The Relationship between Bone and Ash Weight to Age, Body Weight and Body Length of Thai Adults after Cremation

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Background: *Cremation is the most common Thai funeral mode. In Thailand, there have not been any previous reports of bone and ash weight after cremation.*
Objective: *Collect the bone and ash weight after the cremation and find the variables that affected the bone and ash weight.*
Material and method: *One hundred and ten samples, including fifty-five males and fifty-five females, were collected from the Thai population. A Thai crematorium (Series Tiger 1) that could produce a temperature of approximately 850 C-1,200 C was employed. It took about 1-1.5 hours to complete the incineration.*
Results: *The average bone and ash weight of the males was 2.68 kg with SD 1.41; female was 2.12 with SD 1.25; and total was 2.40 with SD 1.36. The present study supported that age and body weight affected the bone and ash weight while the body length (height) did not. The fitted equation was* $\hat{y} = 1.969 - 0.01846$ *(age) +* 0.03087 *(body weight), where* $\hat{y}$ *= predicted bone and ash weight.*
Conclusion: *The present study shows that age and body weight affected the bone and ash weight. From this information, the authors could find the predicted value of either age or body weight. If the authors would like to find the age, the authors can employ the fittest equation* $\hat{y} = 76.097 - 3.219$ *(Bone and ash weight) where* $\hat{y}$ *= predicted age. Additionally, if the authors would like to find the body weight, we can employ the fittest equation = 51.930 + 1.673 (Bone and ash weight) where* $\hat{y}$ *= predicted body weight.*

Keywords: *Cremation, Incineartion, Bone, Ash weight*

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Cremation is the practice of disposing of a corpse by burning. It is a mode of funeral practice worldwide, but especially in Thailand. The modern cremation often takes place in a crematorium or crematory whereas the traditional cremation is regularly done in the open environment and consumes a lot of wood fuel. For the traditional cremation, the process takes several hours; the actual time is difficult to predict due to the many factors such as humidity, weather, and other possible environmental conditions. The temperature can reached up to 800 C to 1,000 C, which, of course, destroys the human body. During the cremation process a large part of the body, especially the organs and other soft tissue, is vaporized due to the heat and is discharged through the exhaust system. However, most of the time, the body is not completely incinerated. Normally, after the cremation, the bone fragments, representing about five percent of the body's original mass remain. For the modern cremation, the entire process usually takes about one to one and a half hour hours and the complete incineration of a human body takes about 2-3 hours[1]. Additionally, the temperature during the modern cremation ranges between 850 C and 1,200 C (9, 10) where intense heat is supplied, either by electrical heaters, liquid or

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gaseous fuel burners. People choose cremation for a variety of reasons, including religious, personal, environmental reasons, and cost[2].

The data about ash and bone weights after cremation usually comes from references from western countries[3-7]. In spite of the large number of cremations in Thailand, little is known about weights of cremated remains of Thais, which should be different from western countries due to different body weight, length, and bone mass. Among the most difficult cases for law enforcement and medicolegal investigators to investigate are those where the victims have been deliberately burned to cover up a crime. This difficulty arises from the fact that the bodies may be destroyed or fragmented[8] or possibly, more than one body in the same coffin for cremations to cover up a crime. In bodies recovered from house fires the extent of consumption by the fire was usually less pronounced than in bodies retrieved from burned-out vehicles which is close to the temperature for cremations but shorter in duration[9]. Even severely burned bone remains, sometimes, offer diagnostic possibilities with regard to sex, age, individual marks, and previous injuries[11-14]. The present study aimed to find out the relationship between bone and ash weight to body weight and body length of Thai adults after cremation.

Material and Method

The cremation of one hundred and ten samples, from Wat Chai Mongkol, Ang Thong Province was recorded. The gender ratio of male and female is 1:1 (55 males and 55 females). The samples (humans' death bodies) must be completed in all cases. Samples that were dissected or missing some parts of the bodies were excluded. All dead bodies were cremated via the Thai crematorium. The age ranges between 9 and 107.

The Thai crematorium (Tiger 1) is made of concrete. It uses solar oil for fuel and is significantly unpolluted. It consumes about 40 liters of solar oil per each cremation. The temperature during the cremation ranges between 850 C and 1,200 C. It consists of two chambers, one for burning the dead body and another one for cleaning up the waste product after the crematorium. The length, width, and height are 3 3 3 meters.

With each cremation, the coffin is normally burnt with the dead body. Therefore, it is vital to find the ash weight of the coffin after the cremation. The standard coffin traditionally used is made from particleboard, with the width 0.51 m, length 1.83 m, height 0.39 m, and the thickness of 0.003 m. It takes approximately one hour to complete the incineration of the coffin. The empty coffin ash weighs 0.3 kg.

All the measurements use the metric system. The information of each sample was collected before and after the cremation, including, name, gender, age, body length, and body weight.

Statistical analysis

Pearson correlation coefficient was used to find out the relationship between variables. Mean, standard deviation and standard error used 95%CI were used to summarize all variables. Linear regression equation ($Y = A + BX$) was applied to predict age, body weight and body length toward bone and ash weight. Student t-test was used to find the significance of coefficients of variables. A p-value of less than 0.05 was considered statistical significance.

Results

The data consists of four variables that are age, body weight, body length, and bone & ash weight. The mean, standard deviation, and 95% confidential interval of four variables are shown in Table 1.

From Table 1, except the age, the average values of body length, body weight, and bone & ash weight of males are higher than females. The average bone and ash weight after the cremation of Thai adults (both male and female) is 2.40 kg. The coefficient correlations and p-value among the four variables are illustrated in Table 2.

From Table 2, there is a significant relationship among the age, body weight, and bone & ash weight at p-value < 0.05. The relationship between body height and bone & ash weight is not significant. Also, the relationship between age and body weight is not significant. As a result, it is possible to find the linear equation among age, body weight, and bone & ash weight. There are two types of variables; independent and dependent. Age and body weight are independent variables while bone & ash weight is the dependent variable. The result of the statistical analysis is shown in Table 3.

From Table 3, at the level of significance $\alpha = 0.05$, the authors find that bone & ash weight depends on the age and body weight. The fitted linear equation is given below:

Bone & Ash weight = 1.969 – 0.018 (Age) + 0.030 (Body weight)

Table 1. Mean, SD, and 95% Confidential Interval of personal variables

Data		$\bar{x} \pm$ SD	95%CI
Male	Age	63.47 ± 18.89	58.37-68.59
	Body Length (cm)	164.71 ± 7.90	162.57-166.85
	Body Weight (kg)	59.78 ± 10.04	57.07-62.50
	Bone & Ash (kg)	2.68 ± 1.41	2.30-3.06
Female	Age	73.27 ± 17.32	68.59-77.96
	Body Length (cm)	158.45 ± 6.23	156.77-160.14
	Body Weight (kg)	52.11 ± 9.80	49.46-54.76
	Bone & Ash (kg)	2.12 ± 1.25	1.78-2.46
Total	Age	68.37 ± 18.70	64.84-71.91
	Body Length (cm)	161.58 ± 7.75	160.12-163.05
	Body Weight (kg)	55.95 ± 10.60	53.94-57.95
	Bone & Ash (kg)	2.4 ± 1.36	2.14-2.66

Table 2. The coefficient correlations and p-value among four variables (Age, body length, bodyweight, and bone & ash weight) of total subjects

Variables		r	p-value
Age	Body weight	0.089	0.356
	Body length	0.147	0.126
	Bone & ash weight	0.233*	0.014
Body	Body length	0.501*	0.000
Weight	Bone & ash weight	0.214*	0.025
Body Length	Bone & ash weight	0.018	0.853

* Significant at p-value < 0.05

Table 3. Estimates, SE, t-value, and p-value of age and body weight (Bone & ash weight is a dependent variable)

Variable	Estimates	SE	t-value	p-value
Constant	1.969	0.773	2.546	0.012
Age	-0.018	0.007	-2.779	0.006
Body weight	0.030	0.012	2.584	0.011

There is a negative correlation between bone & ash weight and age and there is a positive correlation between bone & ash weight and body weight. This equation can be used to predict only about the population from which the sample was drawn and should be used only within the interpolation. From this equation, the authors can interpret as follows. If the age increases one year, the bone & ash weight will decrease by 0.018 kg while body weight is controlled. If the body weight increases one kg, the bone & ash weight will increase by 0.030 kg, while the age is controlled.

As the authors know that age and body weight affects the bone & ash weight, the authors would like to know that if the dependent variable is changed, will it be possible to predict the bone & ash weight? In other words, if only one variable either age or body weight is known, can the authors predict the bone &

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

Variable	Estimates	SE	t-value	p-value
Constant	76.097	3.552	21.421	0.000
Bone & ash weight	-3.219	1.290	-2.49	0.014

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

Variable	Estimates	SE	t-value	p-value
Constant	51.930	2.024	25.663	0.000
Bone & ash weight	1.673	0.735	2.277	0.025

ash weight? For doing this, the authors need to find the two fittest equations.

First, the authors would like to find the fittest equation, which the dependent variable is age while the independent variable is bone & ash weight. The result from statistical analysis is shown in Table 4.

From Table 4, at the level of significant = 0.05, it is found that age depends on the bone & ash weight. The fitted linear equation is given below:

Age = 76.097 – 3.219 (Bone and ash weight)

From this equation, there is a negative correlation between age and bone & ash weight. The authors can interpret that if the bone & ash weight increases one kilogram, the age will decrease by 3.219 years. This equation can be utilized to predict only the population from which the sample was drawn and shall be used only within the interpolation.

Second, the authors would like to find another equation, for which the dependent variable is body weight, while the independent variable is bone & ash weight. The result from statistical analysis is shown in Table 5.

From Table 5, at the level of significant = 0.05, it is found that body weight depends on the bone & ash weight. The fitted linear equation is given below:

Body weight = 51.930 + 1.673 (Bone and ash weight)

From this equation, there is a positive correlation between age and bone & ash weight. The authors can interpret that if the bone & ash weight increases one kilogram, the age will increase by 1.673 kilogram. This equation can be used to predict only about the population from which the sample was drawn and shall be used only within the interpolation.

Discussion

The weight of a standard coffin, used in the present study, after cremation, was approximately 0.3 kg. However, the weight of the coffin might vary due to several variables such as material, thickness, and different types of wood etc. Usually, in Thailand the coffin is burnt with the dead body. As a consequence, the varieties of coffins may, in fact, affect the bone & ash weight after the cremation. In the present study, all of the samples employed standard coffins.

The age of samples was in the narrow range. The mean of age was 68.37. The equation $\hat{y}$ = 1.969 – 0.018 (age) + 0.030 (body weight), where $\hat{y}$ = predicted bone & ash weight, could not apply to the entire population of Thai people because most samples were aged above 60 years old, mean = 68.37 years old with the range of 9-107 years old, and the sample size was only one hundred and ten.

From the equation, the present study obtained the negative correlation between age and bone & ash weight. This means that when the age increases, the bone & ash weight tends to decrease, while body weight is controlled. Osteoporosis may play an important role since most samples were aged above 60 years old, which is supported by Bass WM and Jantz RL[10]. In the present study the average bone & ash weight (in kg) of male was 2.68 and female was 2.12. Bass WM and Jantz RL[10] also support the higher average bone & ash weight in males.

If the average age of the present study ranges 20-30 years old, the authors predict that the

relationship between age and bone & ash weight would have positive correlation. In the present study, due to the average higher age group, the level of sex hormones (i.e. testosterone and estrogen) and the activity involved with osteoporosis and the evaluation of bone density was not considered and measured.

The coefficient of determination (R^2) was equal to 0.11. This means that age and body weight can explain the total variation of bone & ash weight only 11%. The equation of the present study $\hat{y} = 1.969 – 0.018(age) + 0.030(body\ weight)$, where $\hat{y}$ = predicted bone & ash weight was for both male and female samples. The equation of each gender could not be accomplished since there were not enough samples. If there were more samples, the equation of each gender could be possible and the total equation (both male and female) would be changed.

The present study shows that age and body weight affects the bone & ahs weight. If the bone and ash weight it known it would be possible to find the predicted age from the fittest equation = 76.097 – 3.219 (Bone and ash weight) where = predicted age. However, this equation might not be accurate in the real situation since this equation will be valid only when the predicted age is in the interpolation. In other words, if the predicted age is out of the range 64.84-71.91, the result obtained from this equation might not be accurate.

In addition, if the bone and ash weight is known, it would be possible to find the predicted body weight from the fittest equation = 51.930 + 1.673 (Bone and ash weight) where = predicted body weight. This equation can predict the body weight only when the result is in the narrow range 53.94 -57.95.

The bone & ash weight after the cremation of North American males was 3.0-3.5 kg and American females was 2.5-3.0 (3,10). Comparing this information with the result from the present study, Thai males were 2.3-3.06 kg (95% confident interval) and Thai females were 1.76-2.46 kg. The present study apparently showed that the bone and ash weight of Thai people was less than Americans. Noticeably, America employed different types of crematoriums, which in general utilized electrical power and produced heat up to 1,000 C-1,500 C.

The crematorium in the present study is the Series Tiger 1, with a temperature as high as 850 C-1,200 C and took approximately 1-1.5 hour to cremate. The authors hypothesized that if the present study employed other types of crematoria and used different temperatures - either higher or lower, it might produce different results. In addition, the difference in body weight, types of coffin, duration of cremation and age of the sample cases were also being considered. However, this information needs more samples for studying.

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ความสัมพันธ์ระหว่างน้ำหนักกระดูกและขี้เถ้ากับ น้ำหนักและความสูงของประชากรไทยภายหลังการฌาปนกิจศพ

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การฌาปนกิจศพเป็นประเพณีปฏิบัติสากลของไทย ภายหลังการฌาปนกิจ ร่างกายสลายเป็นเถ้าถ่าน การหาความสัมพันธ์ระหว่างน้ำหนักกระดูกและขี้เถ้ากับน้ำหนักและความสูงของประชากรไทยภายหลังการฌาปนกิจศพยังไม่เคยมีรายงานการศึกษานี้มาก่อนในประเทศไทย จุดประสงค์ของการศึกษาครั้งนี้คือ ต้องการเก็บข้อมูลน้ำหนักกระดูกและขี้เถ้าภายหลังการฌาปนกิจ รวมทั้งหาตัวแปรที่มีผลต่อน้ำหนักกระดูกและขี้เถ้า จากการเก็บตัวอย่างเถ้ากระดูกภายหลังการฌาปนกิจของประชากรไทยหนึ่งร้อยสิบตัวอย่าง เป็นชาย 55 ตัวอย่างและหญิง 55 ตัวอย่าง การศึกษานี้ใช้เตาเผาศพรุ่น ไทเกอร์วัน (Tiger 1) ซึ่งสามารถให้ความร้อนได้ถึง 850°C – 1200°C เฉลี่ยแล้วใช้เวลาประมาณ 1-1.5 ชั่วโมงในการเผาศพให้กลายเป็นเถ้าถ่าน ค่าเฉลี่ยของน้ำหนักกระดูกและขี้เถ้าของเพศชายมีค่าเท่ากับ 2.68 กิโลกรัม โดยมีส่วนเบี่ยงเบนมาตรฐาน เท่ากับ 1.41 กิโลกรัม ของเพศหญิงมีค่าเฉลี่ย 2.12 กิโลกรัม โดยมีส่วนเบี่ยงเบนมาตรฐาน 1.25 กิโลกรัม ทั้งเพศชายและเพศหญิงมีค่าเฉลี่ย 2.40 กิโลกรัม โดยมีส่วนเบี่ยงเบนมาตรฐาน 1.36 กิโลกรัม จากการศึกษาพบว่า อายุ กับน้ำหนักศพ เป็นตัวแปรที่มีผลต่อน้ำหนักกระดูกและขี้เถ้า ในขณะที่ส่วนสูงเป็นตัวแปรที่ไม่มีผล สมการการถดถอยเชิงซ้อนที่ได้คือ $\hat{y}$ = 1.969 – 0.01846 (อายุ) + 0.03087 (น้ำหนักศพ) เมื่อ = ค่าประมาณ น้ำหนักกระดูกและขี้เถ้า

จากการศึกษาครั้งนี้พบว่าน้ำหนักและอายุมีผลต่อน้ำหนักกระดูกและขี้เถ้า ดังนั้นค่าประมาณของอายุ และค่าประมาณของน้ำหนักตัวสามารถหาได้ ถ้าเราทราบน้ำหนักกระดูกและขี้เถ้า โดยใช้สมการการถดถอย = 76.097 – 3.219 (น้ำหนักกระดูกและขี้เถ้า) เมื่อ = ค่าประมาณอายุ เมื่อต้องการหาอายุ และใช้สมการการถดถอย = 51.930 + 1.673 (น้ำหนักกระดูกและขี้เถ้า) เมื่อ = ค่าประมาณน้ำหนัก เมื่อต้องการหาน้ำหนัก