Correlation of Internal Organ Weight with Body Weight and Length in Normal Thai Adults

Piyanun Mathuramon MD*, Thamrong Chirachariyavej MD, PhD*,
AVM Vichan Peonim MD*, Mana Rochanawutanon MD*

** Department of Pathology, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand*

Objective: *To retrospectively review forensic autopsy cases of a Thai population to show the relationship between the normal internal organ weight and body weight and body length.*
Material and Method: *The present study included 561 autopsies from Ramathibodi Hospital from August 2003 to June 2007. The subjects were from sudden unnatural death following criteria. The weighed organs included brain, heart, lungs, liver, spleen, and kidneys.*
Results: *The ages ranged from 15 to 89 years and there were 461 males and 100 females. The Mean were represented by males and females; 1330/1208, 302/259, 831/659, 1390/1211, 96/81, and 252/222 in brain, heart, lungs, liver, spleen, and kidneys respectively.*
Conclusion: *Relationship was found between internal organs weight and body weight and body length of males whereas, in females the weight of internal organs except the kidneys was not related to body length.*

Keywords: *Body height, Body weight, Organ weight*

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At an autopsy, the pathologist examined the organs and considered whether they showed pathological changes or not. The organ weight is one of regular criteria by the pathologist during an autopsy to detect what is abnormal. The findings were compared to what is normal for a specific organ. The determination of abdominal organs in particular has significant potential clinical value. For example, liver volumes are important not only in determining disease states and disease progression but in estimating segmental liver volumes for transplant donors and planning the extent of hepatectomy in cancer patients[1]. The spleen commonly increases in size in response to conditions such as infection and hematologic or metabolic disorders[2,3]. There is a good correlation between platelet count and spleen volume, and splenic volume detects serious liver disease and correlates with splenic hyperfunction[4]. Kidney size bears a relation to the degree of renal diseases.

Correspondence to: Mathuramon P, Forensic Division, Department of Pathology, Faculty of Medicine, Ramathibodi Hospital, Bangkok 10400, Thailand. 0-2201-1145, E-mail: porcupine.38@hotmail.com

There are several standard textbooks that show the normal internal organs weight such as that of Ludwing[5] and Sunderman and Borner[6]. All of these are always referenced; however, most indicators are from the populations of Caucasoid and there are very few from the populations of Asian, most of whom are from Japan, China, Korea, and India. In the past, Thailand normally used references from American or European textbooks and publication papers. The problem is that the differences of these factors make the indicators different: race, body structure, genetic, environment, living condition, life style, and food. Therefore, the importance of this point was to find out the normal weight of internal organs of a Thai population and to determine its correlation with body weight.

In fact, there is such research by Thamrong C et al[7]. Their finding is reliable and able to be referred to Thai population. However, the 250 subjects that were used as the sample size is quite small. The researchers thought it should be increased, as it would make the data more qualitative and reliable for referencing.

Besides internal organs weight, the other factors of the subjects such as gender, age, height, and

weight were also collected for the determination of the correlation with internal organs weight.

Material and Method

From Thamrong C et al[7] 's date, which were collected from 1st August 2003 to 28th February 2005 from 250 forensic autopsies, researcher continuously collected from 1st March 2005 to 1st June 2007, another 561 specimen. The additional subjects were forensic autopsies in the Department of Pathology, Faculty of Medicine, Ramathibodi Hospital. All of the subjects were adult Thai people that who died from injury with short survival time (< 15 min), excluding macroscopic evidence of disease or histological abnormalities. The subjects of fire related death[8,9] and decomposition were deleted, because, they would affect internal organs weight and body weight. The following subjects were also deleted: natural manner of death or unnatural manner of death that had been treated. Therefore, most of the subjects in the present study were from accidents, suicide, and homicide manner of death.

The weight and the height of the body were measured by the mortuary technicians but were supervised by the forensic pathologist responsible for the autopsy. The body length measured was the head to heel length. All the bodies were weighed naked with the same weighing machine (KERN & SOHN GramBlt TB-TM SNR 2564664-10 c/+40 c kg from Germany). All of them were refrigerated at the same temperature (4°c) before weighing. As the delay between death and autopsy might alter organ weights, all autopsies were performed by forensic pathologists within 24 hours after death. The weighed organs included heart, lungs, liver, spleen, kidneys, and brain. The hearts were weighed after being dissected and washed to remove clotted blood from the chambers. The weighing machines used were of the same type (CHATILLON, capacity 9 Kilos x 10 gram 3 x 10 from New York - USA). They were calibrated daily before the beginning of autopsy with a reference weight of one kilogram. They were reset before each weighing during autopsy.

The data would be collected and analyzed with SPSS Program. They were divided into gender: male/female with weight, height, and internal organs weight for analyzing mean, standard derivation, maximum, and minimum. Then, the results were plotted in a graph form to find the trend and predict relationship of two variables. After that, Pearson's correlation coefficient would be used to analyze the relationship between body weight and internal organs weight, body length and internal organs weight with statistical significance at $p < 0.05$. Simple linear regression was performed using the fitted equation; ($y = a + bx_1 + cx_2 + dx_3$) between the weight of internal organs (dependent) and body weight, body length, age, and sex (independent) variables. - y axis depends upon seven values: a is a "constant" and is the value of y when x is zero; b, c, and d are the "slope" of the line, the amount by which the y value increases (or decreases, for negative slope) for each unit of increase in the x value; x is the value of x itself. The four variables including body weight, body length, age, and sex were important for analysis because of the fact that body weight and body length was related with every organ in statistic value while age was quite variable in statistic value: lowest age was at 15, highest age was 89. Therefore, these variables were effective to value. Finally, the last variables was sex. The internal organs weight in males was significantly different from that in females in every case in statistic value. This was the reason why the three variables were calculated for simple linear regression analysis in the present study.

Results

The 561 subjects were divided into two groups: 461 males and 100 females (Table 1). The number of organs is less than autopsies because some of them have been lost and destroyed by the cause of death such as car accident or from a fall. The authors collected the data and analyzed it to find a correlation between body weight and weight of internal organs. External parameters including age, weight, and height are shown in Table 2. Internal organs weight (brain, heart, lungs, liver, spleen, and kidneys) are shown with the mean, the standard deviation and the range of the internal organs weight at studied population in Table 3. Table 4 shows the correlation between internal

Table 1. The number and percent of internal organs of males and females

	Male (n = 461)		Female (n = 100)	
	n	Percent	n	Percent
Brain	447	97.0	93	93.0
Heart	459	99.5	100	100.0
Lung	460	99.7	100	100.0
Liver	460	99.7	99	99.0
Spleen	453	98.0	98	98.0
Kidney	455	98.6	99	99.0

Table 2. Mean, standard deviation, minimum and maximum of age (year), BW and BL of males and females

	Male		Female	
	Mean ± SD	Min-Max	Mean ± SD	Min-Max
Age (y)	35 ± 14	15-89	37 ± 17	15-86
BW (kg)	59.44 ± 11.84	30-115	52.37 ± 9.39	33-86
BL (cm)	166.93 ± 6.64	150-188	156.18 ± 5.93	142-173

Table 3. The norm of IOW (gram) shown in the form of mean ± standard deviation of males and females

	Male (mean ± SD)	Female (mean ± SD)
Brain	1330.62 ± 127.45	1208.71 ± 131.44
Heart	302.15 ± 54.44	259.50 ± 60.02
Lung	831.19 ± 277.45	659.30 ± 241.04
Liver	1390.76 ± 283.20	1211.31 ± 269.62
Spleen	96.47 ± 36.74	81.93 ± 36.17
Kidney	252.93 ± 53.56	222.32 ± 44.35

Table 4. Correlation between internal organ weight and body weight and body length of males and females

Organs	Body weight		Body length	
	Male (r)	Female (r)	Male (r)	Female (r)
Brain	0.314**	0.147	0.233**	0.082
Heart	0.471**	0.362**	0.195**	-0.033
Lungs	0.148**	0.111	0.145**	-0.006
Liver	0.338**	0.379**	0.201**	0.086
Spleen	0.246**	0.169	0.203**	0.075
Kidneys	0.356**	0.416**	0.205**	0.222*

* Correlation is significant at $p < 0.01$
** Correlation is significant at $p < 0.05$

organs weight and body weight and body length by dividing males and females. It shows the values of the r and p, which revealed that the value of weight of females' brain, lungs, and spleen. Those with a p-value higher than 0.05 are not related to body weight. The other female organs (heart, liver, and kidneys) are significant at $p < 0.001$. Every male organ has a relationship with body weight at $p < 0.001$ and every internal organ weight has a relationship with body weight. Correlation between weight of internal organs and body length shows value of the r and p at the same value for every organ. Female internal organs weight is not related to body length except kidneys. Every male organ has positive correlation to body length at $p < 0.001$.

The result revealed that if body weight increases, the weight of internal organs will increase as shown in Fig. 1-6. Similarly, this is also related to the body height in Fig. 7-12. Due to the variation of age, the general result, according to the trend of weight in each range of age, shows that at the age after 60 the weight of internal organs tends to decrease, except the heart weight, as shown in Table 5. Tables 6 and 7 show the regression of the correlation and relationship of the six variables by slope b, c and d whereas x_1, x_2 and x_3 are variables of body weight or body length, age, and sex, respectively.

Discussion

Trying to find out the normal internal organs weight is still going on by two methods, radiology such as ultrasound or computer tomography, and weighing the organs from autopsy. However, there are both positive and negative effect for each method. Researcher is interested in the weighing method, directly from autopsies according to the criteria because it is part of the routine work. Subjects that are selected are cases of unnatural death because there is more variety of morbid anatomical lesions or disease than the cases of natural death.

In the past, there were studies showing causes of death that had an effect on the internal organs weight[10,11], such as hypovolumic shock which makes it decrease[11]; however, the results from other studies are in disagreement with the point of spleen weight[12]. Pearl and Bacon[13] underlined the limitation of hospital autopsy records as a suitable source of material for establishing tables of organ weight. They also stated that the ideal subjects for establishing anatomical standards would be in those dying in violent accidents.

Fig. 1 Brain weight-body weight

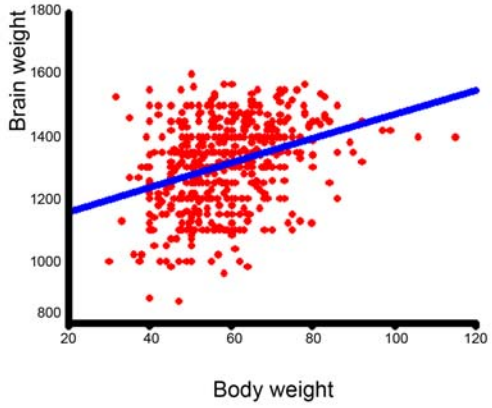

Fig. 2 Heart weight-body weight

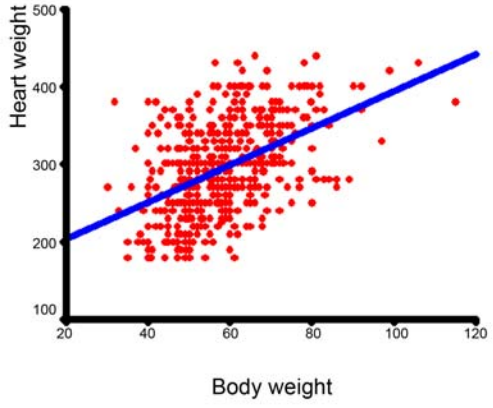

Fig. 3 Lungs weight-body weight

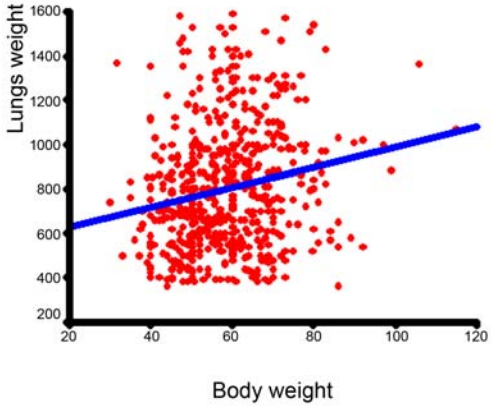

Fig. 4 Liver weight-body weight

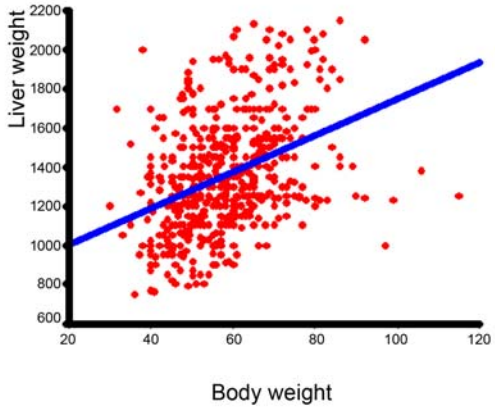

Fig. 5 Spleen weight-body weight

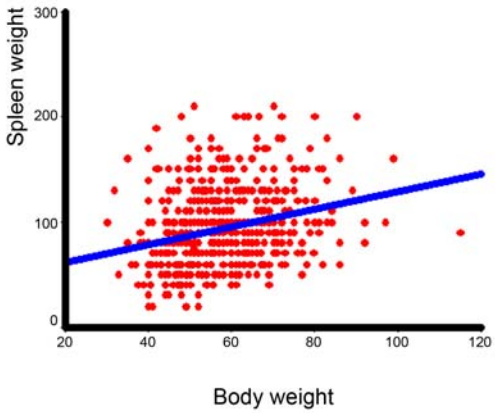

Fig. 6 Kidneys weight-body weight

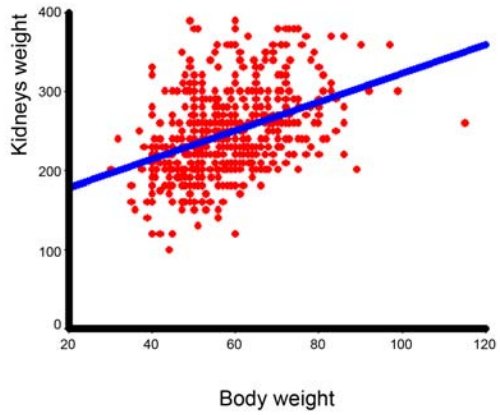

Fig. 1-6 The trend of internal organs weight compared to body weight

Fig. 7 Brain weight-body length

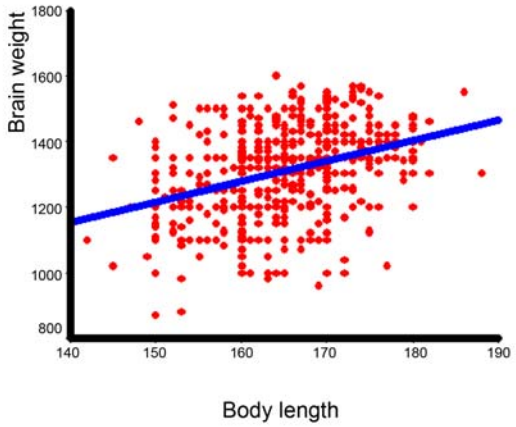

Fig. 8 Heart weight-body length

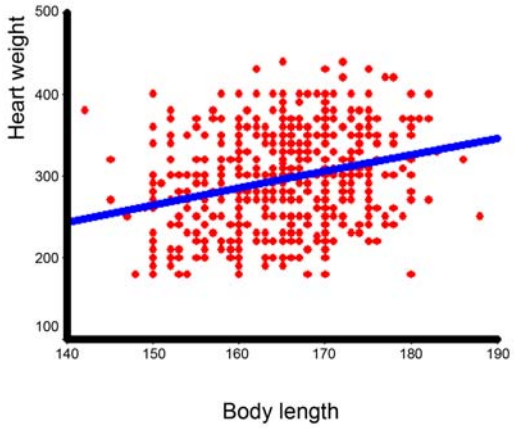

Fig. 9 Lungs weight-body length

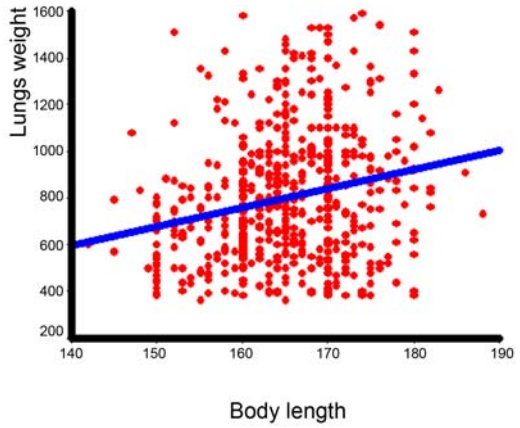

Fig. 10 Liver weight-body length

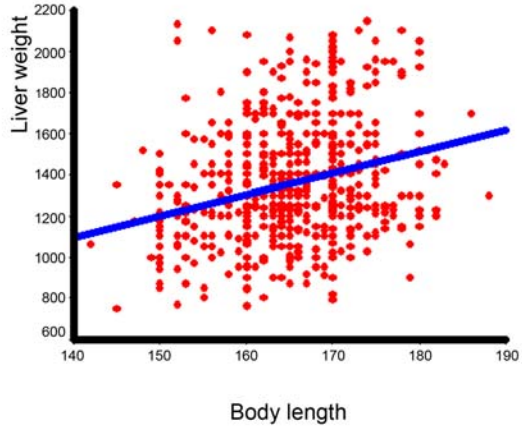

Fig. 11 Spleen weight-body length

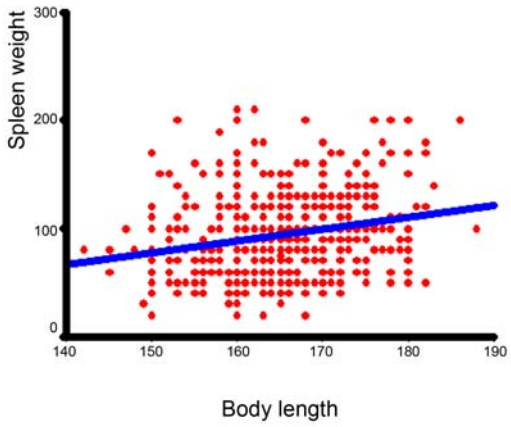

Fig. 12 Kidneys weight-body length

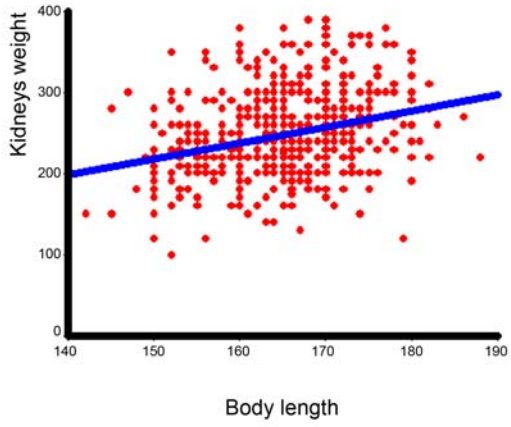

Fig. 7-12 The trend of internal organs weight compared to body length

Table 5. Trend of internal organs weight in each range of age

Age (year)	Brain (gm)	Heart (gm)	Lungs (gm)	Liver (gm)	Spleen (gm)	Kidneys (gm)
15-20	1358.89 ± 120.61	267.95 ± 53.07	759.73 ± 252.20	1297.53 ± 283.21	104.00 ± 39.02	238.56 ± 54.58
21-30	1312.04 ± 135.46	281.90 ± 54.96	791.51 ± 285.85	1315.34 ± 266.65	99.23 ± 36.27	244.70 ± 50.46
31-40	1307.86 ± 131.60	295.27 ± 52.80	812.25 ± 263.72	1414.50 ± 269.90	87.42 ± 33.73	250.55 ± 50.44
41-50	1311.04 ± 125.68	310.86 ± 55.18	887.44 ± 305.08	1489.02 ± 312.38	91.60 ± 37.90	259.01 ± 59.02
51-60	1266.43 ± 158.16	314.43 ± 57.62	766.60 ± 269.74	1360.00 ± 292.61	86.82 ± 36.77	258.14 ± 53.29
61-89	1253.78 ± 148.18	346.25 ± 53.76	739.25 ± 267.11	1232.75 ± 291.22	83.85 ± 39.71	232.00 ± 56.26

Table 6. Regression equation of the relationship between internal organ weight with body weight, age and sex

Organ	Body weight	
	$Y = a + bx_1 + cx_2 + dx_3$	R^2
Brain	Brain weight = 1093.64 + 3.15(body weight) – 1.38(age) + 97.32(sex)	0.20
Heart	Heart weight = 82.30 + 2.28(body weight) + 1.53(age) + 30.44(sex)	0.42
Lungs	Lungs weight = 469.80 + 3.41(body weight) + 0.29(age) + 148.53(sex)	0.07
Liver	Liver weight = 704.06 + 8.52(body weight) + 1.63(age) + 123.38(sex)	0.17
Spleen	Spleen weight = 55.95 + 0.74(body weight) – 0.34(age) + 8.63(sex)	0.09
Kidneys	Kidneys weight = 127.70 + 1.69(body weight) + 0.24(age) + 19.58(sex)	0.17

Unit: Organ weight = gram, Body weight = kilogram, age = year
Sex: male = 1, female = 0

Table 7. Regression equation of the relationship between internal organ weight with body length, age and sex

Organ	Body length	
	$Y = a + bx_1 + cx_2 + dx_3)$	R^2
Brain	Brain weight = 695.06 + 3.55(body length) – 1.13(age) + 81.30(sex)	0.16
Heart	Heart weight = -128.74 + 2.10(body length) – 1.63(age) + 24.32(sex)	0.26
Lungs	Lungs weight = -215.43 + 5.44(body length) + 0.67(age) + 115.03(sex)	0.07
Liver	Liver weight = -258.69 + 8.90(body length) + 2.11(age) + 89.00(sex)	0.09
Spleen	Spleen weight = -46.21 + 0.89(body length) – 0.28(age) + 4.52(sex)	0.06
Kidneys	Kidneys weight = -75.88 + 1.83(body length) + 0.35(age) + 11.95(sex)	0.09

Unit: Organ weight = gram, Body length = centimeter, age = year
Sex: male = 1, female = 0

The present study has found that the weight of male's brain weight was 1330.62 ± 127.45 gm and that of the females 1208.71 ± 131.44 gm. These findings are similar to those of Thamrong C et al[7] and others, except the weight from the present study was quite less than the weight of the studies from Europe and United States[14-20]. It was also found that the weight of male's brain had a positive correlation with both body weight and body length. Zechoch's[21] found a correlation for body weight in both sexes, but the body length was correlated only in males. From the studies of Chrzanowska[18] or Koha[22], it was found that there is a significant correlation in body length in male but not in female participants. Furthermore, when the authors distributed the weight according to the range of age, the brain weight was reduced as the age

increases. This is because under-nutrition in the elderly has a relative effect on brain weight, probably because the brain contains only small amounts of glycogen and neutral fat[23].

Researchers found that body length and heart weight in females are not correlated, according to Dadgar[24], Coard[25], and Hangartner[26]. However, the heart weight in males is correlated to body weight and body length, whereas the heart weight in females is correlated only to body weight, similar to the finding of Hanzlick[27], Oqui et at[28], Scholr DG[29]. The heart weight is almost constant or even increased with increasing age. This phenomenon is also observed during middle age and has attracted the attention of researchers[30,31]. Undiagnosed systolic hypertension is frequently seen in the middle-aged and elderly, mainly accounting for the increase in heart weight. When the authors substituted the variables, body weight, or body length, age, and sex in regression equation, it could predict heart weight better than other organs (R^2 = 0.42 and 0.26 in body weight and body length respectively).

Whenever the authors calculated the correlation between total lung weight and body weight and body length, it was found that it will be related to each other in males but not in females, because in acute death the postmortem lung weight may primarily depend on an individual's lung volume and persistent circulatory disturbance (congestion and edema) before death which is related to vital activity (gender and age) and survival time[9], it causes the lungs weight to change easily after death.

When the authors compare the liver weight of males and females, it was found that the liver weight in males was heavier because body weight makes liver weight heavier, according to the finding of Andersen's[32]. Liver weight is positive by correlation to body weight in both males and females, and positive by correlation to body length in only males, according to the research of Thamrong C.[7]. That is because of vital activity or persistent circulatory disturbance before death.

According to other researchers, it was found that spleen weight will reduce in older age. Spleen of females is lighter than males[11] and Sprogoe-Jakobsen[33] found that there is positive correlation with body weight and body length in males, but not in females.

The authors found a positive correlation between kidneys weight and body weight and body length in both sexes, which is similar to several researchers such as Kasiske[34]. The presented data also confirmed the result of Sahni D[35], who found that the weight of kidneys in males was heavier than that in females.

The present research shows internal organs weight that can be used for Forensic and Non-Forensic pathologists when making an autopsy in a Thai population. This is because reference from Americans or European populations may not be suitable for Thai population. The organ weight will remain a good diagnostic criterion of autopsy only if normality is accurately and regularly defined. This includes three variable equations used to calculate each internal organ weight validly and reliably. Although the number of subjects in the present research is double than in the previous research, there should still be more study done as more subjects will gives more qualitative results. It will be better if the subjects of females are increased because they are fewer compared to those of males and may affect statistic evaluation.

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ศึกษาค่าปกติของน้ำหนักอวัยวะภายในและความสัมพันธ์ระหว่างน้ำหนักตัวและส่วนสูงกับน้ำหนักอวัยวะภายในของคนไทยที่คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี

ปิยนันต์ มธุรมน, ธำรง จิรจริยาเวช, วิชาญ เปี้ยวนิ่ม, มานะ โรจนวุฒนนท์

การศึกษาค่าปกติของน้ำหนักอวัยวะภายในของคนไทย และหาความสัมพันธ์กันระหว่างน้ำหนักอวัยวะภายใน กับ น้ำหนักตัว และส่วนสูง โดยศึกษาจากศพ ทั้งหมด 561 ราย จาก โรงพยาบาลรามาธิบดี ตั้งแต่ 1 สิงหาคม พ.ศ. 2546 ถึง 1 มิถุนายน พ.ศ. 2550 ที่เสียชีวิตผิดธรรมชาติ โดยตัดจำพวกศพที่ผ่านการรักษาในโรงพยาบาลมาก่อนเสียชีวิต ศพที่เน่าเปื่อย หรือศพถูกไฟเผาไหม้ โดยเก็บอวัยวะดังต่อไปนี้ คือ สมอง หัวใจ ปอด ตับ ม้าม และไต แล้วนำมาวิเคราะห์หาค่าปกติ และหาความสัมพันธ์ระหว่างอวัยวะภายใน กับน้ำหนักตัว และส่วนสูงของศพ โดยใช้วิธีทางสถิติ พบว่า ในศพผู้ชายและผู้หญิง น้ำหนักอวัยวะภายในเฉลี่ย คือ 1330/1208, 302/259, 831/659, 1390/1211, 96/81 และ 252/222 ใน สมอง หัวใจ ปอด ตับ ม้าม และไต ตามลำดับ และพบความสัมพันธ์ระหว่างน้ำหนักอวัยวะภายใน กับ น้ำหนักตัว และส่วนสูงของศพในทุกอวัยวะของผู้ชาย แต่พบว่าในผู้หญิงมีเพียงเฉพาะหัวใจ, ตับ และไต เท่านั้นที่สัมพันธ์กับ น้ำหนักตัว ส่วนความสัมพันธ์กับ ส่วนสูงในผู้หญิง พบว่ามีเฉพาะไตเท่านั้นที่มีความสัมพันธ์กัน