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Descriptive Quantitative Analysis of Rearfoot Alignment Radiographic Parameters

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ABSTRACT

Although the radiographic parameters of the transverse talocalcaneal angle (tTCA), calcaneocuboid angle (CCA), talar head uncovering (THU), calcaneal inclination angle (CIA), talar declination angle (TDA), lateral talar–first metatarsal angle (lTFA), and lateral talocalcaneal angle (lTCA) form the basis of the preoperative evaluation and procedure selection for pes planovalgus deformity, the so-called normal values of these measurements are not well-established. The objectives of the present study were to retrospectively evaluate the descriptive statistics of these radiographic parameters (tTCA, CCA, THU, CIA, TDA, lTFA, and lTCA) in a large population, and, second, to determine an objective basis for defining "normal" versus "abnormal" measurements. As a secondary outcome, the relationship of these variables to the body mass index was assessed. Anteroposterior and lateral foot radiographs from 250 consecutive patients without a history of previous foot and ankle surgery and/or trauma were evaluated. The results revealed a mean measurement of 24.12°, 13.20°, 74.32%, 16.41°, 26.64°, 8.37°, and 43.41° for the tTCA, CCA, THU, CIA, TDA, lTFA, and lTCA, respectively. These were generally in line with the reported historical normal values. Descriptive statistical analysis demonstrated that the tTCA, THU, and TDA met the standards to be considered normally distributed but that the CCA, CIA, lTFA, and lTCA demonstrated data characteristics of both parametric and nonparametric distributions. Furthermore, only the CIA ($R = -0.2428$) and lTCA ($R = -0.2449$) demonstrated substantial correlation with the body mass index. No differentiations in deformity progression were observed when the radiographic parameters were plotted against each other to lead to a quantitative basis for defining "normal" versus "abnormal" measurements.

Pes planovalgus is a structural deformity of the lower extremity that is defined using both clinical and radiographic parameters. It is common practice to use a radiographic approach to objectively define the anatomic location, plane, and severity of the deformity preoperatively and as an assessment of the postoperative correction. The standard weightbearing anteroposterior radiograph is primarily used for evaluation of the transverse plane, with measurement of the talocalcaneal angle (tTCA or Kite's angle), calcaneocuboid angle (CCA), and talonavicular articulation as a percentage of the talar head uncovering (THU). The standard weightbearing lateral radiograph is primarily used for evaluation of the sagittal plane, with measurement of the calcaneal inclination angle (CIA), talar declination angle (TDA), lateral talar–first metatarsal angle (lTFMA or Meary's angle), and lateral talocalcaneal angle (lTCA). Although numerous objective parameters can be calculated, these have traditionally formed the basis of preoperative procedure planning and postoperative surgical evaluation.

However, most authoritative texts and other sources with respect to the etiology, evaluation, and management of the adult pes planovalgus deformity have not cited a specific work for the reported "normal" value of these measurements, have not cited normative values at all, have referred back to a small sample of epidemiologic studies of the deformity, or have presented normative values from relatively small, asymptomatic control groups used for comparative analysis (1–43). We have previously reported on the relative lack of objective evidence and scientific rigor used for the determination of the "normal" radiographic measurements during evaluation of the hallux abductovalgus deformity (44). Our present review of the published data on this specific topic has indicated that even less evidence might be available and more limitations present for the measurement of the rearfoot alignment radiographic parameters.

Only 1 study was identified with a primary objective of assessing the normative data of rearfoot radiographic parameters in a normal

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adult population, and the study included only 28 patients (16). They found a mean ± standard deviation of 24.5° ± 3.0° (range 17° to 32°) for the CIA, 21.4° ± 4.1° (range 14° to 30°) for the TDA, 45.4° ± 2.6° (range 34° to 56°) for the lTCA, and 18.0° ± 5.0° (range 7° to 29°) for the tTCA.

The objectives of the present study were to evaluate the descriptive statistics of the tTCA, CCA, THU, CIA, TDA, lTFMA, and lTCA in a large population and to determine an objective basis for defining "normal" versus "abnormal" measurements. As a secondary outcome, the relationship of these variables to the study cohort's body mass index (BMI) was assessed.

Patients and Methods

The radiographs of patients from the Temple University Foot and Ankle Institute were retrospectively reviewed for the present investigation. Included in the present study were consecutive patients who had undergone radiographic evaluation with at least a weightbearing anteroposterior foot radiograph and a weightbearing lateral foot radiograph. The radiographs were excluded if the patient had a history of previous foot or ankle surgery and/or evident osseous trauma.

All radiographs were taken using a standard technique for the angle and base of gait and were performed by 1 or 2 radiologic technicians with a combined 50 years of clinical experience (45). 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 both heels during the gait cycle. At our facility, the patient is positioned into the angle and base of gait by the radiology technician after an observation of the gait and stance. The radiographic measurements were made by 1 of us (M.W.) using computerized digital software (OpalRAD PACS, Viztek, Garner, NC), which measures to a precision of 0.1°.

Three measurements were recorded from each standard weightbearing anteroposterior radiograph: the TCA, CCA, and THU. For the anteroposterior radiograph, the image receptor was placed in a horizontal position flat on the orthoposer with the tube head angled 15° from vertical, directed posteriorly, and aimed at the second metatarsocuneiform joint (45). The TCA was defined as the resultant angular relationship between the longitudinal axis of the talar head and neck and a tangent drawn along the lateral side of the calcaneus (1). The CCA was defined as the resultant angular relationship between a tangent drawn along the lateral side of the cuboid and a tangent drawn along the lateral side of the calcaneus (1). The THU was defined as the percentage of the articular surface of the talar head that articulates with the navicular (1). The talar head is a curved and convex structure that articulates with the curved and concave structure of the proximal navicular. The entire articular potion of the talar head from medially to laterally was considered inclusive, and a ratio was calculated for which the percentage of this cartilage was found within the concavity of the navicular compared with medial to it. The THU was not calculated as a continuous variable but in increments of 5%.

Four measurements were recorded from each standard weightbearing lateral radiograph: the CIA, TDA, lTCA, and lTFMA. For the lateral radiograph, the image receptor was 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 (45). The CIA was defined as the resultant angulation between the supporting surface and the calcaneal inclination line (a line created by 2 points on the plantar surface of the calcaneus [the anterior, plantar extent of the calcaneal tuberosity and the most plantar point of the calcaneocuboid articulation]) (1). The TDA was defined as the resultant angulation between the supporting surface and the talar declination line (a perpendicular line connecting 2 points on the talar head [the superior articular point of the head of the talus with the navicular and the anteroinferior superimposition of the articular surface of the talus by the calcaneus]) (1). The lTFMA was defined as the resultant angulation between the talar declination line and the first ray longitudinal bisection (a line drawn through the bisections of the proximal and distal diaphysis of the first metatarsal) (1). We defined a positive measurement as a first metatarsal longitudinal bisection relatively dorsal to the talar declination line, and a negative measurement as the first metatarsal longitudinal bisection relatively plantar to the talar declination line. The lTCA was defined as the resultant angulation between the calcaneal inclination line and the talar declination line (1).

The BMI was obtained from the electronic medical records of each patient at the date of the radiograph. At our institution, height and weight measurements are taken for all patients during the initial evaluation by nurses, medical assistants, or students and entered into the electronic medical record, which automatically calculates a numerical BMI measurement.

After taking the radiographic measurements, the data were stored in a personal computer for subsequent statistical analysis. All statistical analyses were performed using Statistical Analysis Systems software, version 9.2 (SAS Institute, Cary, NC). Descriptive statistics were calculated for each parameter, including the mean, median, standard deviation (SD), 95% confidence interval (CI), range, interquartile range, and skewness. Each parameter was individually depicted graphically on a histogram and normal Q–Q plot to assist in evaluation of the normalcy of the data population.

Determining the normalcy of a data population can be both a challenging and a subjective, but also critically important, exercise. A normally distributed (or parametric) population is one in which approximately 68% of the data will be within 1 SD of the mean and approximately 95% of the population will be within 2 SDs of the mean (46–53). This has important consequences in terms of both data reporting and comparative statistical analysis within medical studies. Generally, descriptive data from parametric populations are more appropriately reported in terms of the mean and SD, with 95% CIs used to further describe the precision of the mean. Descriptive data from nonparametric populations are more appropriately reported in terms of the median and interquartile range. Furthermore, given a common comparative study design used within the field of foot and ankle surgery (eg, comparing the preoperative and postoperative radiographic parameters), data from parametric populations should be analyzed using certain specific comparative statistical tests (ie, the Student's *t* test). Other specific statistical tests are more appropriately used if the data are not normally distributed (ie, the Wilcoxon signed-rank test) (46–53).

Although a functional mathematical formula is not necessarily available to determine whether a population carries a parametric distribution, analysis of the descriptive statistics can provide some important information with respect to normalcy. We used 2 objectives to evaluate whether the data were normally distributed.

First, if the SD was >50% of the mean and/or if the 2 SDs above or below the mean were outside the range, we considered the data to be nonparametric. Second, the data were graphically depicted using both a histogram and a normal Q–Q plot to visualize the data. A parametric population would be expected to have a bell-shaped curve on the histogram and relatively firm adherence to the normal line on a Q–Q plot. Evaluation of a bell-shaped curve on a histogram can be assisted by calculation of the skewness, which is generally symmetrically distributed around a mean of 0 for a parametric population. Negative values of skewness represent a skew to the left (left tailed) and positive values, a skew to the right (right tailed). Generally, a normally distributed population has a skewness with a range of −1 to 1 (46–53).

Finally, each parameter was graphically depicted against each other on a frequency scatter plot and analyzed with a regression line and uniform loess best line to further evaluate for relationships among the variables.

Results

A total of 250 feet (117 left feet) in 250 patients (116 male) were included in the present analysis during a 4-month data collection period (December 2013 to March 2014). The patient age range was 12 to 83 (mean 49.9 ± 14.1) years. The patient BMI range was 18.2 to 54.4 (mean 31.6 ± 7.0) kg/m^2.

Transverse Plane Descriptive Data

A summary of the descriptive data for the measurement of the 3 transverse plane radiographic parameters is listed in Table 1.

Transverse Talocalcaneal Angle

The mean ± SD of the tTCA measured 24.12° ± 5.65° (95% CI 23.42° to 24.82°, range 9.20° to 44.20°), the median measured 23.80° (interquartile range 20.10° to 27.70°), and the skewness was 0.448. Fig. 1*A* displays the histogram of the tTCA data, and Fig. 1*B* displays the normal Q–Q plot of the tTCA data.

The tTCA passed the first test of normalcy, because the SD was less than one half of the mean (5.65 < 12.06), and the 2 SDs above

Table 1
Descriptive statistics of transverse plane radiographic parameters (N = 250 radiographs)

Descriptive Statistical Measure	tTCA (°)	CCA (°)	THU (%)
Mean ± SD	24.12 ± 5.65	13.20 ± 7.20	74.32 ± 11.01
95% CI	23.42 to 24.82	12.30 to 14.10	72.95 to 75.69
Range	9.2 to 44.2	1.20 to 35.70	50.0 to 100.0
Median	23.80	12.65	75.0
Interquartile range	20.10 to 27.70	7.88 to 18.10	65.0 to 80.0
Skewness	0.448	0.488	0.231

Abbreviations: CCA, calcaneocuboid angle; CI, confidence interval; tTCA, transverse talocalcaneal angle; THU, talar head uncovering; SD, standard deviation.