflexion, HAA, and HIPA |
|----------------|----------------|----------------|
| Measurement | Statistical Analysis | Hallux DF | HAA | HIPA |
| Hallux DF | Pearson’s correlation | N/A | 0.059 | −0.082 |
| | P value | 0.485 | 0.339 |
| HAA | Pearson’s correlation | 0.059 | N/A | −0.111 |
| | P value | 0.485 | 0.193 |
| HIPA | Pearson’s correlation | −0.082 | −0.111 | N/A |
| | P value | 0.339 | 0.193 |

Abbreviations: HAA, hallux abductus angle; HIPA, hallux interphalangeus angle; DF, dorsiflexion; N/A, not applicable.
Figure 2. Radiographic representation of a foot with hallux valgus (a) and hallux rigidus (b).

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References