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Original Article

Inter- and intraobserver reliability of the first metatarsal sagittal alignment measurements

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Abstract

Objective: First, analyze the inter- and intraobserver reliability of the angular measurements used to evaluate the first metatarsal sagittal alignment. Second, evaluate whether the anatomical type of foot interferes with the reliability of the measurements.

Methods: The angular measurements used were all those found in the literature, such as first metatarsal declination angle (MDA), first distal metatarsal articular angle (DMAA), first proximal metatarsal articular angle (PMAA), lateral intermetatarsal angle (LIMA), and the angle described by Day. To evaluate interobserver reliability, the Intraclass Correlation Coefficient (ICC) was used; to evaluate intraobserver reliability, the Lin Correlation Coefficient of Agreement (LCCC) was used.

Results: Among all the measurements obtained, the MDA presented the highest ICC and LCCC values in the 40 radiographs evaluated, regardless of the anatomical type of foot.

Conclusion: The first MDA represents an adequate radiographic tool for measuring the first metatarsal sagittal alignment when evaluated by the CCI and LCCC.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Metatarsal bones; Reliability of results; Radiography.

Introduction

Radiographic measurements are often used to indicate and program orthopedic procedures for forefoot deformities and postoperative follow-up. The first metatarsal is a bone structure with an important function in weight bearing, static, and dynamic. It is commonly related to forefoot deformities such as hallux valgus and hallux rigidus and other complex foot deformities such as progressive collapsing foot deformity[1]. Under these conditions, it is often necessary to evaluate whether flexion or extension of the first metatarsal is associated with deformity or after its surgical correction[2,3]. However, it is necessary to use measures in which the values are reproducible among surgeons, regardless of the training time[4-6].

The objective of this study was first to analyze the inter- and intraobserver reliability of the angular measurements used to evaluate the first metatarsal sagittal alignment. Second, evaluate whether the anatomical type of foot interferes with the reliability of the measurements.

Methods

This is a cross-sectional observational study to evaluate the intra- and interobserver reliability of angular measurements of the first metatarsal sagittal alignment. This study was approved by the Institutional Review Board under the number 64658522.2.0000.0070.

All measurements were performed on a profile view with the foot with a load. The feet radiographs with previous surgeries, equinus deformities, severe cavus feet, and primary or secondary osteoarthritis were excluded from the study. The angular measurements used were all those found

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in studies inserted in the main indexed databases (Pubmed, Scielo, Medline, Cochrane, Scopus, and Web of Science), such as (1) first metatarsal declination angle (MDA), (2) first distal metatarsal articular angle (DMAA), (3) first proximal metatarsal articular angle (PMAA), (4) lateral intermetatarsal angle (LIMA), and (5) the angle described by Day.[1,7,8] The references for measuring the first MDA are the angle between one line of the first metatarsal long axis and another line parallel to the ground (Figure 1A). The first DMAA is formed between the anatomical axis of the first metatarsal and a line connecting the dorsal and plantar aspects of the distal joint of the first metatarsal proximal to the sesamoid apparatus (Figure 1B). The first PMAA is formed by the anatomical axis of the first metatarsal and a joint line from the base of the first metatarsal (Figure 1C). The LIMA is obtained between the dorsal cortex of the diaphysis of the first and second metatarsals (Figure 1D). Finally, the angle described by Day is measured by a line drawn from the back to the plantar edge of the first proximal articular surface of the first metatarsal. Another line is drawn parallel to the diaphysis of

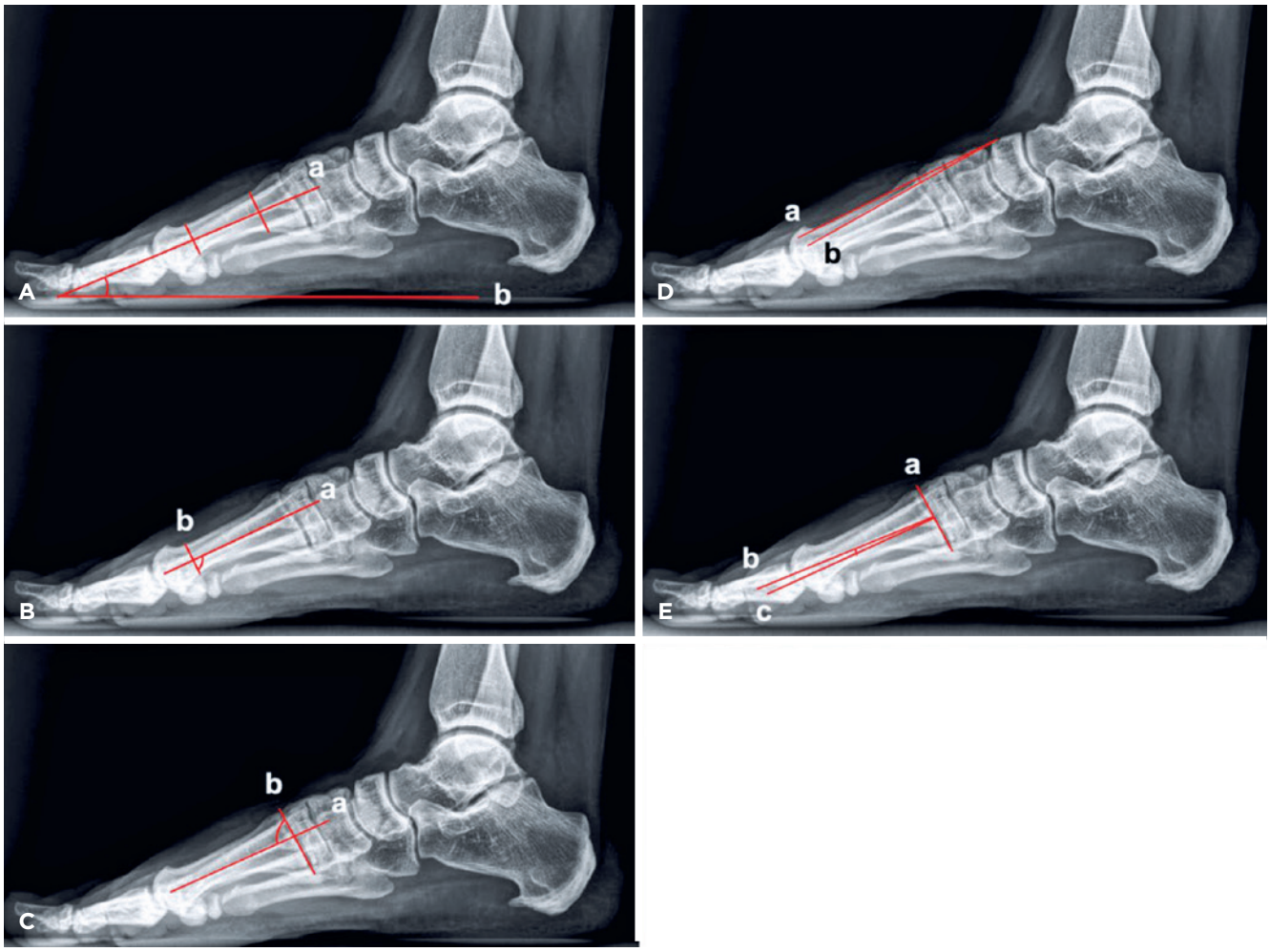

Figure 1. (A) The first MDA is measured from two lines, one the long axis of the first metatarsal (line a) and the other parallel to the ground (line b). **(B)** The first DMAA is obtained by the anatomical axis of the first metatarsal (line a) and the line connecting the dorsal and plantar faces of the distal joint of the first metatarsal proximal to the sesamoid apparatus (line b). **(C)** The first PMAA is formed by the anatomical axis of the first metatarsal (line a) and the articular line of the base (line b). **(D)** The LIMA is obtained between two lines, one along the dorsal cortical of the diaphysis of the first metatarsal (line a) and the other along the dorsal cortical of the second metatarsal (line b). **(E)** The angle described by Day is obtained with three lines. The first is drawn from the dorsal edge to the plantar edge of the proximal articular surface of the first metatarsal (line a). Then, another line is drawn parallel to the diaphysis of the first metatarsal, dividing its head in half (line b). The third is plotted at 90º to the first (line c). The difference between lines b and c form the angle. Abbreviations: First MDA: First metatarsal declination angle; First DMAA: First distal metatarsal articular angle; First PMAA: First proximal metatarsal articular angle; LIMA: Lateral intermetatarsal angle.

the first metatarsal distal to the osteotomy site, bisecting the metatarsal head. The amount that this measurement differs from 90º determines the dorsiflexion angle (Figure 1E). Linear measurements (length) found in the literature were excluded from the study, as their reference points and values can be influenced by the radiographic technique applied in each service.

The measurements were performed by four observers, two newly graduated fellows in foot and ankle surgery (less than one year), and two specialists with more than five years of experience. The sample calculation was previously obtained, which estimated 40 radiographs; therefore, there was significance in the measured values. Inter- and intraobserver reliability assessments were performed on all feet and separately on flatfoot, physiological feet, and cavus feet, according to the Meary angle. When above 10º, the feet were considered cavus, and below -10º, flatfoot.[9] All observers performed the measurements at two different times, with an interval of four weeks. To obtain intraobserver measurements, the most experienced observers were named O1 and O2, and the newly fellows observers were named O3 and O4. The software used to standardize the measurements was the OsiriX software (OsiriX, Switzerland).

Statistical Analysis

To evaluate interobserver reliability, the Intraclass Correlation Coefficient (ICC) was used; to evaluate intraobserver reliability, the Lin Correlation Coefficient of Agreement (LCCC) was used. Both measures determine the degree of correlation among the variables. When the value is < 0.2, the correlation was considered poor; between 0.21-0.4, reasonable; between 0.41-0.60, moderate; between 0.61-0.80, good and > 0.80, excellent (10.11). Statistical analyses were performed with Jamovi 2.4.8, JASP 0.18, and SAS 9.4 software (SAS Institute Inc, Cary, NC). A p-value of < 0.05 was considered significant.

Results

The first MDA presented the highest ICC values among all the measurements obtained. Considering the 40 feet, the correlation was classified as good, with a value of 0.8 in the first week and 0.78 in the second week (Table 1). When divided into groups according to the anatomical type of feet, the first MDA also showed better ICC values in the first- and second-week. The physiological feet presented the first MDA values of 0.66 in the first week and 0.71 in the second week, which was considered good. For cavus feet, the measurement of the first week was considered good (0.64), and in the second week it was considered moderate (0.56). Both measurements were considered moderate in the flatfoot, with 0.58 in the first week and 0.60 in the second week. As for the other measures, all values were below 0.29 (Table 2).

The first MDA also presented the highest values in intraobserver reliability. Considering the 40 feet, the LCCC presented a good correlation, with values above 0.74 for all members in the first- and second-week. The other measures showed a poor to moderate correlation, with values below 0.48 (Table 3). The values obtained in the evaluation of O1 and O2 were higher, but those obtained by O3 and O4 were close. In the LCCC evaluation, according to the anatomical type of foot, the values of all measurements were variable between observers. The first MDA generally presented higher and closer values (Table 4). The first MDA correlation of O1 and O2 for the physiological feet was considered good, with

Table 1. Intraclass Correlation Coefficient results of all feet after first- and second-week measurements

Measures	N	ICC Week 1	95% CI	ICC Week 2	95% CI
First MDA	40	0.81	0.71–0.88	0.78	0.67–0.86
DA	40	0	-0.11–0.16	0.11	-0.03–0.28
First DMAA	40	0	-0.11–0.16	0.17	0.03–0.35
First PMAA	40	0.17	0.03–0.35	0.11	0.11–0.45
LIMA	40	0.16	0.02–0.34	0	0–0.31

ICC: Intraclass Correlation Coefficient; CI: Confidence Interval; First MDA: First metatarsal declination angle; DA: Angle described by Day; First DMAA: First distal metatarsal articular angle; First PMAA: First proximal metatarsal articular angle; LIMA: Lateral intermetatarsal angle.

Table 2. Intraclass Correlation Coefficient results after first and second-week measurements, according to the type of foot

	N	ICC Week 1	95% CI	ICC Week 2	95% CI
Physiological feet - First MDA	14	0.66	0.42–0.85	0.71	0.48–0.88
Physiological feet - DA	14	0	-0.16–0.31	0.07	-0.12–0.40
Physiological feet - First DMAA	14	0.07	-0.12–0.39	0.12	-0.09–0.45
Physiological feet - PMAA	14	0.27	0.03–0.60	0.29	0.04–0.61
Physiological feet - LIMA	14	0.27	0.02–0.59	0.19	-0.04–0.52
Cavus feet - First MDA	13	0.64	0.38–0.85	0.56	0.29–0.80
Cavus feet - DA	13	0	-0.17–0.32	0.19	-0.04–0.54
Cavus feet - First DMAA	13	0.03	-0.15–0.36	0.01	-0.16–0.34
Cavus feet - First - PMAA	13	0.21	0.03–0.55	0.26	0.01–0.60
Cavus feet - LIMA	13	0.09	-0.11–0.44	0.22	-0.02–0.57
Flatfoot - First MDA	13	0.58	0.31–0.82	0.60	0.33–0.83
Flatfoot - DA	13	0.07	-0.12–0.42	0	-0.17–0.32
Flatfoot - First DMAA	13	0	-0.17–0.32	0.19	-0.04–0.54
Flatfoot - First PMAA	13	0.02	-0.15–0.35	0.10	-0.10–0.45
Flatfoot - LIMA	13	0.07	-0.13–0.41	0	-0.17–0.32

ICC: Intraclass Correlation Coefficient; CI: Confidence Interval; First MDA: First metatarsal declination angle; DA: Angle described by Day; First DMAA: First distal metatarsal articular angle; First PMAA: First proximal metatarsal articular angle; LIMA: Lateral intermetatarsal angle.

Table 3. Lin Correlation Coefficient of Agreement results after measurements of the four observers, considering all feet

Measures	N	LCCC O1	95% CI	LCCC O2	95% CI	LCCC O3	95% CI	LCCC O4	95% CI
First MDA	40	0.90	0.83–0.95	0.80	0.66–0.89	0.74	0.56–0.85	0.76	0.59–0.86
DA	40	-0.06	-0.36–0.25	-0.14	-0.43–0.16	0.03	-0.16–0.22	0.03	-0.16–0.22
First DMAA	40	0.43	0.20–0.62	0.19	-0.11–0.46	-0.14	-0.34–0.08	-0.02	-0.27–0.23
First PMAA	40	0.46	0.19–0.67	0.37	0.08–0.61	0.47	0.19–0.67	0.03	-0.28–0.33
LIMA	40	0.26	-0.05–0.52	0.32	0.06–0.55	0.48	0.21– 0.68	0.10	-0.14–0.32

N: Number of radiographs; LCCC: Lin Correlation Coefficient of Agreement; ICC: Intraclass Correlation Coefficient; CI: Confidence Interval; O: observer; First MDA: First metatarsal declination angle; DA: Angle described by Day; First DMAA: First distal metatarsal articular angle; First PMAA: First proximal metatarsal articular angle; LIMA: Lateral intermetatarsal angle.

Table 4. Lin Correlation Coefficient of Agreement results after first-week measurements of four observers, according to the type of foot

Measures	N	LCCC O1	95% CI	LCCC O2	95% CI	LCCC O3	95% CI	LCCC O4	95% CI
Physiological feet - First MDA	14	0.79	0.55–0.91	0.90	0.74–0.96	0.55	0.20–0.78	0.44	-0.07–0.77
Physiological feet - DA	14	0.04	-0.45–0.52	-0.06	-0.54–0.45	0.10	-0.20–0.40	-0.17	-0.43–0.11
Physiological feet - First DMAA	14	0.31	-0.08–0.62	0.29	-0.25–0.70	0.03	-0.09–0.15	-0.20	-0.59–0.26
Physiological feet - PMAA	14	-0.03	-0.33–0.27	0.69	0.27–0.89	0.64	0.27–0.84	-0.24	-0.66–0.30
Physiological feet - LIMA	14	0.43	-0.06–0.76	0.42	-0.09–0.75	0.64	0.27–0.84	0.04	-0.28–0.35
Cavus feet - First MDA	13	0.88	0.67–0.96	0.55	0.18–0.78	0.68	0.23–0.89	0.53	0.02–0.82
Cavus feet - DA	13	-0.33	-0.71–0.21	0.15	-0.23–0.49	-0.17	-0.60–0.33	0.10	-0.22–0.40
Cavus feet - First DMAA	13	0.75	0.41–0.91	0.28	-0.21–0.66	0.17	-0.29–0.57	0.22	-0.32–0.65
Cavus feet - First - PMAA	13	0.38	-0.16–0.75	0.43	-0.11–0.77	0.50	-0.03–0.81	0.13	-0.41–0.60
Cavus feet - LIMA	13	0.29	-0.27–0.70	0.45	0.05–0.73	0.34	-0.13–0.69	-0.19	-0.55–0.23
Flatfoot - First MDA	13	0.76	0.41–0.91	0.52	0.04–0.80	0.41	-0.15–0.77	0.56	0.10–0.82
Flatfoot - DA	13	-0.10	-0.58–0.43	-0.24	-0.53–0.09	0.05	-0.08–0.18	0.17	-0.25–0.54
Flatfoot - First DMAA	13	0.24	-0.09–0.52	0.21	-0.04–0.43	-0.45	-0.78–0.06	-0.08	-0.40–0.25
Flatfoot - First PMAA	13	0.39	-0.16–0.75	-0.46	-0.80–0.09	0.13	-0.36–0.56	0.38	-0.17–0.75
Flatfoot - LIMA	13	0.07	-0.45–0.56	-0.14	-0.51 – 0.28	0.44	-0.06–0.76	0.35	-0.17–0.71

N: Number of radiographs; LCCC: Lin Correlation Coefficient of Agreement; ICC: Intraclass Correlation Coefficient; CI: Confidence Interval; O: observer; First MDA: First metatarsal declination angle; DA: Angle described by Day; First DMAA: First distal metatarsal articular angle; First PMAA: First proximal metatarsal articular angle; LIMA: Lateral intermetatarsal angle.

values above 0.70. The values of O3 and O4 were below 0.60. For cavus feet, the values of O1 and O3 were classified as good, with values above 0.60. The LCCC measurements obtained by O2 and O4 were below 0.60. For flatfoot, only O1 obtained values considered good, above 0.70. The remainder presented values below 0.60.

Discussion

Any measure used to classify deformities and schedule the surgical procedure must present reproducible values. Our study showed that of all the angles previously described to evaluate the first metatarsal sagittal alignment, the first MDA had the highest inter- and intraobserver correlation values.

In the literature, few studies address the angular measurements used in the forefoot in profile view. Many evaluated only the inter- and intraobserver reliability of radiographic measurements in anteroposterior (AP) view in pathologies such as hallux valgus and metatarsal adduction. Chi et al. demonstrated in a 32-foot study that the distal metaphyseal joint angle presented low interobserver reliability, measured by Scheffe's F test. The images were evaluated by three residents in training and foot and ankle surgery [12]. Dawoodi and Perera evaluated three measurements' inter- and intraobserver reliability to calculate forefoot adduction at AP view in 50 radiographs. Only one observer obtained measurements with an interval of three weeks. The ICC values obtained were from 0.85 to 0.92 [13]. A new measure to evaluate the extent of the first metatarsal in profile view in patients with hallux valgus and hallux rigidus was described by Bouaicha et al. To obtain the measurement, the authors used a circumference centered on the head of the first metatarsal and a line on its dorsal cortical as references. Despite presenting excellent interobserver correction (ICC = 0.90), the measurement was linear and not angular [1]. In contrast, we did not conduct a study to evaluate a new measure but to investigate whether those already described are reliable enough to be used in clinical practice. In addition, only the angular measurements

were included to avoid possible technical interference in the radiographs. Gibboney et al. performed a study with radiographic measurements of the foot and ankle in profile view, in which specialist, resident, and academic physicians calculated the values. They demonstrated that the highest values of interobserver reproducibility were found in the group of residents, followed by specialists and academics[6].

The higher ICC and LCCC values observed in the first MDA measurements can be justified by their more evident reference points, based on the first metatarsal and the ground line, with less interference caused by the cuneiforms overlap, metatarsals, and smaller toes. Thomas et al. evaluated measurements of the forefoot in the AP and profile views and demonstrated that the boundary of reference points is usually inconsistent [14]. The low values observed in the other measurements possibly reflect the difficulty that observers had in accurately identifying the proximal joint surfaces and dorsum of the second metatarsal. In a study that evaluated the first metatarsal sagittal alignment after correction of hallux valgus with the Lapidus technique, Nishikawa et al. [2] demonstrate that the first MDA is reproducible with excellent ICC, with mean values of 0.90. Unlike what was observed in our study, Lamm et al. [3] obtained high ICC values in the first PMAA (0.739) and the first DMAA (0.814) measurements in the 24-foot analysis. However, all evaluations were performed by senior surgeons, and there was no division of radiographs into anatomical types of foot.

Our study is the first to include the most used measures to estimate the first metatarsal sagittal alignment and evaluate its inter- and intraobserver reliability. The importance of its results is to assist in the choice of angular measurement with more evident reference points and more reproducible results, thus facilitating the programming of procedures and postoperative follow-up.

The study has limitations regarding the number of radiographs and technical limitations. However, the sample calculation was previously obtained, so the result was relevant. Although we exclude conditions that could technically interfere with obtaining an adequate radiograph, the radiographic analysis is two-dimensional, which can influence the foot position[15,16].

Conclusion

The first MDA represents an adequate radiographic tool for measuring the first metatarsal sagittal alignment when evaluated by the CCI and LCCC.

In addition, among all the angles evaluated, the first MDA presented higher values in intra- and interobserver correlation, regardless of the anatomical type of foot. However, more studies are needed to corroborate our results and define the best measures.

Authors' contributions: Each author contributed individually and significantly to the development of this article: DRCN *(https://orcid.org/0000-0003-0227-2440), and DLR *(https://orcid.org/0000-0003-0183-8641), and PBR *(https://orcid.org/0000-0002-7215-8187) Conceived and planned the activities that led to the study, wrote the article, participated in the revision process and approved the final version; PBR *(https://orcid.org/0000-0002-7215-8187), and DKPG *(https://orcid.org/0000-0001-7552-6590), and TBS *(https://orcid.org/0009-0002-9385-2044), and DAS *(https://orcid.org/0009-0008-8395-8797) Performed all radiographic measurements that were the subject of evaluation in the study; PBR *(https://orcid.org/0000-0002-7215-8187),and DRCN *(https://orcid.org/0000-0003-0227-2440), and DLR *(https://orcid.org/0000-0003-0183-8641), and TSM *(https://orcid.org/0000-0003-4168-0981), and CDF *(https://orcid.org/0000-0002-6649-2066), and FDPR *(https://orcid.org/0009-0007-9143-1162). Interpreted the results and participated in the review process and formatting of the article. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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