Stature Estimation of Modern Thais from Long Bones: A Cadaveric Study

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ABSTRACT

Objective: The lengths of long bones of adult skeletons are commonly used to estimate stature. The regression equations for calculating stature were established from the relationship between the height and the length of long bones.

Methods: We measured 275 adults, ranging in age from 25 to 97 years. The length of six long bones; humerus, radius, ulna, femur, tibia and fibula were measured out. For both femur and tibia, they were measured in 2 different methods; maximum length and anatomical length. Microsoft Excel 2003 and Minitab 14, a statistical computer software ($\alpha = 0.05$) were used to calculate and establish the regression equations for stature estimation of three groups of the differently sexual identification; male, female and unknown sex.

Results: The length of two long bones, especially femur (max) + tibia (max) provides the most accuracy of stature estimation in all three groups. For the one long bone length, femur is the most accurate in every group.

Conclusion: The overall of the results show that the upper extremities present the accuracy of stature estimation more than the lower extremities (except femur) in the male group. On the other hand, femur, tibia and fibula of the female group provide more accurate stature estimation than the upper extremities.

Keywords: Stature, long bone, modern Thai, regression equation, male, female, unknown sex

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INTRODUCTION

Stature estimation is one of the basic analysis of human bone. It generally is applied to provide the demographic data which much relate to the health of the ancient people in the archaeological issue, and also can be useful for personal identification in case of the forensic anthropological study. Because of the difference of the proportion between Thai and western people, it is very important to develop the formulae from the modern Thai. There were some previous researches[1,2,3,4] established the equations from the measurements of long bones length of Thais. Some researchers had an effort to develop the equations from the humeral[5] and femoral fragments[5,6] of Thai people. It could be claimed that the formulae which this research carried out are developed from the largest amount of number of the sample. It also provides the equations for estimating stature in different sexual identification; male, female and unknown sex.

MATERIALS AND METHODS

275 Thai adults in the age group of 25 to 97 years were studied in this research. They comprise of 142 males and 133 females. The number of the long bones which were collected is shown in Table 1. All the samples were the bodies which were donated by the authority of their own to the Department of Anatomy, medical school of Siriraj Hospital, Mahidol University on the year of 2005-2008.

The body height of the cadavers was collected by measuring from the vertex to the plantar of the foot approximately to the joint between talus and calcaneus. After cleaning up the surface of the long bones, especially the area of the joints, the measurements were taken following the methods in Standards for Data Collection from Human Skeletal Remains[7] by using the "Paleo-Tech" field osteometric board and spreading caliper.

TABLE 1. The number of the long bones which were collected in the research

	Male			Female		
	Left	Right	Total	Left	Right	Total
Humerus	62	55	117	55	67	122
Radius	120	119	239	124	119	243
Ulna	121	119	240	125	120	245
Femur	114	114	228	101	104	205
Tibia	120	120	240	116	116	232
Fibula	120	119	239	115	115	230

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TABLE 2. Descriptive Statistics from the body height and long bone length of the mix group (male+female)

Bones	Measurements (cm)	N	Mean	SD	SE	Range
Humerus	Body Height	239	158.110	8.470	0.548	133.00 - 180.00
	Humerus	239	29.697	1.999	0.129	20.90 - 36.80
Radius	Body Height	482	158.150	8.540	0.389	133.00 - 180.00
	Radius	482	23.290	1.665	0.076	18.50 - 29.20
Ulna	Body Height	485	158.090	8.530	0.387	133.00 - 180.00
	Ulna	485	25.036	1.634	0.074	20.70 - 30.60
Femur	Body Height	433	158.360	8.240	0.396	133.00 - 180.00
	Femur (max)	433	41.890	2.550	0.123	32.50 - 50.10
Femur	Body Height	432	158.340	8.250	0.397	133.00 - 180.00
	Femur (ana)	432	41.598	2.560	0.123	32.00 - 50.00
Tibia	Body Height	472	158.100	8.140	0.375	133.00 - 180.00
	Tibia (max)	472	35.002	2.252	0.104	27.80 - 42.60
Tibia	Body Height	471	158.120	8.130	0.375	133.00 - 180.00
	Tibia (ana)	471	33.435	2.134	0.098	26.40 - 41.10
Fibula	Body Height	469	158.260	8.200	0.378	133.00 - 180.00
	Fibula	469	34.572	2.245	0.104	27.50 - 45.70
Humerus + Radius	Body Height	232	158.180	8.430	0.554	133.00 - 180.00
	Humerus + Radius	232	53.056	3.486	0.229	42.40 - 66.00
Femur + Tibia	Body Height	421	158.340	8.180	0.398	133.00 - 180.00
	Femur (max) + Tibia (max)	421	76.938	4.545	0.222	62.10 - 92.60
Femur + Tibia	Body Height	420	158.330	8.180	0.399	133.00 - 180.00
	Femur (ana) + Tibia (ana)	420	75.085	4.408	0.215	60.40 - 90.80

(max) = maximum length (ana) = anatomical length

After the measurements of six long bones, the data were subjected to statistical analysis for studying the relationship between the height of the body and the length of long bone. These include Mean, Range, Standard Deviation, Standard Error, Pearson's 'r'-Value and Linear Regression Equation by using Microsoft Excel 2003 and Minitab 14 statistical computer software ($\alpha = 0.05$).

RESULTS

Descriptive statistics from the body height and long bone length of the mix group (both male and female) are shown in Table 2. From the Table 3, the results indicate that the equations which using two long bone lengths are more accurate than the others that using only one long bone length. Femur (max) + tibia (max) shows the highest result of Coefficient of Determination (R^2 = 85.3%) and the lowest result of Standard Error (SE = ± 3.14333). That means this equation is the most accurate for stature estimation of the human skeleton which is unknown sex. Respectively, femur (ana) + tibia (ana) and humerus + radius are less accurate for estimating stature. For the one long bone length, femur length is the most accurate, and humerus is the least accurate for stature estimation of the unknown sex skeleton.

Descriptive statistics from the body height and long bone length of male and female are shown in Table 4 and Table 6 respectively. From the Table 5 and Table 7, the results indicate that the equations using the length of two long bones in both male and female groups are more accurate than the equations that using only one long bone length. Especially the femur (max) + tibia (max) shows the highest result of Coefficient of Determination (male R^2 = 80.1%, female R^2 = 72.1%) and the lowest result of Standard Error (male SE = ± 2.83059, female SE = ± 3.00056). That means this equation is the most accurate for estimating stature of the human skeleton which identifies sex into male and female. Respectively, femur (ana) + tibia (ana) is less accurate for estimating stature. For the one long bone length in male, femur (both max and ana) is the most accurate. Tibia (ana) and fibula are the least accurate for stature estimation of the male skeleton.

TABLE 3. Regression Equation of the stature estimation of long bones (unknown sex)

Bones	Equation (cm)	SE	R^2
Humerus	Stature = 3.5782(Hu) + 51.847	4.53902	0.714
Radius	Stature = 4.5227(Ra) + 52.816	4.03047	0.778
Ulna	Stature = 4.5079(Ul) + 45.225	4.29704	0.747
Femur (max)	Stature = 2.8683(Fe) + 38.205	3.80761	0.787
Femur (ana)	Stature = 2.8339(Fe) + 40.460	3.93009	0.774
Tibia (max)	Stature = 3.1368(Ti) + 48.305	4.04334	0.754
Tibia (ana)	Stature = 3.2382(Ti) + 49.849	4.29223	0.722
Fibula	Stature = 3.1053(Fi) + 50.906	4.31292	0.724
Humerus + Radius	Stature = 2.1480(Hu+Ra) + 44.221	3.88901	0.788
Femur (max) + Tibia (max)	Stature = 1.6607(Fe+Ti) + 30.572	3.14333	0.853
Femur (ana) + Tibia (ana)	Stature = 1.7043(Fe+Ti) + 30.364	3.23626	0.844

(max) = maximum length (ana) = anatomical length

TABLE 4. Descriptive Statistics from the body height and long bone length of male

Bones	Measurements (cm)	N	Mean (X)	SD	SE	Range
Humerus	Body Height	117	164.130	6.300	0.583	164.00 - 180.00
	Humerus	117	30.911	1.720	0.159	25.50 - 31.00
Radius	Body Height	239	164.200	6.270	0.405	146.50 - 180.00
	Radius	239	24.439	1.259	0.081	21.40 - 29.20
Ulna	Body Height	240	164.160	6.240	0.403	146.50 - 180.00
	Ulna	240	26.137	1.245	0.080	22.50 - 30.60
Femur	Body Height	228	163.700	6.320	0.419	146.50 - 180.00
	Femur (max)	228	43.310	2.210	0.146	32.50 - 43.25
Femur	Body Height	227	163.690	6.340	0.421	146.50 - 180.00
	Femur (ana)	227	42.993	2.248	0.149	32.00 - 50.00
Tibia	Body Height	240	163.600	6.220	0.402	146.50 - 180.00
	Tibia (max)	240	36.284	1.855	0.122	32.30 - 42.60
Tibia	Body Height	240	163.600	6.220	0.402	146.50 - 180.00
	Tibia (ana)	240	34.648	1.837	0.119	31.10 - 41.10
Fibula	Body Height	239	163.900	6.060	0.392	147.00 - 180.00
	Fibula	239	35.834	1.928	0.125	31.90 - 45.70
Humerus + Radius	Body Height	115	164.030	6.310	0.588	146.50 - 180.00
	Humerus + Radius	115	55.312	2.905	0.271	47.10 - 66.00
Femur + Tibia	Body Height	222	163.580	6.320	0.424	146.50 - 180.00
	Femur (max) + Tibia (max)	222	79.561	3.713	0.249	69.30 - 92.60
Femur + Tibia	Body Height	221	163.570	6.340	0.426	146.50 - 180.00
	Femur (ana) + Tibia (ana)	221	77.601	3.581	0.241	69.10 - 90.80

(max) = maximum length (ana) = anatomical length

TABLE 5. Regression Equation of the stature estimation of long bones (male)

Bones	Equation (cm)	SE	R^2
Humerus	Stature = 2.8754(Hu) + 75.250	3.92109	0.616
Radius	Stature = 3.9038(Ra) + 68.796	3.89320	0.616
Ulna	Stature = 3.8089(Ul) + 64.605	4.06856	0.577
Femur (max)	Stature = 2.3866(Fe) + 60.334	3.49894	0.695
Femur (ana)	Stature = 2.3130(Fe) + 64.252	3.63158	0.673
Tibia (max)	Stature = 2.5686(Ti) + 70.402	3.92100	0.605
Tibia (ana)	Stature = 2.4612(Ti) + 78.322	4.28737	0.528
Fibula	Stature = 2.2844(Fi) + 82.073	4.16902	0.528
Humerus + Radius	Stature = 1.7817(Hu+Ra) + 65.486	3.62049	0.673
Femur (max) + Tibia (max)	Stature = 1.5235(Fe+Ti) + 42.369	2.83059	0.801
Femur (ana) + Tibia (ana)	Stature = 1.5734Fe+Ti) + 41.478	2.90794	0.790

(max) = maximum length (ana) = anatomical length

For the one long bone length in female, fibula and tibia (max) is the most accurate, respectively. Humerus is the least accurate for stature estimation of the female skeleton.

DISCUSSION AND CONCLUSION

From the study of the relationship between the body height of modern Thai people and their long bone length, the result represented the statistically significant level ($\alpha = 0.05$). The regression equation analysis were divided into three groups of stature estimation; male, female and unknown sex.

The length of two long bones (femur and tibia, humerus and radius) provided the most accurate results in all three groups. For the one long bone length, the lower extremities are more accurate than the upper extremities, especially femur.

In the overall of long bone lengths (except femur) of the male group indicated that the upper extremities; such as humerus and radius, provide more accurate stature estimation than the lower extremities (tibia and fibula). On the opposite side, femur, tibia and fibula of the female group provide more accurate stature estimation than the upper extremities.

In addition, the study of accuracy of the equations for the unknown sex group are more accurate when compare to those for the known sex group (male and female). However, the standard errors of the equations for the known sex group (male and female) are more likely less than those of the equations for the unknown sex group. This result shows the direct variation to the numbers of the sample.

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TABLE 6. Descriptive Statistics from the body height and long bone length of female

Bones	Measurements (cm)	N	Mean (X)	SD	SE	Range
Humerus	Body Height	122	152.340	5.860	0.530	133.00 - 166.50
	Humerus	122	28.534	1.496	0.135	20.90 - 29.50
Radius	Body Height	243	152.200	5.890	0.378	133.00 - 166.50
	Radius	243	22.160	1.169	0.075	18.50 - 24.60
Ulna	Body Height	245	152.140	5.850	0.374	133.00 - 166.50
	Ulna	245	23.958	1.192	0.076	20.70 - 26.75
Femur	Body Height	205	152.420	5.670	0.396	133.00 - 165.50
	Femur (max)	205	40.312	1.893	0.132	34.30 - 43.70
Femur	Body Height	205	152.420	5.670	0.396	133.00 - 165.50
	Femur (ana)	205	40.052	1.917	0.134	34.00 - 44.70
Tibia	Body Height	232	152.410	5.560	0.365	133.00 - 165.50
	Tibia (max)	232	33.675	1.786	0.117	27.80 - 40.70
Tibia	Body Height	231	152.420	5.570	0.366	133.00 - 165.50
	Tibia (ana)	231	32.175	1.633	0.107	26.40 - 35.80
Fibula	Body Height	230	152.370	5.540	0.365	133.00 - 166.50
	Fibula	230	33.261	1.748	0.115	27.50 - 39.90
Humerus + Radius	Body Height	117	152.430	5.940	0.549	133.00 - 166.50
	Humerus + Radius	117	50.839	2.431	0.225	42.40 - 55.55
Femur + Tibia	Body Height	199	152.510	5.670	0.402	133.00 - 165.50
	Femur (max) + Tibia (max)	199	74.012	3.480	0.247	62.10 - 80.80
Femur + Tibia	Body Height	199	152.510	5.670	0.402	133.00 - 165.50
	Femur (ana) + Tibia (ana)	199	72.291	3.460	0.245	60.40 - 78.90

(max) = maximum length (ana) = anatomical length

TABLE 7. Regression Equation of the stature estimation of long bones (female)

Bones	Equation (cm)	SE	R^2
Humerus	Stature = 2.7436(Hu) + 74.051	4.19312	0.491
Radius	Stature = 3.8215(Ra) + 67.514	3.83902	0.576
Ulna	Stature = 3.5796(Ul) + 66.377	4.01318	0.532
Femur (max)	Stature = 2.4121(Fe) + 55.186	3.36370	0.649
Femur (ana)	Stature = 2.3858(Fe) + 56.683	3.35386	0.651
Tibia (max)	Stature = 2.5335(Ti) + 67.089	3.23794	0.662
Tibia (ana)	Stature = 2.7574(Ti) + 63.706	3.27585	0.655
Fibula	Stature = 2.6019(Fi) + 65.829	3.17354	0.673
Humerus + Radius	Stature = 1.9068(Hu+Ra) + 55.430	3.72712	0.610
Femur (max) + Tibia (max)	Stature = 1.3839(Fe+Ti) + 50.080	3.00056	0.721
Femur (ana) + Tibia (ana)	Stature = 1.3864Fe+Ti) + 52.277	3.03243	0.716

(max) = maximum length (ana) = anatomical length

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