Development of a Foot Sizing System for Malaysian Women

Shaliza Mohd SHARIFF*[1,6,7], Yii Bonn BONG[1], ASMA Ahmad SHARIFF[1,3], Makiko KOUCHI[4], Kozo KIMURA[5], Amir Feisal MERICAN[1,2], Omar bin Mohd RIJAL[8], Norliza Mohd NOOR[9]
[1] Centre of Research for Computational Sciences and Informatics in Biology, Bio industry, Environment, Agriculture and Healthcare, University of Malaya, Kuala Lumpur, Malaysia;
[2] Institute of Biological Sciences, Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia;
[3] Centre for Foundation Studies in Science, University of Malaya, Kuala Lumpur, Malaysia;
[4] Digital Human Research Center, National Institute of Advanced Industrial Science and Technology, Tokyo, Japan;
[5] I-Ware Laboratory Co., Ltd, Minoh City, Osaka, Japan;
[6] Institute Postgraduate Studies, University of Malaya, Kuala Lumpur, Malaysia;
[7] Fashion Department, Faculty of Art & Design, University Technology MARA, Shah Alam, Selangor, Malaysia;
[8] Institute of Mathematical Sciences, Faculty of Science, University of Malaya, Kuala Lumpur Malaysia;
[9] School of Engineering and Advanced Technology, University of Technology, Malaysia, Campus Jalan Semarak, Kuala Lumpur, Malaysia

http://dx.doi.org/10.15221/14.093

Abstract

In this study we used the INFOOT USB 3D scanning system (I- Ware Laboratory Co., Ltd, Japan) to collect foot size data measurement. Based on this study, we used five measurement definitions based on their anatomical landmarks: foot length, ball girth, instep length, foot breadth, and fibulare instep length. The reliability and accuracy of the observers were evaluated using intra- and inter- observer errors measurement. Accuracy of the measurement is based on Technical Error Measurement (TEM). A TEM value of less than 2 mm for the determined landmarks is considered accurate and consistent. Result from the experiment showed that the reliability is between 93.3% and 98.3%, respectively thus, foot-landmarking was consistent and reliable. We hope to develop a new shoe sizing system based on the Malaysian women's foot sizes and shapes, and to replace the current sizing system used in the country. This research will eventually advocate the interest and needs of shoe manufacturers to produce women footwear based on the new sizing system and ensure customer satisfaction for shoe size and shoe fitting.

Keywords: Foot size, foot landmarks, 3D foot scanning technology, Malaysian women, Footwear sizing system

1. Introduction

Malaysian women face problem of getting the right size when buying shoes. This is mainly because Malaysian women have unique foot shapes, particularly at the girth and width part [1]. Lee [2] stated that there exists intrinsic foot shapes among different people living in different countries. Currently, Malaysia is using the ISO 9407 [3] Mondo-Point system of shoe sizing and marking.

A survey was conducted among 300 Malaysian women to determine the problem faced in terms of shoe sizing. The purpose of this study was to understand the real issue of shoe fitting and shoe sizing. Since ethnicity influences the foot shapes [4], all three major ethnic groups (Malay, Chinese and Indian) were taken into consideration. The age of subjects in this study ranges from 20 to 60 years old. Age determines the growth of human foot [5]. During childhood period, the growth of a child's feet is about half an inch a year until he or she is 10 years old. Foot growth reaches maturity around 19 to 20 years old. After 20 years of age, the growth of foot will cease [5, 6].

The result from the survey showed that 60.3% of Malaysian women did not have ample choices in choosing comfortable shoe size while 66.3% were dissatisfied and faced difficulties in choosing the right shoe size. As there is no guarantee in comfort, most of them were uninterested in getting different type of shoes. In addition, more than two-third of the surveyed subjects preferred a change in the current shoe size standard and agreed that the country should have a newly-developed standard for shoe sizing system used in the country.

*shaliza478@gmail.com / shalizashariff@siswa.um.edu.my; +6019-369-8231

This survey clearly demonstrated the severity of shoe sizing problem faced by Malaysian women. However, to the best of the author's knowledge, this problem has yet to be addressed.

As such, it timely to introduce a new shoe sizing standard which conforms to the originality of Malaysian women's feet shape for comfort and health reasons. The new standard for shoe sizing system suits the local population better and is hoped to replace the current sizing system. A good sizing system contributes to shoe lasting and brings more profit for shoe manufacturer [2]. It is hoped that the findings from this study will help to transform footwear manufacturer in Malaysia in becoming the pioneer in shoe sizing among Asian countries and produce quality women's footwear. The usage of new standard for shoe sizing system will certainly improve the market needs for footwear business in Malaysia.

2. Method

2.1. Subjects

The total number of subjects in this study was 223 Malaysian women. Subjects were divided into different work categories. This survey focused on long hours working women (wearing shoes for more than 8 hours per day, i.e. nurses, waitresses, sales girls and factory workers), less than 8 hours (working in office such as academic staffs and students) and those wearing their shoes for less than 3 hours per day (housewives).

2.2. Equipment

The INFOOT 3 dimensional foot scanner (Infoot high type scanning system, I – Ware Laboratory Co. Ltd. Japan) was used to collect the foot dimensions. This high type INFOOT scanner has 6 lasers and 12 cameras. The high type INFOOT scanner can capture images of the foot until the calf area. It scans the foot form and anatomical landmark points, measuring almost 20 measurements using landmarks automatically.

2.3. 3-dimensional Infoot scanner experiment

Before being scanned, subjects were required to complete a survey form. This form was adopted from ISO 15535 (General requirements for establishing anthropometric databases) with some amendments for the local requirements. The survey form contained bio data of the subjects, current shoe size as well as comments regarding the sizing problems. Subjects were then briefed about the experiment and weight measurements were taken in accordance to standard procedure. Before stepping into the foot scanner, foot was cleansed using sprayed with ethanol on tissue. Ethanol is used as a cleaning medium to ensure that the foot arch surface is clean from dust which might introduce noises and disturbances during scanning.

Researcher touched and identify the exact position of the bones to place the landmarks related to foot length, ball girth circumference, instep fibulare, foot breadth and fibulare instep length. These five landmarks defined the body dimensions as well as the anatomical correspondence between two different body scans to create a homologous model for the foot [7]. Subject is required to step into the scanner with one of their feet (left or right) touching the glass plate inside the scanner while the other foot outside the scanner should be parallel with it. Subjects stood in a relax position and body weight should be distributed equally on both feet. No movement was allowed until the scanning process is done. The glass plate was cleaned with ethanol and the whole process was repeated for the other foot.

A total of fifteen foot dimensions were retrieved by the scanner: foot length, ball girth circumference, foot breadth, instep circumference, heel breadth, instep length, fibular instep length, height of top of ball girth, height of instep, toe # 1 angle, toe # 5 angle, height of navicular, angle of heel bone, heel girth circumference and foot size. However, we were only interested in five dimensions for foot size estimation as suggested by Kouchi (personal communication). All measurements were in millimeter and were converted into 3D models automatically. Data were printed out and kept for record purpose.

2.4. Accuracy of measurement - Technical Error Measurement (TEM)

Technical error measurement is the mean of identified accuracy of measurement representing the measurement quality and control [8]. Technical error measurement (TEM) includes both inter- and intra– error measurements. On the other hand, inter- measurer technical error is defined as the differences between a minimum number of two observers taking the same landmark on the same subjects with a minimum of 40 subjects [7].

The intra- observer technical error measurement (TEM) is based on the formula:

$$\sqrt{random\ error\ variance} = \sqrt{\frac{\sum_{i=1}^{N} d_i^2}{2N}}$$

With

N = 60 samples

d_i = difference of first and second measurement

VAV = Variable average value

$$\frac{(1^{st} + 2^{nd}\ \text{measurement}) / 2}{N}$$

The procedure for inter- observer technical error measurement calculation is the same as intra-observer TEM [8]. However, for inter- observer TEM, the d_i is the difference between the measurements from the first and second observer on the same subject.

The inter- observer technical error measurement (TEM) is based on the formula:

$$\sqrt{random\ error\ variance} = \sqrt{\frac{\sum_{i=1}^{N} d_i^2}{2N}}$$

Where

N = 60 samples

d_i = difference of measurement from first observer and second observer

VAV = Variable average value

$$\frac{(1^{st} + 2^{nd}\ \text{measurement}) / 2}{N}$$

N should be more than 40 subjects based on ISO 20685:2010.(M.Kouchi, personal communication).

2.5. Reliability

Intra- measurer reliability is defined as a measurement technique assessing the intraclass correlation coefficients (ICC) and standard error of measurement (SEM) [9]. Reliability test is also defined as a dependent variable measured as precisely as possible [10] and it shows the consistency of the result produced from an experiment [11]. Reliability is also refers to the consistency or the repeatability of a measure [12].

Bland and Altman [14] plots were in this study to calculate the reliability. This plot can be used to provide an illustration of the spread of differences in readings, the mean difference and the upper and lower limit of agreement for both intra- and inter- observer reliability [13]. The mean difference between the first measurement and second measurement was plotted. Possible relationship between the measurement error and the true value of the measurement were investigated, thus providing information to assess the magnitude of disagreement, to spot outliers and to see if there is any trend such as the increase of the difference for high values. Most differences on the x-axis are expected to lie between $\bar{d} - 2s$ and $\bar{d} + 2s$ (or more precisely, between $\bar{d} - 1.96s$ and $\bar{d} + 1.96s$) and these can be referred as “the limits of agreement”.

Bland and Altman [14] stated that high correlation between two methods does not mean an agreement as the correlation measures the strength of the relation between two variables and not the agreement between them. In addition, high correlation can be produced by the data which seem to be in poor agreement too. It is also depending on the range of the true quantity of the sample. If the quantity is wide, the correlation will be greater as compared to if the quantity is narrow.

3. Result

3.1. Technical Error Measurement (TEM)

The results from observer 1 and observer 2 technical error measurements were shown in Table 1. TEM values of less than 2 mm for foot dimensions suggested that the measurements by both observers for determined landmarks are accurate and consistent [15].

Table 1: Result for Technical Error Measurement

Foot Measurement	**Intra-observer 1 TEM (mm)** $\sqrt{\frac{\sum_{i=1}^{N} d_i^2}{2N}}$	**Intra-observer 2 TEM (mm)** $\sqrt{\frac{\sum_{i=1}^{N} d_i^2}{2N}}$	**Inter-observer TEM (mm)** $\sqrt{\frac{\sum_{i=1}^{N} d_i^2}{2N}}$
Foot length (Left foot)	0.6551	1.053249	1.096054
Ball Girth circumference (Right foot)	1.3457	1.764889	1.970575
Ball Girth circumference (Left foot)	1.2540	1.669281	1.463102
Foot breadth (Right foot)	0.7799	1.059796	1.216141
Foot breadth (Left foot)	0.7898	1.201492	0.597355
Instep length (Right foot)	1.2600	1.401993	1.75069
Instep length (Left foot)	1.2716	1.586873	1.790577
Fibulare Instep length (Right foot)	1.0028	0.919511	1.972477

3.2. Bland – Altman analysis for reliability test

Table 2 showed the final result for intra observer 1 and intra observer 2. The result demonstrated high percentage of agreements for observer 1 (93.3% and 98.3%). Meanwhile intra observers 2 also showed relatively high percentage of agreement (95.0% and 98.3%). Using the Bland Altman plots, it is suffice to say that the reliability is in between 93.3% to 98.3%.The reliability of foot landmarking between the two observers was consistent and reliable. Marquez [11] claimed that different people performing different task of experiment will affect the result of reliability testing.

Table 2: Result for reliability test

N0:	Foot Measurement	Intra-observer 1 Reliability (%)	Intra-observer 2 Reliability (%)	Inter-observer Reliability (%)
1	Foot length (Right foot)	93.3	95.0	93.3
2.	Foot length (Left foot)	95.0	96.6	96.6
3.	Ball Girth circumference (Right foot)	96.7	98.3	93.3
4.	Ball Girth circumference (Left foot)	95.0	96.6	95.0
5.	Foot breadth (Right foot)	96.7	96.6	98.3
6.	Foot breadth (Left foot)	95.0	96.6	95.0
7.	Instep length (Right foot)	96.7	98.3	96.6
8.	Instep length (Left foot)	93.3	96.6	95.0
9.	Fibulare Instep length (Right foot)	98.3	96.6	98.3
10.	Fibulare Instep length (Left foot)	96.7	95.0	95.0

4. Conclusions

The study concluded that the accuracy and reliability of foot landmark using 3D foot scan measurement was excellent as the results produced by the two observers were consistent and reliable. Further study will be carried out for the development of new standard shoe sizing system using the 3D foot scanner. It is hoped that the newly developed standard will overcome the dissatisfaction and uncomfortable problems of shoe sizing faced by Malaysian women.

Acknowledgements

This study is supported by UMRG grant number RP004B-13AFR to OMR and PPP grant number UM.TNC2/IPP/PPGP/638/PPP to SMS. We would like to thank to NurKhairany Amyra Mokhtar for assistance in the study and all subjects for their cooperation.

References

[1] R. Ibrahim and LYB. Khedifb, "Modeling 3D Surface of the Footprint - Malaysian Women Perspective" (2004) – accessed 2013 http://gmm.fsksm.utm.my/~cogramm/cgi-bin/2004/upload_files/full_paper_backup/144408.pdf
[2] Y. C.Lee, W. Y. Choa, and M.J Wang, "Developing a New Foot Shape and Size System for Taiwanese Females". In The 19th International Conference on Industrial Engineering and Engineering Management, Springer Berlin Heidelberg, 2013, pp.959-968. http://link.springer.com/content/pdf/10.1007%2F978-3-642-38427-1_101.pdf
[3] ISO 9407 Mondopoint and landmarking shoe sizing, ISO 9407, 1991(E).

[4] I.Krauss, S.Grau, P.Jassen, C. Maiwald, M. Mauch and T.Horstmann. “Gender Differences in Foot Shape”. Reterive May 15, 2013 from, www.http.inga.krauss@med.uni-tuebingen.de www.http.inga.krauss@med.uni-tuebingen.de

[5] H.O.Ozkan, “A research on Footwear and Foot Interaction through Anatomy and Human Engeneering”, Master of Science in Industrial Product Design, Izmir Institute of Technology, Turkey, 2005. http://library.iyte.edu.tr/tezler/master/endustriurunleritasarimi/t000429.pdf

[6] T.L.A. Thomson, B. Zipfel and S. Eagleton, “Human factors and ergonomics in consumer product Design”, CRC press, taylor & francais LLC, 2011, pp 347.

[7] M. Kouchi and M. Mochimaru, “Errors in landmarking and the evaluation of the accuracy of traditional and 3D anthropometry”, Applied Ergonomic, Vol: 42: Issues 3. 2011, pp. 518-527. http://ac.els-cdn.com/S0003687010001614/1-s2.0-S0003687010001614-main.pdf?_tid=7bd92d46-21da-11e4-9c0d-00000aab0f6c&acdnat=1407818479_fac30ba0bc3bb40c660a389eadd3fe0a

[8] T.A. Perini, G. L. Oliveira, J.D.S Ornellas and F.P Oliveira, “Technical Error of Measurement in Anthropometry”, Rev Bras Med Esporte : Vol. 11, Issues. 1, 2005, pp. 86-90 www.scielo.br/pdf/rbme/v11n1/en_24109.pdf

[9] M.B.L. Pohl Farr, “A composition of foot arch measurement reliability using both digital photography and caliper method. Journal of Foot and Ankle Research”, Vol.3 Issues 14, 2010, pp 6. www.j**foot**ankleres.com/content/3/1/14

[10] A. Field and G. Hole “How to design and report experiments”, SAGE Publications Ltd,2013, pp. 54-105.

[11] G.M. Marquez.I. Mittelberg, S.Coulson. S. and J.M. Spivey, “Methods in Cognitive Linguistic”, John Benjamins Publishing Co.2007, pp.69-75.

[12] A. Hayen, R. J. Dennis and C. F. Finch, “Determining the intra- and inter-observer reliability of screening tools used in sports injury research”, Journal of Science and Medicine in Sport : Vol. 10, 2007, pp. 201-210.

[13] H. Jamaiyah, A. Geeta , M.N Safiza, G.L Khor, N.F. Wong, C.C Kee, R. Rahmah , A.Z. Ahmad, S.Suzana, W.S.Chen, M. Rjaah and B. Adam, “Reliability, Technical Error of Measurements and Validity of Length and Weight Measurements for Children Under Two Years Old in Malaysia”, Med J Malaysia : Vol. 65, Supplement A, 2010 [page number?] www.e-mjm.org/2010/anthropometri-measurements.pdf

[14] J. M. Bland and D. G. Altman, “Statistical Methods for Assessing Agreement between Two Methods of Clinical Measurement”. Lancet : Vol. 1, 1986, pp. 307-310 www.medicine.mcgill.ca/epidemiology/hanley/tmp/surveys/ba.pdf www.ncbi.nlm.nih.gov/pubmed/17194623

[15] International Society Standardization Advanced in Kinanthropometry (ISAK), ISO 20685, 2010.

[16] General requirements for establishing anthropometric databases, ISO 15535, 2012.