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Kertas Asli/*Original Article*

Stature Approximation of Malays, Chinese and Indian in Malaysia Using Radiographs of Femur, Tibia and Fibula

(Anggaran Ketinggian bagi Melayu, Cina dan India di Malaysia Menggunakan Radiograf Femur, Tibia dan Fibula)

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ABSTRACT

The study was conducted to create specific formulae for stature estimation of adult male population in Malaysia based on measurements of femur, tibia and fibula lengths using radiographic method. A number of thirty two Malaysians from hospitals involved as subjects in this study. The subjects were Malays (14), Chinese (8) and Indians (10) from 25-45 years old. The standing height of the subject was recorded before femur, tibia and fibula were scanned with an x-ray machine. The bones length was measured on the x-ray film in centimetres (cm) and analysed using Statistical Package for Social Sciences (SPSS) version 19.0 for Windows. The results showed a significant relationship (p < 0.05) between stature and measurements of length of femur, tibia and fibula. Stature of Malays and Indians were significant (p < 0.05) with measurements of length of femur, tibia and fibula but insignificant in Chinese. Simple Linear Regression Analysis was used to derive regression equation for single bone and Multiple Linear Regression Analysis was used to derive regression equation for combination of femur, tibia and fibula. Six formulae for stature estimation of adult male population in Malaysia were derived. The formulae consist of three formulae for single bone, a formulae for combination bones with unknown race, a formulae for combination bones of Malays population and a formulae for combination bones of Indians population. Formulae for combination bones had the highest correlation coefficient compared to the formula using a single bone. Standard error was found to be high in all the formulae due to small sample size. Extension for this study is essential to provide Malaysia with accurate formulae.

Keywords: Stature, Radiography, Femur, Tibia, Fibula, Bone, Lower Limb, Forensic Science

ABSTRAK

Kajian ini bertujuan untuk menghasilkan formula khusus untuk menganggar ketinggian populasi lelaki dewasa di Malaysia berdasarkan pengukuran panjang tulang femur, tibia dan fibula menggunakan kaedah radiografi. Seramai tiga puluh dua orang subjek dari hospital-hospital kerajaan terlibat dalam kajian ini. Subjek adalah Melayu (empat belas), Cina (lapan) dan India (sepuluh) yang berumur dari 25-45 tahun. Ukuran tinggi berdiri subjek dicatat sebelum tulang femur, tibia dan fibula diimbas dengan menggunakan mesin x-ray. Panjang tulang-tulang diukur diatas filem x-ray dalam unit sentimeter (sm) dan dianalisa menggunakan Pakej Statistik untuk Sains Sosial (SPSS) versi 19.0 untuk Windows. Hasil kajian menunjukkan terdapat hubungan signifikan (p < 0.05) antara ketinggian dan panjang tulang femur, tibia dan fibula. Ketinggian subjek Melayu dan India juga signifikan (p < 0.05) dengan panjang ukuran tulang femur, tibia dan fibula tetapi tidak signifikan bagi subjek Cina. Analisis Regressi Garis Lurus Mudah digunakan untuk menghasilkan persamaan untuk satu tulang dan Analisis Regressi Garis Pelbagai digunakan untuk menghasilkan persamaan bagi kombinasi tulang femur, tibia dan fibula. Enam formula untuk menganggar ketinggian populasi lelaki dewasa di Malaysia telah dihasilkan. Formula-formula tersebut terdiri daripada tiga formula yang menggunakan salah satu tulang, satu formula yang menggunakan kombinasi tulang yang tidak diketahui bangsa, satu formula yang menggunakan kombinasi tulang bagi populasi Melayu Malaysia dan satu formula yang menggunakan kombinasi tulang bagi populasi India Malaysia. Formula kombinasi tulang mempunyai korelasi yang paling tinggi berbanding formula untuk salah satu tulang. Ralat juga dikenalpasti tinggi dalam semua formula disebabkan saiz sampel yang terlalu kecil. Sambungan bagi kajian ini sangatlah penting bagi menyediakan Malaysia dengan formula yang lebih tepat.

Kata kunci: Ketinggian, Radiografi, Femur, Tibia, Fibula, Tulang, Anggota Bawah Badan, Sains Forensik

INTRODUCTION

Forensic anthropology is a field that analyse human skeletal remains of unexplained death. Sometimes, skeletal remains can be the only source of information that can be used to identify the victims in forensic cases. The most important data that can be deduced from the analysis are age, ancestry, sex and stature of the victims. This study was conducted to estimate the stature using radiographic measurements of femur, tibia and fibula.

Stature can be measured from five skeletal structures which are the skull, vertebra, pelvic, lower extremity and ankle bones (Byers 2008). Basically, stature reconstruction was based on the measurement of bones from individual with known living height. This information was used to create a formula to correlate the measurement of bone length with the unknown height. Approximation of stature can be done by anatomical or mathematical method (Dayal et al. 2008). The anatomical method was introduced by Dwight (1894). It is a method which used the total height of the skeleton to determine the living height of the skeleton. In the mathematical method, the length of one or more long bones, height tables and regression formulae were used to determine the skeletal or living height.

The measurements of bones can be conducted either by direct or indirect method. This study involved the measurements of bones indirectly by scanning the bones using radiographic techniques. The x-ray image is measured to determine the length of the actual bone. This technique was used in earlier study by Breitinger in 1937 and was also used by Munoz et al. (2001). Hasegawa et al. (2009) also used the same method to create formulae to estimate the stature in modern Japanese population.

Stature estimation can be performed by using either all of the bones that composed stature, particular types of bones, or fraction of a particular type of bones. Estimation of stature by using all the bones which composed stature has been used by Fully (1956) for stature reconstruction. Total measurements of body segments' length which build the stature is used to estimate the stature. Correction factor was used to represent the soft tissues. One of the problems encountered in this method was that not every bone were present especially in forensic cases. Long bones of the arms and legs for stature approximation are the most common method employed (Byers 2008). Femur was used in a study conducted by Hauser et al. (2005). Radoinova et al. (2002) used femur, tibia and humerus while Trotter and Gleser (1952, 1958) used long bones such as humerus, radius, ulna, femur, tibia and fibula in their study. Other skeletal elements that were used were metacarpal, metatarsal and vertebral column (Byers 2008). A study to determine the relationship between bones fracture and total length of the bones was conducted by (Chibba & Bidmos 2007).

METHODOLOGY

SUBJECTS

Subjects in this study were 32 adult male Malaysian which consisted of fourteen Malays, eight Chinese and ten Indians. The age of the subjects ranged from 25 - 45 years old with no trauma or pathological condition especially to their lower limb bones.

HEIGHT MEASUREMENT

The subject has to fill a consent letter to enable the study to be conducted. Standing height of subject was recorded in centimetres (cm) using a stadiometer in an anatomical position (Saladin 2007). The subject had to breathe in and hold it until the sliding horizontal rod touched subject's head. The height was recorded after the subject stepped away from the stadiometer.

RADIOGRAPHY METHOD

In radiography method, the x-ray was measured in kilovolt peak (kvp) and miliampere per second (mAs). The usual x-ray film and tube which was located from the ceiling on a track which allowed the tube to move in any direction was used in this study. Some pre-examination procedures need to be conducted before the subject lie on a panel with both legs in a straight position. A 35 X 43 cm cassette was placed under the leg where the involved bone is located and make sure that the leg was in antero-posterior position. The leg was then scanned and the image produced copied on the x-ray film before it could be measured.

MEASUREMENTS OF BONE IMAGES

The measurements that need to be recorded were the maximum length of each bone. For femur, the maximum length was taken from the head of femur to the horizontal line which touches the distal ends of both condyles (Martin & Knussmann 1988). The maximum length of tibia was the distance from the articular surface of lateral condyle until the tip of medial malleolus. The maximum length for fibula was a distance from the apex of the head of fibula to the furthest point of the lateral malleolus. All of the measurements of the bones were recorded in centimetre (cm). The statistic analyses were conducted by using Statistical Package for Social Sciences (SPSS) version 19.0 for Windows. Statistical analyses conducted were Shapiro-Wilk, Pearson Correlation, Simple Linear Regression and Multiple Linear Regression.

FORMULAE DERIVATION

The formulae were derived from Simple Linear Regression Analysis using standard equation below (all values in cm):

Stature = constant + (coefficient * length of bone) ± standard error

The formulae were derived from Multiple Linear Regression Analysis using standard equation below (all values in cm):

Stature = constant + [(coefficient * length of femur) + (coefficient * length of tibia) + (coefficient * length of fibula)] ± standard error

RESULTS

The thirty two subjects were involved in this study were fourteen Malays, eight Chinese and ten Indians. Based on Shapiro-Wilk, which is a normality test, the data obtained were normally distributed.

Three scatter-plot graphs of stature versus length of femur, tibia and fibula were plotted (Figure 1, 2 and 3) and linear pattern of relationship were observed. Pearson correlation analysis showed significant relationship between stature and length of femur, tibia and fibula. Correlation coefficient value (R) were 0.830 (femur), 0.796 (tibia) and 0.765 (fibula) respectively. R-squared values (R^2) are 0.689 for femur, 0.633 for tibia and 0.586 for fibula. The value of F-ratio for femur, tibia and fibula were 66.466, 51.746 and 42.460. The constant values (β_0) were 17.009 (femur), 60.202 (tibia) and 73.457 (fibula). Coefficient values (β_1) for each of the bones were 3.161 (femur), 2.668 (tibia) and 2.461 (fibula). Standard error values (ε_0) for femur was ±18.73, while tibia was ±15.23 and fibula was ±14.78. All of these values were tabulated in Table 1.

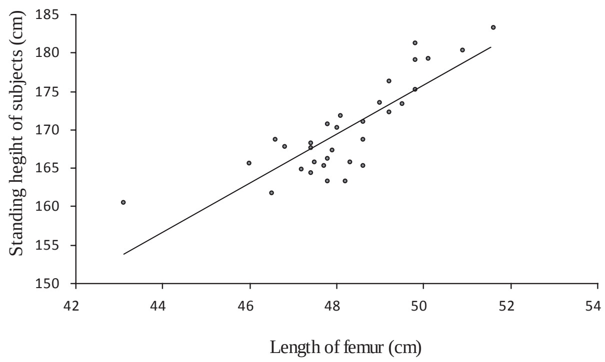

FIGURE 1. Graph of standing height of subjects versus length of femur

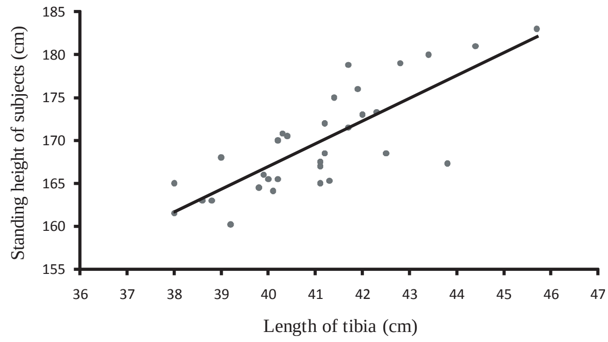

FIGURE 2. Graph of standing height of subjects versus length of tibia

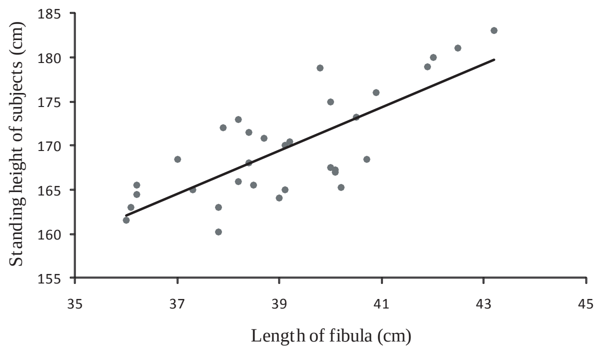

FIGURE 3. Graph of standing height of subjects versus length of fibula

TABLE 1. Constant (β_0), coefficient (β_1), standard error (ε_0), correlation coefficient (R), R-squared (R^2), and F-ratio values of simple linear regression

Bones	β_0	β_1	ε_0	R	R^2	F-ratio
Femur	17.009	3.161	18.734	0.830	0.689	66.466
Tibia	60.202	2.668	15.231	0.796	0.633	51.746
Fibula	73.457	2.461	14.781	0.765	0.586	42.460

The results for Pearson correlation analysis based on different were tabulated in Table 3. For Malays, there were significant relationship between stature and all of the bones. Correlation coefficient values for each of them were 0.885 (femur), 0.891 (tibia), and 0.835 (fibula). The association between stature and all of the bones were also significant in Indians and correlation coefficient values for each bones were 0.929 (femur), 0.766 (tibia) and 0.773 (fibula). No significant correlation between stature with tibia and fibula was observed in Chinese.

Multiple linear regression analysis was conducted to observe the relationship between stature with femur, tibia and fibula. Based on the analysis, the correlation coefficient (R) value was 0.938, R-squared value (R^2) was 0.881 and F-ratio value was 68.819. The constant value (β_0) was -3.003, coefficient values (β_1) were 2.136 (femur), 0.663 (tibia) and 1.081 (fibula) while standard error value (ε_0) was ±12.38. All the values obtained in this analysis were tabulated in Table

2. Multiple regressions were also used to analyse relationship between stature and all of the bones in different races. Only two races involved which were Malays and Indians. This was due to no significant relationship between stature with tibia and fibula in Chinese, so there was no need for multiple regression analysis. Based on the analysis, correlation coefficient (R) values for Malays was 0.960 and 0.984 for Indians. R-squared (R^2) values were 0.921 for Malays and 0.967 for Indians while the F-ratio for Malays was 39.044 and for Indians was 59.408. The constant value (β_0) for each Malays and Indians were -25.459 and 24.702 and standard error value (ε_0) for Malay and Indian were ± 23.53 and ± 11.36. Coefficient values (β_1) for Malays were 2.596 (femur), 0.846 (tibia) and 0.881 (fibula) while for Indians were 2.360 (femur), -0.724 (tibia) and 1.577 (fibula). All of these values were tabulated in Table 3.

TABLE 2. Constant (β_0), coefficient (β_1), standard error (ε_0), correlation coefficient (R), R-squared (R^2), and F-ratio values of multiple linear regressions

Bones	β_0	β_1	ε_0	R	R^2	F-ratio
Femur		2.136				
Tibia	–3.003	0.663	±12.382	0.938	0.881	68.819
Fibula		1.081				

TABLE 3. Constant (β_0), coefficient (β_1), standard error (ε_0), correlation coefficient (R), R-squared (R^2), and F-ratio values of multiple linear regressions based on different races

Race	Bones	β_0	β_1	ε_0	R	R^2	F-ratio
Malay	Femur		2.596		0.885		
	Tibia	–25.459	0.846	±23.529	0.891	0.921	39.044
	Fibula		0.881		0.835		
Chinese	Femur				0.810		
	Tibia	–	–	–	0.695	–	–
	Fibula		–		0.590		
Indian	Femur		2.360		0.929		
	Tibia	24.702	–0.724	±11.355	0.766	0.967	59.408
	Fibula		1.577		0.773		

When multiple linear regression analysis was conducted, there was a possibility of multicolinearity to occur. No multicolinearity was observed. This was determined by tolerance values obtained which were 0.684 (femur), 0.260 (tibia) and 0.296 (fibula) and variance inflation values which were 1.463 (femur), 3.850 (tibia) and 3.374 (fibula). There was also no multicolinearity in multiple linear regressions which was conducted to determine the relationship between stature and length of bones based on different races. This was based on tolerance values obtained for Malays which were 0.433 (femur), 0.188 (tibia) and 0.259 (fibula) while the variance inflation factor value were 2.309 (femur), 5.328 (tibia) and 3.866 (fibula). For Indians, tolerance values were 0.490 (femur), 0.239 (tibia) and 0.334 (fibula) while the variance inflation factor were 2.042 (femur), 4.188 (tibia) and 2.995 (fibula).

Six regression equations for estimation of stature of adult male population in Malaysia were developed. All of the measurements are in centimetre (cm). The equations are as follow:

1. Regression equation for stature estimation based on measurements of femur length:

   Stature = 17.009 + (3.161 * length of femur) ± 18.73

2. Regression equation for stature estimation based on measurements of tibia length:

   Stature = 60.202 + (2.668 * length of tibia) ± 15.23

3. Regression equation for stature estimation based on measurements of fibula length:

   Stature = 73.457 + (2.461 * length of fibula) ± 14.78

4. Regression equation for stature estimation based on measurements of femur, tibia and fibula length:

   Stature = -3.003 + [(2.136 * length of femur) + (0.663 * length of tibia) + (1.081* length of fibula)] ± 12.38

5. Regression equation for stature estimation based on measurements of femur, tibia and fibula length in Malays:

   Stature = -25.459 + [(2.596 * length of femur) + (0.846 * length of tibia) + (0.881 * length of fibula)] ± 23.53

6. Regression equation for stature estimation based on measurements of femur, tibia and fibula length in Indians:

   Stature = 24.702 + [(2. 360 * length of femur) + (-0.724 * length of tibia) + (1.577 * length of fibula)] ± 11.36

DISCUSSION

In this study, long bones of lower limb were chosen because of highly correlated to stature compared to long bones of upper limb (Choi et al. 1997). Adult males were chosen due to high relationship between stature and lower limb long bones in male compared to woman (Petrovecki et al. 2007). Besides, it was difficult to recruit female subject in this study.

Pearson correlation showed a positive relationship between stature and all of the bones involved. High correlation coefficient values show correlation value in real population. There was also significant relationship between stature and all of the bones involved in this study. In a study to estimate stature in modern Japanese population, the correlation coefficient values obtained by Hasegawa et al. (2009) for femur and tibia are 0.9032 and 0.885

respectively. Correlation coefficient values obtained by Hauser et al. (2005) based on measurement of femur was 0.923 while in another study conducted by Dayal et al. (2008), correlation coefficient obtained for femur, tibia and fibula were 0.92, 0.88 and 0.87 respectively. Therefore, femur had the highest correlation with stature followed by tibia and fibula. According to Hauser et al. (2005), this was due to closed relationship between length of femur and adult stature. Tibia was also best used to predict stature after femur. Based on Hasegawa et al. (2009), femur and tibia were highly associated to stature. Besides, lower limb bones are also a good predictor for stature if the sex of the bones contributor is known (Petrovecki et al. 2007). Fibula was the last predictor used if there was no femur or tibia found but it was still a good bone that could be used to estimates stature compared to humerus, radius or ulna (Dayal et al. 2008).

Correlation between stature and lower limb long bones varies in different populations, races or ethnics due to different proportion in different parts of the body in different groups (Byers 2008). In this study, bones of Malays showed the highest correlation to stature followed by Indian and Chinese. In Malays and Indians, all bones were significantly correlated to stature, but in Chinese only femur showed significant correlation to stature. This may be due to small sample size obtained for Chinese subjects.

Based on linear regression analysis, R-squared (R^2) values for femur, tibia and fibula were relatively high. Femur had the highest value of R-squared (R^2) followed by tibia and fibula. The effect of length of femur, tibia and fibula on stature was also based on these values but presented in percentages which were 68.9% (femur), 63.3% (tibia) and 58.6% (fibula). This pattern were similar with results by Dayal et al. (2008), Agnihotri et al. (2009) and Sheta et al. (2009). High correlation value is due to direct contribution of lower limb bones in stature (Sheta et al. 2009).

High value of standard error was obtained in this study. In a study of correlation between post-mortem stature and dried limb bones length of Korean adult males, Choi et al. (1997) also obtained high value of standard error. Besides, Nath and Nath (2007) reported the same pattern of results. Both these studies used small sample size. However, the standard error in this study was much higher. This may be due to different method used to measure the length of lower limb bones. According to Hauser et al. (2005), direct measurements gave more accuracy compared to radiographic method. As direct measurement was not an option in Malaysia, so in order to obtain high accuracy in radiographic method, large sample size is granted.

Multiple linear regression was conducted to determine relationship between stature and all of bones in this study, R-squared (R^2) value obtained was 0.881 which means that the effect of all the bones on stature estimation was 88.1%. The R-squared (R^2) value in this analysis was the highest values compared to R-squared (R^2) in regression analysis of single bones. In a situation in where all of these bones were present in a crime scene, a regression equation which combined femur, tibia and fibula was the most accurate due to its relation with stature. According to Hasegawa et al. (2009), combination of measurements of femur and tibia will decreased the standard error. Similar result was obtained by Dayal et al. (2008) because according to Byers (2008), equation which was produced by multiple regression could increase the accuracy.

In multiple linear regressions, R-squared values (R^2) for Malay and Indian were 0.921 and 0.967 respectively. The effects of bones length on stature was higher in Indians (96.7%) compared with Malays (92.1%). The standard error for Malays regression equation was also much higher than in Indians. This may also due to small sample size used in this study which was also a limitation (Petrovecki et al. 2007).

Basically, regression equation for stature estimation was divided according to different races due to different body proportion in different races (Dayal et al. 2008). Shields (2005) stated that variation in population is not only due to environmental factor but genetic factor as well. This was supported by Dayal et al. (2008) who stated that different proportion of body occurred due to differences in genetic, isolation factor and bio-cultural history. Hasegawa et al. (2009) suggested that the data obtained in a particular ethnic group cannot be applied into other ethnic group because of long bone proportion to stature varies and depending on the specific populations. Thus, it is important for the different races in Malaysia such as Malays, Chinese and Indians to have their own regression equation for stature estimation based on length of lower limb bones.

CONCLUSION

In conclusion, six regression equations derived can be used to estimate stature of adult male population in Malaysia based on length of femur, tibia and fibula. These equations formulae limited to adult male Malays, Chinese and Indians in Malaysia. It is hoped that the equation formulae would help the identification of human remains in Malaysia.

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