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Quantitative Assessment of the Obliquity of the First Metatarsal-Medial Cuneiform Articulation

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A R T I C L E I N F O

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A B S T R A C T

The so-called obliquity of the first metatarsal-medial cuneiform articulation has been described as an atavistic trait of human foot morphology, and it is commonly proposed as a relative risk factor for development of the hallux abductovalgus (HAV) deformity. The objectives of this investigation were to 1) provide descriptive normative radiographic data on a series of first metatarsal-medial cuneiform articulations and 2) correlate these findings to other common radiographic parameters used to define the HAV deformity. We measured radiographic parameters including the first intermetatarsal angle, hallux abductus angle, tibial sesamoid position, Engel's angle, and 2 measures of obliquity in the transverse and sagittal planes on a consecutive series of 136 weightbearing foot radiographic projections from subjects without a history of foot/ankle surgery or fracture/dislocation. Measurements were considered as continuous variables, graphically depicted against each other on frequency scatter plots, and analyzed by means of Pearson correlation coefficients. Only 1 bivariate comparison demonstrated a weak negative correlation (Engel's angle versus Obliquity_1 [Pearson −0.259; $p = .002$]). The results of this investigation did not demonstrate a statistically significant or clinically substantial relationship between the obliquity of the first metatarsal-cuneiform joint and common radiograph parameters of the HAV deformity. Although not specifically studied here, these results might potentially indicate function, as opposed to structure, in the developmental pathogenesis of the HAV deformity.

The so-called obliquity of the first metatarsal-medial cuneiform articulation has been described as an atavistic trait of human foot morphology, and it is a commonly proposed relative risk factor for development of the hallux abductovalgus (HAV) deformity (1–4). Despite this, there is a relative lack of objective analysis into this joint, and previously published literature often present somewhat contradictory results with respect to its association with the HAV deformity (5–11).

First, it is interesting to consider the actual definition and meaning of the term "atavistic." In fact, atavism refers to a genetic reversion or the recurrence of a specific inherited trait within a population following a period of prolonged absence (12). This likely does not describe accurately the context of our contemporary use of the term, although it does at least loosely describe some relation to ancestral function. Although it has been fairly well established that larger primates who ambulate with a more erect, bipedal gait generally have less obliquity to this articulation in comparison to our arboreal ancestors, it might also be unfair to characterize this angulation as a "deformity" given that it is a part of the natural history of the human species (13).

It might be additionally inaccurate to assume or imply that the human species is progressing toward a point where there is less or no obliquity. Hyer et al (5) evaluated 87 osseous first metatarsal specimens from the Cleveland Museum of Natural History and measured the angulation of the first metatarsal base to the longitudinal axis of its shaft. The mean angle was 3.42° ± 2.54°, and interestingly ranged from −3° to 8°. In other words, a continuous range of positive and negative values were observed. Doty et al (8) also found considerable variation in the morphology of the articular cartilage on the anterior aspect of the medial cuneiform in a series of 39 cadaveric specimens.

Second, a review of the published medical literature has not conclusively established a relationship between this joint and the HAV deformity. In fact, Hatch et al (7) categorized 3 groups of subjects (no HAV, moderate HAV, and severe HAV) and measured the angular obliquity of the first metatarsal-cuneiform joint axis relative to the first metatarsal and the medial cuneiform. They found no difference in the obliquity of the distal aspect of the cuneiform between feet with normal and severely increased intermetatarsal angles. Similarly, Doty et al (8) found no association between measurements of hypermobility with the Klaue device and radiographic

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measurement of obliquity relative to the transverse tarsal line in their group of cadaveric limbs.

Conversely, Erduran et al (9) found that an angle created between the longitudinal axis of the medial cuneiform and the articular surface increased with progressive HAV deformity, as did an angle created between the longitudinal axis of the medial cuneiform and the longitudinal axis of the first metatarsal. In addition, Doty et al (8) did observe positive correlations between the medial inclination of the first metatarsal-medial cuneiform joint and hallux valgus angles in their cadavers.

In the absence of conclusive objective data demonstrating a clear association between obliquity and the HAV deformity, it is at least possible that this represents a relatively incidental finding providing confirmation bias to surgeons viewing this joint as the apex of the HAV deformity. Therefore, the objectives of this investigation were to 1) provide descriptive normative data on a radiographic series of first metatarsal-medial cuneiform articulations and 2) correlate these findings to other common radiographic parameters used to define the HAV deformity.

Materials and Methods

After international review board approval, we measured radiographic parameters on a consecutive series of weightbearing foot radiographic projections from subjects without a history of foot/ankle surgery or fracture/dislocation. All radiographs were taken with standard technique in the angle and base of gait (14). The purpose of the angle and base of gait is to radiographically represent the structure of the foot during weightbearing midstance. The angle of gait was defined as the degree of abduction or adduction of the foot from the midline during gait, and the base of gait was defined as the distance between the 2 heels during the gait cycle. At our facility, the subject was positioned into the angle and base of gait by the radiology technologist after an observation of gait and stance. The radiographic measurements were made by 2 authors (K.P. and T.H.) and reviewed by the senior author (A.J.M.) using computerized digital software (Opal-RAD PACS; Viztek, Garner, NC) which measured to a precision of 0.1°.

Five measurements were recorded from each standard weightbearing anterior-posterior (AP) radiograph. The AP radiograph was defined as the image receptor placed in a horizontal position flat on the orthoposer with the tube head angulated 15° from vertical, directed posteriorly, and aimed at the second metatarsocuneiform joint (14). The first intermetatarsal angle was defined as the angular relationship between the longitudinal bisectors of the first and second metatarsal shafts. Bisectors were determined by individually identifying the proximal and distal midpoints of the diaphyseal-metaphyseal junctions and then forming a line connecting the 2 points. The hallux abductus angle was defined as the angular relationship between the bisectors of the first metatarsal and hallux proximal phalanx shafts. The tibial sesamoid position was measured on a 7-point scale as described by Hardy and Clapham (15). Engel's angle was defined as the angular relationship between the bisectors of the second metatarsal shaft and the intermediate cuneiform (16).

An additional measurement of first metatarsal-medial cuneiform obliquity was recorded from each standard weightbearing AP radiograph. We considered Obliquity_1 as the angular relationship between a perpendicular to the longitudinal bisection to the second metatarsal and a line parallel to the first metatarsal-medial cuneiform articulation (Fig. 1). Higher values therefore indicated increased joint medial obliquity away from the longitudinal axis of the second metatarsal compared with the first intermetatarsal angle.

One measurement was recorded from each standard weightbearing lateral radiograph. The lateral radiograph was defined as the image receptor placed in an upright, vertical position in the orthoposer with the tube head angulated at 90° from vertical, directed medially, and aimed at the lateral cuneiform/cuboid (14). We defined Obliquity_2 as the resultant angulation between the weight-bearing surface and the first metatarsal-medial cuneiform articulation (Fig. 2).

Data were stored in a password-protected personal computer for subsequent statistical analysis. All statistical analyses were performed using Statistical Analysis Systems software (version 25; SAS Institute, Cary, NC) by the senior author (A.J.M.). Measurements were considered as continuous variables, graphically depicted against each other on frequency scatter plots, and analyzed by means of Pearson correlation coefficients.

Results

We measured radiographs of 136 feet in 99 subjects. Twenty-eight (28.28%) of the subjects were male. Seventy (51.47%) of the feet were right-sided. The mean ± standard deviation age of the subject cohort was 47.43 ± 14.98 (range 18 to 78) years.

Fig. 1. Obliquity of the first metatarsal-medial cuneiform joint in the transverse plane. We defined Obliquity_1 as the angular relationship between a perpendicular to the longitudinal bisection to the second metatarsal and a line parallel to the first metatarsal-medial cuneiform articulation. Higher values therefore indicate increased joint medial obliquity away from the longitudinal axis of the second metatarsal compared with the first intermetatarsal angle.

The Obliquity_1 measurement was 16.94° ± 6.43° (range 4.6° to 38.5°). The Obliquity_2 measurement was 63.70° ± 4.16° (range 53.4° to 75.3°). Fig. 3 represents the frequency scatter plot of Obliquity_1 versus Obliquity_2. A statistically significant negative correlation was observed between these 2 measurements (Pearson correlation −0.361; $p < .001$). In other words, as the joint axis became increasingly medially inclined away from the second metatarsal in the transverse plane, it also tended to be more inclined relative to the weightbearing surface in the sagittal plane.

First Intermetatarsal Angle

The measured first intermetatarsal angle was 10.37° ± 2.70° (range 4.0° to 21.0°). No statistically significant nor clinically substantial correlations were observed between the first intermetatarsal angle and Obliquity_1 (Pearson 0.117; $p = .176$) or Obliquity_2 (Pearson 0.077; $p = .370$) measurements (Figs. 4 and 5, respectively).

Hallux Abductus Angle

The measured hallux abductus angle was 17.67° ± 8.18° (range 1.7° to 36.3°). No statistically significant nor clinically substantial correlations were observed between the hallux abductus angle and

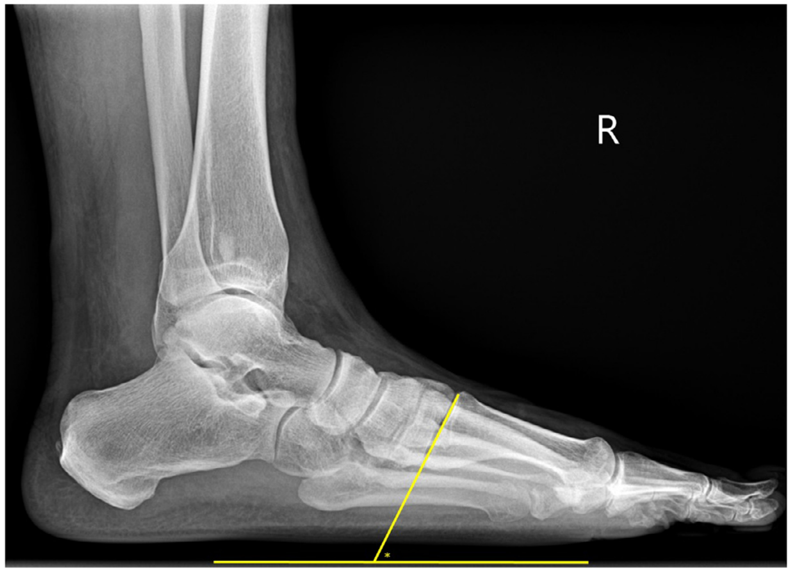

Fig. 2. Obliquity of the first metatarsal-medial cuneiform joint in the sagittal plane. We defined Obliquity_2 as the resultant angulation between the weightbearing surface and the first metatarsal-medial cuneiform articulation.

Obliquity_1 (Pearson 0.093; $p = .279$) or Obliquity_2 (Pearson −0.045; $p = .605$) measurements (Figs. 6 and 7, respectively).

Engel's Angle

The Engel's angle measurement was 22.10° ± 5.75° (range 9.0° to 39.5°). We observed a statistically significant weak negative correlation between Engel's angle and Obliquity_1 (Pearson −0.259; $p = .002$). In other words, as Obliquity_1 increased, Engel's angle tended to decrease (Fig. 8). No statistically significant nor clinical substantial correlations were observed between Engel's angle and Obliquity_2 (Pearson 0.114; $p = .186$) measurements (Fig. 9).

Tibial Sesamoid Position

The mean ± standard deviation (range) tibial sesamoid position was 3.6 ± 1.1 (range 2 to 7). No statistically significant nor clinically substantial correlations were observed between the tibial sesamoid position and Obliquity_1 (Pearson 0.136; $p = .115$) or Obliquity_2 (Pearson 0.121; $p = .161$) measurements (Figs. 10 and 11, respectively).

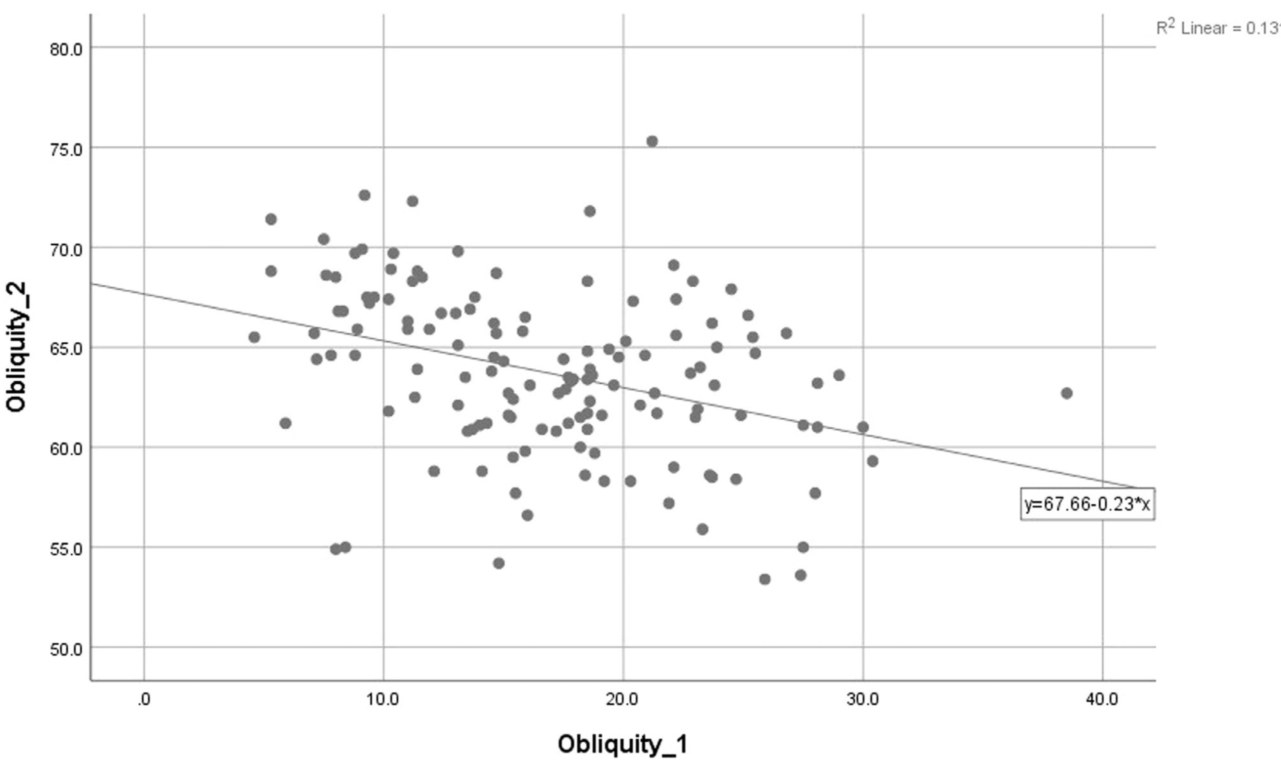

Fig. 3. Frequency scatter plot of Obliquity_1 versus Obliquity_2.

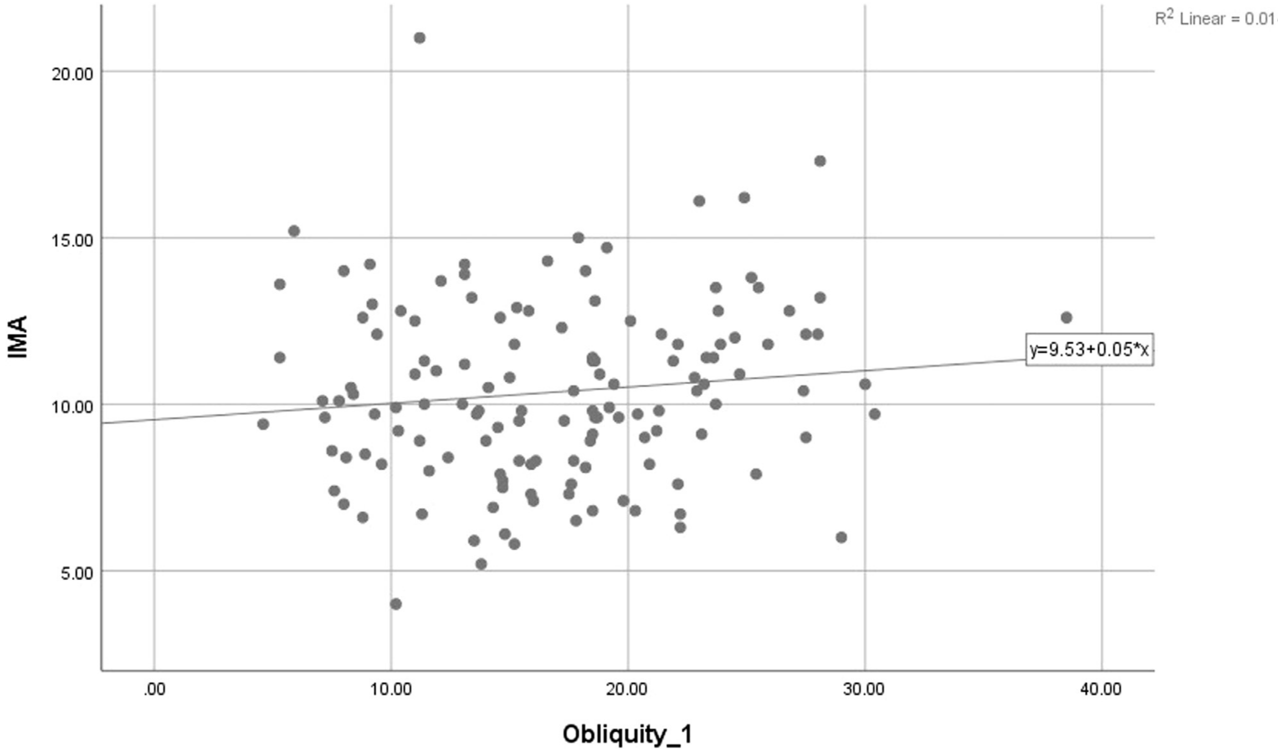

Fig. 4. Frequency scatter plot of Obliquity_1 versus the first intermetatarsal angle (IMA).

Discussion

As with any scientific investigation, critical readers are encouraged to review the methodological design and specific results to reach their own independent conclusions; the following represent our conclusions based on the preceding results. We also never consider data to be definitive, but do think that these results might be worthy of attention and future study.

This cross-sectional investigation analyzing radiographic parameters as continuous variables indicates that there is no statistically significant

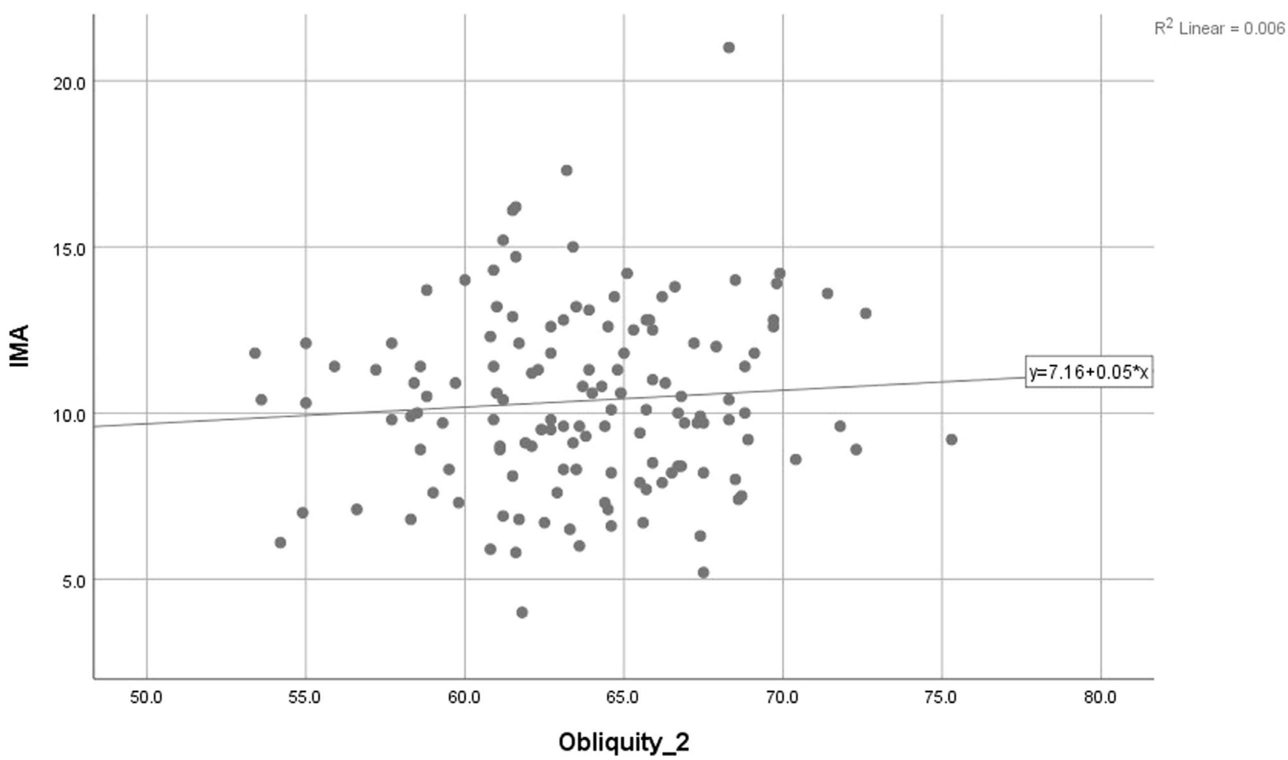

Fig. 5. Frequency scatter plot of Obliquity_2 versus the first intermetatarsal angle (IMA).

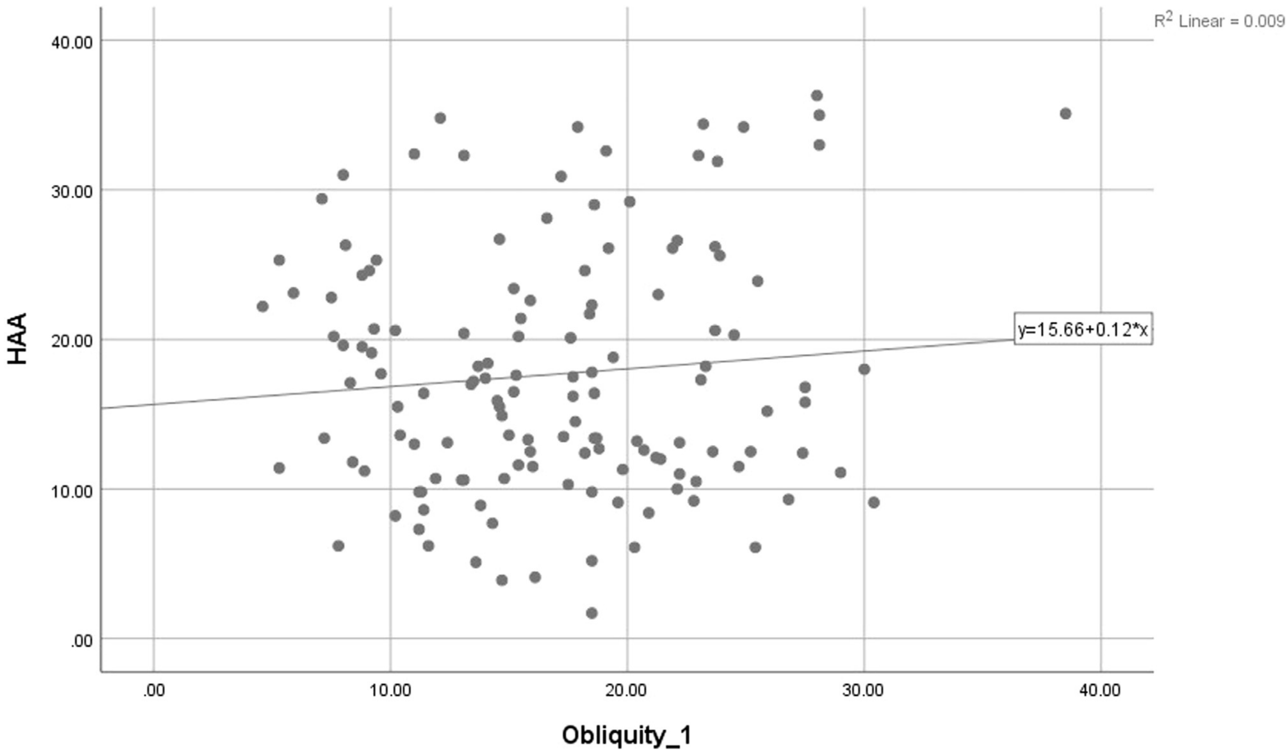

Fig. 6. Frequency scatter plot of Obliquity_1 versus the hallux abductus angle (HAA).

or clinically substantial association between the relative obliquity of the first metatarsal-medial cuneiform articulation and the HAV deformity. Using 4 radiographic parameters commonly used for evaluation of the HAV deformity—2 measures of first metatarsal-medial cuneiform joint obliquity and 2 different cardinal body planes —only 1 bivariate comparison demonstrated a weak negative correlation (Engel's angle versus Obliquity_1 [Pearson −0.259; $p = .002$]).

This might be considered a somewhat surprising finding that does not appear in line with conventional thinking of the first ray. Increased articular obliquity has traditionally been thought to be associated with

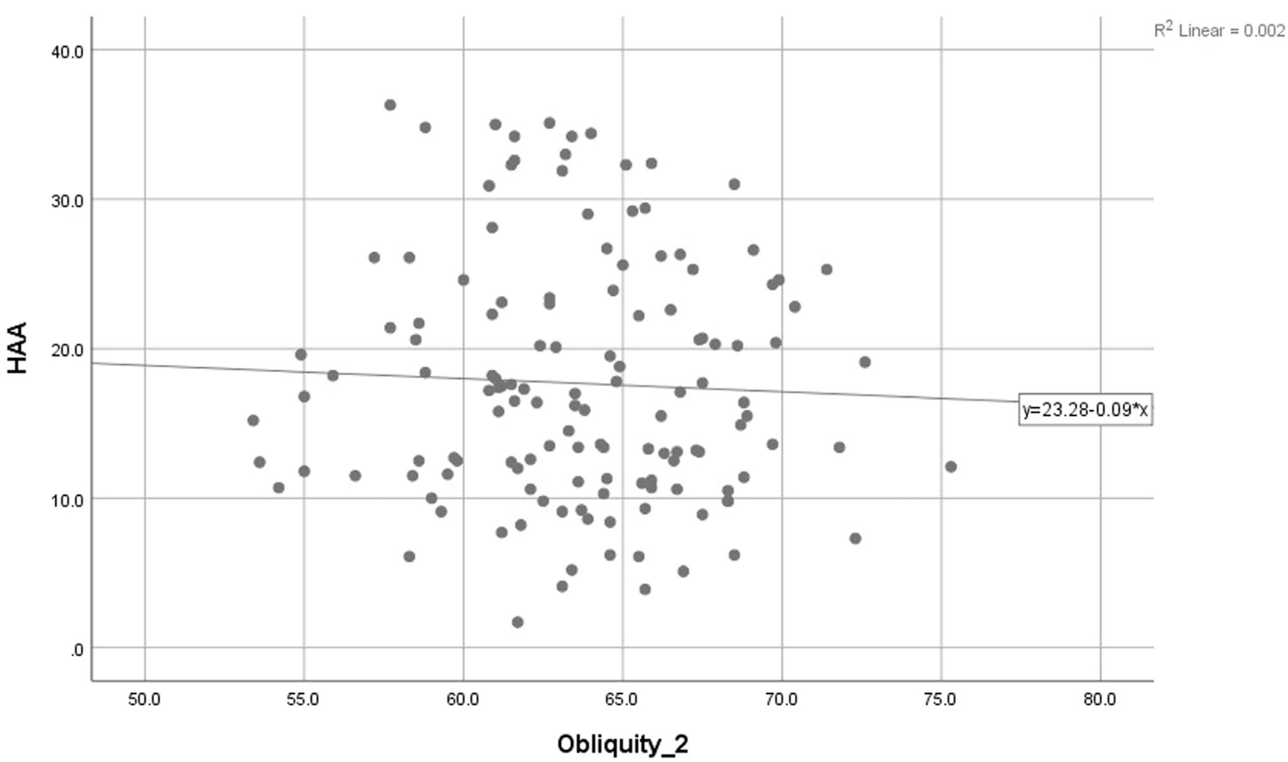

Fig. 7. Frequency scatter plot of Obliquity_2 versus the hallux abductus angle (HAA).

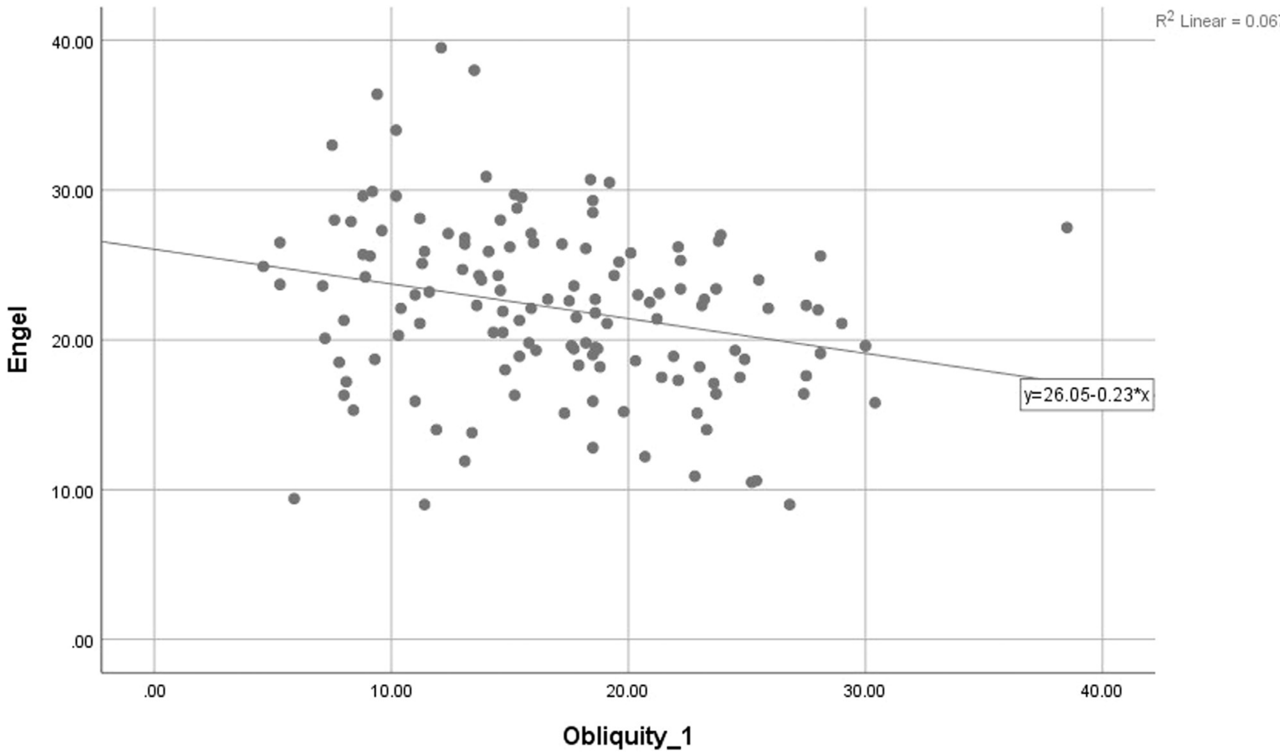

Fig. 8. Frequency scatter plot of Obliquity_1 versus Engel's angle.

HAV deformity (1–4). This even seems common sense to some degree, as the articular facet on the distal aspect of the medial cuneiform is oriented in a distal, medial, and plantar direction (8,17). It therefore stands to reason that a more medial articular facet would have a tendency to "push" the first metatarsal in a more medial direction and away from the second ray. We believe these results might challenge the static structural position of the first metatarsal-medial cuneiform joint as a risk factor for HAV development, and might instead point toward a

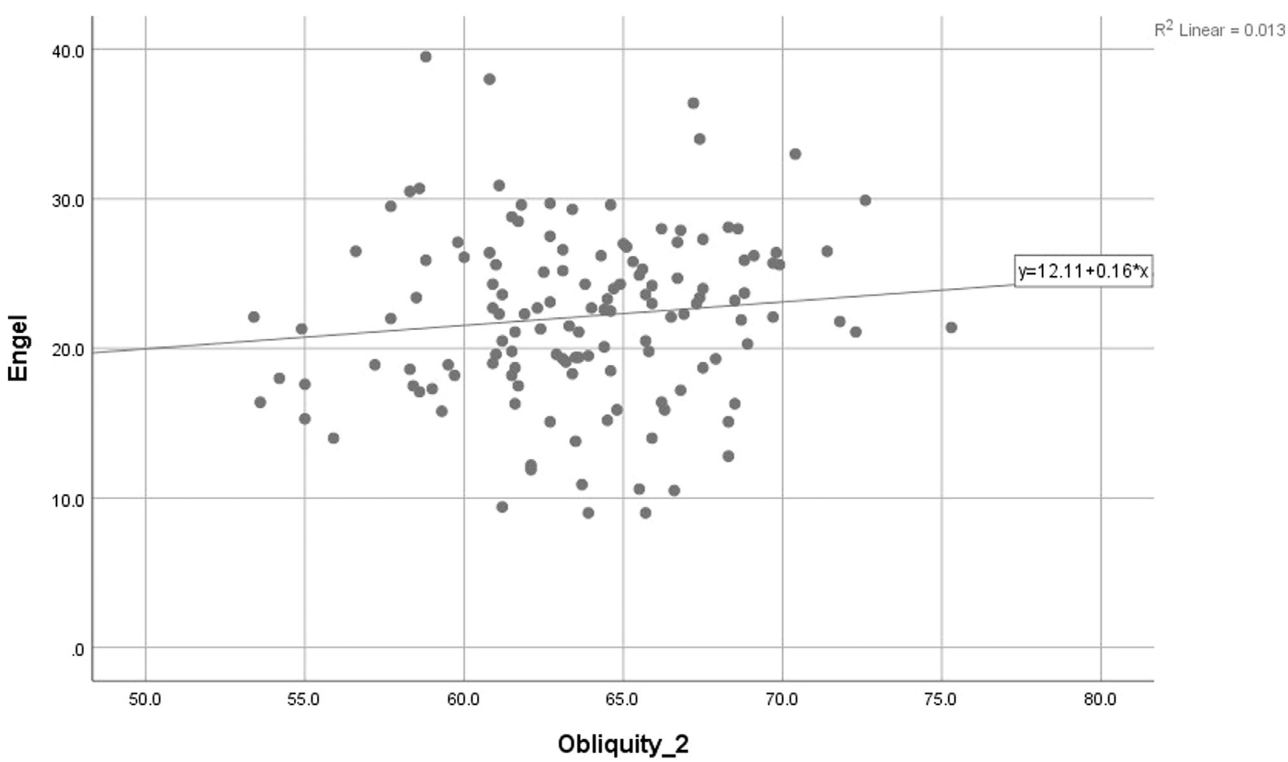

Fig. 9. Frequency scatter plot of Obliquity_2 versus Engel's angle.

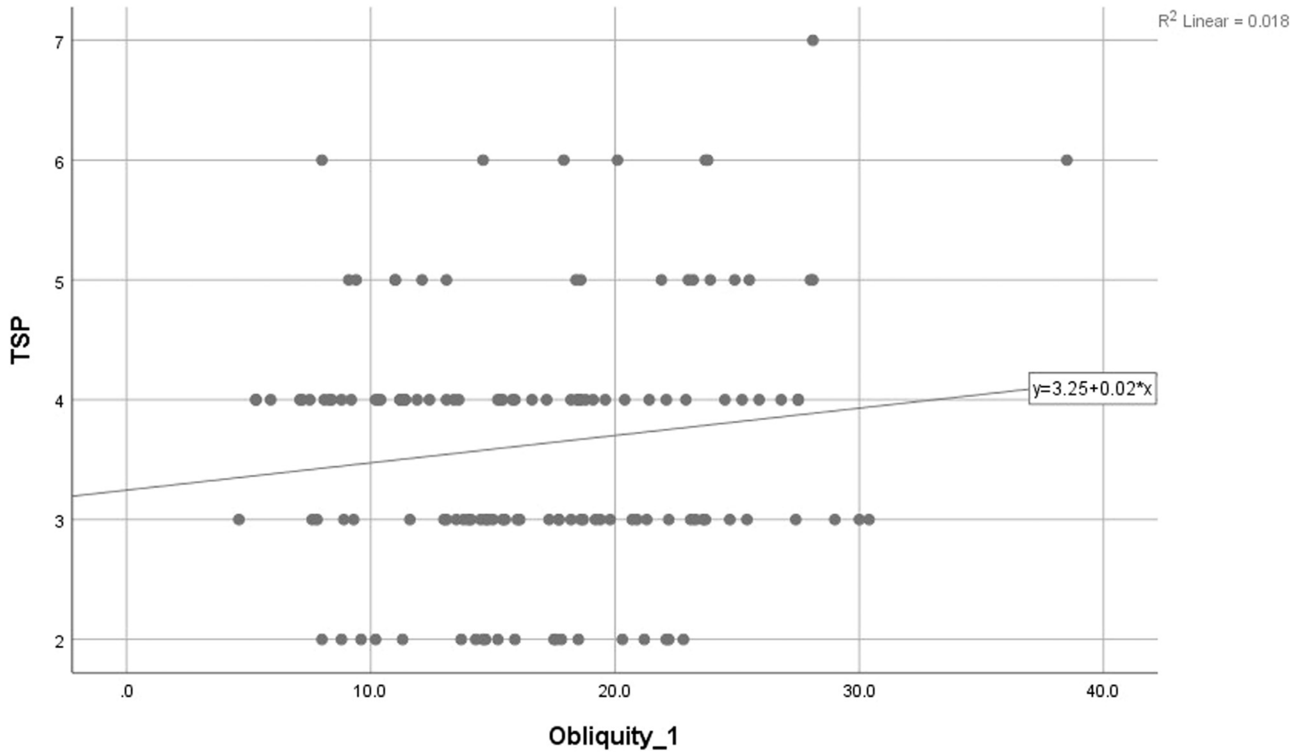

Fig. 10. Frequency scatter plot of Obliquity_1 versus the tibial sesamoid position (TSP).

more dynamic, functional role of the joint in the deformity. The dynamic function of this joint was not specifically studied within this methodology; however, this represents an interesting avenue for future investigation.

All studies have limitations, and this one has several important ones to consider. Data were collected from a single institution, using a limited number of subjects; therefore, these results might not be representative of our entire institution or other institutions. The subjects were

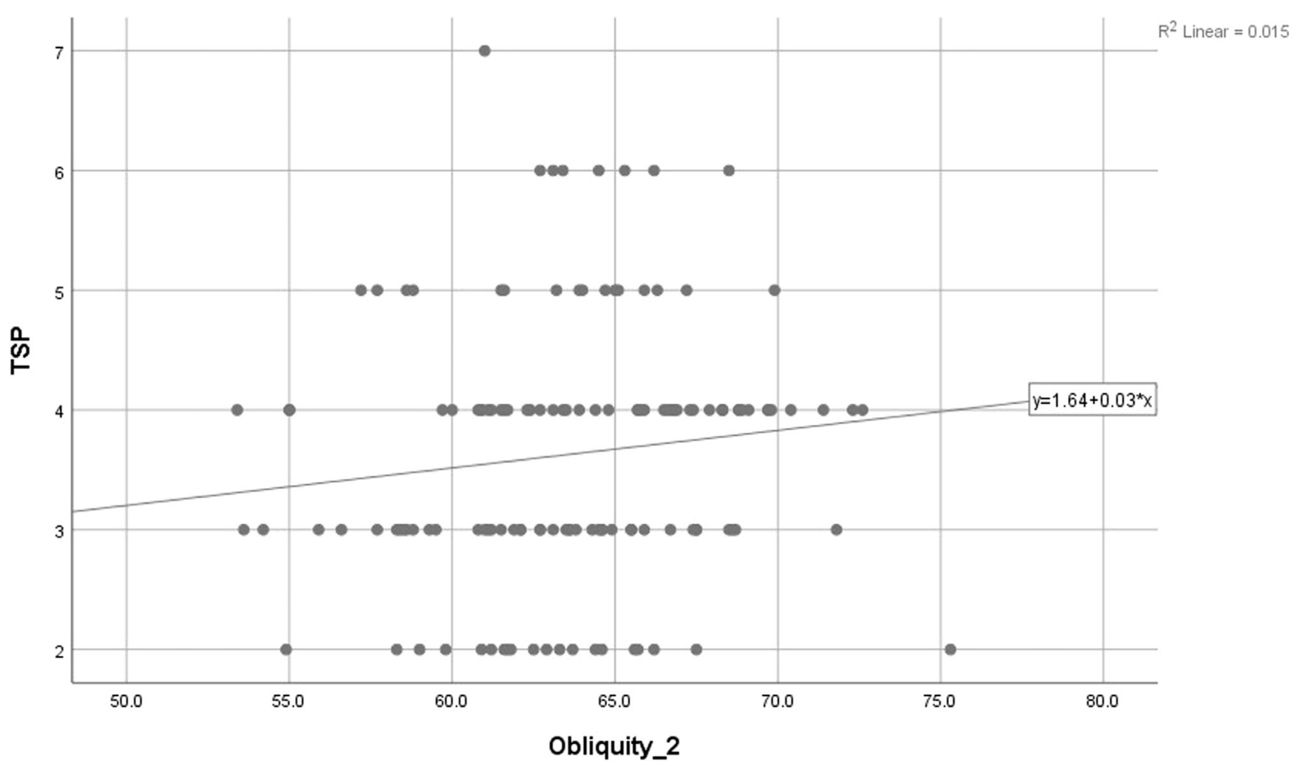

Fig. 11. Frequency scatter plot of Obliquity_2 versus the tibial sesamoid position (TSP).

also being evaluated for some type of foot and ankle complaint, and they were not taken from a random human population; therefore, at least some degree of selection bias is likely present.

There may also be some disagreement among foot and ankle surgeons with respect to the specific radiographic measures that we included in this investigation. We did not evaluate all possible radiographic measurements that can be used in the evaluation of the HAV deformity, and there may be some additional disagreement with respect to the exact definition and measurement of these angles. For example, none of our measurements would be expected to account for frontal plane components to this deformity. Furthermore, there is no standardized radiographic definition for measurement of the obliquity of the first metatarsal-medial cuneiform joint axis. Previous studies have measured this relative to the longitudinal axis of the first metatarsal, the longitudinal axis of the medial cuneiform, and the transverse tarsal axis in the transverse plane (5,7,8–10). We chose to measure the joint axis relative to longitudinal axis of the second metatarsal, as this seemed more in line with traditional measurements of the first intermetatarsal angle for HAV.

Another limitation of any radiographic study is the variability of the positioning and projection of the radiographs, particularly when multiple radiographic technicians are involved. This is particularly true for measurement of the first metatarsal-medial cuneiform articulation, as several investigators have described difficulties and differences in radiographic appearance based on positioning (18–20).

In conclusion, we did not observe a statistically significant or clinically substantial relationship between the obliquity of the first metatarsal-medial cuneiform joint and common radiograph parameters used in evaluation of the HAV deformity.

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