Original Article

Approach for measuring the angle of hallux valgus

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Abstract

Background: There is medium correlation between the current anthropometric method and the radiography in the angle of hallux valgus (AoH) measurement, so this study aimed at designing a reliable and more accurate approach to measure the AoH (AoH).

Materials and Methods: Fifteen age, body weight, and height matched male students were included and those with foot disorders, deformities, or injuries were excluded from the study. The dorsal protrusions of the first metatarsal and the hallux were marked by palpating from three experienced observers; then their barefoot model in standing was collected by a three dimensional laser scanning system. The AoH was defined in the X-Y plane by the angle between the line joining the marks of centre of head and centre of base of metatarsal shaft and the one connecting the marks of the centre of metatarsal head and the hallux. The same procedure was repeated a week later. Besides, other measures based on the footprint, outline, and the radiography were also available for comparisons. Paired *t*-test, linear regression, and reliability analysis were applied for statistical analysis with significant level of 0.05 and 95% confidence interval.

Results: There were no significant differences recorded between the new method and the radiographic method ($P = 0.069$). The AoH was superior to the methods of footprint and outline and it displayed a relative higher correlation with the radiographic method ($r = 0.94$, $r^2 = 0.89$). Moreover both the inter and intraobserver reliabilities of this method were proved to be good.

Conclusion: This new method can be used for hallux valgus inspection and evaluation.

Key words: Hallux valgus, angle of hallux valgus, foot print, radiography, three dimensional laser foot scanning

Introduction

Hallux valgus a common deformity, makes the hallux deviate from the normal array to lateral side and shift the first metatarsophalangeal joint (MPJ) medially. Hereditary factor[1-3] was deemed as a major reason leading to the deformity, however, environment influences such as wearing unfit footwear was also considered to be an important but easily ignored factor. Since the occurrence of hallux valgus not only enlarged the width of forefoot, but also changed the normal loading patterns at forefoot,[4] it was more likely to make the feet hurt. Thereby, correct diagnosis of this deformity appeared to be crucial. A direct way to describe this deformity was to measure the angle of hallux valgus (AoH), which indicates the relative position between the hallux and first metatarsal. As this angle objectively and quantitatively reflected the degree of deformity, it has been widely applied in the clinical and scientific studies.

The radiographic way, measure the AoH is based on the radiographic image taken from the dorsal side in weight-bearing posture and the angle was constructed between the centre longitudinal axis of the first metatarsal and the axis of the hallux;[4-8] while according to either the footprint or the foot outline, the anthropometric way measured the angle directly. Although the radiographic way provided both accurate and reliable data,[5,6] fear of radiation hence limited its wide application. Unfortunately, current anthropometric measure was only moderately correlated with the radiographic approaches.[5,6,9-11] Moreover, this moderate precision could not satisfy the requirements used in the clinical diagnosis and quantitative scientific analysis. Thereby an alternative way should be designed to improve the accuracy of the outcomes. One effective attempt was made by Kilmartin and Bishop,[12] who invented the Kilmartin Finger Goniometer to measure the AoH. When the subject stood barefoot on the flat and hard surface, this goniometer was directly located over the first MPJ with one arm touching the prominence of the hallux and the remaining arm being stretched against the mid line of the medial surface of the first metatarsal shaft. This way

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considered the array of the metatarsal shaft, nevertheless it was still far away from the result of radiography, where only a medium correlation coefficiency was gained.[12]

Stimulated by the idea from Kilmartin and Bishop,[12] a question was proposed that if the dorsal protrusions of the first metatarsal head and base and the hallux were recognized and marked by the way of palpation, and then the AoH was determined by the relative position of those marks, would the accuracy of this method be promoted and a better correlation coefficiency comparing with that of the radiography would be observed?

Therefore, this study was first aimed to design such an anthropometric way to measure the AoH; and then the validity and reliability of this method were systematically evaluated. Since the method combined the merits from both traditional ways, one hypothesis was suggested that a better and more accurate outcome from this method would be obtained.

Materials and Methods

Fifteen age-, body weight-, and height-matched and healthy male students were included in this study. Students with lower limb disorders, foot deformities, or injuries were excluded by visual inspection. The aim and procedure was explained and written consent was given by all the participants before the measurements. This study was supervised by the ethics committee of University and the measurement procedure followed the declaration of Helsinki.

Measurement of the angle of hallux valgus (a) based on laser scanning system

At first, a foot model with both sides in upright barefoot standing was collected by a three dimensional laser scanning system (INFOOT USB: Standard type, I-Ware Laboratory Co., Ltd, Japan). The reliability of this system has been proved to be excellent.[13] The scanning area is 400 (L) ×200 (W) ×150 (H) mm, the frequency is 50/60Hz, the scanning speed is 30 mm/s and the error is 1-2 mm in Y-Z and Y-X plane, respectively. Prior to the scanning, the dorsal protrusions of the first metatarsal head and base (along the centre axis of first metatarsal shaft) and the hallux were identified by palpation from three experienced observers who are professional clinicians in the university and then marked by the textile dots [Figures 1-5]. When the scanning was completed, the marked foot 3D model output was uploaded to the Powershape software (Powershape, Delcam Co., Ltd, UK) for further analysis. One line was drawn joining the marks on the first metatarsal head and base, whereas another line connects the marks on the first metatarsal head and the hallux. Thereby, in the X-Y plane, the angle between the two lines was defined as the AoH [Figure 1]. Another measurement was repeated a week later with the same procedure and by the same observers.

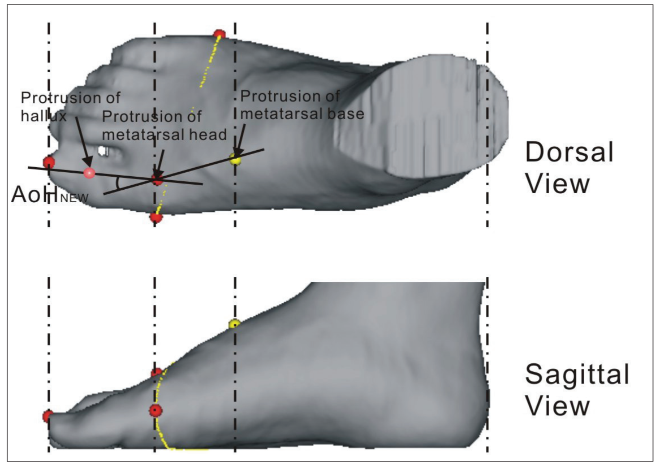

Figure 1: Foot model with marks was scanned by the three-dimensional laser scanning system and AoH was measured according to these marks

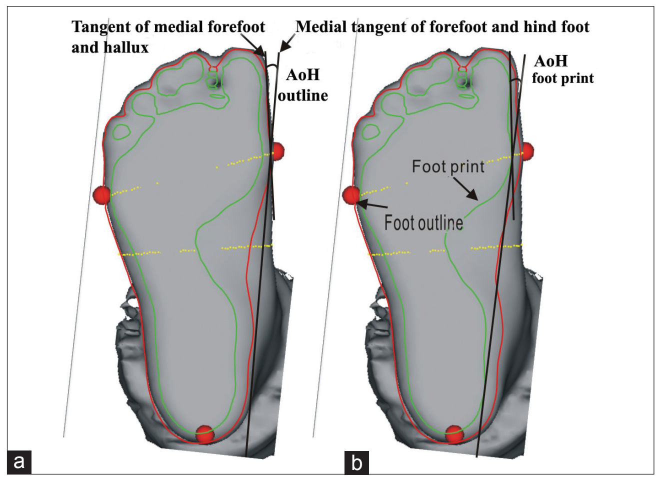

Figure 2: Anthropometric ways in AoH measurement based on the footprint and outline. (a) indicates the AoH which is measured according to the outline, and that of (b) is determined by the footprint

Figure 3: Radiographic approaches in AoH measurement

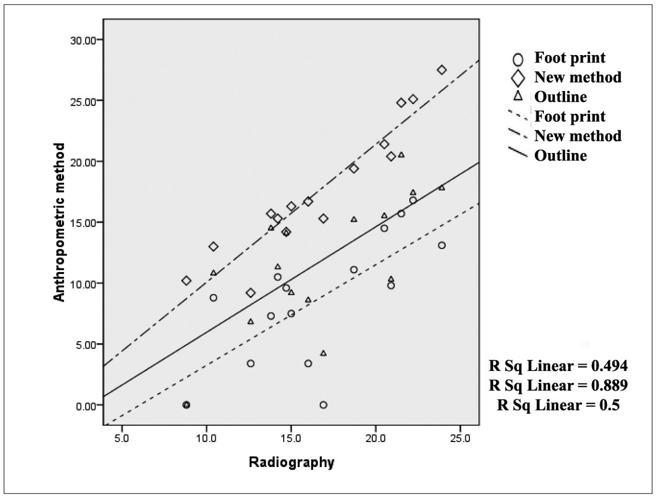

Figure 4: Linear correlations between the anthropometric and radiographic methods. The dot indicates the data measured based on the foot print, whereas the diamond and triangle present the results obtained from the way of new method and outline irrespectively. Further, the line type of dashes, dash-dot and solid imply the linear correlation of the foot print, new method and outline with the radiographic approach in the AoH assessment

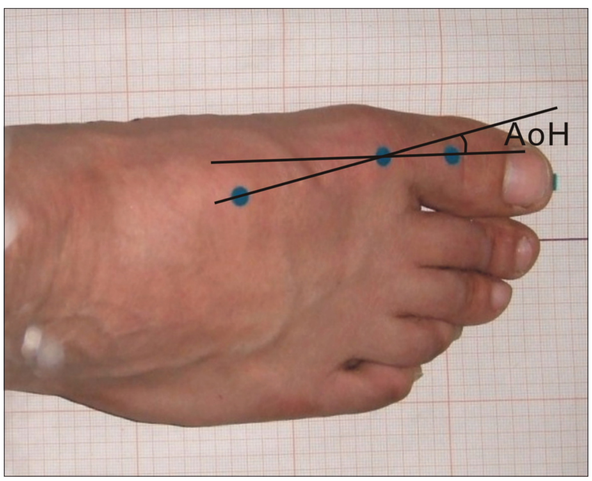

Figure 5: Foot with marks was pictured in dorsal viewpoint

(b) based on the footprint and the foot outline

The footprint was defined as the first frame of the foot model in X-Y plane, whereas the outline was considered as the frame with the largest area, where both the foot length and width were the largest [Figure 2]. With the help of Powershape, lines indicating the footprint and outline were extracted from the foot model. Based on footprint and outline, the $AoH_{footprint}$ and $AoH_{outline}$ were constructed by the medial tangent of fore-hind foot and one of the hallux-forefoot.

(c) based on radiography

When the foot was in upright standing posture, X-ray photograph was first captured by a radiographic scanner (1/2P18DK-80S, Shimadzu Corporation, Japan). The distance of tube from foot is 90cm, voltage and ampere of current is 65 KVP and 1.7 mAS respectively. Then this picture was analyzed by the CorelDraw software (Version 12.0, Corel Corporation, Ottawa, Canada). The $AoH_{X\text{-}ray}$ was defined as an angle between the lines of centre longitudinal axis of the first metatarsal and the axis of hallux connecting with the first MPJ [Figure 3].

Statistical analysis

In order to assure the independency of this study, only the right foot was analyzed; besides, the normal distribution was examined. Differences between the anthropometric methods and radiography and between the traditional anthropometric ways and the method used in this study were explored by Paired *t*-test and linear regression; whereas the intra and interobserver reliability of the new method was assessed by the variables of coefficiency of variance (CoV) and the intraclass correlation coefficiency (ICC).[14] All statistical models were executed using the SPSS software (V16.0, SPSS Inc., USA) with the significant level of 0.05 and confidence interval (CI) of 95%.

Results

The mean age of participants is 23 ± 0.2 years, mean height is 1.72 ± 0.02 m, mean body weight is 60.5 ± 2.5 kg, and mean body mass index (BMI) is 20.55 ± 0.77. All the data confirms the normal distribution.

No significant differences existed between AoH and $AoH_{X\text{-}ray}$ ($P = 0.069$), whereas significant differences were reported between the $AoH_{footprint}$, $AoH_{outline}$, and $AoH_{X\text{-}ray}$ ($P = 0.000$ for both); similarly, prominent differences were also found between the $AoH_{footprint}$, $AoH_{outline}$, and AoH ($P = 0.000$ for both pairs) [Table 1].

The linear correlations between the AoH, $AoH_{footprint}$, $AoH_{outline}$, and $AoH_{X\text{-}ray}$ are shown in Table 2 [Figure 4] and the AoH demonstrated the highest correlation with $AoH_{X\text{-}ray}$ (ICC = 0.927, $r = 0.94$, $r^2 = 0.89$, CoV = 7.8%, $P = 0.000$), whereas a medium correlation coefficiency was found for $AoH_{footprint}$ (ICC = 0.692, $r = 0.71$, $r^2 = 0.50$, CoV = 19.6%, $P = 0.001$), and $AoH_{outline}$ (ICC = 0.693, $r = 0.70$, $r^2 = 0.49$, CoV = 21.3%, $P = 0.001$). The linear correlations between the traditional anthropometric methods ($AoH_{footprint}$ and $AoH_{outline}$) and the new one (AoH) were better than those with $AoH_{X\text{-}ray}$ ($r = 0.79$, ICC = 0.880, $P = 0.000$ for $AoH_{outline}$; $r = 0.79$, ICC = 0.883, $P = 0.000$ for $AoH_{footprint}$).

The intraobserver reliability from two independent trails was seen to be excellent, where the CoV was 9.2% and ICC was 0.940 ($P = 0.000$); furthermore, the interobserver reliability

Table 1: Paired *t*-tests between the angle of hallux valgus, angle of hallux valgus -footprint, angle of hallux valgus-outline and angle of hallux valgus-X-ray

	Differences	95% CI		*P*
		Lower	Upper	
(AoH-new) vs (AoH-X-ray)	1.0	-0.1	2.0	0.069
(AoH-outline) vs (AoH-X-ray)**	-4.9	-7.1	-2.7	0.000
(AoH-print) vs (AoH-X-ray)**	-7.9	-10.0	-5.8	0.000
(AoH-outline) vs (AoH-new)**	-5.8	-7. 8	-3.9	0.000
(AoH-print) vs (AoH-new)**	-8.7	-10.8	-6.9	0.000

**significant less than 0.001, CI = Confidence interval, AoH = Angle of hallux valgus

Table 2: Linear correlations between the angle of hallux valgus-new, angle of hallux valgus-footprint, angle of hallux valgus-outline, and angle of hallux valgus-X-ray

	r	r^2	CoV (%)	ICC	95% CI		*P*
					Lower	Upper	
(AoH-new) vs (AoH-X-ray)**	0.94	0.89	7.8	0.927	0.80	0.97	0.000
(AoH-print) vs (AoH-X-ray)*	0.71	0.50	19.6	0.692	0.30	0.89	0.001
(AOH-outline) vs (AoH-X-ray)*	0.70	0.49	21.3	0.693	0.30	0.89	0.001
(AoH-outline) vs (AoH-new)**	0.79	0.62	8.9	0.880	0.47	0.92	0.000
(AoH-print) vs (AoH-new)**	0.79	0.62	9.1	0.883	0.42	0.93	0.000

*significant less than 0.05; **significant less than 0.001, CI = Confidence interval, AoH = Angle of hallux valgus, CoV = Coefficiency of variance, ICC = Intraclass correlation coefficiency

from three testers was also displayed well, as the COV was 6.3% and ICC was 0.846 (*P* = 0.000).

Discussion

This study provided a way to measure the angle of hallux valgus based on the dorsal protrusions of the hallux and the first metatarsal. Comparisons were made between the method used and the approaches of radiography and anthropometry. Moreover, the inter and intraobserver reliability of the new method was evaluated by three independent observers according to the data obtained in two independent sessions with 1 week interval. Results showed that our AoH was not only superior to the $AoH_{footprint}$ and $AoH_{outline}$ by displaying a relative higher linear correlation with the radiographic way, but our outcomes also were demonstrated to be reliable in terms of intra and interobserver.

Identification of the protrusion of the foot by the way of palpation was first proposed by Spooner[2] and he also contrasted the result of palpation with the radiography. He suggested that the way of palpation was as accurate as that of the radiography. Unfortunately, he did not discuss the potential application of the way of palpation in the AoH measurement. In terms of anthropometric method, Kilmartin[9] reported his Goniometer with a moderate linear correlation when comparing with the radiographic one ($r = 0.75$, $r^2 = 0.56$). While, Park[12] measured both the footprint and X-ray picture of 26 participants aged between 15 and 70 and the correlation coefficiency between the two methods was recorded as $r = 0.75$. Similarly, the rank correlation coefficiency implied by Sander[11] was $r = 0.90$.

In our study, on the one hand the result of $AoH_{footprint}$ and $AoH_{outline}$ confirmed the above studies; on the other hand the correlation between our new method and the radiography was improved ($r = 0.94$, $r^2 = 0.89$), where no significant differences were seen between them ($P = 0.069$). Moreover, as suggested by Spooner, our new method with merits of simplicity, reliability and accuracy matched the requirements of a qualified study protocol.[2]

Limitations of the study are its small sample size and absence of female population. The majority patients who suffered from the hallux valgus were women,[1-3] therefore, future with both female and male subjects and larger amount of sample size are required to further examine the effectiveness of this method in hallux valgus diagnosis.

Clinical implication of the method is that the clinician only needs to identify and mark the dorsal protrusions of the first metatarsal and the hallux connecting the first MTJ at first; and then to take a picture on dorsal viewpoint; finally the AoH can be measured based on the picture [Figure 5].

To conclude method designed in this study combines the principles of radiography and anthropometry and an optimal result in the AoH measurement was gained. Besides, this new method was proved to be both reliable within and between observers. Overall, this new method is effective and can be easily, directly, and quickly used as an alternative traditional approach in routine hallux valgus inspection and evaluation.

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