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Autopsy Standards of Body Parameters and Fresh Organ Weights in Nonmacerated and Macerated Human Fetuses

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ABSTRACT

Standards for body parameters and organ weights are important tools in fetal and perinatal pathology. Previously there has been only a weak emphasis on the effect of maceration on dimensions and weights. This study provides autopsy standards for body weight, body dimensions, and fresh organ weights for nonmacerated fetuses and for mildly, moderately, and markedly macerated fetuses at 12 to 43 weeks of gestation. Cases were selected from a consecutive series of 1800 fetal and perinatal autopsies. Cases with malformations, hydrops, infection, or chromosomal abnormality, fetuses from multiple births, and infants who lived longer than 24 h were excluded. In each case the maceration was graded and body weight and 4 body dimensions were recorded before organ examination. Organs were weighed immediately and before fixation. Growth curves were fitted according to appropriate mathematical methods and the effects of maceration on each value were tested statistically. We found that weights of the liver, thymus, and spleen markedly decrease with increasing maceration. The weights of the lungs, kidneys, and adrenals decreased modestly, whereas weights of the heart and brain changed only slightly. Body length increased slightly with maceration, whereas body weight and head circumference were unaffected. User-friendly charts and tables of mean values and standard deviations for nonmacerated and macerated fetuses are provided.

Key words: autopsy, body parameters, fetal growth, growth standards, maceration, organ weights

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INTRODUCTION

The aim of this study was to provide practically useful growth curves for nonmacerated and macerated fetuses. Charts of body dimensions and organ weights are essential tools in the evaluation of a fetal autopsy case. They must reflect the average weights and dimensions in the autopsy population examined. Standards can never accurately reflect the normal population because fetuses and infants that have died are never normal. Many sets of standards have been presented [1–8] and some of these are currently in use. Previous standards were inaccurate in regard to age of gestation [3,4]. For some standards, it is not clear whether the organs were weighed fresh or after fixation in formalin [2,8], although weight is influenced by fixation [9]. Criteria of exclusion have differed and many standards cover only a part of the pregnancy. The standards in a given hospital are dependent on many factors such as ethnic variation, social and economic statuses, and level of health care in the population. The autopsy procedure is also important. Therefore, it is relevant for large centers to provide standards based on their own material.

Previously macerated cases were excluded from most studies, and there has been only a weak emphasis on the effects of maceration on body parameters and organ weights, which is surprising due to the huge load of macerated cases in routine pathology.

METHODS

Materials

Data were extracted from records of a consecutive series of 1800 fetal and perinatal autopsies from the Copenhagen area performed in a 15-year period from 1989 to 2003. All autopsies were performed with the same standard procedure and were performed or supervised by 1 of the authors (N.G.). The gestational age of each case was registered as the clinically estimated gestational age in full weeks, which is based on parameters obtained by ultrasonography, which is routine in Danish pregnancies.

Exclusion criteria were (1) gestational age younger than 12 weeks at time of death, (2) newborns that lived longer than 24 h, (3) malformation, (4) known abnormal karyotype or any other genetic disease, (5) maternal or fetal infection (cases with neutrophils in the distal airways due to chorioamnionitis were included, but those with interstitial inflammation in the lungs or funisitis were excluded), (6) multiple pregnancies, (7) hydrops, and (8) formalin fixation before examination.

In macerated cases intrauterine postmortem changes were graded according to macroscopic external appearance by using a system set up in advance based on principles described previously [10–12]. Mild maceration was defined as bullae or skin slipping on extremities or small parts of the face or trunk. Moderate maceration was defined as extensive skin slipping and reddish discoloration of the skin and umbilicus. Marked maceration was defined as brownish, tan, or yellowish skin discoloration, overlapping cranial bones, loose joints, and/or mummification.

Autopsy method

Body weight and 4 body dimensions (crown-heel length, CH; crown-rump length, CR; foot length, FL; and head circumference) were recorded. After opening the corpse by an inverse Y-shaped incision, intestines were removed, followed by careful dissection and removal of the entire thymus. The heart was examined in situ and then the visceral block was removed, usually in 1 piece. After dissection of the block according to standard procedures, organs were weighed in the fresh state. Weights of the brain, lungs, liver, heart, thymus, spleen, kidneys, and adrenals were included in the study. Paired organs were weighed together. All weights were registered to an accuracy of 0.01 g. Samples were not taken before weighing. The brain was always carefully removed and placed directly into a can containing fixation fluid that was weighed in advance and immediately after ensuring an accurate weight of the entire brain also in macerated cases. When an organ could not be removed intact, the organ weight was not registered.

Statistical processing

Nonmacerated fetuses

Data from nonmacerated cases were used to provide standards as a user-friendly set of charts.

It was assumed that nonmacerated fetuses had died at the time of birth, i.e., the clinically estimated gestational age in weeks of gestation (GW) equals the estimated time of death (ETD). Males and females and liveborns and stillborns initially were computed separately. Raw data for each body and organ parameter were plotted against GW. Foot length and body weight were compared statistically as described below. No statistically significant difference was found between the sexes or between liveborns and stillborns. Therefore, these data were pooled.

The great variation in sample size for different GW values complicated the mathematical processing. For each parameter, mean value, standard deviation (SD), and 5th and 95th percentiles were modeled by using a procedure based on the method recommended by Altman and Chitty [13]. Based on the assumption that at each GW the data derived from a population with a normal distribution, 3 steps were performed. First, the adequate mathematical model to fit the mean value was chosen based on a combination of its statistical significance, coefficient of determination for multivariate analysis, and visual appearance of the curve. For most parameters, the chosen model was a quadratic polynomial regression. An exception was the spleen, to which a 4-degree polynomial regression was applied. Second, the SD was modeled as a function of GW by using the residuals between the observed values and the fitted mean curve. For each parameter, a linear or a quadratic regression model was chosen for the fitted SD, and then the mean curve was refitted to take into account an increase in SD with gestation. To avoid "peculiarities" such as negative values, some further adjustments had to be made on data with very small values. Third, the 5th and 95th percentiles were calculated as the fitted mean ± 1.645 × SD.

Macerated fetuses

Data from the 3 groups of macerated fetuses were compared and statistically analyzed in relation to the nonmacerated fetuses.

In the macerated cases, the clinically estimated gestational age based on information about last menstrual period did not reflect the time of death. Because FL is assumed to be the autopsy parameter that most accurately predicts the age of gestation at time of death [10,14], we designated a corrected gestational age (CorrGA) assumed to be equal to the ETD. The CorrGA was calculated from the FL by converting the equation of the mean FL from the nonmacerated group:

$$\text{CorrGA} = \{-b + [b2 - 4c(a - \text{FL})]^{1/2}\}/2c,$$

where *a, b,* and *c* are constants from the equation of the mean FL of nonmacerated cases. Cases with a CorrGA younger than 12 weeks were excluded from the study.

For each parameter from the macerated fetuses, mean value was modeled as described above and the constants of the equation of the chosen mathematical model for the markedly macerated cases were statistically compared with those of the nonmacerated group by using standard *t* tests. Whenever a statistically significant difference ($p < 0.05$) was found, data from cases of mild and moderate maceration were modeled and statistically compared with the nonmacerated cases. SD values for the macerated cases were the same as those for the nonmacerated cases.

RESULTS

The total number of cases studied was 796. Among these, 388 (49%) were nonmacerated, 82 (10%) were mildly macerated, 180 (23%) were moderately macerated, and 146 (18%) were markedly macerated. The clinically estimated age ranged from 12 to 43 GW. The macerated cases ranged in CorrGA age from 12 to 47 weeks. The number of cases for each GW value showed great variation (Table 1).

Values for some parameters were missing. Sample sizes for the parameters were 794 for FL, 788 for CR, 788 for CH, 763 for head circumference, 793 for body weight, 500 for brain weight, 706 for liver weight, 760 for lung weight, 759 for heart weight, 743 for thymus weight, 718 for spleen weight, 748 for kidney weight, and 746 for adrenal weight.

For nonmacerated cases, charts of the fitted mean for each parameter with 5th and 95th percentiles are presented in Figs. 1 to 13. A user-friendly presentation of all fitted means and SDs are listed in Tables 2 and 3.

For macerated cases, there was a slight but statistically significant increase in body lengths (CR and CH) of 3% to 8% in the markedly macerated versus nonmacerated cases. For cases of mild and moderate maceration, the changes were smaller but also statistically significant. For head circumference and body weight, there was no statistical difference between markedly macerated and nonmacerated cases.

Except for the mildly macerated thymus and kidneys, statistical differences were found for all groups of macerated organs. The liver was the organ in which weight was most severely affected by maceration because liver weight gradually decreased by 30% to 50% for the markedly macerated, 20% to 30% for the moderately macerated, and 0% to 17% for the mildly macerated compared with the nonmacerated. In addition, the thymus and spleen showed weight decreases of up to 50% in the markedly macerated. Lung weight was decreased up to 30%, kidney weight up to 20%, and adrenal weight up to 35%. Heart and brain weights were only slightly affected, showing differences less than 15%. Plots of fitted means by GW (GW = CorrGA = ETD in the macerated cases) comparing the 4 groups are presented in Fig. 14. Mean and SD values for organ weights that differed more than 10% to 20% from values of the nonmacerated fetuses are listed in Tables 2 and 3.

Table 1 Number of cases with no, mild, moderate, and marked maceration for each week of gestation

GW	No. cases	Mild	Moderate	Marked	Total
12	3	1	1	6	11
13	15	1	16	17	49
14	19		14	29	62
15	22	2	10	15	49
16	35	5	18	14	72
17	33	4	8	10	55
18	30		1	10	41
19	29	2	7	6	44
20	35	4	6	2	47
21	29		2	6	37
22	32		1	7	40
23	19	5	2		26
24	19	2	1	3	25
25	6	1	3	2	12
26	9		5	1	15
27	2	3	4	2	11
28	2		3	1	6
29		1	3	2	6
30	2	1	2	3	8
31	1	2	4	1	8
32	2		2	1	5
33	2		3	1	6
34	1		7		8
35	2	4	7	1	14
36	2	3	2		7
37	2	2	8	3	15
38	2	5	6		13
39	8	13	9		30
40	9	4	4		17
41	12	4	6	2	24
42	3	6	12	1	22
43	1	2	1		4
44		2	1		3
45		1	1		2
46					0
47		2			2
Total	388	82	180	146	796

GW; weeks of gestation.

DISCUSSION

The present study, which is based on autopsies of nonmacerated and macerated fetuses, provides new standards of growth parameters in the second and third trimesters. The validity of the results is supported by the uniformity in sampling of cases, autopsy procedure, and statistical method and ensures maximal strength in the third trimester, when the number of observations is smaller than in the second trimester. In this study we did not include considerations of cause of death because it is often unknown and because it would require extensive clinicopathologic correlation in each case. Therefore, different causes of death may have had different influences on body parameters and organ weights in the different groups.

For the nonmacerated cases we decided to present standards as plots with fitted mean values and 5th and 95th percentiles (Figs. 1 to 13) and as user-friendly tables of fitted mean and SD values (Tables 2 and 3). By comparing the present data with other standards, we found that the FL values are in accordance with those presented by Streeter in 1920 [1] and with the data of Gruenwald and Minh [2], but that the FL values of this study are slightly longer than those of Singer et al. [7]. In the second trimester, the present body weights correspond well with those of most other standards [3,6–8]. In the third trimester, the body weights of this study are somewhat higher than in some previous studies, especially close to term [2,7], but there is a good accordance with a recent set of standards [6]. This may be due to large variations in the observations in the third trimester; however, because the body weight means of this study are even lower than ultrasound-determined body weight means in our background population [15], we believe that the difference is due to variations in fetal growth rate in different populations. This correlates well with our personal observation that third-trimester fetuses in our part of Scandinavia in general are larger than expected when using previous standards of body parameter and organ weight.

The present study of the effects of maceration is unique in the detailed comparison of macerated with nonmacerated fetuses. We defined grades of maceration based on descriptions of external intrauterine postmortal changes from textbooks [10,11] and from the study of stillborns by Genest and Singer [12]. To prove that these signs reflected increasing periods of intrauterine death from mild to marked maceration, the regression lines of the FL values as a function of clinically estimated gestational age were plotted for the nonmacerated fetuses and the 3 groups of macerated fetuses (not presented). By observing the parallel displacement of the regression line, the average period of intrauterine death could be

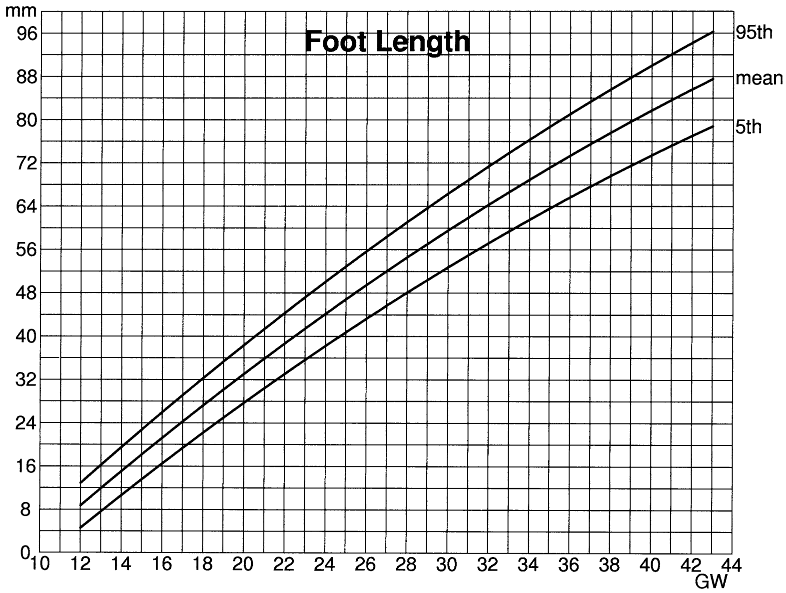

Figure 1 Plot of fitted mean curve for FL from nonmacerated cases with 5th and 95th percentiles.

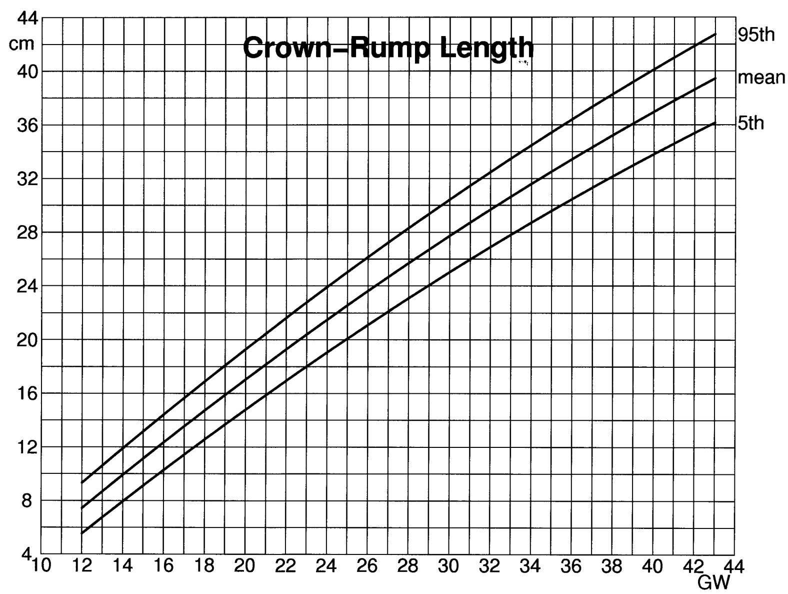

Figure 2 Plot of fitted mean curve for CR from nonmacerated cases with 5th and 95th percentiles.

approximated. The markedly macerated fetuses had been dead in utero for approximately 4 weeks, moderately macerated fetuses had been dead up to 2 weeks on average, and the mildly macerated showed no deviation, which means that they had been dead no longer than a few days. By using the FL value to designate a CorrGA for each fetus to reflect the ETD, we ensured that the 4 groups were comparable. The larger variation in the values by increasing gestation, which is present for all parameters including the FL, resulted in a few macerated cases with a CorrGA of up to 47 weeks. These were retained for statistical processing, but only values from 12 to 43 weeks are presented in the plots and tables.

For the macerated cases, the study showed only small differences in fetal body parameters. Body lengths (CR and CH) increased slightly with marked maceration (Fig. 14). Body weight and head circumference were not significantly affected. It also showed that organ weights decrease with maceration, but with striking differences for the various organs.

The effects of maceration on body dimensions and organ weights have been discussed only briefly in some textbooks [10,11]. With macera-

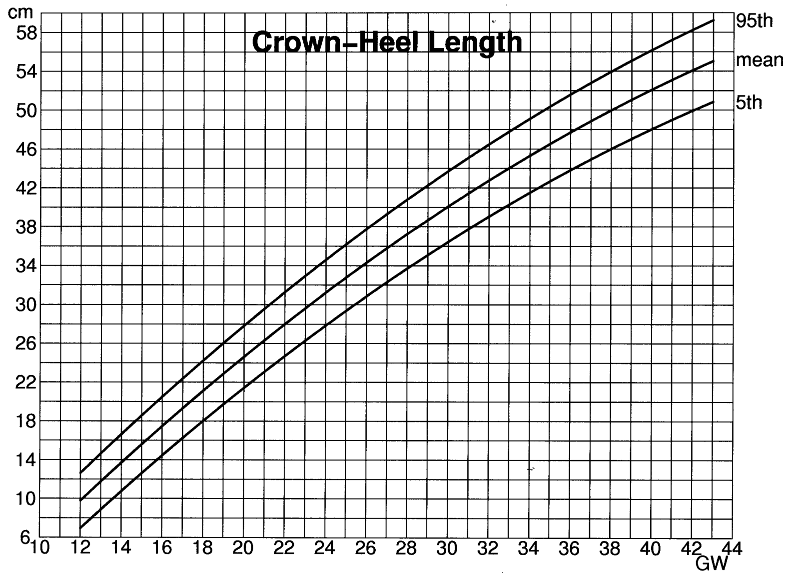

Figure 3 Plot of fitted mean curve for CH from nonmacerated cases with 5th and 95th percentiles.

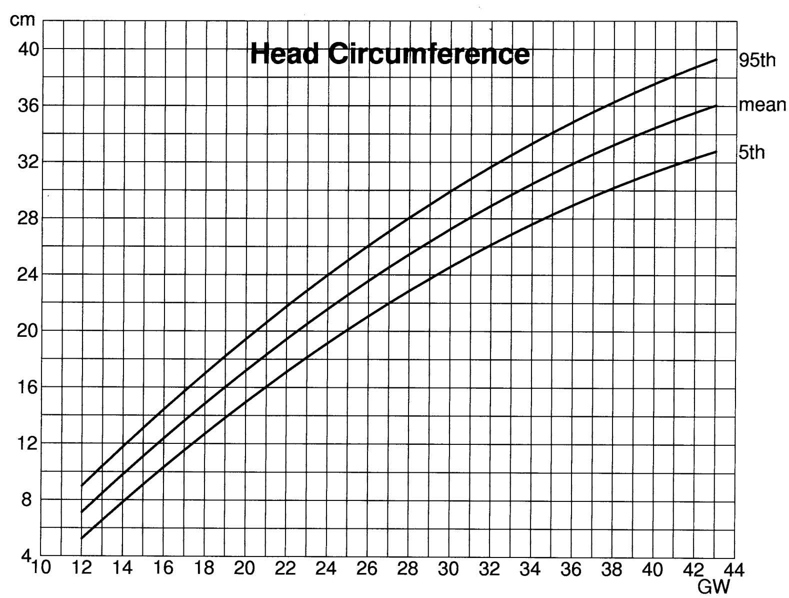

Figure 4 Plot of fitted mean curve for head circumference from nonmacerated cases with 5th and 95th percentiles.

tion, body lengths have been stated to increase and organ weights to decrease. The weights of intra-abdominal organs and the brain have been stated to be the most severely affected [10]. It was beyond the scope of this study to examine the physiologic mechanisms of maceration; however, the present study supports the common assumption that organ weights decrease with maceration and shows that the liver, thymus, and spleen weights are the most severely affected and that the heart and brain weights are only slightly affected. Brain weight is very dependent on the autopsy technique. We always remove the brain carefully to ensure that even a macerated and liquefied brain is weighed in toto. The study also shows that body weight is not affected by maceration in the present type of material. Therefore, it seems reasonable to assume that with maceration some organs lose fluid and/or tissue into the body cavities. The different amounts of fluid loss by different organs cannot be explained by the site of the organ or by the severity of microscopic autolytic changes. Therefore, the organs must differ by unknown mechanisms in their ability to bind water after death due to their specific histology and chemical composition.

For the liver, lungs, and thymus, the study shows a clear picture of a consistent decrease in weight throughout pregnancy with increasing

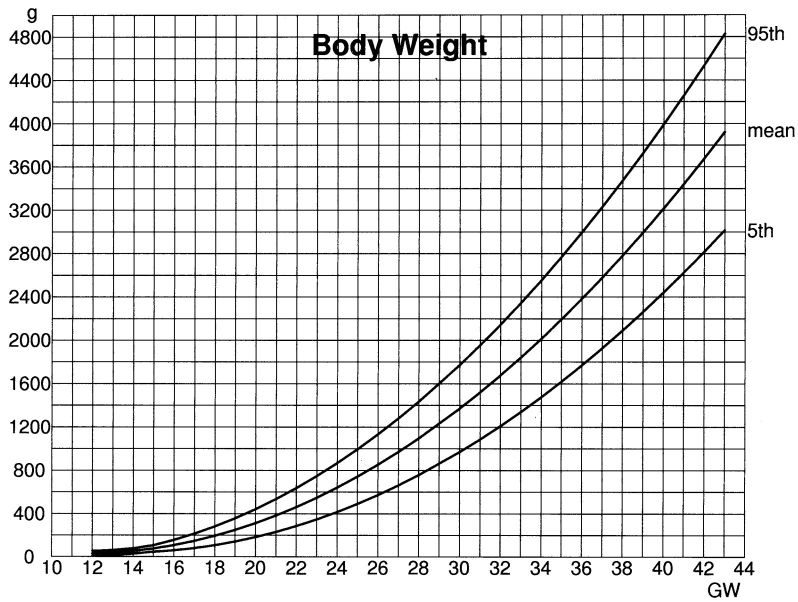

Figure 5 Plot of fitted mean curve for body weight from nonmacerated cases with 5th and 95th percentiles.

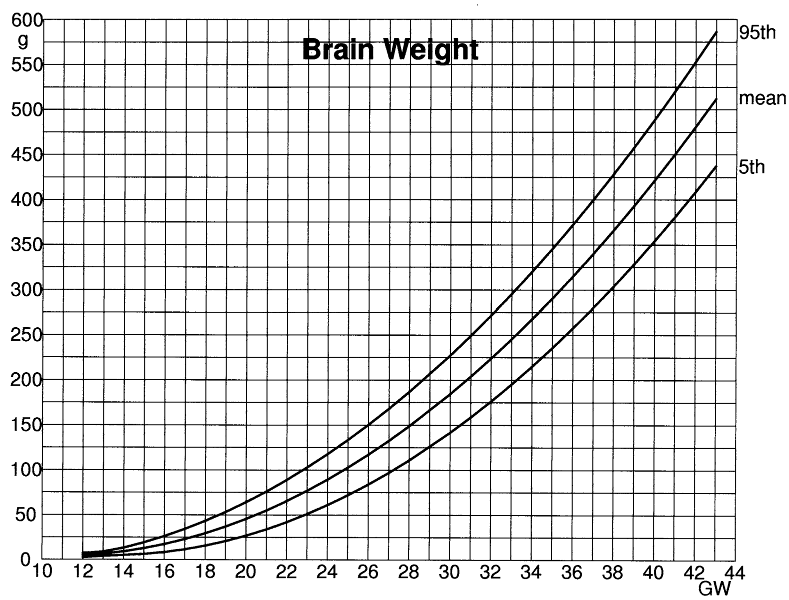

Figure 6 Plot of fitted mean curve for brain weight from nonmacerated cases with 5th and 95th percentiles.

grade of maceration. For the spleen, kidneys, and adrenals, the picture is blurred by overlapping curves (Fig. 14). The reason for this may be the large variation in the distribution of values for these organs. A larger sample might clarify the picture to the same level as for the liver, thymus, and lungs.

The practical effect of this study is obvious. When evaluating organ weights, some pathologists use ratios of organ weight to body weight [16]. In addition, organ/organ ratios are in use, such as the liver/brain ratio used to estimate the presence of asymmetric growth retardation [16]. As an example, according to the present data, the liver/brain ratios on average are 1:2.6 in the nonmacerated fetus and 1:4.5 in the markedly macerated fetus. This study clearly shows that organ/organ and organ weight/body weight ratios differ in nonmacerated and macerated fetuses.

Although there are statistical differences between at least the markedly macerated and the nonmacerated in all parameters except for body weight and head circumference, many of these differences are too small to justify the use of a separate set of standards. Due to the large SD values in organ weights in general, we believe

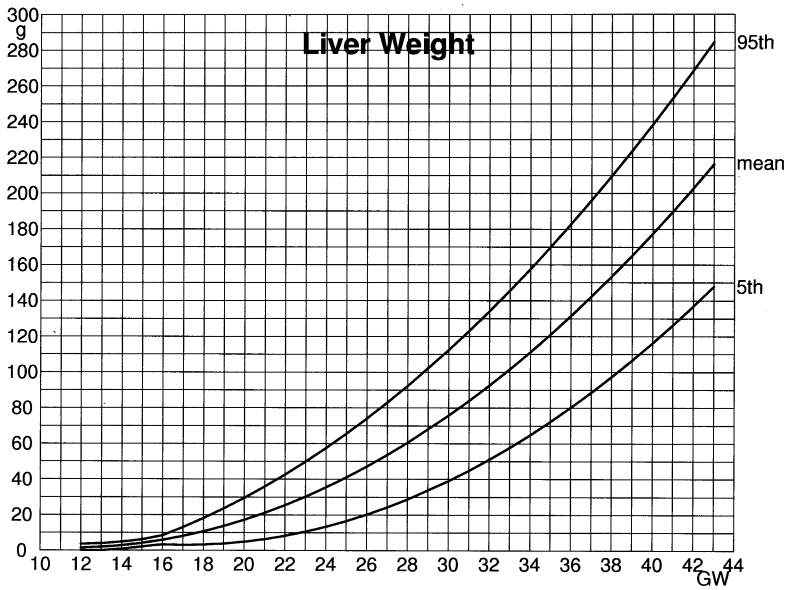

Figure 7 Plot of fitted mean curve for liver weight from nonmacerated cases with 5th and 95th percentiles.

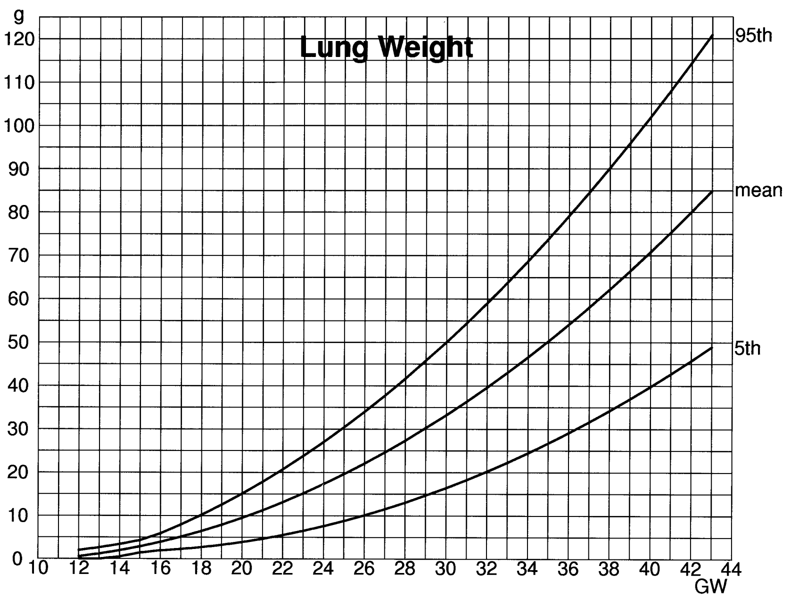

Figure 8 Plot of fitted mean curve for lung weight from nonmacerated cases with 5th and 95th percentiles.

using separate standards for organ weights of nonmacerated fetuses are necessary only when they differ more than 10% to 20% from the values of the nonmacerated fetuses. Thus, in practice, we recommend using separate standards only for liver, lungs, thymus, spleen, kidney, and adrenal weights in moderately and markedly macerated fetuses. Accordingly, only these values are included in the user-friendly Tables 2 and 3. We found no justification to use separate standards for body parameters and body weight.

When evaluating a fetal autopsy, different approaches are possible. The SD or percentiles can be used to decide whether a specific measurement lies within the normal range for a specific age range, but, because of the great variability in organ weights, important deviations from expected values may be overlooked. Therefore, our approach is to study the pattern of organ weights by relating them to the fitted mean values presented in Tables 2 and 3. The estimated gestational age is determined from body measurements, mainly the FL. For each organ we record the GW appropriate to the actual organ weight. In standard cases, the variation in this age measurement is small. When the GW appropriated to an organ differs more

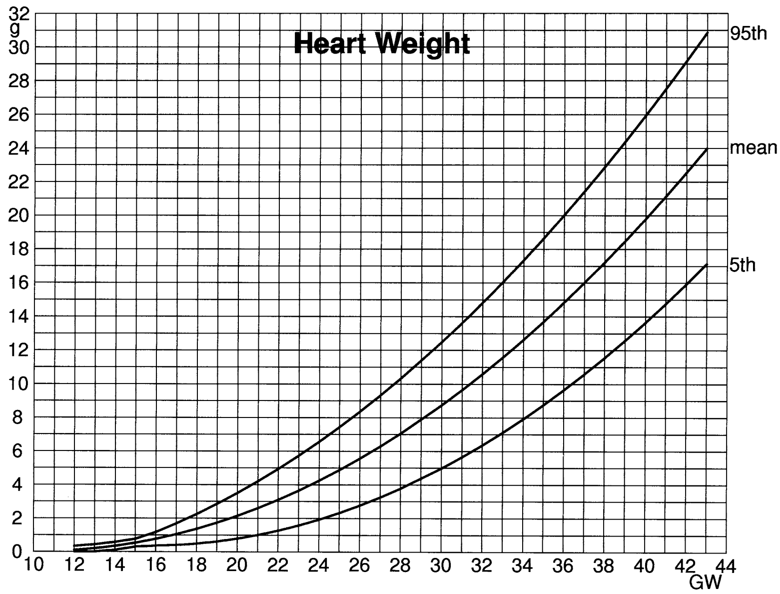

Figure 9 Plot of fitted mean curve for heart weight from nonmacerated cases with 5th and 95th percentiles.

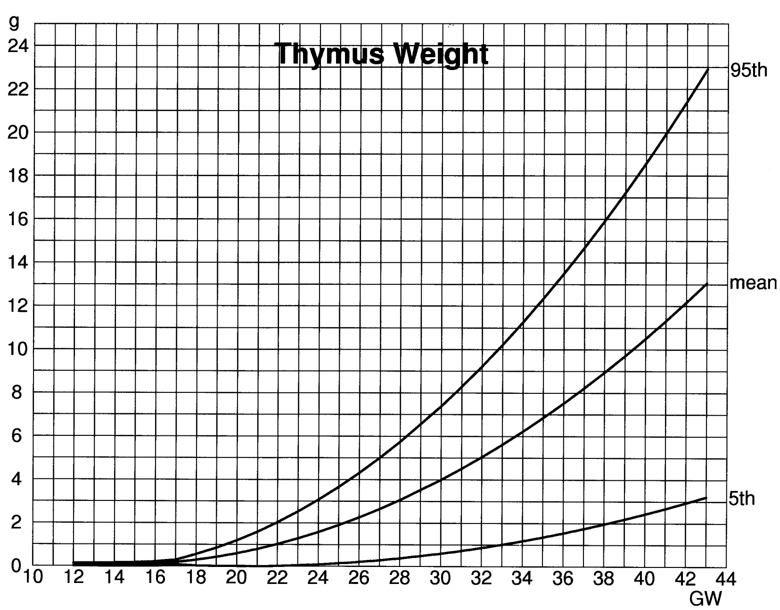

Figure 10 Plot of fitted mean curve for thymus weight from nonmacerated cases with 5th and 95th percentiles.

than 2 weeks from other measurements and weights, we consider this pathologic, even if the actual weight lies within the normal range.

This study provides new insight into the effects of maceration on body parameters and organ weights. These new standards can be an important and useful tool in countries with populations and health care comparable to the Danish. The findings on macerated stillborns likely can be extrapolated to standards from other populations, and we expect that the use of the present findings will increase the accuracy of the evaluation of fetal and perinatal autopsies in macerated cases.

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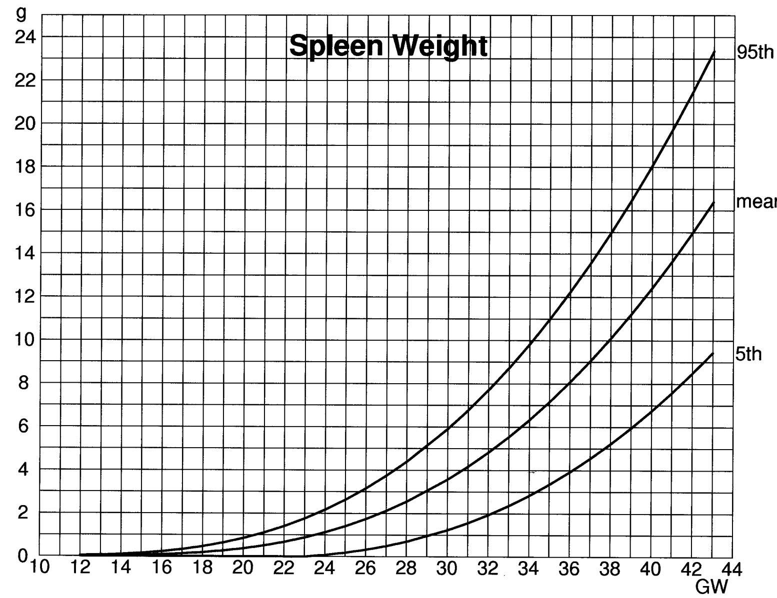

Figure 11 Plot of fitted mean curve for spleen weight from nonmacerated cases with 5th and 95th percentiles.

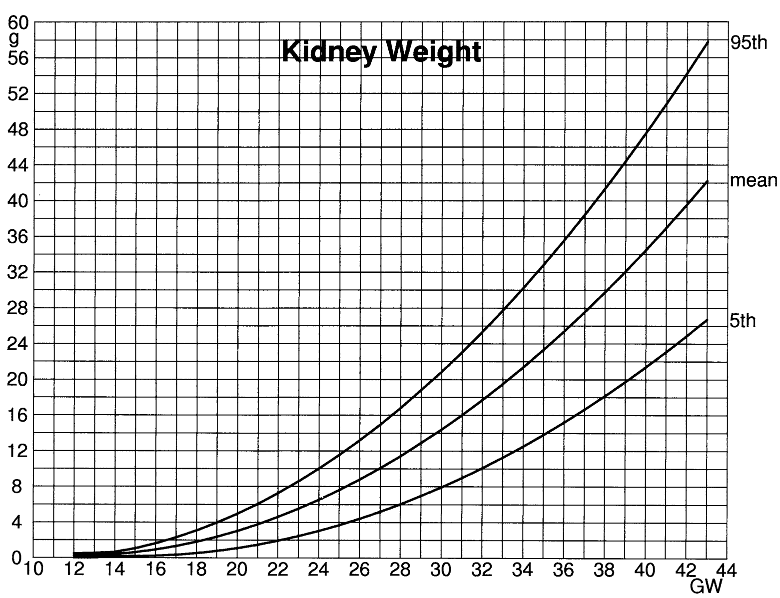

Figure 12 Plot of fitted mean curve for kidney weight from nonmacerated cases with 5th and 95th percentiles.

contribution in the statistical processing of the present data.

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Table 2 Fetal autopsy standards at 12 to 27 weeks of gestation

		FL	CR	CH	HDC	Body	Brain	Liver			Lungs		Heart	Thymus			Spleen		Kidneys		Adrenals	
Age (GW)	Maceration[a]	0–3	0–3	0–3	0–3	0–3	0–3	0–1	2	3	0–1	2–3	0–3	0–1	2	3	0–1	2–3	0–1	2–3	0–1	2–3
		mm	cm	cm	cm	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g
12	Mean	9	7.4	9.8	7.1	29.6	4.8	1.5	1.4	1.3	0.6	0.9	0.10	0.03			0.01		0.25	0.19	0.04	0.11
	SD	*3*	*1.1*	*1.7*	*1.1*	*14.9*	*1.4*	*1.2*	*1.2*	*1.2*	*0.9*	*0.9*	*0.14*	*0.06*			*0.02*		*0.15*	*0.15*	*0.18*	*0.18*
13	Mean	12	8.7	11.8	8.5	37.4	6.5	2.0	1.7	1.7	1.2	1.2	0.20	0.04			0.02	0.08	0.3	0.2	0.17	0.17
	SD	*3*	*1.2*	*1.8*	*1.2*	*14.9*	*1.4*	*1.2*	*1.2*	*1.2*	*0.9*	*0.9*	*0.14*	*0.06*			*0.03*	*0.03*	*0.1*	*0.1*	*0.18*	*0.18*
14	Mean	15	9.9	13.7	9.8	53.0	9.1	2.9	2.4	2.3	2.0	1.5	0.3	0.05	0.07	0.05	0.04	0.14	0.4	0.3	0.3	0.2
	SD	*3*	*1.2*	*1.8*	*1.2*	*14.9*	*2.5*	*1.2*	*1.2*	*1.2*	*0.9*	*0.9*	*0.1*	*0.06*	*0.06*	*0.06*	*0.04*	*0.04*	*0.1*	*0.1*	*0.2*	*0.2*
15	Mean	18	11.1	15.6	11.1	76.5	12.7	4.2	3.3	3.2	2.9	2.1	0.5	0.07	0.08	0.06	0.06	0.17	0.6	0.5	0.5	0.3
	SD	*3*	*1.2*	*1.8*	*1.2*	*18.5*	*3.9*	*1.2*	*1.2*	*1.2*	*0.9*	*0.9*	*0.1*	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*	*0.3*	*0.3*	*0.2*	*0.2*
16	Mean	21	12.4	17.5	12.4	108	17.3	5.9	4.5	4.2	3.9	2.7	0.8	0.11	0.12	0.09	0.09	0.17	0.9	0.8	0.6	0.4
	SD	*3*	*1.3*	*1.8*	*1.3*	*41*	*5.4*	*1.5*	*1.5*	*1.5*	*1.2*	*1.2*	*0.2*	*0.06*	*0.06*	*0.06*	*0.08*	*0.08*	*0.4*	*0.4*	*0.3*	*0.3*
17	Mean	24	13.5	19.3	13.6	147	22.9	8.1	6.1	5.4	5.1	3.5	1.0	0.18	0.18	0.12	0.13	0.16	1.3	1.1	0.8	0.5
	SD	*3*	*1.3*	*1.9*	*1.3*	*53*	*6.9*	*3.0*	*3.0*	*3.0*	*1.7*	*1.7*	*0.4*	*0.06*	*0.06*	*0.06*	*0.12*	*0.12*	*0.6*	*0.6*	*0.4*	*0.4*
18	Mean	27	14.7	21.1	14.8	194	29.4	10.7	7.9	6.8	6.4	4.4	1.4	0.3	0.3	0.2	0.19	0.15	1.8	1.5	1.0	0.7
	SD	*3*	*1.3*	*1.9*	*1.3*	*65*	*8.4*	*4.5*	*4.5*	*4.5*	*2.3*	*2.3*	*0.5*	*0.2*	*0.2*	*0.2*	*0.17*	*0.17*	*0.8*	*0.8*	*0.4*	*0.4*
19	Mean	30	15.9	22.9	16.0	249	37.0	13.8	10.1	8.4	7.9	5.4	1.7	0.4	0.4	0.3	0.3	0.15	2.4	2.0	1.2	0.8
	SD	*3*	*1.3*	*1.9*	*1.3*	*78*	*9.8*	*6.0*	*6.0*	*6.0*	*2.8*	*2.8*	*0.7*	*0.3*	*0.3*	*0.3*	*0.2*	*0.22*	*1.0*	*1.0*	*0.5*	*0.5*
20	Mean	33	17.0	24.6	17.2	312	45.5	17.2	12.5	10.2	9.5	6.5	2.1	0.6	0.5	0.3	0.4	0.17	3.0	2.5	1.4	1.0
	SD	*3*	*1.4*	*1.9*	*1.4*	*92*	*11.3*	*7.5*	*7.5*	*7.5*	*3.4*	*3.4*	*0.8*	*0.4*	*0.4*	*0.4*	*0.3*	*0.29*	*1.2*	*1.2*	*0.6*	*0.6*
21	Mean	36	18.2	26.3	18.3	382	55.0	21.1	15.2	12.3	11.2	7.8	2.6	0.8	0.7	0.4	0.5	0.22	3.8	3.1	1.7	1.2
	SD	*3*	*1.4*	*2.0*	*1.4*	*107*	*12.8*	*9.0*	*9.0*	*9.0*	*4.0*	*4.0*	*1.0*	*0.5*	*0.5*	*0.5*	*0.4*	*0.36*	*1.4*	*1.4*	*0.7*	*0.7*
22	Mean	39	19.3	28.0	19.4	461	65.4	25.5	18.2	14.5	13.1	9.2	3.1	1.0	0.9	0.6	0.7	0.3	4.6	3.8	1.9	1.4
	SD	*3*	*1.4*	*2.0*	*1.4*	*122*	*14.3*	*10.4*	*10.4*	*10.4*	*4.6*	*4.6*	*1.1*	*0.6*	*0.6*	*0.6*	*0.4*	*0.4*	*1.6*	*1.6*	*0.8*	*0.8*
23	Mean	41	20.4	29.6	20.5	547	76.9	30.2	21.6	16.9	15.1	10.7	3.6	1.3	1.1	0.7	0.9	0.4	5.5	4.6	2.2	1.6
	SD	*4*	*1.5*	*2.0*	*1.4*	*122*	*15.8*	*11.9*	*11.9*	*11.9*	*5.3*	*5.3*	*1.3*	*0.8*	*0.8*	*0.8*	*0.5*	*0.5*	*1.9*	*1.9*	*0.8*	*0.8*
24	Mean	44	21.5	31.2	21.6	641	89.3	35.4	25.2	19.5	17.3	12.4	4.2	1.6	1.3	0.8	1.1	0.6	6.5	5.5	2.5	1.8
	SD	*4*	*1.5*	*2.0*	*1.5*	*137*	*17.2*	*13.4*	*13.4*	*13.4*	*5.9*	*5.9*	*1.4*	*0.9*	*0.9*	*0.9*	*0.6*	*0.6*	*2.1*	*2.1*	*0.9*	*0.9*
25	Mean	47	22.6	32.8	22.6	743	103	41.1	29.1	22.3	19.6	14.1	4.9	1.9	1.6	1.0	1.4	0.8	7.6	6.4	2.8	2.0
	SD	*4*	*1.5*	*2.1*	*1.5*	*154*	*19*	*14.9*	*14.9*	*14.9*	*6.6*	*6.6*	*1.6*	*1.1*	*1.1*	*1.1*	*0.7*	*0.7*	*2.4*	*2.4*	*1.0*	*1.0*
26	Mean	50	23.6	34.3	23.6	853	117	47.1	33.4	25.3	22.0	16.0	5.6	2.3	1.9	1.2	1.7	1.1	8.8	7.4	3.1	2.3
	SD	*4*	*1.5*	*2.1*	*1.5*	*171*	*20*	*16.4*	*16.4*	*16.4*	*7.3*	*7.3*	*1.7*	*1.2*	*1.2*	*1.2*	*0.9*	*0.9*	*2.7*	*2.7*	*1.1*	*1.1*
27	Mean	52	24.7	35.8	24.5	971	133	53.6	37.9	28.6	24.6	18.0	6.3	2.6	2.2	1.4	2.1	1.4	10.1	8.4	3.4	2.5
	SD	*4*	*1.6*	*2.1*	*1.5*	*188*	*22*	*17.9*	*17.9*	*17.9*	*8.0*	*8.0*	*1.8*	*1.4*	*1.4*	*1.4*	*1.0*	*1.0*	*3.0*	*3.0*	*1.2*	*1.2*

CH, crown-heel length; CR, crown-rump length; FL, foot length; GW, weeks of gestation; HDC, head circumference; SD, standard deviation.

[a]0 = none, 1 = mild, 2 = moderate, 3 = marked.

Table 3 Fetal autopsy standards at 28 to 43 weeks of gestation

		FL	CR	CH	HDC	Body	Brain	Liver			Lungs		Heart	Thymus			Spleen		Kidneys		Adrenals	
Age (GW)	Maceration[a]	0–3	0–3	0–3	0–3	0–3	0–3	0–1	2	3	0–1	2–3	0–3	0–1	2	3	0–1	2–3	0–1	2–3	0–1	2–3
		mm	cm	cm	cm	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g
28	Mean	55	25.7	37.3	25.5	1096	149	60.6	42.7	32.0	27.4	20.2	7.1	3.1	2.5	1.6	2.5	1.8	11.4	9.6	3.7	2.8
	SD	*4*	*1.6*	*2.2*	*1.6*	*206*	*23*	*19.3*	*19.3*	*19.3*	*8.7*	*8.7*	*2.0*	*1.6*	*1.6*	*1.6*	*1.1*	*1.1*	*3.3*	*3.3*	*1.3*	*1.3*
29	Mean	57	26.7	38.7	26.4	1230	166	67.9	47.8	35.6	30.2	22.5	7.9	3.5	2.9	1.8	3.0	2.2	12.9	10.8	4.1	3.1
	SD	*4*	*1.6*	*2.2*	*1.6*	*225*	*25*	*20.8*	*20.8*	*20.8*	*9.5*	*9.5*	*2.1*	*1.8*	*1.8*	*1.8*	*1.3*	*1.3*	*3.6*	*3.6*	*1.4*	*1.4*
30	Mean	60	27.7	40.1	27.2	1371	185	75.7	53.3	39.4	33.2	24.9	8.7	4.0	3.3	2.1	3.6	2.7	14.4	12.1	4.5	3.4
	SD	*4*	*1.6*	*2.2*	*1.6*	*244*	*26*	*22.3*	*22.3*	*22.3*	*10.2*	*10.2*	*2.3*	*2.1*	*2.1*	*2.1*	*1.4*	*1.4*	*3.9*	*3.9*	*1.4*	*1.4*
31	Mean	62	28.7	41.4	28.1	1520	204	83.9	59.0	43.4	36.3	27.4	9.6	4.5	3.7	2.3	4.2	3.3	16.0	13.4	4.8	3.8
	SD	*4*	*1.7*	*2.2*	*1.7*	*264*	*28*	*23.8*	*23.8*	*23.8*	*11.0*	*11.0*	*2.4*	*2.3*	*2.3*	*2.3*	*1.6*	*1.6*	*4.3*	*4.3*	*1.5*	*1.5*
32	Mean	64	29.7	42.8	28.9	1677	224	92.6	65.0	47.6	39.6	30.0	10.6	5.0	4.2	2.6	4.8	3.9	17.7	14.9	5.2	4.1
	SD	*4*	*1.7*	*2.3*	*1.7*	*285*	*29*	*25.3*	*25.3*	*25.3*	*11.8*	*11.8*	*2.6*	*2.5*	*2.5*	*2.5*	*1.8*	*1.8*	*4.6*	*4.6*	*1.6*	*1.6*
33	Mean	67	30.6	44.0	29.7	1842	245	102	71.3	52.1	43.0	32.8	11.6	5.6	4.6	2.9	5.5	4.5	19.5	16.4	5.6	4.5
	SD	*4*	*1.7*	*2.3*	*1.7*	*306*	*31*	*27*	*26.7*	*26.7*	*12.6*	*12.6*	*2.7*	*2.8*	*2.8*	*2.8*	*1.9*	*1.9*	*5.0*	*5.0*	*1.7*	*1.7*
34	Mean	69	31.6	45.3	30.5	2015	268	111	77.9	56.7	46.6	35.7	12.6	6.2	5.1	3.2	6.3	5.2	21.4	18.0	6.0	4.8
	SD	*4*	*1.8*	*2.3*	*1.7*	*328*	*32*	*28*	*28.2*	*28.2*	*13.5*	*13.5*	*2.9*	*3.1*	*3.1*	*3.1*	*2.1*	*2.1*	*5.4*	*5.4*	*1.8*	*1.8*
35	Mean	71	32.5	46.5	31.2	2195	291	121	84.8	61.5	50.3	38.7	13.7	6.9	5.7	3.5	7.2	6.0	23.3	19.6	6.5	5.2
	SD	*5*	*1.8*	*2.3*	*1.8*	*350*	*33*	*30*	*29.7*	*29.7*	*14.3*	*14.3*	*3.0*	*3.3*	*3.3*	*3.3*	*2.3*	*2.3*	*5.8*	*5.8*	*1.9*	*1.9*
36	Mean	73	33.4	47.7	31.9	2383	315	132	92.1	66.5	54.1	41.9	14.8	7.5	6.2	3.8	8.1	6.7	25.4	21.4	6.9	5.6
	SD	*5*	*1.8*	*2.4*	*1.8*	*373*	*35*	*31*	*31.2*	*31.2*	*15.2*	*15.2*	*3.2*	*3.6*	*3.6*	*3.6*	*2.5*	*2.5*	*6.2*	*6.2*	*2.0*	*2.0*
37	Mean	76	34.3	48.9	32.6	2580	340	142	100	71.7	58.1	45.1	16.0	8.2	6.8	4.2	9.1	7.5	27.5	23.2	7.4	6.0
	SD	*5*	*1.8*	*2.4*	*1.8*	*397*	*36*	*33*	*33*	*32.7*	*16.1*	*16.1*	*3.3*	*3.9*	*3.9*	*3.9*	*2.7*	*2.7*	*6.6*	*6.6*	*2.1*	*2.1*
38	Mean	78	35.2	50.0	33.2	2784	366	154	107	77.2	62.2	48.5	17.2	8.9	7.4	3.9	10.1	8.3	29.8	25.0	7.8	6.5
	SD	*5*	*1.9*	*2.4*	*1.8*	*421*	*38*	*34*	*34*	*34.2*	*17.0*	*17.0*	*3.4*	*4.2*	*4.2*	*4.2*	*3.0*	*3.0*	*7.1*	*7.1*	*2.2*	*2.2*
39	Mean	80	36.1	51.1	33.8	2996	394	165	116	82.8	66.5	52.1	18.5	9.7	8.0	5.0	11.2	9.1	32.1	27.0	8.3	6.9
	SD	*5*	*1.9*	*2.4*	*1.9*	*446*	*39*	*36*	*36*	*35.6*	*18.0*	*18.0*	*3.6*	*4.6*	*4.6*	*4.6*	*3.2*	*3.2*	*7.5*	*7.5*	*2.3*	*2.3*
40	Mean	82	37.0	52.1	34.4	3215	422	177	124	88.6	70.9	55.7	19.8	10.5	8.6	5.4	12.4	9.9	34.5	29.0	8.8	7.4
	SD	*5*	*1.9*	*2.5*	*1.9*	*471*	*41*	*37*	*37*	*37.1*	*18.9*	*18.9*	*3.7*	*4.9*	*4.9*	*4.9*	*3.4*	*3.4*	*8.0*	*8.0*	*2.4*	*2.4*
41	Mean	84	37.8	53.1	35.0	3443	451	190	133	94.6	75.4	59.5	21.2	11.3	9.3	5.8	13.7	10.7	37.0	31.1	9.3	7.9
	SD	*5*	*1.9*	*2.5*	*1.9*	*497*	*42*	*39*	*39*	*38.6*	*19.9*	*19.9*	*3.9*	*5.3*	*5.3*	*5.3*	*3.7*	*3.7*	*8.4*	*8.4*	*2.5*	*2.5*
42	Mean	86	38.6	54.1	35.5	3678	481	203	142	101	80.1	63.4	22.5	12.2	10.0	6.2	15.0	11.5	39.6	33.3	9.9	8.4
	SD	*5*	*2.0*	*2.5*	*2.0*	*524*	*44*	*40*	*40*	*40*	*20.9*	*20.9*	*4.0*	*5.6*	*5.6*	*5.6*	*4.0*	*4.0*	*8.9*	*8.9*	*2.6*	*2.6*
43	Mean	88	39.4	55.0	36.0	3922	512	216	151	107	84.9	67.4	24.0	13.1	10.7	6.6	16.4	12.2	42.2	35.5	10.4	8.9
	SD	*5*	*2.0*	*2.5*	*2.0*	*551*	*45*	*42*	*42*	*42*	*21.9*	*21.9*	*4.2*	*6.0*	*6.0*	*6.0*	*4.2*	*4.2*	*9.4*	*9.4*	*2.7*	*2.7*

CH, crown-heel length; CR, crown-rump length; FL, foot length; GW, weeks of gestation; HDC, head circumference; SD, standard deviation.
0 = none, 1 = mild, 2 = moderate, 3 = marked.

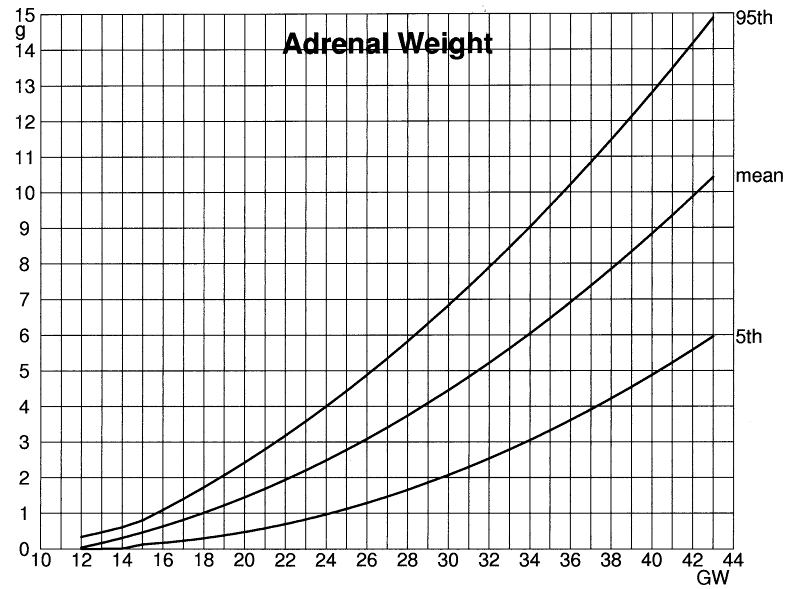

Figure 13 Plot of fitted mean curve for adrenal weight from nonmacerated cases with 5th and 95th percentiles.

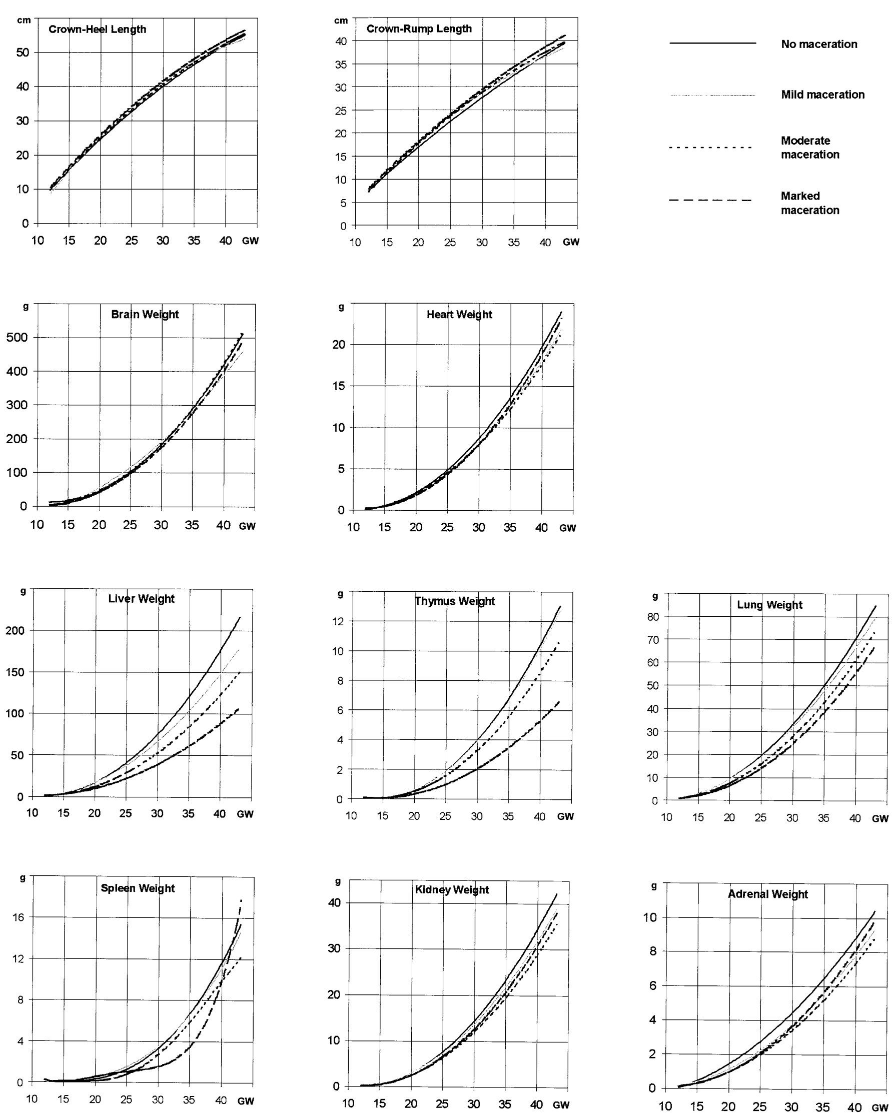

Figure 14 Plots of fitted mean curves for nonmacerated and macerated cases for each body parameter and organ weight, except body weight and head circumference, where no statistical difference was found.

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