The Relationship between Bone and Ash Weight to Body Weight and Body Length of Thai Corpses in Bangkok and Central Part of Thailand after Cremation

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Background: *Although information about bone and ash weight compare to body weight and body length of Thai people exists, it was based on a few samples.*
Objective: *Collect data of the bone and ash weight after cremation and find out the relationship between bone and ash weight, body weight, body length, and age.*
Material and Method: *Two hundred and twenty three corpses, 97 females and 126 males were collected from four temples, three temples from Bangkok and one temple from Angtong province. The crematoria used in the present study created a temperature between 850°C and 1,200°C. Each cremation took about 1-1.5 hours.*
Results: *The average with SD of bone and ash weight of males was 2.44 kg ± 0.9 Kg, while the weight of females was 2.07 ± 0.89 Kg, and the average of bone and ash weight of total subjects was 2.28 ± 0.95. There was negative correlation between age and bone & ash weight, while there was positive correlation between body length and body weight, body length and bone & ash weight, and body weight and bone & ash weight. The results of the present study indicated that age and body weight affected the bone and ash weight. The fitted linear equation was Log (bone & ash weight +1) = 0.413 – 0.001 (age) + 0.003 (body weight).*
Conclusion: *Age and body weight affect bone and ash weight. Moreover, the age, body weight, and body length could be estimated by using the bone and ash weight.*

Kewords: *Cremation, Bone and ash weight, Body weight, Body length*

J Med Assoc Thai 2007; 90 (9): 1872-8
Full text. e-Journal: *http://www.medassocthai.org/journal*

Bone is living and growing tissue. It forms a protective and supportive framework, the skeleton. Adult human skeletons consist of 206 bones and all are held in place by connective tissue such as tendons and ligaments. The skeleton acts as the cores of various structures of the body and protects important internal organs. Moreover, bones are used for estimating sex, race, and stature of an unknown dead person[1-8]. Burnt corpses that have become ash, may not be used for estimation of sex or stature. The remains are unreliable to find out genetic profile and they are not suitable for forensic purposes *e.g.* identification, paternity testing[9,10]. Therefore, bone and ash weight may be the only available evidence in finding missing persons. In the past, the data of bone and ash weight from the United States were used[11-13]. In addition, the data of bone and ash weight was also used to estimate the body weight and body length. However, this information about Thai corpses is very rare[14]. Moreover, this information was collected only from Angthong province.

The modern cremation is done in a closed environment as the dead body is placed in a small closed chamber (crematory) where intense heat (range between 850°C and 1,200°C)[15,16] from the burner passes through the corpse and yields white powdery ash. This reduces air pollution for people around the temple.

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If studied, the collected material could be beneficial for forensic science in the future, especially for law enforcement and medico-legal investigations of victims who have been deliberately burned to cover up a crime, specially, when there is more than one body in the same coffin during cremation. The present study aimed to find out the relationship between bone and ash weight to body weight and body length of Thai corpses in Bangkok and the central part of Thailand.

Material and Method

Two hundred and twenty three corpses from three temples in Bangkok and one temple in Angtong province were collected. The gender ratio of male and female was 1.3:1 (126 male and 97 female). The ages were between 9 and 107 years.

The standard coffin of 51 cm wide, 186 cm long and 43 cm height is usually made from particle board. In cremation, the coffin is usually burnt with the corpse. Therefore, it is vital to find the ash weight of the coffin after cremation. The approximate ash weight of an empty coffin is 0.3 kg.

The crematories (unpolluted) from four temples are made of concrete. They use diesel or gas for fuel. About 40 liters of diesel oil or 48 kg of gas is used for each cremation. The temperature is between 850□C and 1,200□C and take about 1-1.5 hours.

The name, gender, age, body length, and body weight of each corpse are recorded before cremation. Bone and ash weight is collected after the cremation.

Statistical analysis

Mean and standard deviation (SD) standard error of mean (SE) were applied for age, body length, body weight, and bone and ash weight. Pearson correlation analysis was used to find correlation coefficient r among variables. Linear regression analysis was used to find the fitted equation among the variables. A p-value of less than 0.05 was considered statistically significant.

Results

The information of an individual corpse consists of age, body weight, body length, and bone and ash weight. The mean, standard deviation and 95% confidence interval of four variables are shown in Table 1.

From Table 1, the average values of body weight, body length, and bone and ash weight of the males are higher than females except age. The average bone and ash weight of total subjects (males and females) after cremation is 2.28 kg. The correlation coefficients and p-value among the four variables are shown in Table 2.

From Table 2, there are significant relationships among four variables at p-value < 0.05. While the relationships between age and body length, and between age and body weight are not significant. There is negative correlation between age and bone & ash weight, while there is positive correlation between body length and body weight, body length, and bone & ash weight, and body weight and bone & ash weight. Finding linear equation among these variables is possible. Let bone & ash weight be a dependent variable while age, body length, and body weight are independent variables. The result of the statistical analysis from regression is shown in Table 3.

From Table 3, at the level of significance □= 0.01, the authors found that bone & ash weight depends on age and body weight. Then the authors can

Table 1. Mean, SD, and 95% confidence interval of personal variables

Variables		$\overline{X} \pm$ SD	95% CI
Male (n =126)	Age	59.57 ± 17.79	56.44-62.71
	Body length (cm)	164.41 ± 6.52	163.26-165.56
	Body weight (kg)	61.69 ± 9.04	60.09-63.28
	Bone & ash weight (kg)	2.44 ± 0.89	2.29-2.60
Female (n = 97)	Age	69.16 ± 18.02	65.53-72.80
	Body length (cm)	157.15 ± 5.66	156.01-158.30
	Body weight (kg)	52.55 ± 9.43	50.64-54.45
	Bone & ash weight (kg)	2.07 ± 0.99	1.87-2.27
Total (n = 223)	Age	63.74 ± 18.47	61.31-66.18
	Body length (cm)	161.25 ± 7.13	160.31-162.19
	Body weight (kg)	57.71 ± 10.25	56.36-59.06
	Bone & ash weight (kg)	2.28 ± 0.95	2.15-2.41

find three fitted linear equations for the total number of subjects. The fitted linear equation for the total number of subjects is written as:

Log (bone & ash weight +1) = 0.413 – 0.001 (age) + 0.003 (body weight)

There is positive correlation between bone & ash weight and body weight while there is a negative correlation between bone & ash weight and age.

In a real situation, the authors do not know about age, body length, and body weight of the burnt corpse so the authors would like to convert bone and ash weight to these variables by using these following equations. First, if the authors would like to estimate age by using bone & ash weight as independent variable, the authors can use the statistical analysis results from Table 4.

From Table 4, at the level of significance □= 0.05, the authors find that age is a negative correlation to bone & ash weight. The fitted linear equation is given as:

Age = 70.905 – 3.141 (Bone & ash weight)

From this equation, the authors can interpret that if the bone & ash weight increase one kilogram, the age will decrease 3.141 years.

The second, if the authors would like to estimate body length the authors can use the equation from the result in Table 5.

From Table 5, at the level of significance □= 0.05, we find that body length is a positive correlation to bone & ash weight. The fitted linear equation is written as:

Body length = 158.935 + 1.017 (Bone & ash weight)

Table 2. The correlation coefficients and p-value among age, body length, body weight, and bone & ash weight of total subjects (n = 223)

Variables		r	p-value
Age	Body length	-0.017	0.797
	Body weight	-0.018	0.789
	Bone & ash weigh	-0.162*	0.015
Body length	Body weight	0.529**	0.000
	Bone & ash weight	0.136*	0.043
Body weight	Bone & ash weight	0.207**	0.002

* Significant at p-value < 0.05
** Significant at p-value < 0.01

Table 3. Estimate coefficients, SE, t-value, and p-value of age and body weight

Variables	Estimate	SE	t-value	p-value
Constant	0.413	0.053	7.747**	0.000
Age	-0.001	0.000	-2.917**	0.004
Body weight	0.003	0.001	3.695**	0.000

** Significant at p-value < 0.01

Table 4. Estimate coefficients, SE, t-value, and p-value of bone & ash weight (Age is dependent variable)

Variables	Estimate	SE	t-value	p-value
Constant	70.905	3.180	22.298**	0.000
Bone & ash weight	-3.141	1.288	-2.440*	0.015

* Significant at p-value < 0.05
** Significant at p-value < 0.01

Table 5. Estimate coefficients, SE, t-value, and p-value of bone & ash weight (Body length is dependent variable)

Variables	Estimate	SE	t-value	p-value
Constant	158.935	1.232	129.002**	0.000
Bone & ash weight	1.017	0.499	2.038*	0.043

* Significant at p-value < 0.05
** Significant at p-value < 0.01

Table 6. Estimate coefficients, SE, t-value, and p-value of bone & ash weight (Body weight is dependent variable)

Variables	Estimate	SE	t-value	p-value
Constant	52.625	1.750	30.072**	0.000
Bone & ash weight	2.231	0.709	3.148**	0.002

** Significant at p-value < 0.01

From this equation, the authors can interpret that if bone & ash weight increase one kilogram, the body length will increase 1.017 centimeters.

Lastly, if the authors would like to estimate body weight by using bone & ash weight as an independent variable, the authors can use the equation from the result in Table 6.

From Table 6, at the level of significance $\alpha = 0.05$, the authors find that body weight is positive correlation to bone & ash weight. The fitted linear equation is given as:

Body weight = 52.625 + 2.231 (Bone & ash weight)

From this equation, the authors can interpret that if bone & ash weight increase one kilogram, the body weight will increase 2.231 kilograms.

However, these equations can be used to predict only about the population that samples were drawn from and shall be used only within the interpopulation.

Discussion

The ideal cremation for the present study is the cremated corpses that become only ash or leaving small pieces of bones. Whereas in a real situation, there are bone remains varying from small to large pieces as reported by Bohnert[17]. There are many factors concerning the cremation process such as duration, temperature, and equipment of the cremation oven. The duration of cremation in the present study took about 1-1.5 hours at temperature between 850ºC and 1,200ºC (common procedure at temples). This strategy is sufficient for breaking the body apart but not efficient for burning the corpses to become only ash. Whereas, Prokop[18] suggest that burning the body at temperatures ranging from 850ºC to 1,200ºC about 45 to 120 minutes, depending on size and water contents, leave only ash weighing 1-3 kg while DiMaio[19] stated that it takes 1.5-2.5 hours to completely cremate a human body at temperatures around 1,000ºC. However, it should be noted that the present study is useful to apply in the areas of crime. It is hardly possible to destroy a body completely since even severely burned bone remains sometimes and offer diagnostic possibilities with regard to sex, age, individual marks, and previous injuries[1]. The burners of all crematories in the present study were positioned at the head end of the crematory chamber; therefore, the upper parts of the body were affected faster than the lower parts.

Usually the coffin is burnt with the corpse so the weight of the coffin will affect bone & ash weight. This means that, the types of the coffin materials and size of the coffin affect the coffin weight and bone & ash weight respectively. However, the standard coffin used in the present study was made of particleboard, as it is the major type most often used because of its lower cost. The ash weight of this standard coffin is approximately 0.3 kg after cremation.

The average bone & ash weight of males is 2.44 kg while this weight of females is 2.07, so this weight of males is higher than females about 0.37 kg. The present result corresponds to those of many authors but is different from that of Bass[15], which suggests that weights of cremated remains of males obtained from East Tennessee is approximately 1 kg higher than females. While Perper[13] found that, the average

cremation weight of males and female is 3.04 kg and 2.51 kg, respectively. Whereas, Chirachariyavej[14] found that, the weight of males was 2.68 kg while the weight of females was 2.12. The weight of males was therefore 0.56kg higher than females.

The average bone & ash weight of males from the present study is higher than females. This may be due to age, body length, and body weight as in this study the mean age of males was lower than females while the body length and the body weight of males were higher than females. Moreover, the co-efficient correlation between bone & ash weight and body weight is higher than age and body length. Therefore, the body weight is more affected by bone & ash weight than other variables in the present study. These effect of these three variables on the bone correspond to other authors' findings but are different from significant levels of variables from Nelson[20]. He stated that greater body size among U.S. black women may contribute to greater bone density, and fat component of body mass may be a more important factor in body composition. Zhang[21] suggested that males had significantly larger bone size than females and that height was the major predictor for bone size. About age, males lose less bone during aging so the bone mineral density at any age is higher in males than in females[22]. This may be caused by the sex hormones, as estrogen and testosterone play an important role in maintaining bone strength and they decline in old age.

The authors compared the equations in the present study and the only existent equation of Thai adults[14]. The present study found that the fitted equation of bone & ash weight from Bangkok and the central part of Thailand is written as: Log (bone ash weight +1) = 0.413 – 0.001 (Age) + 0.003 (Body weight); whereas the existent equation from Angtong province is bone & ash weight = 1.969 – 0.018 (Age) + 0.038 (Body weight). In addition, the equations that were calculated from bone & ash weight are not the same. These different equations may be due to the present study's having more samples: 113. However, both fitted equations have age and body weight as correlation to bone & ash weight. The age of the samples from both studies had a trend towards older age, so the negative correlation between the bone & ash weight and age is present. In addition, the equation from bone & ash weight of both studies are different. This may be because of the number of samples used. Furthermore, the present study also presents the equation between body length and bone & ash weight while the previous study did not. However, the bone & ash weight equation of males and females from the present study is not present while past studies had it. This may be due again to the number of samples used. Therefore, the analysis in the lower age group should be studied further and the sample size increased.

Conclusion

The findings could be summarized as follows:

The averages age, body length, and body weight of males are 59.57 $\pm$ 17.79 years, 164.41 $\pm$ 6.52 cm, and 61.69 $\pm$ 9.04 kg. While the averages age, body length, and body weight of females are 69.16 $\pm$ 18.02 years, 157.15 $\pm$ 5.66 cm, and 52.55 $\pm$ 9.43 kg. Therefore, the average age, body length, and body weight of total samples are 63.74 $\pm$ 18.47 years, 161.25 $\pm$ 7.13 cm, and 57.71 $\pm$ 10.25 kg.

The variables that affect the bone & ash weight are: body weight, age, and body length. When the body length was excluded from the fitted equation, it left three independent variables.

The fitted equations that were found in the present study at the level of significance was a = 0.5.

Bone & ash weight, Age, Body weight

Total: Log (boneash weight +1) = 0.413 -0.001 (Age) + 0.003 (Body weight)

Age, bone & ash weight

Total: Age= 70.905 – 3.141 (Boneash weight)

Body length, Bone & ash weight

Total: Body length = 158.935 + 1.017 (Boneash weight)

Body weight, Bone & ash weight

Total: Body weight = 52.625 + 2.231 (Boneash weight)

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ความสัมพันธ์ระหว่างน้ำหนักกระดูกและเถ้ากระดูกกับน้ำหนักตัวและส่วนสูงของศพคนไทยภายหลังการฌาปนกิจจากกรุงเทพมหานครและภาคกลางของประเทศไทย

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การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อเก็บข้อมูลและหาความสัมพันธ์เกี่ยวกับน้ำหนักกระดูกและเถ้ากระดูกหลังการฌาปนกิจ กับน้ำหนักตัวและส่วนสูงของศพคนไทยในกรุงเทพมหานครและภาคกลางของประเทศไทย ในการศึกษานี้ใช้ตัวอย่างศพทั้งหมด 223 ตัวอย่าง เป็นหญิง 97 ตัวอย่างและชาย 126 ตัวอย่างจากสามวัดในกรุงเทพมหานคร และอีกหนึ่งวัดในจังหวัดอ่างทอง เตาเผาศพที่ใช้ให้ความร้อนอยู่ในช่วง 850℃ ถึง 1,200℃ จากการศึกษาพบว่า ค่าเฉลี่ยของน้ำหนักกระดูกและเถ้ากระดูกของตัวอย่างศพชาย เท่ากับ 2.44 กิโลกรัม โดยมีส่วนเบี่ยงเบนมาตรฐานเท่ากับ 0.89 กิโลกรัม และค่าเฉลี่ยของน้ำหนักกระดูกและเถ้ากระดูกของตัวอย่างศพหญิง เท่ากับ 2.07 กิโลกรัม โดยมีส่วนเบี่ยงเบนมาตรฐานเท่ากับ 0.90 กิโลกรัม ในขณะที่ค่าเฉลี่ยของน้ำหนักกระดูกและเถ้ากระดูกของตัวอย่างศพทั้งหมด เท่ากับ 2.28 กิโลกรัมโดยมีส่วนเบี่ยงเบนมาตรฐานเท่ากับ 0.95 กิโลกรัม นอกจากนี้พบว่าอายุและน้ำหนักตัวนั้นเป็นตัวแปรที่มีผลต่อน้ำหนักของกระดูกและเถ้ากระดูก โดยสมการถดถอยประมาณที่ได้คือ Log (น้ำหนักกระดูกและเถ้ากระดูก +1) = 0.413 - 0.001 (อายุ) + 0.003 (น้ำหนักตัว) นอกจากนี้สามารถจะประมาณค่าอายุ น้ำหนักตัว ส่วนสูงจากน้ำหนักกระดูกและเถ้ากระดูกภายหลังการฌาปนกิจ เพื่อนำไปใช้กับสถานการณ์จริงได้