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Organ weight in 684 adult autopsies: new tables for a Caucasoid population

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Abstract

The weights of normal organs were retrospectively culled for the years 1987–1991 from 684 forensic autopsy cases. All the subjects were Caucasoid adults who died of external causes and showed no pathological changes. The weights of the following organs were available: the heart, the right and the left lung, the liver, the spleen, the pancreas, the right and the left kidney and the thyroid gland. The external parameters used for statistical correlation were the age, the height, the body weight and the body mass index (BMI) of the deceased. The weight of all the organs was shown to correlate with at least one external parameter, with the exception of thyroids in females. Organ weights decreased with age except for the heart and the thyroid, and increased in relation to body height and/or BMI. Except for the heart, the organ weight showed a better statistical correlation with the body height than the BMI. These updated tables of organ weight were compared with the data collected in previous studies. Such tables have to be regularly updated by pathologists in order to keep organ weight as a good criterion to be used in post-mortem diagnosis. © 2001 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Normal organ weight; Autopsy; Body mass index (BMI)

1. Introduction

The organ weight is one of the criteria regularly used by the pathologist during an autopsy to detect what is pathological. Reference material on which normality is based must be defined in order to enable a relevant comparison. The standard anatomical tables of organ weights of Ludwig [1] and Sunderman and Borner [2] are frequently used in this context but are already old. Even if the human population only changes slowly, it would be more accurate to compare such autopsy findings as organ weight with recent collected data. The aim of our study was to update tables of organ weights, to formulate standard reference values and to provide a range of values, taking into account the variables of age, sex, body height and body mass index (BMI). The study did not include the weight of the brain and was limited to a French Caucasoid population.

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2. Materials and methods

From 1987 to 1991, 684 forensic autopsies were performed at the Department of Forensic Medicine and Pathology. The weight and height of the body as well as the organ weights were collected from post-mortem records of 355 adult males and 329 adult females. All the subjects selected were Caucasoid who died of injury with short survival time (<1 h) and all those who showed any macroscopic evidence of disease or histological abnormalities were excluded. 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 height measured was the head-to-heel length. All the bodies were weighed naked with the same weighing machine (TESTUT of type K.B.I., 0–300 kg range, 100 g intervals). All of them were refrigerated at the same temperature (4°C) before weighing. As the delay between death and autopsy can alter organ weights, all necropsies were performed by forensic pathologists within 48 h after death. The weighed organs included the heart (with epicardial fat), the right and the left

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Table 1
Height subgroups for both males and females[a]

	Height (cm)					
	Males			Females		
	144–165	166–175	176–190	126–155	156–165	166–180
Mean (cm)	160	170	180	150	160	170
S.D.	4.5	3.1	3.8	4.6	2.8	3.6
n	55	178	122	78	167	84

[a] S.D.: standard deviation.

Table 2
BMI subgroups for both males and females[a]

	BMI (kg m^{-2})					
	Males			Females		
	14–21	22–24	25–34	13–20	21–24	25–40
Mean (kg m^{-2})	20	23.5	27	18.5	23	28.5
S.D.	1.6	0.9	1.9	1.9	1.1	3.2
n	152	111	92	139	109	81

[a] S.D.: standard deviation.

lung, the liver, the spleen, the pancreas, the right and the left kidney and the thyroid gland. Except for the heart, the organs were weighed before being dissected and cut open. Hearts were weighed after being dissected and washed to remove clotted blood from the chambers. The organ weights were carefully reported after each autopsy in accordance with the European Recommendation on the harmonisation of medico-legal autopsy rules [3]. The electronic weighing machines used were of the same type (METTLER of type PJ 6000, ISO 9001 certified, 0–6000 g range, 0.1 g intervals). They were daily calibrated before the beginning of autopsy with a reference weight of one kilogram. They were reset before each weighing during autopsy.

In this study, three height and BMI subgroups were defined for both sexes. The BMI was calculated using the formula [4]

$$\mathrm{BMI} = \frac{\text{Body weight (kg)}}{\text{Height}^2\ (\text{m}^2)}$$

Three height subgroups were defined for both males and females (see Table 1). Three BMI subgroups were defined for both males and females (see Table 2).

Each subgroup was defined so as to correspond to subdivisions of the population with a number strong enough to be statistically representative of variations in inter-individual morphology. The mean of organ weight has been determined for each subgroup.

Correlations between organ weights and body height, BMI and age, respectively, were studied by performing linear regressions using a least squares fitting method. R^2 values (i.e. coefficient of determination) of the linear regressions were determined. We classified the strength of the correlation between organ weight and the parameters in three categories: strong ($R^2 > 0.5$), weak but significant ($0.1 \leq R^2 \leq 0.5$) and not significant ($R^2 < 0.1$).

3. Results

The external parameters considered were the age, the height, the body weight and the BMI of the deceased. The corresponding values are shown in Table 3. All these parameters fitted to a Gaussian distribution curve except for the age, which showed that the majority of the individuals in the sample were less than 50 years old.

The mean, the standard deviation and the range of the organ weight of the studied population are shown in Table 4.

Table 3
External parameters for males and females[a]

	Males ($n = 355$)		Females ($n = 329$)	
	Mean	S.D.	Mean	S.D.
Age (years)	42	17	49	20
Height (cm)	172	7.5	161	7.5
Body weight (kg)	68	11	58	13.2
BMI (kg m^{-2})	22.8	3.3	22.5	4.5

[a] S.D.: standard deviation.

Table 4
Comparative data of organ weight (g) of males and females[a]

	Males ($n = 355$)		Females ($n = 329$)	
	Mean ± S.D.	Range	Mean ± S.D.	Range
Heart	365 ± 71	90–630	312 ± 78	174–590
Right lung	663 ± 239	200–1593	546 ± 207	173–1700
Left lung	583 ± 216	206–1718	467 ± 174	178–1350
Liver	1677 ± 396	670–2900	1475 ± 362	508–3081
Spleen	156 ± 87	30–580	140 ± 78	33–481
Pancreas	144 ± 39	65–243	122 ± 35	60–250
Right kidney	162 ± 39	53–320	135 ± 39	45–360
Left kidney	160 ± 41	50–410	136 ± 37	40–300
Thyroid	25 ± 11	12–87	20 ± 9	5–88

[a] S.D.: standard deviation.

Table 5
Mean and standard deviation of organ weight (g) according to height (cm)

	Males			Females		
	$144 \le H \le 165$	$165 \le H \le 175$	$176 \le H \le 190$	$126 \le H \le 155$	$156 \le H \le 165$	$166 \le H \le 180$
Heart	344 ± 75	360 ± 75	381 ± 56	320 ± 88	308 ± 79	311 ± 67
Right lung	616 ± 210	625 ± 207	741 ± 274	494 ± 202	545 ± 183	597 ± 243
Left lung	523 ± 190	551 ± 178	658 ± 257	450 ± 146	472 ± 181	491 ± 204
Liver	1455 ± 370	1637 ± 369	1831 ± 384	1275 ± 321	1496 ± 331	1624 ± 380
Spleen	120 ± 51	150 ± 88	180 ± 90	122 ± 67	139 ± 79	160 ± 82
Pancreas	138 ± 35	143 ± 39	147 ± 39	111 ± 25	122 ± 35	138 ± 41
Right kidney	150 ± 49	157 ± 36	170 ± 37	117 ± 32	137 ± 40	148 ± 36
Left kidney	155 ± 53	164 ± 38	175 ± 38	120 ± 41	136 ± 35	148 ± 33
Thyroid	25 ± 7	25 ± 13	25 ± 9	20 ± 11	18 ± 6	20 ± 11

The mean and the standard deviation of the organ weight corresponding to each subgroup of height are shown in Table 5. The same data but corresponding to each subgroup of BMI are shown in Table 6.

The weight of all the organs was correlated statistically with at least one external parameter with the exception of the thyroid in women which could not be correlated with any parameters. R^2 values (i.e. coefficient of determination) of the linear regressions are given in Table 7.

When there was correlation, the organ weight increased with body height and/or BMI. Except for the heart, the organ weight was more correlated with body height than BMI. For

Table 6
Mean and standard deviation of organ weight (g) according to BMI (kg m^{-2})

	Males			Females		
	$14 \le \mathrm{BMI} \le 21$	$22 \le \mathrm{BMI} \le 24$	$25 \le \mathrm{BMI} \le 34$	$13 \le \mathrm{BMI} \le 20$	$21 \le \mathrm{BMI} \le 24$	$25 \le \mathrm{BMI} \le 40$
Heart	342 ± 58	370 ± 75	400 ± 69	287 ± 74	308 ± 68	362 ± 77
Right lung	670 ± 249	651 ± 241	663 ± 217	536 ± 178	547 ± 203	561 ± 256
Left lung	593 ± 224	579 ± 201	569 ± 221	450 ± 146	472 ± 181	491 ± 204
Liver	1581 ± 372	1730 ± 405	1769 ± 390	1346 ± 328	1521 ± 331	1609 ± 419
Spleen	143 ± 83	157 ± 83	175 ± 93	126 ± 70	150 ± 93	152 ± 67
Pancreas	131 ± 38	143 ± 34	162 ± 38	114 ± 33	129 ± 38	125 ± 32
Right kidney	156 ± 40	163 ± 37	169 ± 37	126 ± 35	139 ± 40	144 ± 40
Left kidney	158 ± 43	170 ± 41	174 ± 35	126 ± 32	139 ± 38	146 ± 38
Thyroid	24 ± 11	25 ± 7	28 ± 13	19 ± 7	19 ± 8	20 ± 11

Table 7
Linear interpolation results (R^2 values) of organ weights with height, BMI and age for males and females[a]

	Males			Females		
	Height	BMI	Age	Height	BMI	Age
Heart	0.64	0.77	0.87	0.01 (ns)	0.61	0.78
Right lung	0.41	0.01 (ns)	0.05 (ns)	0.43	0.18	0.03 (ns)
Left lung	0.49	0.06 (ns)	0.04 (ns)	0.4	0.13	0.02 (ns)
Liver	0.88	0.61	0.33	0.8	0.57	0.62
Spleen	0.7	0.11	0.17	0.42	0.21	0.11
Pancreas	0.08 (ns)	0.28	0.05 (ns)	0.69	0.07 (ns)	0.04 (ns)
Right kidney	0.4	0.39	0.3	0.72	0.66	0.21
Left kidney	0.45	0.36	0.32	0.68	0.62	0.28
Thyroid	0.26	0.21	0.22	0.01 (ns)	0.08 (ns)	0.08 (ns)

[a] ns: Non significant.

men, the liver, the heart and the spleen weights were strongly positively correlated with the body height. The correlation was weak or non significant for the other organs. For women, the pancreas, the kidney, and the liver weights were strongly correlated with body height. The correlation was weak for the spleen and the lungs. No correlation with body height was found for the thyroid weight and the heart weight in our adult female population.

For men, the heart and the liver were strongly positively correlated with the BMI. The correlation was weak or non significant for the other organs. For women, the heart, the liver and the kidney weights were strongly correlated with the BMI. The correlation was weak for the spleen and the lungs. No correlation with BMI was found for the thyroid weight and the pancreas weight.

When there was correlation, the organ weight decreased with age except for the heart and the thyroid and the weight of these two organs increased significantly with age.

4. Discussion

Organ weight references are only valid over a limited period of time. Thus, values of organ weight obtained by autopsy should not be compared with outdated reference tables but with more recently collected statistical data. Indeed the use of incorrect tables may lead to a wrong judgement on the pathological or not-pathological features of the organ, especially in forensic cases in which histology is not always performed. This implies the necessity to establish updated reference tables from appropriate autopsy material that must be without any pathological change secondary to disease. A non hospital population of deceased persons subjected to an autopsy would consequently provide this type of control material because the organs in patients succumbing to a wide variety of morbid anatomical lesions or disease processes as it would be the case in hospital autopsies cannot in any case be considered as normal. Such control autopsy material is easily available in a Department of Forensic Medicine especially from cases of sudden traumatic death.

Previous studies [5,6] have shown that the cause of death could have a major influence on the organ weight. Boyd [6] noted that the weight of an organ tends to decrease in any condition producing hypovolemic shock. However, the latter observations were in disagreement with those of Myers and Segal [7] who found no alteration in the spleen's weight in relation to cause of death or to excessive blood loss. Pearl and Bacon [8] 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.

With regards to the values for heart weight, our study found that heart weight is positively correlated with age and BMI for both sexes. The finding of a clear relationship between heart weight and body weight agrees with the studies of Smith [9], Gray and Mahan [10] and more recently of Hanzlick and Rydzewski [11]. The correlation which has been found between heart weight and age agrees with the studies of Greenwood and Brown [12], and Hanzlick and Rydzewski [11]; the mean heart weight in 201 white young American men in this last study was almost exactly the same than ours (364 g $\pm$ 62 versus 365 g $\pm$ 71). The body height was shown to be a poor predictor of heart weight [13] contrary to the findings of Zeek [14].

Comparison of our data with previous studies must take into account the not insignificant variation from one study to another of the different characteristics of population. For example, whether the subject indulged in physical activity, which induces cardiac hypertrophy [13], is usually unknown at the time of autopsy. In the same manner the wide upper limit found for heart weight could mean undiagnosed systemic hypertension even though a clinical history of hypertension was unknown for all the cases of our study.

The weight of right and left lungs of our study is positively correlated with height for both males and females. The range of corresponding weight values is wide. These strong inter-individual variations could be partially explained by the degree of terminal pulmonary oedema and congestion which differs from one individual to another.

The liver weight is very positively correlated with height and BMI for both sexes. The liver weight decreases with age as Boyd [6] already stated. Our results on spleen weight are comparable with those of Sprogoe-Jakobsen and Sprogoe-Jakobsen [15] who also found a correlation with body height but not with age. Owing to this study, the weight of the spleen is also positively correlated with body weight and with the degree of acute congestion of the spleen. Our data confirm those of Myers and Segal [7] who found a higher spleen weight in the young and in male subjects. Our results about pancreas weight are a little paradoxical according to sex because the weight is related to height for females and to BMI for males. It would mean that the effect of pancreatic lipomatosis on the organ weight would be greater for men than for women because the BMI characterises the fat rate [4]. It has been shown that the degree of pancreatic lipomatosis was significantly correlated with age and body overweight [16,17]. But the males in our study were on average not older or bigger than the women. So these two parameters cannot explain the difference of correlation according to sex.

The kidney weight as well as the heart weight are related to height and BMI, but not to body weight. These results conflict with those of Rasmussen et al. [18] who found by ultrasound that the total renal volume correlated with the body weight. The difference could be related to the fact that renal volume is not correlated with renal weight.

The total lack of correlation of thyroid weight with all the external parameters in females confirmed the works of Berghout et al. [19] who measured thyroid volume by ultrasonography in 50 healthy adults. However, the same authors found a correlation between thyroid volume and body weight for males. It has also stated that lean body mass was presumably a more accurate determinant of thyroid volume than body weight [19]. This could explain why we have found a slight correlation between thyroid weight and BMI in males in our study. Our values showed like Pankow et al. [20] that the weight of the average female adult thyroid was smaller than that of the male. The difference in thyroid gland volume between males and females is only explained by a difference in body weight [19,21]. However, the values of our study are higher than these of Pankow et al. [20]. The major influence on thyroid weight is the iodine intake [22]: all the subjects of our study were living in a non-iodine deficient area, which could not consequently explain the difference observed between the two studies.

Our study has established updated tables of organ weights and those might be useful for the forensic or non-forensic pathologist when performing autopsies in a Caucasoid population. We must emphasise that our tables are not exhaustive and will have a limited value in time because of data collected 10 years ago. Pathologists have to be aware to steadily update such tables for the population on which they perform autopsies. Normal values of organ weight change with time probably under the influence of genetic factors and environmental factors such as dietary habits, daily water intake and climatic conditions. The organ weight will remain a good diagnostic criterion of autopsy only if normality is accurately and regularly defined.

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