

Validity of the footprint assessment method using contrast imaging method

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KEYWORDS

Footprint;
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ABSTRACT

Foot-print recording is a popular method of foot parameter measuring as it offers ease and convenience amid use. Radiographic images are both highly reliable and accurate amid clinical diagnosis, though this method incorporates a relatively high cost in regards to evaluating the contrast imaging validity of a foot print. Twenty-nine healthy participants with 57 normal feet were assessed for demographic data. Participants' foot parameters were assessed via dry footprint and contrast imaging method. For contrast imaging, participants were instructed to stand in a clear box containing black poster colouring. The assessor then took a photo of the normal foot. Study parameters included arch width, plantar arch index (PI), Clarke's angle, Chip index, and Staheli index. The assessor calculated footprint parameters using a ruler in addition to contrast imaging (kinovea program). Pearson correlation coefficients were applied to calculate the validity of both tools. Significant correlations existed between PI ($r=0.50$, p -value=0.0001), Chip index ($r=0.41$, p -value=0.001), and Staheli index ($r=0.50$, p -value=0.0001). Moreover, there were no significant correlations in regards Clarke's angle ($r=-0.2$, p -value=0.13) and arch width ($r=0.22$, p -value=0.096). Evaluation of PI, Chip index, and Staheli index may be performed via footprint parameters and the contrast imaging method. Clinical measurements pertaining to PI, Chip index, and Staheli index provide valid information in relation to the footprint method and contrast imaging.

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Introduction

In the feet we can observe a reduced medial longitudinal arch condition which potentially leads to flat foot and internal rotation⁽¹⁾ especially during weight-bearing. Factors related to flat feet are many, including genetics, shoe type, obesity and over-use⁽²⁾ i.e. standing and walking over extended periods. In addition, flat-feet result in fatigue to the soles of the feet, the feet and ankles, the lower extremities, and back alignment. Currently, clinical assessment methods for flat feet diagnosis are available, such as observation for Valgus Heel - Calcaneovalgus, flattened medial longitudinal arch and forefoot abduction. Methods of observation encompass qualitative data, thus making them less reliable⁽³⁾ due to human-error⁽⁴⁾. Nevertheless, there are advantageous methods which are simply applied. Clinical evaluation of footprint imaging offers ease of use and convenience in that numerous indicators may be read, for instance, arch index (AI) which renders 86.26% sensitivity. Notwithstanding, as mentioned, the disadvantages are that it takes time to prepare the equipment, and recording surface, moisture of color, and fabric must be appropriate. If the moisture of color is inappropriate, image-clarity and parameters will be negatively affected. Medical assessment methods comprise of radiographic images which are highly reliable (ICC=0.98)⁽⁵⁾ in terms of great accuracy amid clinical diagnosis⁽⁶⁾. However, this method poses difficulties and a relatively high cost.

Image processing is the use of a computer to process digital images through an algorithm. Accordingly, the image is converted into a gray scale and filtered. This technique enhances gray scale image contrast⁽⁷⁾. Image-based processing- methods are employed to detect the "standard" in wound healing which may present the disadvantages of the necessity for high cost equipment along with an algorithm program⁽⁸⁾. Such disadvantages may also be associated with image processing systems widely applied to monitor the repair of wounds in diabetic patients⁽⁹⁾.

A gap in the study arose from photography with a mobile phone or camera imaging which was then run through an application to observe

the pressure point or wound healing⁽⁸⁾, as well as wound repair in diabetic patients, where a narrower image is witnessed. The image used to calculate the area is observed on a gray scale⁽⁹⁾. which is highlighted through a filter to produce a black and white image. This principle incorporated in this research is based on the principle of contrast of black and white imaging clearly being able to indicate boundary areas amid the measuring of foot parameters. As a consequence, the latest foot-measuring method (contrast imaging) may be a clinical foot assessment option in the future. Hence, the aim of this particular study was to evaluate contrast imaging and foot-print validity.

Materials and methods

The study was observational in design and conducted from June 1 to July 31, 2019 at the physical therapy laboratory, Burapha University, Thailand. The present study was approved by the Burapha University Ethics Committee in Human Research. All participants provided their consent through written consent. The study recruited 29 healthy participants from Muang District, Chonburi Province. Inclusion criteria consisted of being aged between 15-25 years, no pain at the lower extremities during standing, no injury at the ankle or foot within 6 months prior, no history of surgery at the lower extremities within the previous 6 months, no wounds to the feet or ankles, no skin diseases, and no poster coloring or food coloring allergies. Exclusion criteria consisted of the difference in the length of both legs being greater than 2 centimeters, pathological conditions of the musculoskeletal system affecting weight bearing during standing, and any pathological conditions concerning the nervous system affecting balance^(5,10-12). Participants were assessed for demographic data including age and gender, BMI Navicular Drop Test (NDT), leg length discrepancies, and bodily pain. Measured while standing and utilizing Vernier calipers NDT is employed to measure the difference in the height of the navicular bone position during sitting and loading. So, NDT was measured in both feet in each subject. An ND of ≥ 10 mm indicated

flat-feet⁽¹⁰⁾. Skin allergies were assessed via the patch test whereby the researcher applied poster colouring and foot colouring to participants' skin in order to observe for any skin irritation over the course of 30 minutes. If the volunteer presented no allergies, they then proceeded to the footprint and novel method measurement taking. Participants' foot parameters were then assessed via dry footprint and contrast imaging methods. Sample size was calculated through a computer program (Sigma stat). Determined correlation coefficient was 0.5, power 0.95, and alpha 0.05. The number of volunteers rendered 47 feet as decreased with a 20 percent drop-out rate from an original total of 57 feet.

Intervention

For dry footprint recording (Figure 1) participants had their footprint taken while in the standing position. For contrast imaging (Figure 2),

participants were instructed to stand in a clear box containing black poster coloring. The box was set approximately a foot from the ground. The assessor then took a photo of the foot. Participants were given 5 minutes rest between tests. Study parameters integrated arch width, plantar arch index (PI), Clarke's angle, Chip index and Staheli index. Boasting 6 years of clinical orthopedic experience, the physical therapist calculated footprint parameters using a ruler for distance and degree, with contrast imaging conducted using the kinovea program. For each subject, approximately 10 minutes were required. Subsequently, tool validity was calculated using Pearson correlation coefficients (normal distribution) or Spearman rank correlation coefficients (non-normal distribution).

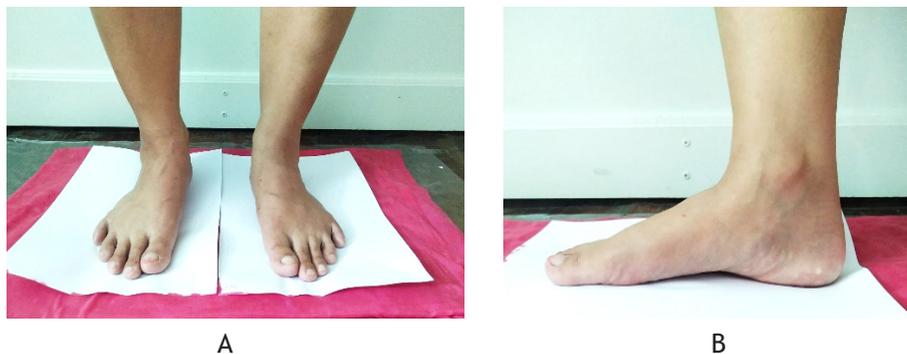


Figure 1 Dry footprint method A: Anteroposterior view, B: Mediolateral view



Figure 2 Contrast imaging method and calibration procedure

Measurement outcomes

Outcomes of the treatment methods applied in this study (figure 3).

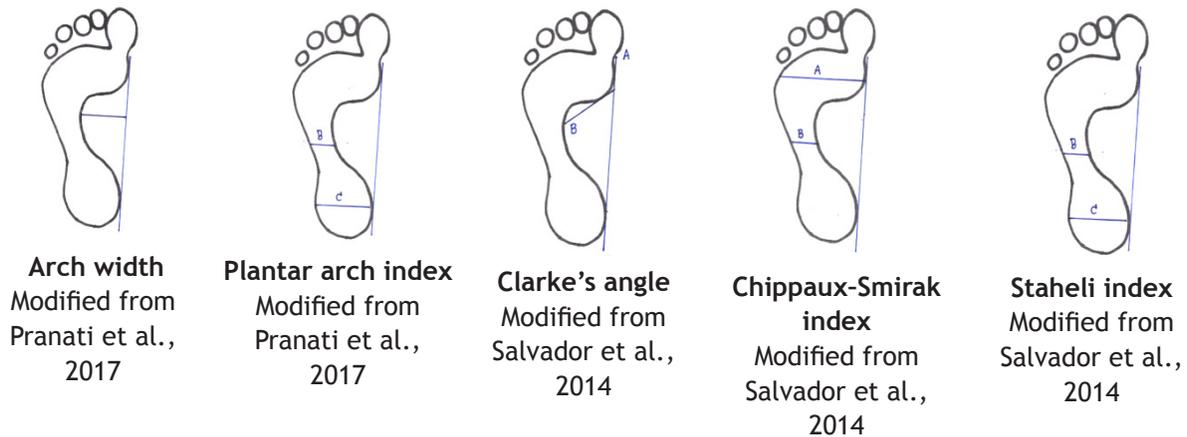


Figure 3 Foot parameters

Arch width signifies the width of the soles of the feet. We measured the distance in centimeters⁽¹³⁾. Plantar arch index (PI) accounts for the width ratio of A and B. Read in centimeters, A is the width of the center of the footprint. B is the width of the heel amid the footprint⁽¹³⁾. Measured in degrees, Clarke's angle is the angle that passes through the metatarsal bone and the tangent line of the foot⁽¹⁴⁾. Chip index (Chippaux-Smirak index) is the ratio of the length of line B, to the length of line A which is on the same parallel line. Line B is the narrowest point of the foot arch. A is the widest line of the foot arch ($B/A \times 100, \%$) with the distance measured in centimeters⁽¹⁴⁾. Staheli index is the ratio of the length of line B, to the length of line C. C is the widest line of the heel. Line B is the narrowest point of the foot arch. Readings are taken in centimeters ($B/A \times 100, \%$)⁽¹⁴⁾.

Statistical analysis

Descriptive statistical analysis was employed to describe participants' demographic and clinical characteristic data with mean (standard deviation). The Shapiro-Wilk test was employed to explore the 5 normalities of all variables. Statistical significance was set at p -value < 0.05. Pearson correlation was applied to test the correlation between both methods. Correlation

level may be divided into excellent level $r = 0.75 - 1$, moderate level, $r = 0.5 - 0.74$, average level, $r = 0.25 - 0.49$, and low level, $r = 0 - 0.24$ ⁽⁹⁾.

Results

Fifty-seven feet of 29 participants (25 female, 4 male) with normal feet were recruited. Participants' demographic data are shown in Table 1.

Table 1 Participant characteristics

Variables	Values
Age (years)	20.29 ± 0.59
Gender (Female/Male)	25 / 4
NDT (mm.) (Right side)	4.71 ± 0.27
NDT (mm.) (Left side)	4.33 ± 3.16
BMI (kg/m ²)	21.97 ± 4.23
Leg length (cm.) (Right side)	82.58 ± 4.59
Leg length (cm.) (Left side)	82.77 ± 4.77
Dominant foot (Right side/ Left side)	29/0

Note: *NDT=Navicular Drop Test; BMI=Body Mass Index

Mean and standard deviation for the footprint and contrast imaging measurement parameters are demonstrated in Table 2. There were significant differences between groups in all parameters except for PI and Chip index. The correlation of parameters between the footprint and contrast imaging methods are shown in Table 3. Significant correlations existed between the PI, Chip index, and Staheli index. The validity test

for the PI, Chip index, and Staheli index exhibited moderate values ($r=0.50, 0.41$ and 0.50 , respectively). Moreover, the validity test showed no difference in arch width and Clarke's angle between the 2 techniques. An example of the results taken from the contrast imaging method employing the kinovea program is shown (Figure 4).

Table 2 Dependent Variable Group Means (Mean \pm SD)

Variable	Footprints	Contrast imaging	p ^a
Arch width (cm)	3.88 \pm 0.687	4.43 \pm 0.63	0.01*
Plantar arch index (PI)	0.67 \pm 0.15	0.63 \pm 0.12	0.02*
Clarke's angle (°)	41.26 \pm 9.45	29.84 \pm 7.33	0.0001*
Chip index	0.35 \pm 0.08	0.33 \pm 0.06	0.03*
Staheli index	0.67 \pm 0.15	0.63 \pm 0.12	0.02*

Note: * Significant difference (p -value<0.05)

P^a p-value of Independent t- test

cm=Centimetre, °=Degree

Table 3 Pearson r correlation values among foot print and contrast imaging methods

Foot print method	Contrast imaging methods				
	Arch width	Plantar arch index (PI)	Clarke's angle (°)	Chip index	Staheli index
Arch width	0.22	-	-	-	-
p ^b	0.96				
Plantar arch index (PI)	-	0.50	-	-	-
p ^b		0.0001*			
Clarke's angle (°)	-	-	-0.20	-	-
p ^b			0.14		
Chip index	-	-	-	0.41	-
p ^b				0.001*	
Staheli index					0.50
p ^b					0.0001*

Note: P^b p-value of Pearson correlation coefficient

* Significant difference (p -value <0.05)



Figure 4 Results from contrast imaging (kinovea program) cm=Centimetre, °=Degree

Discussion

The purpose of this study was to investigate measurement validity amid foot print measuring and contrast imaging recording. Significant correlations existed between the PI, Chip index and Staheli index. Meanwhile, arch width and Clarke's angle did not demonstrate acceptable validity.

The strength of these findings lies within the reliability of the "gold standard" of foot print measurement taking. Reliability level was at a moderate level. Strength of agreement was poor if correlation ranged from 0-0.40; fair to moderate if the correlation ranged from 0.40-0.75, and excellent if the correlation ranged from 0.75-1.00⁽¹⁵⁾.

Arch width in the original dry-foot footprint assessment was conducted on firm ground while stepping forward into the sagittal plane⁽¹⁶⁾. Hence, weight distribution center of mass was transferred from the posterior to anterior aspect. So, without controlled pressure by individual participants the foot arch tended to be lower (increased NDT test score: main reference to flatfoot diagnosis⁽¹⁷⁾. when compared with the contrast imaging measurement. Contrast imaging employed the water fill principle with the foot placed on the bottom of the acrylic box, with water then filled into the empty space under the foot which represented the non-contact space⁽¹⁸⁾. The length between the foot arch (arch width) amid contrast imaging was much greater than the arch

width method which represented more real contact. Due to the fact that the arch width method included a towel under paper it did not represent firm ground. The standard foot-print measurement operated under the same principle. The degree of contrast imaging was less than Clarke's angle as water fill and firm ground contact cause the medial arch to move closer to the bottom of the acrylic box. In regards to the difference in starting position between the two measurement methods, for the foot-print test participants stepped on one foot and then stepped on the other. For the contrast imaging method participants stood with their feet side by side (one side on the stool the other on the acrylic box). The above maintained participant safety during standing on the acrylic box.

From this point, foot-arch contrast imaging measurement is applied more so amid clinical use as it represents real pressure and flat and firm contact in the same principle as the navicular drop test. The difference in starting position of the two methods may affect weight bearing amount taken during measurement. However, it is possible that produced less weight during the contrast imaging measuring method due to the fact that they shifted their body weight to the left foot to avoid bearing weight on the unstable plastic box. Notably, this could affect the results.

Resultant of numerous causes, different methods attempt to discover the easiest process in addition to novel ideas to explain changes in the foot. From this study, contrast imaging measurement outcomes reported moderate correlations existing between plantar index, Chip index, and Staheli index which are evenly applied to the clinical field for assessment of flat-foot representing any foot region⁽¹⁹⁾. Accordingly, the measurement of variables may be used amid any method. Hence, the clinical implication of this study is that the clinician can evaluate foot parameters in real time using a smart phone or laptop computer. Clinical practice may be used interchangeably and digital files for electronic chart collection may be included which are easily recalled.

All 3 foot parameters demonstrated significant correlation (p -value <0.05) amid both methods, yet arch width and Clarke's angle were insignificant.

The footprint method is a fast, easy, simple, non-invasive technique, though image quality may be ineffective⁽²⁰⁾ as image clarity is dependent on poster coloring or ink suitability. What's more, reading of the values obtained from imaging may be inaccurate as footprint values require the use of a ruler to calculate distance and angle. Meanwhile, the advantage of the contrast imaging method is the same as that of the footprint method, though contrast imaging may render superior image clarity. Reading the values obtained from images may be accurate because the calculation of data from contrast imaging utilises the kinovea program. It uses a computer to open the file which can zoom in to focus on the specific area and adjust picture contrast. Moreover, value reading from a PC allows for a calibration distance of 10 cm prior to calculating foot parameter distance. The calibration procedure is able to measure the length of the ruler (10 cm) which is attached under the acrylic box.

This study took place with normal subjects. Future research ought to study flat-feet and incorporate comparisons with other methods. For the contrast imaging method, data calculation may be improved by using a mobile phone application. Hence, this method may present greater advantages for the user.

Conclusion

Results suggest that PI, Chip index, and Staheli index should be used as a common or standard technique amid foot assessment. Thus, the proposed method may be employed by clinicians as an easily applied tool as it's repeatable and offers electronic file collection amid the patient charting quantifying method.

Take home messages

Clinician can evaluate foot parameters in real-time using a smart phone or laptop computer by the contrast imaging measurement. Clinical practice may be used interchangeably and digital files for electronic chart collection may be included which are easily recalled.

Conflicts of interest

The authors declare no conflict of interest.

Acknowledgements

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