*Malays. Appl. Biol. (2016) 45(2): 113–118*

# BODY WEIGHT ESTIMATION FROM VARIOUS FOOTPRINT LENGTH MEASUREMENTS AMONG IBANS OF EAST MALAYSIA

NATARAJA MOORTHY, T.[1*] and HAIRUNNISA BT MOHD ANAS KHAN[2]

[1]*Associate Professor, Department of Forensic Sciences, Management and Science University, Shah Alam, Selangor, Malaysia*
[2]*Forensic Division, Chemistry Department of Malaysia, Kuching, Sarawak, East Malaysia*
[*]*Email: natrajamoorthy@rediffmail.com; HP: +6 0129224610*

Accepted 27 October 2016, Published online 21 December 2016

## ABSTRACT

Foot impressions are still found at crime scenes. The foot impressions can be used to estimate stature, gender and body weight of an individual. Most of the foot/foot print studies were conducted on mixed population. But racial and cultural aspects of foot morphology must be considered while conducting such studies. Hence the present study aims to estimate body weight from bilateral footprints collected from 240 (120 males, 120 females) consenting adult Iban ethnics, an indigenous groups residing in east Malaysia. Informed consent and Human Ethical Approval were obtained. The body weight of the living individuals and footprints were collected following the standard procedure. The data obtained were analyzed with PASW 20 computer software and derived regression formulae to estimate body from footprint lengths of Iban population. Investigation revealed that all footprint lengths exhibit statistically positive significant correlation with body weight ($p<0.001$). Correlation coefficient (R) values are found to be higher in the pooled sample (0.262–0.356) when compared with males (0.082–0.338) and females (0.104–0.249). The regression formulae derived for the pooled sample can be used to estimate body weight when the sex of the footprint remains unknown, as in real crime scenarios.

**Key words:** Forensic science, body weight estimation, footprint length, Iban ethnics, East Malaysia

## INTRODUCTION

An aspect of human identification that has received scant attention from forensic anthropologists is the study of human footprints made by the feet (Bhasin & Malik, 2002). Person identification using footprint analysis is also an emerging biometric technique (Kumar & Ramakrishnan, 2011). The characteristic features can provide useful clues to establish identity whenever complete or partial footprints are recovered at the crime scenes (Krishan & Abilasha, 2007). Examination of barefoot impressions is important especially in developing countries like India, Malaysia where majority of the rural population like to walk barefooted because of socio-economic and climatic reasons. Foot impressions are still found at crime scenes, since offenders often tend to remove their foot wears either to avoid noise or to gain better grip in climbing walls, etc., while entering or exiting (Nataraja Moorthy *et al.,* 2011). Commonly foot impressions are found on newly waxed floors, freshly cemented surfaces, moistened surfaces, in dust, oil, paint and can be left in blood at the murder scenes (Qamra *et al*., 1980a, b). Researchers have concluded that foot prints can be used to estimate stature (Robin, 1986; Krishan, 2008; Irene & Nashwa, 2010; Vidya *et al.,* 2011; Reel *et al.,* 2012; Ukoha, 2013; Nataraja Moorthy *et al.,* 2014a, b), gender (Derya, 2010; Naomi *et al*., 2013; Kanchan *et al.,* 2014) and body weight (Robin, 1986; Irene & Nashwa, 2010; Abledu *et al*., 2016). Researchers have cautioned that the morphology of human feet show the variations due to heredity, life style, food habits and climatic factors (Nataraja Moorthy *et al.,* 2011, 2014b, 2015; Jayadip & Shila, 2008; Salina *et al.,* 2012; Vidya *et al.,* 2011; Nataraja Moorthy *et al.,* 2015). Hence the present study is aimed to estimate body weight based on bilateral footprints for Iban

* To whom correspondence should be addressed.

ethnics, an indigenous groups residing in Borneo Island, east Malaysia.

## MATERIALS AND METHODS

### Study area

The study was carried out at East Malaysia, north-central Borneo Island. The subjects were from colleges, universities and general public. The Ibans are an indigenous ethnic group mostly residing in East Malaysia.

### Sample collection

Since the subjects are from an indigenous group in Borneo Island, permission was obtained from Sarawak Chief Minister vide No. JKM.P/DEV/16/005/12(44), for sample collection. Informed consent was also obtained from all participants and followed the procedure in accordance with the ethical standards of University Human Research Ethic Committee A sample of 480 bilateral footprints were collected from 240 (120 males, 120 females) consenting adult Iban ethnics, ages ranging between 18 to 64 years. Subjects with any apparent foot-related disease, pregnancy, orthopedic deformity, physical impairment, injury, disorders or under the age of 18 years were excluded from the study. The weight of the subjects was measured and recorded following the standard procedure (Irene & Nashwa, 2010). A cleaned left foot of the subject was advised to step on a footprint ink stained plain glass plate of 8 mm thickness with minimal pressure. Then the inked foot was placed on an A4 plain white paper kept aside on a uniform surface and thus the left footprint was transferred. Before lifting the sole from the paper, anatomical land marks of the feet were marked on the papers close to the footprints which are midrear heel point and most anterior point of all toes (Nataraja Moorthy *et al.,* 2014a, b). Then five diagonal footprint length measurements were taken from the mid-rear heel point (P) to most anterior point of each left toes (LT1, LT2, LT3, LT4, and LT5). The left footprint length measurements were designated as PLT1, PLT2, PLT3, PLT4, and PLT5. The procedure was repeated for the right footprint and the right footprint length measurements were designated as PRT1, PRT2, PRT3, PRT4 and PRT5. The land marks on right footprint are shown in Figure 1. All footprints and information relating to participants were coded with sample ID for anonymity.

### Statistical analysis

The data were analyzed using PASW Statistics version 20 (Predictive Analytic Software). Pearson's correlation coefficient (R) between various footprint lengths and stature was obtained. The linear regression analysis method was employed to derive regression equations for body weight estimation from various footprint lengths.

## RESULTS

Table 1 presents the descriptive statistics of body weights in males, females and pooled sample (combined male and female subjects). The table also shows that the mean body weight of male is found to be comparatively higher (59.2 kg) than the body weight of females (54.7 kg). Table 2 presents the


**Fig. 1.** Landmarks P, the mid-rear heel point, pternion to the most anterior point of toes LT1-LT5 on left footprint.

**Table 1.** Descriptive statistics of body weight in adult males, females and pooled sample of Iban ethnics of east Malaysia (in centimetres)

| Variable | Male (N=120) | | | | Female (N=120) | | | | Pooled sample (N=240) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean | SD | Min | Max | Mean | SD | Min | Max | Mean | SD |
| Body weight (kg) | 44.6 | 76.0 | 59.2 | 7.8 | 30.9 | 74.9 | 54.7 | 8.1 | 30.9 | 76.0 | 57.0 | 8.2 |

Min: minimum; Max: maximum; N: sample size; SD: standard deviation.

**Table 2.** Descriptive statistics of footprint length measurements in males, females and pooled sample of adult Iban ethnics of east Malaysia (in centimetres)

| Variable | Male (N=120) | | | | Female (N=120) | | | | Pooled sample (N=240) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | mean | SD | Min | Max | mean | SD | Min | Max | mean | SD |
| PLT1 | 19.8 | 24.9 | 22.9 | 1.0 | 19.0 | 23.8 | 21.2 | 0.9 | 19.0 | 24.9 | 22.1 | 1.3 |
| PLT2 | 19.4 | 25.7 | 23.1 | 1.1 | 19.1 | 23.9 | 21.3 | 1.0 | 19.1 | 25.7 | 22.2 | 1.4 |
| PLT3 | 18.7 | 25.2 | 22.3 | 1.1 | 18.4 | 23.0 | 20.5 | 0.9 | 18.4 | 25.2 | 21.4 | 1.3 |
| PLT4 | 17.9 | 24.1 | 21.2 | 1.0 | 17.5 | 22.0 | 19.5 | 0.9 | 17.5 | 24.1 | 20.3 | 1.3 |
| PLT5 | 16.6 | 22.0 | 19.6 | 1.0 | 16.4 | 20.0 | 17.9 | 0.8 | 16.4 | 22.0 | 18.8 | 1.2 |
| PRT1 | 20.2 | 25.0 | 22.9 | 0.9 | 19.4 | 23.7 | 21.2 | 0.9 | 19.4 | 25.0 | 22.1 | 1.2 |
| PRT2 | 20.1 | 25.5 | 23.1 | 1.1 | 18.5 | 23.7 | 21.3 | 1.0 | 18.5 | 25.5 | 22.2 | 1.4 |
| PRT3 | 19.4 | 25.0 | 22.3 | 1.1 | 18.1 | 22.9 | 20.4 | 1.0 | 18.1 | 25.0 | 21.4 | 1.4 |
| PRT4 | 18.5 | 23.7 | 21.1 | 1.0 | 17.3 | 21.9 | 19.4 | 0.9 | 17.3 | 23.7 | 20.3 | 1.3 |
| PRT5 | 16.7 | 22.1 | 19.5 | 1.0 | 16.0 | 20.5 | 17.8 | 0.8 | 16.0 | 22.1 | 18.7 | 1.2 |

Min: minimum; Max: maximum; PLT1 to PLT5: left footprint lengths from anterior part of toes LT1- LT5 to mid-rear heel point P; PRT1 to PRT5: right footprint lengths from anterior part of toes RT1-RT5 to mid-real heel point P; SD: standard deviation; N: Sample size.

descriptive statistics of various footprint lengths i.e. diagonal length between the rear heel end (P) and anterior points of each toe in both left (LT1– LT5) and right (RT1–RT5) footprints of males, females and the pooled sample. Here pooled sample (N=240) represents the combination of both male (N=120) and female (N=120) samples. It is observed that the mean footprint lengths of male are found to be larger than the mean footprint lengths of female. It is interested to note that the mean second toe–heel footprint lengths in both left and right (PLT2, PRT2) are found to be the longest in both genders. The investigation reveals the non-existence of significant bilateral asymmetry in both the genders

Tables 3–5 present the linear regression equations for body weight estimation in adult males, females and the pooled sample through various footprint length measurements with ANOVA. The standard error of estimate (SEE) in case of males (4.232-4.660) and females (4.090- 4.961) are comparatively lower than that of pooled samples (5.264-5.829). The tables also show that the correlation coefficient (R) between the stature and various footprint lengths among males, females and pooled sample are statistically significant (<0.001). Correlation coefficient values are found to be more in the pooled sample (0.314–0.356) when compared with males (0.190–0.338) and females (0.110–0.207). Hence statistically significant correlation exists between body weight and all footprint length measurements in Ibans of east Malaysia.

## DISCUSSION

Malaysia is a multi-racial, multi-ethnic and multi-cultural country. The indigenous ethnic groups of Sarawak include Iban, Bidayuh, Melanau, Orang Ulu and so on. The Iban speak a dialect of Malay (Malayan subfamily, Austronesian family) that is distinct from other Bornean languages. Farming is the main occupation of the Ibans and some still hunt wild animals in the jungle by setting traps or using blowpipes. The age range of the subjects in this research is appropriate since stature at 18 years is accepted as adult (Nataraja Moorthy *et al*., 2014a, b; Krishan & Abilasha, 2007). Hence the minimum age was fixed as 18 years to conduct this study. The study shows that statistically significant male–female differences exist in the stature in Iban population. All the footprint length measurements in males are found to be larger than females both in left and right feet. This may be attributed to the general male-female differences and natural size in both sexes (Nataraja Moorthy *et al.,* 2011; Tanuj *et al.,* 2012). The result shows bilateral asymmetry in

**Table 3.** Linear regression equations for body weight estimation from different footprint length measurements on left and right sides among adult Iban males of east Malaysia (in centimetres)

| Variables | Regression Equations | SEE | *R* | ANOVA |
|---|---|---|---|---|
| PLT1 | 16.331 + 1.869PLT1 | 4.582 | 0.235 | 16.928(1, 118) ; P = 0.010 |
| PLT2 | 10.705 + 2.095PLT2 | 4.457 | 0.294 | 11.179(1, 118) ; P = 0.001 |
| PLT3 | 13.482 + 2.495PLT3 | 4.344 | 0.338 | 15.177(1, 118) ; P < 0.001 |
| PLT4 | 10.386 + 2.302PLT4 | 4.418 | 0.310 | 12.525(1, 118) ; P = 0.001 |
| PLT5 | 12.355 + 2.547PLT5 | 4.396 | 0.318 | 13.317(1, 118) ; P < 0.001 |
| PRT1 | 13.517 + 1.555PRT1 | 4.660 | 0.190 | 14.408(1, 118) ; P = 0.038 |
| PRT2 | 15.658 + 1.884PRT2 | 4.540 | 0.257 | 16.322(1, 118) ; P = 0.005 |
| PRT3 | 13.929 + 2.345PRT3 | 4.395 | 0.319 | 14.331(1, 118) ; P = 0.000 |
| PRT4 | 10.473 + 2.306PRT4 | 4.232 | 0.304 | 12.043(1, 118) ; P = 0.001 |
| PRT5 | 14.120 + 2.309PRT5 | 4.472 | 0.288 | 10.658(1, 118) ; P = 0.001 |

PLT1 to PLT5: left footprint lengths from anterior part of toes LT1-T5 to mid-rear heel point P; PRT1 to PRT5: right footprint lengths from anterior part of toes RT1-RT5 to mid-rear heel point P; SEE: standard error of estimate.

**Table 4.** Linear regression equations for body weight estimation from different footprint length measurements on left and right sides among adult Iban female ethnics of east Malaysia (in centimetres)

| Variables | Regression Equations | SEE | *R* | ANOVA |
|---|---|---|---|---|
| PLT1 | 29.630 + 1.185PLT1 | 4.070 | 0.128 | 19.981(1, 118) ; P = 0.162 |
| PLT2 | 34.917 + 0.932PLT2 | 4.088 | 0.110 | 21.440(1, 118) ; P = 0.232 |
| PLT3 | 36.026 + 0.913PLT3 | 4.093 | 0.104 | 27.300(1, 118) ; P = 0.257 |
| PLT4 | 35.651 + 0.981PLT4 | 4.090 | 0.108 | 31.388(1, 117) ; P = 0.241 |
| PLT5 | 33.886 + 1.165PLT5 | 4.105 | 0.116 | 31.584(1, 118) ; P = 0.211 |
| PRT1 | 13.623 + 1.936PRT1 | 4.961 | 0.207 | 11.270(1, 118) ; P = 0.023 |
| PRT2 | 26.048 + 1.350PRT2 | 4.032 | 0.160 | 23.108(1, 118) ; P = 0.081 |
| PRT3 | 26.003 + 1.406PRT3 | 4.022 | 0.168 | 23.409(1, 118) ; P = 0.067 |
| PRT4 | 25.471 + 1.510PRT4 | 4.030 | 0.162 | 23.188(1, 118) ; P = 0.077 |
| PRT5 | 30.653 + 1.349PRT5 | 4.057 | 0.140 | 29.365(1, 118) ; P = 0.127 |

PLT1 to PLT5: left footprint lengths from anterior part of toes LT1- T5 to mid-rear heel point P; PRT1 to PRT5: right footprint lengths from anterior part of toes RT1-RT5 to mid-rear heel point P; SEE- standard error of estimate.

**Table 5.** Linear regression equations for body weight estimation from different footprint length measurements on left and right sides among adult Iban ethnics among pooled sample (in centimetres)

| Variables | Regression Equations | SEE | *R* | ANOVA |
|---|---|---|---|---|
| PLT1 | 12.167 + 2.030PLT1 | 5.829 | 0.314 | 26.056(1, 238) ; P<0.001 |
| PLT2 | 13.756 + 1.946PLT2 | 5.787 | 0.329 | 28.921(1, 238) ; P<0.001 |
| PLT3 | 12.137 + 2.093PLT3 | 5.746 | 0.343 | 31.782(1, 238) ; P<0.001 |
| PLT4 | 14.068 + 2.110PLT4 | 5.772 | 0.334 | 29.922(1, 238) ; P<0.001 |
| PLT5 | 13.638 + 2.312PLT5 | 5.760 | 0.340 | 30.973(1, 237) ; P<0.001 |
| PRT1 | 9.592 + 2.145PRT1 | 5.801 | 0.324 | 27.983(1, 238) ; P<0.001 |
| PRT2 | 12.854 + 1.989PRT2 | 5.779 | 0.332 | 29.457(1, 238) ; P<0.001 |
| PRT3 | 11.150 + 2.144PRT3 | 5.705 | 0.356 | 34.649(1, 238) ; P<0.001 |
| PRT4 | 11.603 + 2.240PRT4 | 5.735 | 0.351 | 33.431(1, 238) ; P<0.001 |
| PRT5 | 14.889 + 2.252PRT5 | 5.264 | 0.337 | 30.523(1, 238) ; P<0.001 |

PLT1 to PLT5: left footprint lengths from anterior part of toes LT1-T5 to mid-rear heel point P; PRT1 to PRT5: right footprint lengths from anterior part of toes RT1-RT5 to mid-rear heel point P; SEE: standard error of estimate.

footprints but not significant. It is noted that the correlation coefficient (R) between body weight and footprint length measurements regardless of sex, i.e. when male and female subjects are pooled together, gave a more significant result than the correlations separately obtained for the males and females. This is in accordance with the previous research findings (Nataraja Moorthy *et al.,* 2015; Hairunnisa

& Nataraja, 2016). Irene has conducted a study on body weight estimation from footprint lengths among 50 male medical students in Egypt and the correlation coefficient (R) was found to be in the range of 4.05–5.28. Many studies have been conducted on estimation of stature from foot and footprint dimensions but a few studies have reported the relationship of body weight with footprints.

## CONCLUSION

This pilot study, the first of its kind in Malaysia, developed population specific regression equations for body weight estimation from foot prints obtained from consented Ibans of east Malaysia using linear regression statistical method. The regression equations derived for the pooled sample can be used to estimate body weight when the sex of the footprint's owner remains unknown, as in real crime scenarios. It would be incorrect to utilize these equations to any other populations either in Malaysia or any other population in the world.

## ACKNOWLEDGEMENTS

The authors thank to all participants who took part in this strenuous study on an indigenous population in Borneo Island. Thanks are due to Sarawak state Chief Minister, Sarawak state Chief Police Officer, and Chemistry Department of Malaysia, Bintulu, East Malaysia for their continuous support and to complete this research successfully. The authors are thankful to Management and Science University for encouraging research and publication.

## REFERENCES

Abledu, J.K., Offei, E.B. & Antwi, E.M. 2016. Estimation of stature and body weight from footprint dimensions among a female population in Ghana. *Australian Journal of Forensic Sciences,* **48(2)**: 195-202.

Kumar, V.D.A. & Ramakrishnan, M. 2011. Legacy of footprints recognition – A review. *International Journal of Computer Applications,* **35**: 9-16.

Bhasin, M.K. & Malik, S.L. 2002. *Anthropology and applications*. Kamla Raj Publisher, New Delhi, India.

Derya, A. 2010. Estimation of sex from the dimensions of foot, footprints, and shoe. *Journal of Biological and Clinical Anthropology*, **68(1)**: 21-29.

Hairunnisa, M.A.K. & Nataraja Moorthy, T. 2016. Stature estimation from foot outline measurements in adult Lun Bawang ethnics of east Malaysia by regression analysis. *Medico-legal Update*, **16(2)**: 187-192.

Irene, A.F. & Nashwa, N.K. 2010. Stature and body weight estimation from various footprint measurement among Egyptian population. *Journal of Forensic Science*, **55**: 884-888.

Jayadip, S. & Shila, G. 2008. Estimation of stature from foot length and foot breadth among Rajbanshi: A indigenous population of north Bengal. *Forensic Science International*, **181**: 55-55.

Kanchan, T., Krishan, K., Prusty, D. & Machado, M. 2014. Heel-Ball index: An analysis of footprint dimensions for determination of sex. *Egyptian Journal of Forensic Sciences*, **4**: 29-33.

Krishan, K. & Abihilasha, S. 2007. Estimation of stature from dimension of hand, feet in north Indian population. *Journal of Forensic Legal Medicine,* **14**: 327-332.

Krishan, K. 2008. Estimation of stature from footprint and foot outline dimensions in Gujjar's of north India. *Forensic Science International*, **175**: 93-101.

Naomi, H., Flavel, A., Ishak, N.I. & Franklin, D. 2013. Sex estimation using anthropometry of feet and footprints in a Western Australian population. *Forensic Science International,* **231(1-3)**: 402 -e6.

Nataraja Moorthy, T., Mazidah, K., Hadzri, M. & Jayaprakash, P.T. 2011. Estimation of stature based on foot length of Malays in Malaysia. *Australian Journal of Forensic Sciences*, **43**: 13-26.

Nataraja Moorthy, T., Ahmad, M., Boominathan, R. & Raman, N. 2014a. Stature estimation from footprint measurements in Indian Tamils by regression analysis. *Egyptian Journal of Forensic Sciences*, **4**: 7-16.

Nataraja Moorthy, T., Ang, Y.L., Saufee, A.S. & Nik, F. 2014b. Estimation of stature from footprint and foot outline measurements in Malaysian Chinese. *Australian Journal of Forensic Sciences*, **46**(2): 136-159.

Nataraja Moorthy, T. & Hairunnisa, M.A.K. 2015. Estimation of stature from footprint anthropometry using regression analysis. *Arab Journal of Forensic Sciences and Forensic Medicine*, **1**(1): 5-11.

Qamra, S.R., Jit, I. & Deodhar, S.D. 1980a. A model for reconstruction of height from foot measurements in an adult population of north west India. *Indian Journal of Medical Research*, **71**: 77-83.

Qamra, S.R., Sharma, B.R. & Kaila, P. 1980b. Naked foot marks – a preliminary study of identification factors. *Forensic Science International*, **16**: 145-152.

Reel, S., Rouse, S., Vernon, W. & Doherty P. 2012. Estimation of stature from static and dynamic footprints. *Forensic Science International*, **219**: 1-3.

Robbin, L.M. 1986. Estimating height and weight from size of footprints. *Journal of Forensic Science*, **31**: 143-152.

Salina, H., Che, R.M. & Mohamad, A.I. 2012. Regression analysis of stature estimation from foot anthropometry in Malaysian Chinese. *Australian Journal of Forensic Sciences*, **44**(4): 333-341.

Tanuj, K., Krishan, K., Shyamsundar, S., Aparna, K.R. & Sankalp, J. 2012. Analysis of footprint and its parts for stature estimation in Indian population. *The foot,* **22**: 175-180.

Ukoha, U.U. 2013. Estimation of stature using footprints in an adult student population in Nigeria. *International Journal of Biomedicine and Advance Research*, **4**(11): 827-833.

Vidya, C.S., Shyamsundar, N.M., Saraswathi, G. & Nanjaiah. 2011. Estimation of stature using footprint measurements. *Anatomica Karnataka*, **5**: 37-39.