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Estimation of Individual Stature from Shoe Dimensions

Anggaran Ketinggian Individu Daripada Dimensi Kasut

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ABSTRACT

Shoes and shoeprints are commonly found evidence at crime scenes, and it is very useful to determine the physical identity of perpetrators such as stature. This study, therefore, was carried out to determine the correlation between stature and shoe dimensions among students of UKM, Bangi, Malaysia. A total of 72 subjects, with 36 males and 36 females, were used in this study. Stature was measured using 206 SECA-bodymeter in centimeters, while the shoe dimensions were measured using a ruler. The shoe dimensions are specified into shoe length: the horizontal distance between the most upper and lower parts of the shoe, and shoe width: the diagonal distance between the most expanded area of the shoe. The data was analysed using SPSS 25.0 software. Pearson correlation test was performed to determine the correlation between stature and shoe dimensions (length and width). The Pearson correlation test showed that there is a positive correlation between stature and shoe dimensions in the male+female group (shoe length, r = 0.644 and shoe width, r = 0.604) while the male group (shoe length, r = 0.542 and shoe width, r = 0.613). However, there is no significant correlation between stature and shoe dimensions in the female group. Conclusively, this study has established that shoe dimensions can be one of the factors in individual stature estimation. However, precautions should be taken into consideration when analysing female shoes as it showed no correlation with stature.

Keywords: forensic science, shoe dimensions, stature estimation, shoeprints

ABSTRAK

Kasut dan kesan tapak kasut merupakan bahan bukti yang biasa dijumpai di tempat kejadian jenayah dan ia amat berguna untuk menentukan identiti fizikal pesalah seperti ketinggian. Oleh itu, kajian ini dijalankan untuk menentukan korelasi di antara ketinggian dan dimensi kasut di kalangan pelajar di UKM, Bangi, Malaysia. Sejumlah 72 subjek iaitu 36 lelaki dan 36 perempuan telah digunakan dalam kajian ini. Tinggi subjek diukur menggunakan 206 SECA-bodymeter dalam sentimeter, manakala dimensi kasut diukur menggunakan pembaris. Dimensi kasut yang diukur adalah panjang kasut: jarak lintang di antara bahagian paling depan kasut dan paling belakang kasut, dan lebar kasut: jarak di antara pepenjuru kasut yang paling terluas. Data kemudiannya dianalisis menggunakan perisian SPSS 25.0. Ujian kolerasi Pearson telah dijalankan untuk menentukan kolerasi di antara ketinggian dan dimensi kasut (panjang dan lebar). Ujian kolerasi Pearson menunjukkan bahawa terdapat kolerasi yang positif di antara ketinggian dan dimensi kasut bagi kumpulan lelaki+perempuan (panjang kasut, r = 0.644 dan lebar kasut, r = 0.604) manakala bagi kumpulan lelaki (panjang kasut, r = 0.542 dan lebar kasut, r = 0.613). Walau bagaimanapun, tiada korelasi signifikan di antara ketinggian dan dimensi kasut bagi kumpulan perempuan. Kesimpulannya, kajian ini telah membuktikan bahawa dimensi kasut boleh digunakan sebagai salah satu faktor dalam menganggarkan ketinggian individu. Akan tetapi, langkah berjaga-jaga perlu dipertimbangkan apabila menganalisis kasut perempuan kerana ia menunjukkan tiada kolerasi dengan ketinggian.

Kata kunci: dimensi kasut, penganggaran tinggi, sains forensik, tapak kasut

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INTRODUCTION

Footwear evidence is one of the most abundant pieces of evidence that can be found in almost every crime scene and may exist either as an impression or a print (Chapman et al. 2023). An impression contains 3-dimensional information (i.e. shoe impression on beach, mud) whilst shoeprints contain 2-dimensional information such as shoeprints on the surface of a glass, the wall or the floor (Panchal & Mia 2022). Since criminals must enter and exit the crime scene, they may leave shoeprints behind. Footwear evidence can be used to determine biological characteristics such as stature, weight and sex of an individual (Kheawpum & Choosakoonkriang 2020; Svabova et al. 2022) hence it may help investigators to identify or eliminate a suspect. Based on previous research, the dimensions of footwear evidence, may it be a shoe, prints or footprint impression, showed a significant correlation with stature. (Asadujjaman et al. 2022; Kheawpun & Choosakoonkriang 2020)

Since footwear evidence are constantly devalued and neglected (Mohamed Izzharif et al. 2024), it is necessary to enlighten the investigators and authorities on how shoeprints can help in complex crime investigations. In terms of identification, shoe wear is used as identification tools, as the shod foots survived burning, decomposition, marine animal depredation, and water damage more consistently than do hands, especially fingerprints (Becker 2013). It was against these backdrops that this study was carried out to determine the correlations between individual stature and shoe dimensions. It is hoped that this study may help establish a general footwear evidence database for Malaysians, and thus ease the investigation.

Besides, very few studies that have been done to determine the correlations that exist between stature and shoe dimensions, especially in Malaysia (Khairulmazidah et al. 2013). Hence, this study aims to estimate the stature of an individual based on their shoe dimensions. Shoe length and width are used as parameters instead of shoe sizes. This study will also determine if there are any differences in the correlations present between male and female.

MATERIALS AND METHODS

A total of 72 subjects aged 18 years old and above from The National University of Malaysia (UKM) population were used in this study. The 72 subjects were randomly chosen from each of the 9 faculties in UKM Bangi. The study focuses on the observation of the correlations between stature and shoe dimensions after consent forms were filled out and the subjects agreed to participate. The types of shoes used in this study were sports shoes or sneakers. Only the right shoe was chosen for further analysis since the sizes of the left and right shoes are similar. The following demographic information was collected from subjects: Sex, age, shoe size (UK) and faculty to establish variability within the populations of UKM, Bangi campus. Pregnant women, person with musculoskeletal disorder that affects body stature and lower limbs are excluded from this study.

The stature of the subjects was measured using SECA 206 bodymeter, with subjects standing without shoes on, heels held together, toes apart and face facing forward. Then, subjects were requested to wear their shoes and stand firmly on the data collection sheet, which is a 70gsm A3 white paper. The outline of the right shoe was drawn using a colored pencil. Then, the shoe length and width were measured from the shoe outline (Figure 1). The landmarks measured refers to method by research by Ekezie et al. (2016), which was simplified in this study.

Shoe length is the horizontal distance between the most anterior and posterior of the shoe while shoe width is the diagonal distance at the anterior expanded area of the shoe. The measurements were done twice in order to eliminate systematic errors and the average value will be taken for further analysis.

Data were analyzed using SPSS software for windows version 25.0. A test-retest reliability assessment was conducted on the two sets of measurements for length and width. The analysis was further followed by Pearson correlation test to determine the relationship between stature and shoe dimensions. The relationships between stature and shoe dimensions were also observed in male and female.

RESULTS AND DISCUSSION

The test-retest assessment was performed to assess the reliability of the measurements taken from shoe length and shoe width. The two measurements yielded test-reliability of 0.987 for shoe length and 0.960 for shoe width. This showed there is no significant difference between the first and second measurements. In this study, the subjects were classified into three groups, the first one is for both genders and the other two groups are specified into male and female' groups. This classification is done to compare which groups give a stronger correlation towards parameters of interest.

The descriptive statistical analysis of shoe length and stature of all measurements in male+female is shown in Table 1, while for male and female groups are shown in Table 2 and Table 3, respectively. These tables show the range of shoe

size (UK), statures; and shoe length and shoe width along with the means and standard deviations. The mean shoe length and width for both genders together are 27.96 ± 1.89 cm and 11.18 ± 0.84 cm respectively. Males have higher anthropometric values with the mean shoe length of 29.37 ± 1.21 cm and mean shoe width of 11.68 ± 0.77 cm as compared to female with mean shoe length of 26.56 ± 1.32 and mean shoe width of 10.68 ± 0.57. This is expected as males are generally much taller than females. Even so, Chiroma et al. (2015) stated that given that if the male and female are of the same stature, males still have longer and broader feet than women

For Pearson Correlation test, it showed that both length and width measurements have a significant positive correlation with stature in the males + females group, with shoe length having the correlation coefficient (r) value of 0.644 ($p<0.05$) and shoe width 0.604 ($p<0.05$) (Table 4). Previous research by Jasuja et al. (1991) also found there was a positive correlation between the stature and shoe length and width, with shoe length showing higher correlation coefficient compared to shoe width. The same goes for a study carried out using 230 subjects from the Nigerian population aged between 18 to 36 years old that showed a positive correlation between an individual's stature and shoe dimension, with the strongest correlation being shoe length rather than shoe width (Okubike et al. 2018). The study by Ekezie et al. (2016), using 211 subjects from the Igbo ethnic group of Nigeria in estimation of stature from footprint and shoeprint, showed that the strongest positive correlation was observed between stature and shoe length ($r = 0.605$). Saxena et al. (2018) studied the relationship between shoeprint length and stature using 500 subjects in the Central Indian population, aged between 18 to 50 years old. Their findings also supported previous studies; as stature increases, shoe length also increases.

In this study, the researchers also attempted to determine the correlation between stature and shoe dimensions between the male and female groups. The study showed that there is a positive correlation between stature and shoe dimensions (shoe length $r = 0.542$, $n=36$, $p<0.05$ and shoe width $r=0.613$, $n=36$, $p<0.05$) in the male group. Shoe width shows a better correlation to stature compared to shoe length. However, for the female group, there is no significant correlation between stature and shoe dimensions ($p>0.05$).

The study by Othman (2010) also obtained similar results, where females showed insignificant correlation between stature and shoeprint dimensions. Othman (2010) conducted a project of estimating stature from foot, barefoot print and shoe print dimensions and in their findings, females showed an insignificant correlation in both the shoeprint length and shoeprint width. They ruled out that foot measurements may provide a much accurate stature estimation than shoe measurements for females (Othman 2010).

One of the reasons we believed this happened is that females tend to wear shoes that are not their actual fit. This may be caused by the shoe designs, especially in the Asian market that do not follow the standard anthropometric standard (Siti et al. 2010). Shariff et al. (2014) also stated that Malaysian women have been facing difficulties in getting the right shoe size and fit when buying shoes due to having unique foot shapes, mainly at the foot length and breadth (Shariff et al. 2019). In their study, 60.3% of Malaysian women did not have ample choices in choosing comfortable shoe sizes and another 66.3% have difficulties finding the right size (Shariff et al. 2014).

As all variables except the female groups are significant, calculation formulas for estimation of stature using shoe length and shoe width are derived using linear regression. The linear regression equation, which is obtained from this study, uses the following format:

$$Y = a + bX \pm SEE$$

where stature is denoted as 'Y', 'a' is a constant and 'b' is the regression coefficient of each independent variable while 'X' is the individual variable.

Table 5 shows the constant, Regression coefficient, R, R2, Adjusted R2 and Standard Error of Estimate (SEE) of male+female group and male group. Table 6 summarizes the stature prediction equations using different variables studied in this research. For male+female group, the shoe length equation; Stature = 95.081 + 2.417 (Shoe Length) has the best prediction power which contributes 40.6% to estimate individual stature. While the shoe width equation; Stature = 105.449 + 5.120 (Shoe Width) with a prediction power of 35.6%. For the males, the linear regression equation is Stature = 98.968 + 2.342 (Shoe Length) with a prediction power of 29.3%. and Stature = 119.204 + 4.157 (Shoe Width) with a prediction power of 37.6%. Shoe width has a higher prediction power to estimate individual statute for the male group as compared to shoe length.

These derived formulae concluded that stature estimation can be obtained using shoe length and width. In this study, there are a few differences in the standard error of estimation (SEE) in all equations ranging from 4.185 to 5.694 (Table 5). The SEE value in this study is much smaller as compared to previous research by Ekezie et al. (2016). The SEE value in research by Ekezie et al. (2016) for shoe length was 6.670 (5.466 and 4.452 in this study) and for shoe width was 7.470 (5.694 and 4.185 in this study). The SEE value of this study is almost similar to Okubike's study (2018),

where their Right Shoe Print Length (RSPL) was 5.700 and Right Shoe Print Breadth (RSPB) was 6.293. For male group however, this study establishes a rather lower SEE value compared to their work, with SEE value of RSPL= 5.607 and RSPB=5.648. The SEE value in this study when compared to another study in Malaysia (Khairulmazidah et al. 2013) is also almost similar, with only a difference of 0.0059 in shoe length.

Several factors may affect the results of this study and should be considered for future studies. We assumed that the weight of the subjects may also have affected our results, since there exists a relationship between the weight of the body and the anthropometry of the foot. A statistically significant correlation can be observed between body weight and foot dimensions (Charmode & Kadlimatti 2019). An overweight male tends to have wider feet than a person with normal weight thus more comprehensive foot shape data is required to inform footwear design (Price & Nester 2016). For future studies, the data of the weight of each subject should be collected for further analysis.

The type of shoes chosen as samples in this study may have also affected the results. Size, fit and dimensions of shoes vary between shoe manufacturers and so does the type of shoes. Poorly manufactured shoes tend to have a smaller width, thus people with wider feet compensate by buying a larger shoe than their actual feet. A bulging at the sides of the shoe is readily seen and is also apparent in the impression left by the shoes (Giles & Vallandigham 1991). The difference in the variations of style, heel stature, materials, patterns, construction and manufacturers may have different measurements and fit even in identical sizes. Eliminating one source of these variations may provide greater accuracy in which in this study, the type of the shoe should be much specified into only one type of shoe.

A small sample size, being below 100 may impact the accuracy of this study. Most previous studies used a sample size between 200 - 500. Hence, it is recommended to obtain a wider sample size for future studies. Despite numerous factors influencing the accuracy of the findings, this research has demonstrated a positive correlation between shoe dimensions (length and width) and stature in both the male+female and male groups.

Based on the results obtained from this research, the use of shoe dimensions (Length and width) among students of UKM, Malaysia was successfully developed regression models to estimate individual stature. The results from this research will have important applications in the formulation of biological profiles during forensic investigations through the providing of the regression equations for stature prediction from shoe dimensions. Since different population may have their own differences in morphology, this present result may be used to estimate stature using shoe dimensions in Malaysian population in the future.

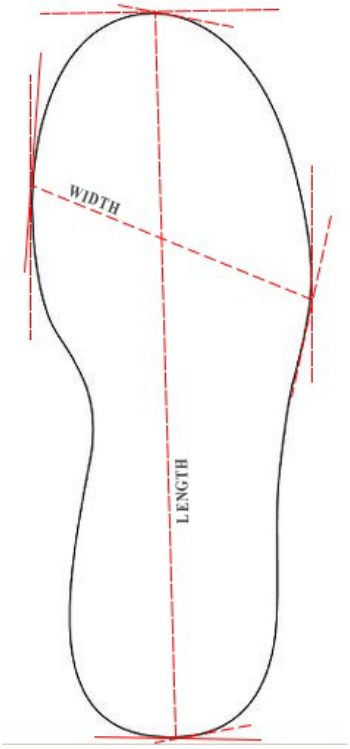

FIGURE 1 Measurement of the right shoe outline

TABLE 1 Descriptive statistics for male+female group

Variables	N	Min	Max	Mean	Std.
Shoe size	72	4.00	12.00	6.82	1.960
Stature	72	142.80	176.60	162.67	7.096
Shoe length	72	22.90	31.95	27.96	1.891
Shoe width	72	9.60	13.00	11.18	0.838

TABLE 2 Descriptive statistics for the male group.

Variables	N	Min	Max	Mean	Std.
Shoe size	36	6.00	12.00	8.28	1.446
Stature	36	156.40	176.60	167.74	5.220
Shoe length	36	27.30	31.95	29.37	1.207
Shoe width	36	10.39	13.09	11.68	0.769

TABLE 3 Descriptive statistics for the female group

Variables	N	Min	Max	Mean	Std.
Shoe size	36	4.00	9.00	5.36	1.150
Stature	36	142.80	165.70	157.60	4.684
Shoe length	36	22.90	29.15	26.56	1.316
Shoe width	36	9.60	11.90	10.68	0.566

TABLE 4 Correlation coefficient (r) between stature and shoe dimensions

	Stature		
Shoe dimension	Male + Female	Male	Female
Length	0.644**	0.542**	-0.089
Width	0.604**	0.613**	-0.140

** Correlation is significant ($p<0.05$)

TABLE 5 Constant, Regression coefficient, R, R^2, Adjusted R^2 and Standard Error of Estimate (SEE) of the male+female group and male group.

Groups		Variables	Constant	Regression coefficient	R	R^2	Adjusted R^2	SEE
Male + Female		**Shoe Length**	95.081	2.417	0.644	0.415	0.406	5.466
		Shoe Width	105.449	5.120	0.604	0.356	0.356	5.694
Male		**Shoe Length**	98.968	2.342	0.542	0.293	0.273	4.452
		Shoe Width	119.204	4.157	0.613	0.376	0.357	4.185

TABLE 6 Regression Equations for estimation of Stature in male+female groups as well as in male group.

Groups	Variable	Equation
Male+Female (N=72)	Shoe Length	Y = 95.081 + 2.417 (Length) ± 5.466
	Shoe Width	Y = 105.449 + 5.120 (Width) ± 5.694
Male (N=36)	Shoe Length	Y_{male} = 98.968 + 2.342 (Length) ± 4.452
	Shoe Width	Y_{male} = 119.204 + 4.157 (Width) ± 4.185

CONCLUSION

This study concluded that stature estimation can be determined from shoe dimensions (length and width) by using a derived linear regression formula. A positive correlation between stature and shoe dimensions can also be seen in the male+female and male groups but not in the female group

REFERENCE

Asadujjaman, M., Rashid, M.H.O., Rana M.S. & Hossain M.M. 2022. Stature Estimation from Footprint Measurements in Bangladeshi adults. *Forensic Sci. Res*. 7(2): 124-131.

Becker, R.F. 2013. Underwater Forensic Investigation. 2nd Ed. Boca Raton: CRC Press.

Chapman, R., Summersby, S., Lang, T., Raymond, J. & Ballantyne, K. 2023. Novices Cannot Fill the Examiners' Shoes: Evidence of Footwear Examiners' Expertise in Shoe Comparisons. *Sci. Justice* 63(5): 598-611.

Charmode, S. H. & Kadlimatti, H. S. 2019. Correlation of Foot Dimensions with Body Weight - A Study in Young Population of Central India. *Transl. Res. Anat.* 16: 100043.

Chiroma, S.M., Philip, J., Attah, O.O. & Dibal, N.I. 2015. Comparison of the Foot Height, Length, Breadth and Foot Types Between Males and Females Ga'anda People, Adamawa, Nigeria. *IOSR J. Dent. Med. Sci.* 14(8): 89-93.

Ekezie, J., Ndubuka, G.I., Danborno, S.B., Okeke, S.N. & Osuchukwu, I.W. 2016. A Study of Correlations and Estimation of Stature from Foot Trace and Shoe Trace Dimensions. *Int. J. Forens. Sci.* 1(3): 000113.

Giles, E. & Vallandigham, P.H. 1991. Stature Estimation from Foot and Shoeprint Length. *J. Forensic Sci*. 36(4): 1134-1151.

Jasuja, O.P., Singh, J. & Jain, M. 1991. Estimation of Stature from Foot and Shoe Measurements by Multiplication Factors: A Revised Attempt. *Forensic Sci. Int.* 50 (2): 203- 215.

Khairulmazidah, M., Nurul Nadiah, A.B. & Rumiza, A.R. 2013. Stature Estimation Using Foot and Shoeprint Length of Malaysian Population. *Int. J. Med. Health Sci.* 7(7): 365-368

Kheawpun, O. & Choosakoonkriang, S. 2020. Estimation of Stature and Sex from Step Length and Shoe Dimensions for Forensic Investigation. *Interdiscip. Res. Rev.* 15(6): 1-5.

Mohamed Izzharif, A.H., Izyan Hani, I., Adlina Syafura, A.S., Mohd Muzamir, M., Umi Kalsum, A.K. & Mohamed Sazif, M.S. 2024. Forensic Investigation to Retrieve 3D Shoe Impression: A Review. *J. Adv. Res. Appl. Sci. Eng. Technol.* 37(2): 104-112.

Okubike, E.A., Nandi, M.E., Iheaza, E.C. & Obun, C.O. 2018. Stature Prediction using Shoe

Print Dimensions of an Adult Nigerian Population. *Arab J. Forensic Sci. Forensic Med.* 1(8): 989-1003

Othman, Z. 2010. *Estimation of Stature (Body Stature) from Foot-, Barefoot Print and Shoe Print Dimensions*. Tesis Dr. Fal, University of Amsterdam.

Panchal, V. & Mia, Rakesh. 2022. Detection of Footprint Impressions at the Scene of Crime – A Review. *J. Forensic Sci. Criminal Inves*. 15(4): 001-004.

Price, C. & Nester, C. 2016. Foot Dimensions and Morphology in Healthy Weight, Overweight and Obese Males. *Clin. Biomech*. 37: 125-130.

Saxena, D., Bimbisar Mukherjee, B., Meshram, R. & Mishra, P.K. 2018. Estimation of Stature from Shoeprint Length in Central Indian Population. *Indian J. Forensic Med. Pathol*. 11(4): 225-228.

Shariff, S. M., Merican, A. F., & Shariff, A. A. 2019. Development of New Shoe-Sizing System for Malaysian Women Using 3D Foot Scanning Technology. *Measurement* 140: 182–184.

Shariff, S.M., Bong, Y.B., Asma Shariff, A., Kouchi, M., Kimura, K., Merican, A.F., Rijal, O.M. and Noor, N.M. 2014. Development of a Foot Sizing System for Malaysian Women. Paper presented at the 2014 5th International Conference on 3D Body Scanning Technologies, 16-17 October, Lugano, Switzerland.

Svabova, P., Caplova, Z., Benus, R., Chovancova, M. & Masnicova, S. 2022. Estimation of Stature and Body Weight from Static and Dynamic Footprints – Forensic Implications and Validity of Non-Colouring Cream Method. *Forensic Sci. Int.* 330: 111105