Jurnal Sains Kesihatan Malaysia **9** (2) 2011: 23-28

Kertas Asli/*Original Article*

Stature and Sex Estimation Using Foot Measurements for Malays and Chinese in Malaysia

(Penentuan Ketinggian dan Seks Menggunakan Ukuran-ukuran Kaki bagi Melayu dan Cina di Malaysia)

PHANG SOOK FUN, KHAIRUL OSMAN, SRI PAWITA ALBAKRI AMIR HAMZAH, NOOR HAZFALINDA HAMZAH, AB HALIM MANSAR & NORMAIZATUL AFIZAH ISMAIL

ABSTRAK

Kajian ini dijalankan untuk membentuk formula demi menganggar ketinggian tubuh badan dan menentukan jantina dengan menggunakan panjang dan lebar kaki. Seramai 150 orang subjek yang berumur 20-30 tahun diambil dari Universiti Kebangsaan Malaysia Kampus Kuala Lumpur (UKMKKL). Subjek tersebut adalah Melayu (45 lelaki dan 45 perempuan) dan Cina (30 lelaki dan 30 perempuan). Ketinggian, panjang dan lebar kaki diukur menggunakan alatan antropometrik dalam ukuran milimeter. Hasil statistik menunjukkan bahawa pelbagai ukuran kaki kanan dan kiri tidak mempunyai perbezaan yang signifikan (Panjang kaki/FL: $t(298) = -0.235$, $p = 0.815$; Lebar kaki/FW: $t(298) = 0.932$, $p = 0.352$). Perbezaan yang signifikan pada semua ukuran pula dapat dilihat pada jantina (Tinggi/S: $t(148) = 12.550$, $p < 0.05$; FL:$t(148) = 11.692$, $p < 0.05$; FW:$t(148) = 8.321$, $p < 0.05$). Bagi kaum, ketinggian tubuh badan kaum Cina adalah lebih tinggi berbanding kaum Melayu secara signifikan ($t(148) = -3.103$, $p < 0.05$) tetapi tiada perbezaan yang signifikan diperhatikan pada ukuran kaki (FL: $t(148) = 0.002$, $p = 0.999$; FW:$t(148) = 1.362$, $p = 0.175$). Korelasi yang paling tinggi telah ditunjukkan antara ketinggian tubuh badan dengan panjang kaki pada semua kumpulan. Analisis Regresi Garis Lurus dan Regresi Berganda telah digunakan untuk membentuk formula menganggar ketinggian tubuh badan. Walau bagaimanapun, didapati formula yang dibentuk dari Regresi Berganda adalah lebih tepat kerana kombinasi panjang dan lebar kaki menghasilkan korelasi koefisen yang lebih tinggi dalam semua formula ($S = 585.298+(4.898xFL)-(1.453xFW)$, $F(2,149 = 149.324$, $p < 0.01$, $R^2 = 0.670$). Formula untuk penentuan jantina juga telah dibina menggunakan Analisis Pokok Klasifikasi. Keputusan menunjukkan ketepatan untuk menentukan jantina seseorang adalah di antara 86.3-87.5% bagi perempuan dan 85.2-85.7% bagi lelaki dengan menggunakan panjang kaki manakala di antara 68.4-76.8% bagi perempuan dan 77.8-81.0% bagi lelaki dengan menggunakan lebar kaki.

Kata kunci: Ketinggian, jantina, panjang kaki, lebar kaki, antropologi forensik

ABSTRACT

The aim of this study was to develop formulae for stature and sex estimation using foot length and foot width. A total of 150 subjects ranging in age from 20 to 30 years were recruited from Universiti Kebangsaan Malaysia Kampus Kuala Lumpur (UKMKKL). The subjects were Malays (45 males and 45 females) and Chinese (30 males and 30 females). Stature, foot length and foot width were measured using anthropometric instruments in millimetres. Statistical analysis indicated that bilateral variation of various lengths was insignificant for all the foot measurements (Foot length/FL: $t(298) = -0.235$, $p = 0.815$; Foot width/FW: $t(298) = 0.932$, $p = 0.352$). Sex differences were found to be highly significant for all the measurements (Stature/S: $t(148) = 12.550$, $p < 0.05$; FL:$t(148) = 11.692$, $p < 0.05$; FW:$t(148) = 8.321$, $p < 0.05$). Stature was highly significant in Chinese rather than Malay ($t(148) = -3.103$, $p < 0.05$) but no significant differences were found in all the foot measurements (FL: $t(148) = 0.002$, $p = 0.999$; FW:$t(148) = 1.362$, $p = 0.175$). The highest correlation was found between stature and foot length in all groups. Linear and Multiple Regression Analysis were used to develop formulae for stature estimation. However, the latter was found to be more accurate as the correlation coefficient was highest in the combination of foot length and foot width in all the formulae ($S = 585.298+(4.898xFL)-(1.453xFW)$, $F(2,149 = 149.324$, $p < 0.01$, $R^2 = 0.670$). Formulae for sex estimation were obtained by using the Classification Tree Analysis. Result had indicated that sex estimation formulae can help to determine the sex with 86.3-87.5% accuracy in females and 85.2-85.7% accuracy in males by using foot length while the accuracy is 68.4-76.8% in females and 77.8-81.0% in males by using foot width.

Keywords: Stature, sex, foot length, foot width, forensic antropology

INTRODUCTION

In mass disasters cases such as air crashes and train accidents it is common to see numerous dismembered and fragmented human bodies. Where else in homicide cases, fragments of body parts are found to be disposed in less visited places for example ditches or rubbish dumping sites. The decomposed condition of the bodies conceals the identity of victims. Thus, making identification difficult task (Zeybek et al. 2008). In general, identity of a victim is commonly determined through unique body marking or body parts (Agnihotri et al. 2007a). Stature and sex are fundamental parameters in establishing identity of an unknown (Jasuja & Singh 2004; Celbis & Agritmis 2006). Studies have proven that measurements of different body parts will provide good approximation on victims' stature and sex, therefore will help in personal identification (Krishan & Sharma 2007). Skull, pelvis, teeth and vertebral column were the most useful anatomical regions for identification purpose. However, these elements cannot be used when they have been destroyed or incomplete.

The foot on the other hand can be useful as the foot is protected by shoes (Rich et al. 2003; Agnihotri et al. 2007a). The foot has been studied widely and has been proven to be able to provide information about an individual when only the foot of the individual is recovered. Attempts have also been made to estimate stature and sex from foot length and foot width based on statistical equations and formulae (Kanchan et al. 2008a).

The purpose of the study was to develop formula to estimate the stature and sex of an unknown individual by using foot length and foot width. Based on past reading, no studies have been attempted to estimate the stature and sex from foot measurements in the Malaysian population specifically.

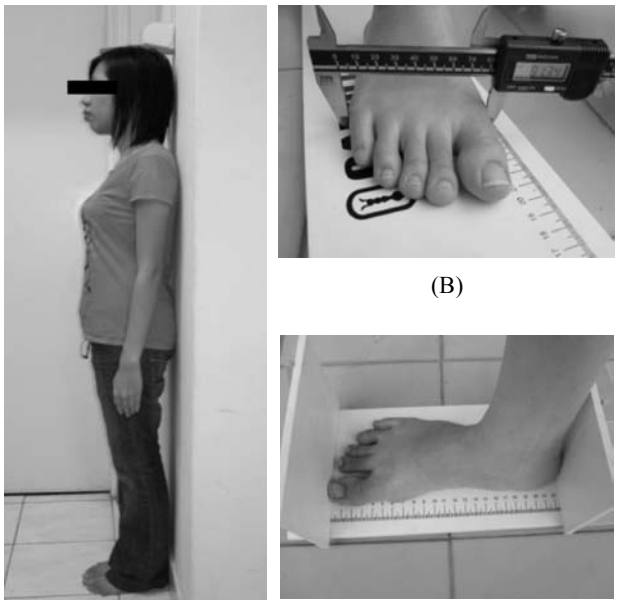
In general, Malaysia consists of various races, Malay, Chinese, Indian and other minorities such as Iban and Kadazan. The population in Malaysia comprise of 67.0% Malays, 24.3% Chineses, 7.4% Indians and the rest 1.3% is accounted by minority groups (DSM 2011). Each racial group needs different formulae as racial and ethnic variations arise in different regions (Moudgil et al. 2008). The formulae can only be used in the same population in which the formulae was developed (Steyn 1997; Hauser et al. 2005). Therefore, the developed formulae could be used effectively in certain races of the Malaysian population.

MATERIALS AND METHODS

The study was conducted among students and staffs of *Universiti Kebangsaan Malaysia Kampus Kuala Lumpur (UKMKKL)*. A total of 150 individuals with age ranging from 20 to 30 years were recruited as subjects. The subjects comprised of Malays (45 males and 45 females) and Chinese (30 males and 30 females). Approval from ethical committee was obtained prior to the start of the study. All the subjects were explained on how the study will be conducted. Subject was selected for study only when the project consent forms were signed. Stature, foot length and foot width were measured using anthropometric instruments consisting of body meter, osteometric board and digital calliper. Subjects were barefooted. Due to the diurnal variation (Krishan & Vij 2007), all subjects were measured in the afternoon (Kanchan et al. 2008a) between 1400-1600 hours.

All measurements were taken in the unit of millimetre (mm). Stature was taken from the vertex to the FLoor in which the subject was in a standing posture using a body meter. The subjects were also required to stand up against the wall, with both feet in close contact with each other and the trunk braced along the wall. The head was held in Frankfurt plane (ear-eye plane) by keeping the lateral palpebral commissure and the tip of auricle of the pinna in a horizontal plane parallel to the feet in the anatomical position (Figure 1A). Right foot length (RFL) and left foot length (LFL) were measured from the most anterior and posterior points of the foot (Figure 1B). Right foot width (RFW) and left foot width (LFL) were measured from the surfaces of first metatarsal bone head to fifth metatarsal bone head (Figure 1C) (Krishan & Sharma 2007; Zeybek et al. 2008).

All the numerical data were subjected to statistical analysis using SPSS 19.0. The measurements were presented in descriptive statistics. Independent T-test was used to compare the right and left foot measurements and foot measurements between sex and races. The relationship between the stature and foot measurements was determined by Pearson Correlation Analysis. Linear and Multiple



(A) (B) (C)

FIGURE 1. Stature and foot measurements. (A) Stature; (B) Foot length; (C) Foot width

Regression Analysis were used to develop formulae for stature while Classification Tree was used to estimate sex of the individual. Level of statistical significance was set at $p < 0.05$.

RESULTS

Comparative statistics with mean value, standard error, standard deviation and p-value for each measurement in sex (male and female), races (Malay and Chinese) and combination of sex and races were tabulated (Table 1, 2, 3). All the measurements were higher in male compared to female. These sex differences were statistically significant (Stature/S: $t(148) = 12.550$, $p < 0.05$; Foot length/FL: $t(148) = 11.692$, $p < 0.05$; Foot width/FW: $t(148) = 8.321$, $p < 0.05$). Table 4 showed the bilateral differences in all the subjects. The mean value of foot length was higher in the right foot whereas mean value of foot width was higher in the left foot. However, there were no statistically significant bilateral differences in the measurements of foot length and foot width (FL: $t(298) = -0.235$, $p = 0.815$; FW: $t(298) = 0.932$, $p = 0.352$). Correlation between stature and foot measurements in sex, races and combination of sex and races was evaluated and tabulated (Table 5, 6, 7). In all groups, the highest correlation between the stature and foot measurements was found in foot length (FL: $r = 0.815$, $p < 0.05$).

Foot length and foot width were evaluated to develop formulae in stature estimation using Linear Regression Analysis. Multiple Regression Analysis was used to develop formulae from the combination of foot length and foot width. Table 8 showed the general regression equations developed for foot of unknown sex and races. Table 9 showed specific regression equations developed for foot of known sex but unknown race. Table 10 showed specific regression equations developed for foot of known sex and races. The multiple regression formulae in all groups showed higher correlation coefficient with stature rather than linear regression formulae.

In Table 11, the deviation point of the sex estimation for foot length was 241.50 mm while foot width was 93.81 mm. In foot length, the values equal to or less than 241.50 mm were evaluated as female while more than 241.50 mm were evaluated as male. In foot width, the values equal to or less than 93.81 mm were evaluated as female while more than 93.81 mm were evaluated as male. When previous data were taken into account, Classification Tree was used for the first time in sex estimation. It gives an overall accuracy of 85.7-86.7% in sex estimation through foot length and 77.8-81% through foot width. The results showed that foot length gives a better prediction in an unknown sex.

TABLE 1. Descriptive statistics for all measurements (mm) in sex

	Male (n = 75)					Female (n = 75)					T-test
	Minimum	Maximum	Mean	S.E.	S.D.	Minimum	Maximum	Mean	S.E.	S.D.	p
S	1559	1862.00	1695.00	6.63	57.40	1724.00	1441.00	1578.00	6.51	56.37	0.000
FL	219.00	287.00	253.00	1.41	12.20	212.00	257.00	232.00	1.09	9.42	0.000
FW	84.79	111.86	98.40	0.66	5.75	80.11	102.74	91.09	0.57	4.98	0.000

TABLE 2. Descriptive statistics for all measurements (mm) in races

	Malay (n = 90)					Chinese (n = 60)					T-test
	Minimum	Maximum	Mean	S.E.	S.D.	Minimum	Maximum	Mean	S.E.	S.D.	p
S	1441.00	1817.00	1620.00	8.49	80.55	1538.00	1862.00	1661.35	9.95	77.10	0.002
FL	212.00	287.00	243.00	1.72	16.35	219.00	276.000	243.00	1.68	13.04	0.999
FW	80.11	11.86	95.33	0.76	7.18	83.88	106.81	93.86	0.67	5.22	0.175

TABLE 3. Descriptive statistics for all measurements (mm) in combination of sex and races

	Malay Male (n = 45)					Chinese Male (n = 30)					T-test
	Minimum	Maximum	Mean	S.E.	S.D.	Minimum	Maximum	Mean	S.E.	S.D.	p
S	1559.00	1817.00	1679.00	8.21	55.09	1611.00	1862.00	1720.00	9.56	52.34	0.002
FL	219.00	287.00	254.00	2.01	13.51	236.00	276.00	252.00	1.83	10.03	0.511
FW	84.79	111.86	99.36	0.97	6.48	86.33	106.81	96.84	0.80	4.38	0.067

	Malay Female (n = 45)					Chinese Female (n = 30)					T-test
	Minimum	Maximum	Mean	S.E.	S.D.	Minimum	Maximum	Mean	S.E.	S.D.	p
S	1441.00	1689.00	1562.00	8.41	56.40	1538.00	1724.00	1603.00	8.68	47.56	0.002
FL	212.00	255.00	232.00	1.51	10.15	219.00	257.00	234.00	1.50	8.24	0.397
FW	80.11	101.89	91.23	0.81	5.46	83.88	102.74	90.88	0.77	4.24	0.774

TABLE 4. Bilateral differences in foot measurements

	Right foot (n = 150)		Left foot (n = 150)		T-test
	Mean	S.E.	Mean	S.E.	p
FL	243.00	1.21	243.00	1.26	0.815
FW	95.10	0.56	94.38	0.53	0.352

TABLE 5. Correlation between stature and foot measurements in male and female

	Stature		
	Male (n = 75)	Female (n = 75)	Study Group (n = 150)
FL			
r	0.594	0.697	0.815
p	0.000	0.000	0.000
FW			
r	0.392	0.265	0.593
p	0.001	0.022	0.000

TABLE 6. Correlation between stature and foot measurements in Malay and Chinese

	Stature		
	Male (n = 90)	Female (n = 60)	Study Group (n = 150)
FL			
r	0.855	0.824	0.815
p	0.000	0.000	0.000
FW			
r	0.667	0.610	0.593
p	0.001	0.000	0.000

TABLE 7. Correlation between stature and foot measurements in combination of sex and races

	Stature			
	Malay Male (n = 45)	Malay Female (n = 45)	Male Chinese (n = 30)	Female Chinese (n = 30)
FL				
r	0.684	0.772	0.643	0.575
p	0.000	0.000	0.000	0.001
FW				
r	0.582	0.307	0.367	0.271
p	0.000	0.040	0.046	0.048

TABLE 8. General formula for stature estimation

	Foot Part	Formula	R	R^2
Study Group (n = 150)	FL	S = 566.471 + (4.408 x FL) ± 62.571	0.815	0.665
	FW	S = 931.916 + (7.440 x FW) ± 78.85	0.593	0.352
	FL + FW	S = 585.198 + (4.898 x FL) – (1.453 x FW) ± 63.497	0.819	0.670

TABLE 9. Spesific formula for stature estimation in sex

	Foot Part	Formula	R	R^2
Male (n = 75)	FL	S = 988.059 + (2.792 x FL) ± 112.328	0.594	0.352
	FW	S = 1316.076 + (3.853 x FW) ± 104.423	0.392	0.153
	FL + FW	S = 997.211 + (3.176 x FL) – (1.083 x FW) ± 113.241	0.598	0.358
Female (n = 75)	FL	S = 609.966 + (4.167 x FL) ± 116.854	0.697	0.485
	FW	S = 1305.573 + (2.996 x FW) ± 116.577	0.265	0.070
	FL + FW	S = 653.593 + (4.656 x FL) – (1.725 x FW) ± 119.144	0.708	0.502

TABLE 10. Spesific formula for stature estimation in combination of sex and races

	Foot Part	Formula	R	R^2
Malay	FL	S = 970.611 + (2.787 x FL) ± 115.370	0.684	0.468
Male	FW	S = 1187.016 + (4.947 x FW) ± 105.031	0.582	0.338
(n = 45)	FL + FW	S = 967.466 + (2.428 x FL) + (0.951 x FW) ± 116.330	0.687	0.472
Malay	FL	S = 568.495 + (4.290 x FL) ± 124.849	0.772	0.596
Female	FW	S = 1272.923 + (3.172 x FW) ± 137.089	0.307	0.094
(n = 45)	FL + FW	S = 608.669 + (4.832 x FL) – (1.816 x FW) ± 125.704	0.786	0.618
Male	FL	S = 874.170 + (3.355 x FL) ± 190.550	0.643	0.413
Chinese	FW	S = 1294.787 + (4.390 x FW) ± 203.517	0.367	0.135
(n = 30)	FL + FW	S = 890.440 + (3.507 x FL) – (0.563 x FW) ± 204.293	0.644	0.415
Female	FL	S = 827.485 + (3.320 x FL) ± 208.417	0.575	0.331
Chinese	FW	S = 1326.221 + (3.043 x FW) ± 185.552	0.271	0.074
(n = 30)	FL + FW	S = 837.773 + (3.412 x FL) – (0.350 x FW) ± 220.538	0.576	0.332

TABLE 11. Category of sex

Foot Part	Deviation Point (mm)	Category	Accuracy (%)	Overall of Accuracy (%)
FL	≤ 241.50	Female	86.3 – 87.5	85.7 – 86.7
	> 241.50	Male	85.2 – 85.7	
FW	≤ 93.81	Female	68.4 – 76.8	77.8 - 81.0
	> 93.81	Male	78.8 – 91.3	

DISCUSSION

The study found that there were no significant bilateral differences in foot length and foot width which support studies done by Krishan and Sharma (2007) and Ozden et al. (2005). However, a number of studies reported that there were significant bilateral differences in foot length and foot width (Tyagi et al. 2004; Krishan & Sharma 2007; Sen & Ghosh 2008; Kanchan et al. 2008a). We feel that the inconsistent findings were due to small sample size used by Krishan and Sharma (2007) and Ozden et al. (2005) compared to the others.

Males were found to be taller than females due to the puberty period. The age of puberty in males was 2 years later than females which allows them an extra time for body growth (Krishan & Sharma 2007). The chromosome Y was also associated closely with stature. Males were taller with increased length of the heterochromatic band Yq12 in chromosome Y (Kanchan et al. 2008a). In addition, males who had a larger body size had a larger foot size to help them to stand firmly (McGinnis 2005). Application of high heel shoes was another factor contributing to the fact that males were taller than females. Calf muscles may contract and tend to shorten over time with regular wear. When foot is forced to be squeezed into a small space, the toes bend and curl to fit into the high heel shoes. The toes became fixed in this position and resulted in a condition known as hammertoe. Over time, the foot size slowly became smaller than it previously was (Silvers & Williams 2010).

Stature was more significant ($t(148) = -3.103$, $p < 0.05$) in Malays than in the Chinese but insignificant in all the foot measurements (FL: $t(148) = 0.002$, $p = 0.999$; FW: $t(148) = 1.362$, $p = 0.175$). Values for Malay males were lower in stature but higher in foot length and foot width compared with Chinese males. Malay females had lower values in stature and foot length but higher foot width than Chinese females. Stature and foot size which are different in races may be due to the genetic factor, nutrition, lifestyle and shoe types (Lai 2006; Savige et al. 2007; Zeybek et al. 2008).

In all groups, the highest correlation between the stature and foot measurements was found in foot length. This result was in concordance with earlier studies conducted by Zeybek et al. (2008) and Kanchan et al. (2008a). This may indicate that foot length has anatomical effect to the stature of a person (Krishan & Sharma 2007). Thus, a formula using foot length was the best parameter for stature estimation (Krishan & Sharma 2007; Agnihotri et al. 2007a). However using multiple regression equations gave better results than linear regression equations (Rastogi et al. 2008) as the correlation coefficient (R value) was highest in the combination of foot length and foot width in all the formulae.

CONCLUSION

Foot measurement is reliable in estimation of stature and sex in forensic investigations. General formulae for stature

estimation can be used for unknown foot regardless of sex and race. There are three general formulae developed which uses either foot length or foot width or combination of both. A formula which uses a combination of foot length and foot width measurements was the most accurate. However, for the unknown foot that has a known sex or combination of sex and race, a specific formula should be used for more reliable results. The classification Tree was used for the first time in sex estimation. It had given an overall accuracy of 85.7%-86.7% in sex estimation through foot length and 77.8%-81% through foot width therefore opening further possibilities of using this technique in the study of forensic anthropology.

REFERENCES

Agnihotri, A., Purwar, B., Googoolye, K., Agnihotri, S. & Jeebun, N. 2007a. Estimation of stature by foot length. *J. Forensic Leg. Med.* 14(5): 279-283.

Celbis, O. & Agritmis, H. 2006. Estimation of stature and determination of sex from radial and lunar bone lengths in a Turkish corpse sample. *Forensic Sci. Int.* 158: 135-139.

DSM. 2011. Population by sex, ethnic group and age, Malaysia, 2010. Department of Statistics Malaysia http://www.statistics.gov.my [25 March 2011].

Hauser, R., Smolinski, J. & Gos, T. 2005. The estimation of stature on the basis of measurements of the femur. *Forensic Sci. Int.* 147(2-3): 185-190.

Jasuja, O. & Singh, G. 2004. Estimation of stature from hand and phalange length. *J. Indian Academy Forensic Med.* 26(3): 100-106.

Kanchan, T., Menezes, R., Moudgil, R., Kaur, R., Kotian, M. & Garg, R. 2008a. Stature estimation from foot dimensions. *Forensic Sci. Int.* 179(2-3): 241.

Krishan, K. & Sharma, A. 2007. Estimation of stature from dimensions of hands and feet in a North Indian population. *J. Forensic Leg. Med.* 14(6): 327-332.

Krishan, K. & Vij, K. 2007. Diurnal variation of stature in three adults and one child. *Anthropologist* 9(2): 113-117.

Lai, C.Q. 2006. How much of human height is genetic and how much is due to nutrition? http://www.scientificamerican.com/article.cfm?id = how-much-of-human-height [6 April 2010].

McGinnis, P. 2005. *Biomechanics of Sport and Exercise.* Ed.: Champaign: Human Kinetics Publishers.

Moudgil, R., Kaur, R., Menezes, R., Kanchan, T. & Garg, R. 2008. Foot index: Is it a tool for sex determination? *J. Forensic Leg. Med.* 15(4): 223-226.

Rastogi, P., Nagesh, K. & Yoganarasimha, K. 2008. Estimation of stature from hand dimensions of north and south Indians. *Leg. Med.* 10(4): 185-189.

Rich, J., Dean, R. & Cheung, Y. 2003. Forensic implications of the foot and ankle. *J. Foot Ankle Surg.* 42(4): 221-225.

Savige, G., Ball, K., Worsley, A. & Crawford, D. 2007. Food intake patterns among Australian adolescents. *Asia Pac. J. Clin. Nutr.* 16(4): 738-747.

Sen, J. & Ghosh, S. 2008. Estimation of stature from foot length and foot breadth among the Rajbanshi: An indigenous population of North Bengal. *Forensic Sci. Int.* 181(1-3): 55.

Silvers, E. M. & Williams, K. D. 2010. High heels: The problem. http://www.advancedfoottexas.com/2010/01/high-heels-the-problem/ [1 April 2010].

Steyn, M. 1997. Sex determination from the femur and tibia in South African Whites. *Forensic Sci. Int.* 90(1-2): 111-119.

Tyagi, A., Rani, M. & Kohli, A. 2004. Sexing by foot index. *J Forensic Med. Toxicol* 21(1): 10-11.

Zeybek, G., Ergur, I. & Demiroglu, Z. 2008. Stature and gender estimation using foot measurements. *Forensic Sci. Int.* 181(1-3): 54.

Phang Sook Fun, Khairul Osman
Sri Pawita Albakri Amir Hamzah
Noor Hazfalinda Hamzah, Ab Halim Mansar
Normaizatul Afizah Ismail
Forensic Science Program
Faculty of Allied Health Sciences
Universiti Kebangsaan Malaysia
Jalan Raja Muda Abdul Aziz
50300 Kuala Lumpur
Malaysia

Correspondence author: Normaizatul Afizah Ismail
Email address: maifor@yahoo.com
Tel: 6 03 26878104, Fax: 6 03 26878108

Received: November 2010
Accepted for publication: July 2011