Foot and Ankle Surgery 18 (2012) 180–186

Contents lists available at SciVerse ScienceDirect

Foot and Ankle Surgery

journal homepage: www.elsevier.com/locate/fas

Reliability of metatarsus adductus angle and correlation with hallux valgus

Aryan I.S. Dawoodi MBChB, MRCSEd, Dip.SEM(GB&I), MSc*, Anthony Perera MBChB, MRCS, MFSEM, FRCS(Orth)

Department of Trauma & Orthopaedic Surgery, Llandough University Hospital, Penlan Road, Llandough CF64 2XX, United Kingdom

ARTICLE INFO

Article history:
Received 12 March 2011
Accepted 6 October 2011

Keywords:
Metatarsus adductus
Angle
Reliability
Hallux valgus

ABSTRACT

Background: Metatarsus adductus is a common congenital foot deformity. Variable prevalence values were reported using different techniques in different populations.

Numerous radiological measurements have been proposed to assess this deformity with a paucity of studies reporting the reliability of these methods.

The metatarsus adductus angle was shown to correlate with the severity of hallux abductovalgus in normal feet and preselected populations of juvenile hallux valgus.

Materials and methods: Weight bearing dorsoplantar radiographs of 150 feet were examined for 5 angles commonly used in assessing metatarsus adductus: angle between the second metatarsus and the longitudinal axis of the lesser tarsus (using the 4th or 5th metatarso-cuboid joint as a reference), Engel's angle and modified Engle's angle. The prevalence of metatarsus adductus was assessed according to published criteria for different techniques. Inter and intra-observer reliabilities of these angles were evaluated on 50 X-rays. Linear regression tests were used to assess the correlation between hallux valgus and different angles used in assessing metatarsus adductus.

Results: Intraclass correlation coefficients were high for intra- as well as inter-observer reliability for the 5 angles tested. Prevalence of metatarsus adductus ranged (45–70%) depending on the angle used in the same population. Only the metatarsus adductus angle using the 4th metatarso-cuboid joint as a reference demonstrated significant correlation between metatarsus adductus and hallux abductovalgus angles.

Conclusion: Five techniques commonly used in assessing metatarsus adductus demonstrated high inter and intra-observer reliability values. Prevalence of metatarsus adductus and the correlation between the severity of this deformity and hallux valgus angle is sensitive to the assessment method.

1. Introduction

Radiological examination of the foot has evolved over the years and became an indispensable tool for evaluation of an array of congenital and acquired deformities. It is also essential in monitoring progress of deformity [1], planning and selecting type of surgery required as well as assessing outcomes especially in procedures involving reconstruction of the osseous architecture [2,3].

A growing body of evidence investigated the reliability of various angular and linear measurements on X-rays of the foot and ankle. The reliability of these measurements has been shown to vary for different methods used. However, a higher interobserver than intraobserver disagreement is common place [4–6]. This may be explained by the lack of unanimity of landmarks used in charting different angular measurements [7].

Metatarsus adductus is defined as a transverse plane deformity where the metatarsals are deviated medially in relation to the midfoot. This can present as one of the deformities associated with clubfeet in paediatric population, or observed in adolescents and adults [8–12].

An array of methods to assess metatarsus adductus have been reported, including: Sgarlato's method (angle between the longitudinal axis of the second metatarsal and the longitudinal axis of the lesser tarsus using the 4th metatarso-cuboid joint as a reference) as shown in Fig. 1 [12–16], modified Sgarlato's technique (angle between the longitudinal axis of the second metatarsal and the longitudinal axis of the lesser tarsus using the 5th metatarso-cuboid joint as a reference) as shown in Fig. 2 [14,17], Engel's angle (the angle between the longitudinal axes of the middle cuneiform and the second metatarsal) as shown in Fig. 3 [14,18–21], talo-first metatarsal angle [22], calcaneo-second metatarsal angle as shown in Fig. 4 [15,23,24], calcaneo-fifth metatarsal angle [25], Lepow's angle [26] and Kilmartin's angle

* Corresponding author. Tel.: +44 07752405220.
E-mail addresses: Aryan@dawoodi.net (Aryan I.S. Dawoodi), footandanklesurgery@gmail.com (A. Perera).

1268-7731/$ – see front matter © 2011 European Foot and Ankle Society. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.fas.2011.10.001

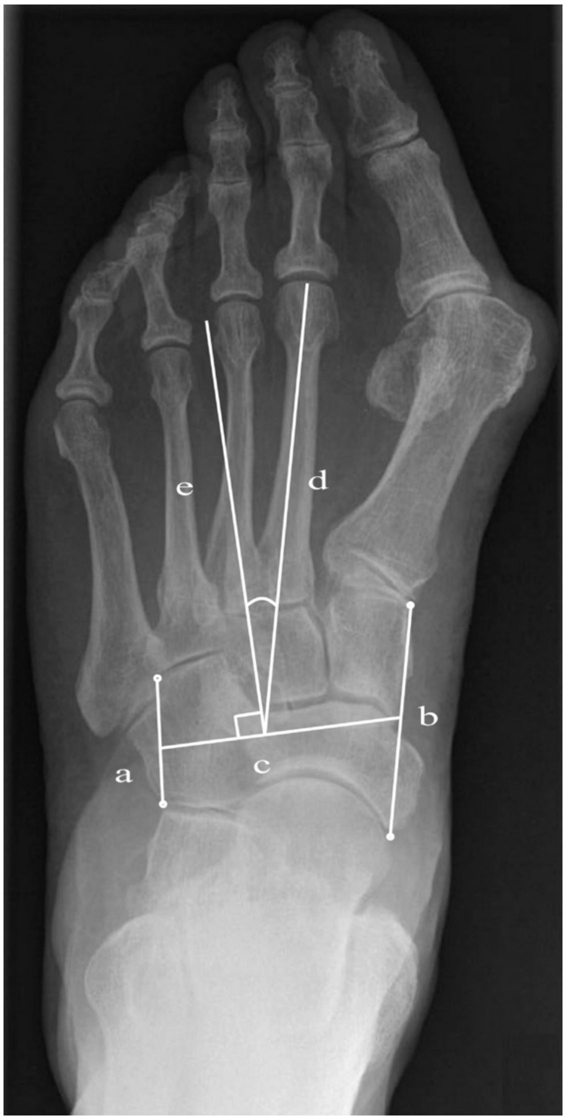

Fig. 1. Traditional (Sgarlato's) metatarsus adductus angle using the 4th metatarso-cuboid point as a reference. Line (a) extends between the most lateral point of the 4th metatarso-cuboid and the calcaneo-cuboid joints. Line (b) extends between the most medial point of the talo-navicular and the medial cuneiform-first metatarsal joints. Line (c) extend between midpoints of lines (a) and (b). Line (d) represents the longitudinal axis of the second metatarsal bone. Line (e) is perpendicular to line (c) and represents the longitudinal axis of the lesser tarsus. Sgarlato's angle is between the lines (d) and (e).

Fig. 2. Modified Sgarlato's metatarsus adductus angle using the 5th metatarso-cuboid point as a reference. Line (a) extends between the most lateral point of the 5th metatarso-cuboid and the calcaneo-cuboid joints. Line (b) extends between the most medial point of the talo-navicular and the medial cuneiform-first metatarsal joints. Line (c) extend between midpoints of lines (a) and (b). Line (d) represents the longitudinal axis of the second metatarsal bone. Line (e) is perpendicular to line (c) and represents the longitudinal axis of the lesser tarsus. Sgarlato's angle is between the lines (d) and (e).

[27]. Thomas et al. recently modified Engel's angle by taking a perpendicular to the proximal articular surface of the middle cuneiform instead of the longitudinal axis as shown in Fig. 5 [28].

A paucity of studies focused on the inter- and intraobserver reliability of these methods. Dominguez and Munuera reported high inter- and intraobserver values for measuring the metatarsus adductus angle whether using the 4th metatarso-cuboid joint or the 5th metatarso-cuboid joint. However, in this study the population inclusion criteria targeted normal feet only [14]. McCluney and Tinley investigated the intraobserver reliability of Kilmartin's angle in the age group 9–16 years old. They reported an intraclass correlation coefficient of 0.889 [29]. Bryant et al. reported a 0.92 intraobserver reliability of the metatarsus adductus angle using the 5th metatarso-cuboid joint as a reference [30]. We could not identify any studies evaluating the reliability of various methods used to assess metatarsus adductus in patients with established diagnosis of symptomatic hallux abductovalgus, where the reliability of preoperative data that substantially affects clinical decisions and planning for surgery are more appropriate.

Metatarsus adductus has long been implicated as a risk factor in the development of hallux abductovalgus [8,31–33]. Pontious et al. suggested that under recognised metatarsus adductus may account for the high recurrence rate in juvenile hallux valgus [20]. The association between metatarsus adductus and hallux valgus has been investigated by several studies. Whilst La Reaux and Lee [19] and Ferrari and Malone-Lee [21] statistically proved that metatarsus adductus was associated with a higher prevalence of hallux abductovalgus in a case–control model; other studies could not demonstrate similar findings [27,29,30].

On the other hand the correlation between HAV and MA angles have been shown to be significantly positive using linear regression models with R squared ranging from 0.128 to 0.478 [21,34,35]. However, techniques used in assessing MA angle and the populations of these studies were not uniform in terms of patients' age and male:female preponderance, which may explain

Fig. 3. Engel's angle. Line (a) bisect the middle cuneiform into. Line (b) represents the longitudinal axis of the second metatarsal bone. Engel's angle is between lines (a) and (b).

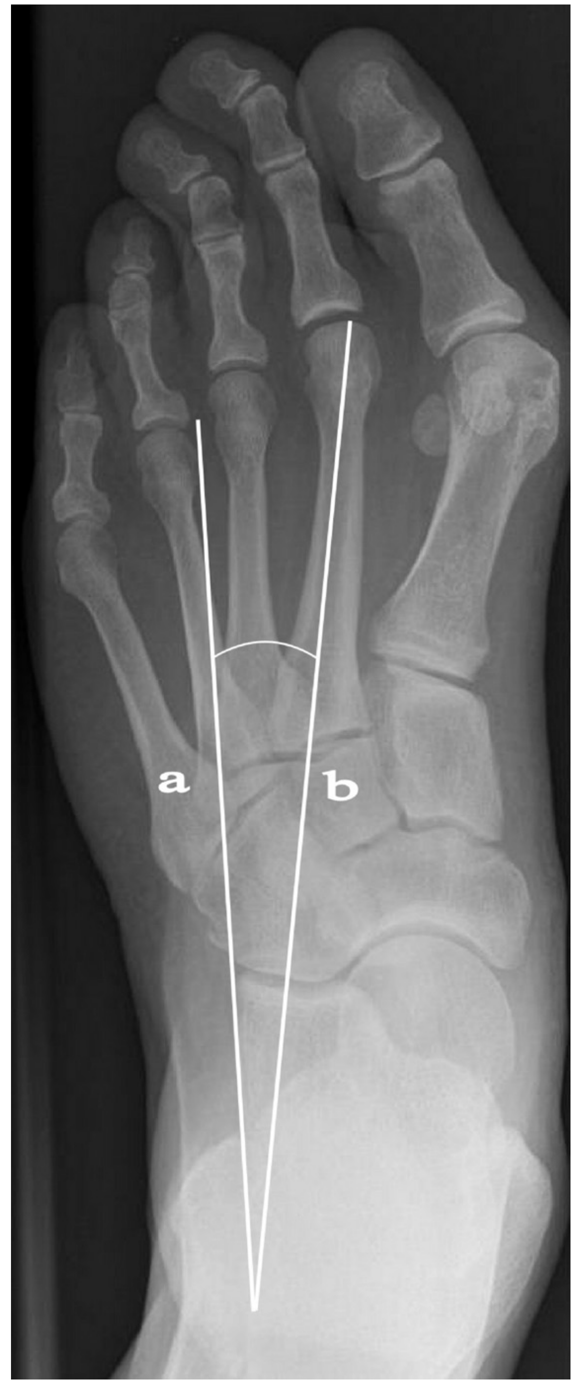

Fig. 4. Rearfoot reference line-second metatarsal angle. Line (a) is parallel to the lateral border of the calcaneum. Line (b) represents the longitudinal axis of the second metatarsal bone.

the variability in *R* squared reported by different authors. D'Arcangelo et al. recently demonstrated a significant correlation between MA angle and HAV severity when using Engel's angle, and no significant correlation when using the traditional MA angle [36]. This may suggest that techniques used to assess the MA angle are critical in assessing the association between MA and HAV. Accordingly further studies are necessary to reliably demonstrate the correlation between metatarsus adductus and HAV.

The objectives of the present study are to establish:

1. Inter- and intraobserver reliability of different techniques used in assessing the MA angle.
2. The effect of MA angle technique on the prevalence of this deformity.
3. The correlation between HAV and different techniques used in assessing MA angle.

2. Materials and methods

One hundred and fifty preoperative dorsoplantar radiographic views for (130) patients were included in the study. The inclusion criteria were: symptomatic hallux abductovalgus, patients listed for corrective surgery, no evidence of foot trauma and no history of previous forefoot surgery. All angles assessed in this study were measured electronically using Impax X-rays viewer software (Agfa Healthcare, Belgium). It has been shown that computerised angular measurements yield more reliable results compared to goniometric methods [37].

The following angles were examined on each X-ray: hallux valgus (HAV), 1st–2nd intermetatarsal (IMA), rearfoot-2nd metatarsal angle (RRL-MT2), Sgarlato's angle (angle between the second metatarsus and the longitudinal axis of the lesser tarsus using the 4th metatarso-cuboid joint as a reference referred to hereafter as LALT-2MT 4th) [15], modified Sgarlato's angle (angle between the

Fig. 5. Modified Engel's angle. Line (a) is parallel to the base of the middle cuneiform articular surface. Line (b) is perpendicular to line (a). Line (c) represents the longitudinal axis of the second metatarsal bone. The modified Engel's angle is between line (b) and (c).

second metatarsal and the longitudinal axis of the lesser tarsus using the 5th metatarso-cuboid joint as a reference referred to hereafter as LALT-2MT 5th), Engel's angle (angle between the longitudinal axis of the middle cuneiform and the longitudinal axis

Table 2
Intraclass correlation coefficients for intra and inter-observer reliability of five different methods to assess MA angle.

Angle	Intra-observer ICC(3,1)	Inter-observer ICC(2,2)
RRL-2MT	0.85	0.87
LALT-2MT(5)	0.92	0.87
LALT-2MT(4)	0.91	0.93
Engel	0.90	0.84
Modified Engel	0.92	0.91

of the second metatarsal) [18], modified Engle's angle (angle between the longitudinal axis of the second metatarsal and a line perpendicular to the proximal articular surface of the middle cuneiform) [28] and the angle between the rearfoot reference line (line parallel to the lateral border of the calcaneum) and the longitudinal axis of the second metatarsal. In our study we considered (20°, 14° and 24°) the upper normal limits for the LALT-2MT 5th, LALT-MT 4th and Engel's angles, respectively. We assumed that modified Engel's angle was to yield similar values to the original Engel's method [28], hence we considered 24° as the upper normal limit. The calcaneo-second metatarsal angle was reported to be $15^\circ \pm 3^\circ$ and hence considered 18° as the upper normal limit [23].

Data were analysed using software (SPSS v 14.0 for Windows). The distribution of all data recorded was evaluated for normality using the Kolomogorov–Smirnov test. The objective of this test is to compare the distribution of sample data to an alternative distribution which, in this case, is hypothesised to be normal. Accordingly, accepting the null hypothesis means that the data are normally distributed.

In order to evaluate interobserver reliability, fifty X-rays were selected randomly and examined independently by the authors (AD and AP) for five techniques to assess MA angle: LALT-MT2 4th, LALT-MT2 5th, Engel's angle, modified Engel's angle and RRL-2MT. Intraclass correlation coefficient was calculated by using two-way random-effect model for absolute agreement ICC(2,1). This is a quantitative test that measures the ratio of two variance derived from analysis of variance (ANOVA). It assesses the reproducibility of random quantitative variables by different observers randomly selected from a larger population of observers [38].

To evaluate intraobserver reliability, one author (AD) measured same five angles on 2 occasions 3 weeks apart on same 50 X-rays. Intraclass correlation coefficient (ICC) using two-way mixed-effect model was calculated to detect consistency of measurements made by this author ICC(3,1). In this test the observer is deemed fixed, however the targets are randomised [38].

Linear regression tests were used to assess the correlation between the different techniques used in this study to assess metatarsus adductus and degree of hallux abductovalgus.

3. Results

A total of 150 dorsoplantar weight bearing foot X-rays for (133 patients) were examined. There were 119 females and 14 males (female:male ratio 8.5), and 73 right and 77 left feet. The mean patients' age was (50.6 years, standard deviation = 15.4) ranging from 14 to 80 years old. Normal distribution of all data was confirmed by Kolomogorov–Smirnov test.

Table 1
Descriptive statistics of different techniques used to evaluate metatarsus adductus in 150 DP foot X-rays.

	HAV	IMA	RRL2MT	LALT-2MT(5)	LALT-2MT(4)	Engel	Modified Engel
Mean ± SD	35.4 ± 7.2	14.4 ± 3.6	12.9 ± 8.9	22.7 ± 6.0	17.1 ± 5.9	23.9 ± 6.3	19.9 ± 6.6
98% COI	34.3–36.6	13.8–14.9	11.4–14.3	21.7–23.7	16.1–18.0	22.9–24.9	18.9–21.0

Table 3
Linear regression results for correlation between HAV and five commonly used angles to assess metatarsus adductus.

	RRL2MT	LALT-2MT(5)	LALT-2MT(4)	Engel's angle	Modified Engel
R	0.051	0.11	0.152	0.090	0.014
R^2	0.003	0.012	0.023	0.008	0.000
Adjusted R^2	−0.004	0.005	0.016	0.001	−0.007
Standard error	7.24	7.2	7.16	7.22	7.25
p value	0.266	0.91	0.032	0.136	0.432

The mean, standard deviation and 95% confidence intervals for the RRL-2MT, LALT-2MT(5th), LALT-2MT(4th), Engel's and modified Engel's angles are presented in Table 1. Interestingly, there was considerable variation in the prevalence of MA measured by different techniques. The prevalence of MA measured by RRL-2MT, LALT-2MT(5th), LALT-2MT(4th), Engel's and modified Engel's angles was (25.3%, 62%, 70%, 45%, and 25.3%), respectively.

Inter and intraobserver reliabilities of metatarsus adductus angle using five different techniques were found to be reliable, with the majority demonstrating intraclass correlation ranging between 0.85 and 0.92 (Table 2). Linear regression results for the correlation between the different techniques used to assess metatarsus adductus and hallux abductovalgus angle are presented in Table 3. The only method that demonstrated a significant positive correlation ($R^2 = 0.152$, $p = 0.032$) with the severity of hallux abductovalgus angle was Sgarlato's method (using the 4th metatarso-cuboid joint as a reference).

4. Discussion

The intraobserver reliability of common angular measurements used in the assessment of various foot disorders has been reported satisfactory [6,39]. An example is the intraobserver reliability of HAV angle was reported to range (ICC 0.86–1.00) and calcaneal inclination angle range (ICC 0.87–0.97) [29,30,40,41]. On the other hand interobserver error of HAV angle was found to be in excess of 5° which may invalidate angular measurements unless evaluated by the same observer [6]. Similar excessive interobserver variability has been demonstrated for the proximal articular angle (PASA) of the first metatarsophalangeal joint [42]. Therefore, interobserver reliability should, whenever possible, be evaluated for any measurement that directly affects clinical decision and/or planning surgery. The reliability of angular measurements used to assess MA received less attention in literature compared to those used in assessing other, perhaps more common, foot disorders. Metatarsus adductus is purported to be a reasonably common factor in the aetiology of hallux valgus [31,32]. In order to investigate this causal relationship, it is essential to establish a consensus on a reliable objective measure which does not bias the measurement of the intermetatarsal angle by under-estimating it.

The intraobserver reliability of MA angle (LALT-2MT 5th) was (ICC = 0.92) in our study. This was found to be in concordance with values reported in other studies (ICC = 0.889–0.92) [14,30].

Interobserver reliability of (LALT-2MT 5th) was (ICC = 0.87) in our study which is lower than values reported by Dominguez and Munuera (ICC = 0.962) [14]. However, it is worth noting that Dominguez et al. investigated the reliability of MA in normal feet, where the mean MA angle they reported ($20.971^\circ \pm 4.479^\circ$) was significantly ($p < 0.05$) lower than that reported in our study ($22.7^\circ \pm 6^\circ$). This may suggest lower reliability when measuring higher angles of metatarsus adductus as landmarks are less readily identifiable using this technique.

Inter- and intraobserver reliability of MA angle measured using (LALT-2MT 4th) in our study demonstrated correlation coefficients (0.93 and 091, respectively) comparable to those reported by Dominguez et al. (0.962 and 0.972, respectively), despite the significantly ($p < 0.05$) higher mean MA angle (17.1 ± 5.9) reported in our study compared to those (14.466 ± 4.121) reported by the latter study. These findings suggest satisfactory inter and intraobserver reliability of metatarsus angle measured using Sgarlato's technique (whether using the 4th or 5th metatarso-cuboid angle as a reference) across a broader spectrum of angles with higher degrees of metatarsus adductus.

We could not identify any studies reporting the reliabilities of the other angles used in assessing MA in our study (Engel's, modified Engel's and calcaneo-second metatarsal angles) for comparison. However, high intraclass correlation coefficients imply sufficient reproducibility of these measures to be used reliably in clinical settings where more than one observer is involved in the assessment of these angles.

The prevalence of MA in patients presented with hallux valgus has been reported with varying proportions ranging from 35% to 75% in the literature [19,22,35]. This may be due to several factors including the variability and/or unreliability of techniques used to assess MA angle and therefore a standardised technique and/or approach is essential in order to produce accurate results. Our intention was to demonstrate the effect of technique factor on prevalence of metatarsus adductus in the same population of individuals. The frequency distribution of three techniques used in assessing metatarsus adductus is presented in Fig. 6. The varying prevalence of MA in our study using different techniques (25.3–70%) has two important clinical implications. One method for determining normal limits used in literature is by comparing proportions of normal values for a standard technique to the one being assessed [18,22]. Since different methods used in assessing MA demonstrated varying sensitivity reflected in a wide range of prevalence, cautious interpretation of reported normal values should be exercised, as well as the need for implementing more robust methods to determine these important parameters. Second, as Engel's and modified Engel's angles yielded vastly different prevalence values (45% and 25.3%, respectively) this demonstrates the paramount significance of different landmarks in what appears to be assessing the same angle.

The correlation between HAV and MA angles was reported with variable results by different authors. The only method that significantly correlated with the hallux abductovalgus angle was that suggested by Sgarlato (LALT-2MT 4th) [15]. A scatter diagram showing this correlation is presented in Fig. 7. This is in concordance with two previous studies where the authors used a similar technique. Griffiths and Palladino [34] reported a significant correlation ($R^2 = 0.128$, $p = 0.001$) between HAV and MA angles in 115 normal feet, where they excluded all X-rays with IMA $> 9^\circ$ and HAV $> 15^\circ$. On the other hand, Banks et al. demonstrated comparable findings ($R^2 = 0.478$, $p = 0.0001$) in 40 patients (72 feet) under 21 years of age presented for repair of juvenile hallux valgus. In the present study, variables such as the IMA angle and age were not controlled compared to the previous two studies. This suggests that MA angle measured by Sgarlato's technique is a reliable method for demonstrating a positive correlation between HAV and MA angles.

Ferrari et al. reported a positive correlation between HAV and MA angles (females: $R^2 = 0.53$, $p < 0.001$; males: $R^2 = 0.48$,

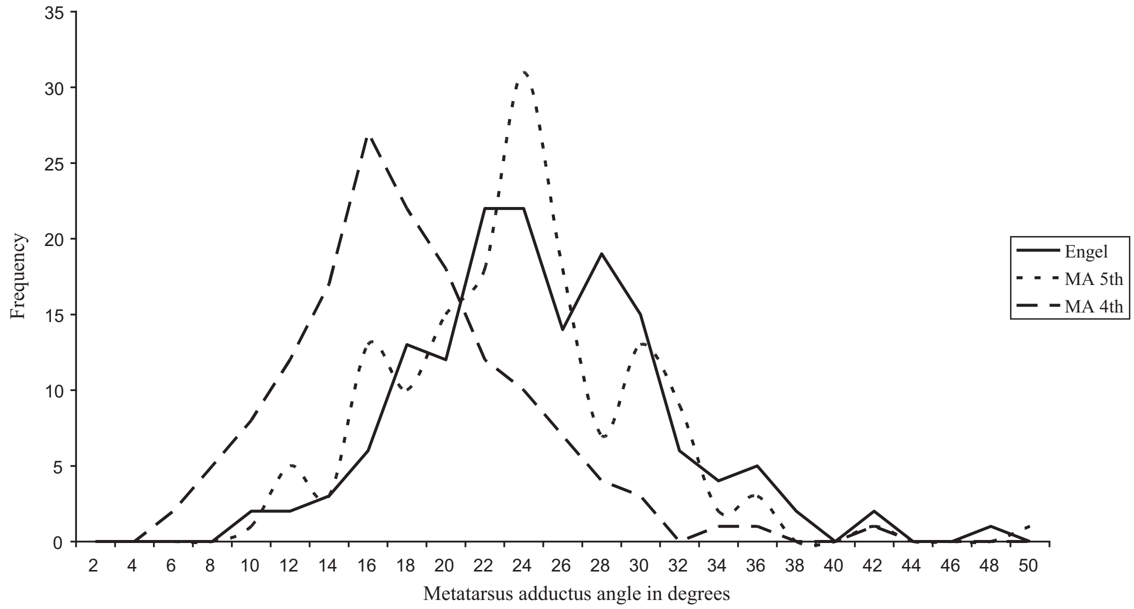

Fig. 6. Frequency chart for 3 metatarsus adductus angles.

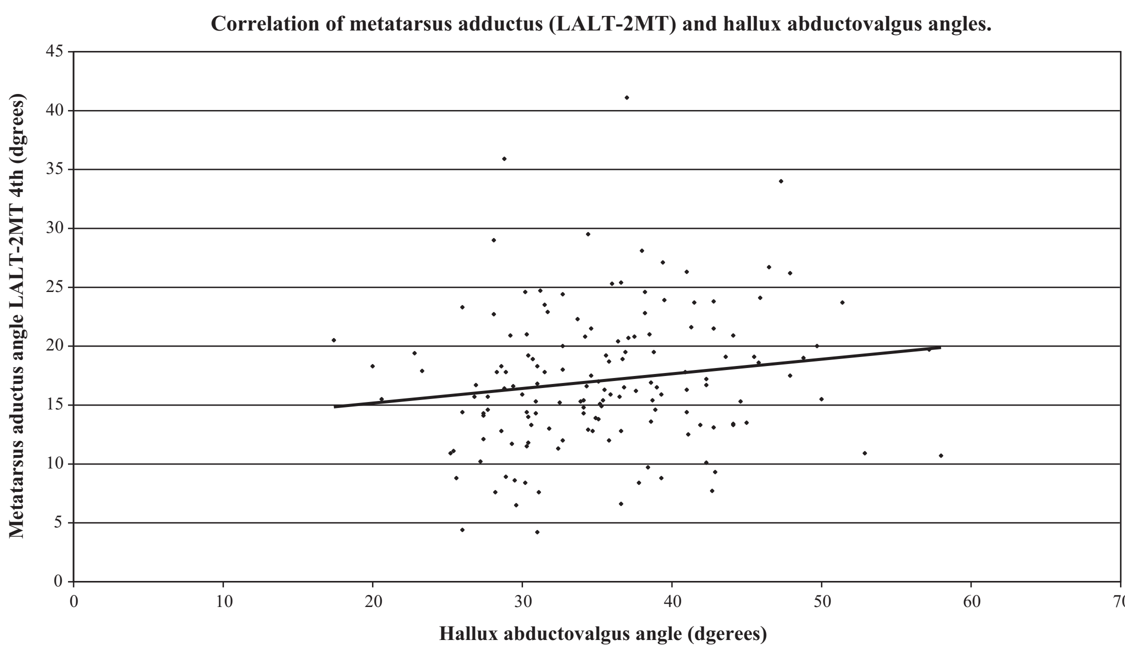

Fig. 7. Scatter diagram displaying the correlation between hallux abductovalgus and metatarsus adductus angles.

$p < 0.001$) using Engel's angle. However, in our study we could not statistically demonstrate a significant correlation ($R^2 = 0.008$, $p = 0.136$), suggesting that although Engel's angle is a reliably reproducible technique, however, it may underestimate the correlation between HAV and MA angles. On the other hand, it may highlight the importance of other factors involved in determining the severity of hallux valgus such as hindfoot pronation and first ray hypermobility [43].

Similarly, the other angles used in the present study (LALT-2MT 5th, RRL-2MT and modified Engel's angle) did not demonstrate a significant correlation with HAV angle. A frequency diagram of three methods used in assessing metatarsus adductus (Sgarlao, modified Sgarlato and Engel's angles) is presented in Fig. 2. An interesting observation is the smooth curve of Sgarlato's method compared to the other two methods. This may in part explain the sensitivity of this method to detecting the correlation between metatarsus adductus and HAV angles.

5. Conclusions

Our study suggest that different techniques used in assessing metatarsus adductus demonstrated high values of intra- as well as interobserver reliability compared to angles used in assessing other deformities e.g. HAV, PASA. However, in the process of assessing metatarsus adductus, using one technique is preferred as different techniques yield dissimilar values with varying implications for screening and/or diagnosis purposes. The MA angle measured by Sgarlato's technique demonstrated the highest inter- and intraobserver reliability as well as reliably demonstrating a significant positive correlation between HAV and MA angles. We suggest that Sgarlato's technique should be considered as the standard method for assessing MA angle in research and clinical settings. The clinical implications include a more reliable diagnosis of MA and planning management for recurrent cases of related forefoot deformities such as hallux abductovalgus. In addition metatarsus adductus causes an underestimate of the intermetatarsal angle which affects decision making in hallux abductovalgus management and the way it affects the selection of surgical procedure, recurrence rate and aetiology. However, it is essential to establish a consensus on what is the most reliable and objective measure.

Conflict of interest

The authors have no conflicts of interest to report.

References

[1] Gutierrez PR, Lara MH. Giannini prosthesis for flatfoot. Foot Ankle Int 2005;26:918–26.
[2] Larholt J, Kilmartin TE. Rotational scarf and akin osteotomy for correction of hallux valgus associated with metatarsus adductus. Foot Ankle Int 2010;31:220–8.
[3] Haeseker GA, Mureau MA, Faber FW. Lateral column lengthening for acquired adult flatfoot deformity caused by posterior tibial tendon dysfunction stage II: a retrospective comparison of calcaneus osteotomy with calcaneocuboid distraction arthrodesis. J Foot Ankle Surg 2010;49:380–4.
[4] Cook DA, Breed AL, Cook T, DeSmet AD, Muehle CM. Observer variability in the radiographic measurement and classification of metatarsus adductus. J Pediatr Orthop 1992;12:86–9.
[5] Schneider W, Csepan R, Kasparek M, Pinggera O, Knahr K. Intra- and interobserver repeatability of radiographic measurements in hallux surgery: improvement and validation of a method. Acta Orthop Scand 2002;73:670–3.
[6] Kilmartin TE, Barrington RL, Wallace WA. The X-ray measurement of hallux valgus: an inter- and intra-observer error study. The Foot 1992;2(1):7–11.
[7] Schneider W, Knahr K. Metatarsophalangeal and intermetatarsal angle: different values and interpretation of postoperative results dependent on the technique of measurement. Foot Ankle Int 1998;19:532–6.
[8] Root ML, Orien WP, Weed JH. Normal and abnormal foot function of the foot. Clinical Biomechanics Corporation; 1977. p. 355.
[9] Rothbart BA. Metatarsus adductus and its clinical significance. J Am Podiatry Assoc 1972;62:187–90.
[10] Kite JH. Congenital metatarsus varus. J Bone Joint Surg Am 1967;49:388–97.
[11] Cramer K. Metatarsus adductus congenitus. Ztschr F chir u mechanische Orthopad 1909;329.
[12] Theodorou DJ, Theodorou SJ, Boutin RD, Chung C, Fliszar E, Kakitsubata Y, et al. Stress fractures of the lateral metatarsal bones in metatarsus adductus foot deformity: a previously unrecognized association. Skeletal Radiol 1999;28:679–84.
[13] Michaud TC. Foot orthoses and other forms of conservative foot care. Williams & Wilkins; 1997.
[14] Dominguez G, Munuera PV. Metatarsus adductus angle in male and female feet: normal values with two measurement techniques. J Am Podiatr Med Assoc 2008;98:364–9.
[15] Sgarlato TE.In: Compendium of podiatric biomechanics. San Francisco: California College of Podiatric Medicine; 1971.
[16] Weissman SD. Biomechanically acquired foot types. In: Weissman SD, editor. Radiology of the foot. Baltimore: Williams and Wilkins; 1989. p. 66–90.
[17] Gentili A, Masih S, Yao L, Seeger LL. Pictorial review: foot axes and angles. Br J Radiol 1996;69:968–74.
[18] Engel E, Erlick N, Krems I. A simplified metatarsus adductus angle. J Am Podiatry Assoc 1983;73:620–8.
[19] La Reaux RL, Lee BR. Metatarsus adductus and hallux abducto valgus: their correlation. J Foot Surg 1987;26:304–8.
[20] Pontious J, Mahan KT, Carter S. Characteristics of adolescent hallux abducto valgus. A retrospective review. J Am Podiatr Med Assoc 1994;84:208–18.
[21] Ferrari J, Malone-Lee J. A radiographic study of the relationship between metatarsus adductus and hallux valgus. J Foot Ankle Surg 2003;42:9–14.
[22] Simons GW. Analytical radiography of club feet. J Bone Joint Surg Br 1977;59-B:485–9.
[23] Ganley JV, Ganley TJ. Metatarsus adductus deformity. In: Banks AS, Downey MS, editors. Comprehensive textbook of foot surgery. Baltimore: Williams & Wilkins; 1992. p. 829–52.
[24] Gamble FO, Yale I. Clinical foot roentgenology. Krieger Publishing; 1975. p. 186–208.
[25] Ponseti IV, Becker JR. Congenital metatarsus adductus: the results of treatment. J Bone Joint Surg Am 1966;48:702–11.
[26] Lepow GM, Lepow RS, Lepow RM, Hillman L, Neville R. Pediatric metatarsus adductus angle. J Am Podiatr Med Assoc 1987;77:529–32.
[27] Kilmartin TE, Barrington RL, Wallace WA. Metatarsus primus varus. A statistical study. J Bone Joint Surg Br 1991;73:937–40.
[28] Thomas JL, Kunkel MW, Lopez R, Sparks D. Radiographic values of the adult foot in a standardized population. J Foot Ankle Surg 2006;45:3–12.
[29] McCluney JG, Tinley P. Radiographic measurements of patients with juvenile hallux valgus compared with age-matched controls: a cohort investigation. J Foot Ankle Surg 2006;45:161–7.
[30] Bryant A, Tinley P, Singer K. A comparison of radiographic measurements in normal, hallux valgus, and hallux limitus feet. J Foot Ankle Surg 2000;39:39–43.
[31] Houghton GR, Dickson RA. Hallux valgus in the younger patient: the structural abnormality. J Bone Joint Surg Br 1979;61-B:176–7.
[32] Mann RA, Coughlin MJ. Hallux valgus – etiology, anatomy, treatment and surgical considerations. Clin Orthop Relat Res 1981;31–41.
[33] Tax HR, Albright T. Metatarsus adducto varus: a simplified approach to treatment. J Am Podiatry Assoc 1978;68:331–8.
[34] Griffiths TA, Palladino SJ. Metatarsus adductus and selected radiographic measurements of the first ray in normal feet. J Am Podiatr Med Assoc 1992;82:616–22.
[35] Banks AS, Hsu YS, Mariash S, Zirm R. Juvenile hallux abducto valgus association with metatarsus adductus. J Am Podiatr Med Assoc 1994;84:219–24.
[36] D'Arcangelo PR, Landorf KB, Munteanu SE, Zammit GV, Menz HB. Radiographic correlates of hallux valgus severity in older people. J Foot Ankle Res 2010;3:20.
[37] Farber DC, Deorio JK, Steel III MW. Goniometric versus computerized angle measurement in assessing hallux valgus. Foot Ankle Int 2005;26:234–8.
[38] Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychol Bull 1979;86:420–8.
[39] Saltzman CL, Brandser EA, Berbaum KS, DeGnore L, Holmes JR, Katcherian DA, et al. Reliability of standard foot radiographic measurements. Foot Ankle Int 1994;15:661–5.
[40] Coughlin MJ, Freund E. Roger A. Mann Award. The reliability of angular measurements in hallux valgus deformities. Foot Ankle Int 2001;22:369–79.
[41] Cavanagh PR, Morag E, Boulton AJ, Young MJ, Deffner KT, Pammer SE. The relationship of static foot structure to dynamic foot function. J Biomech 1997;30:243–50.
[42] Sullivan BT, Robison JB, Palladino SJ. Interevaluator variability in the measurement of proximal articular set angle. J Foot Surg 1988;27:466–8.
[43] King DM, Toolan BC. Associated deformities and hypermobility in hallux valgus: an investigation with weightbearing radiographs. Foot Ankle Int 2004;25:251–5.