

**Spleen weight variation in population of Lithuania – a retrospective study and literature review**

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## **ABSTRACT**

**Background.** The weight of organs is often used to determine whether a pathological condition is present. Spleen weight can vary and correlate with anthropometric indicators and an individual's gender, with the spleen being larger in men compared to women and in heavier individuals. The correlation between age and spleen weight is significant as it aids in understanding age-related changes in spleen function and pathology.

**The aim** of this article is to analyze statistical data and literature on splenic hypertrophy and to find out if there is a correlation between age and spleen weight based on an autopsy study and to discuss three cases of splenic hypertrophy.

**Materials and methods:** This research was designed as a retrospective study. The study sample consisted of 371 autopsy cases from 2016 to 2023.

**Results.** In the entire sample, the average weight of the spleen was 149.7 g. The average spleen weight of men was not significantly different from the average spleen weight of women. There was a statistically significant but weak correlation between the spleen weight and height of the deceased. A weak negative correlation was found between spleen weight and the age of the deceased.

**Conclusions.** As the weight of the spleen can vary between age groups, it is important to know the normal parameters of this to suspect and correctly diagnose pathology. If a larger than normal spleen is detected, it is worth assessing whether the patient has any comorbidities and accompanying significant pathology.

**Keywords:** spleen, splenomegaly, autopsy, pathology, forensic medicine.

## **1. Introduction**

Organ weights are commonly used to assess the presence of pathological conditions. Nonetheless, there is a dearth of precise definitions of aberrant organ weights in the medical literature. A large brain could be a sign of cerebral edema, while a large spleen might be a sign of a possible hematologic cancer. It has been suggested that normal organ weights should only be evaluated in a population of healthy individuals who passed away unexpectedly from traumatic causes to be sufficiently and properly determined (1). With these limitations in mind, we conducted a study analyzing cases of sudden death, excluding those with medical pathology. The correlation between age and spleen weight is significant as it aids in understanding age-related changes in spleen function and pathology. The aim of this article is to analyze statistical data and the literature on splenic hypertrophy in different age groups and find out if there is a correlation between age and spleen weight via autopsy study. This article will also examine the differences and discuss three spleen hypertrophy cases.

The spleen is a coffee-bean-shaped, dark-purplish, highly vascular organ of mesodermal origin that is located between the left kidney, the diaphragm, the fundus of the stomach, and the splenic flexure of the colon at the level of the eighth to eleventh ribs in the left upper quadrant of the abdomen (2). The typical weight range of the spleen for an adult is from 70 grams to 200 grams. Enlargement is defined as a spleen greater than 12 cm in length or over 400 grams in weight. Massive splenomegaly refers to even greater enlargement, with a spleen size larger than 20 cm in length or over 1 kg in weight (3). The size and weight of the spleen may vary and correlate with anthropometric indicators and sex of an individual, with larger spleen sizes seen in men compared to women and in

heavier or taller individuals. Also, spleen parameters can vary depending on race, genetic factors, and disease (4,5,6).

## **2. Materials and methods**

This research was designed as a retrospective study. The study sample consisted of 371 autopsy cases from 2016 to 2023. The State Forensic Medicine Service (Lithuania) provided the autopsy data for 371 cases. In every case, information was provided by the law enforcement agencies, including the possible crime location, time of death, and presumed death mechanism. The study data were analyzed by dividing all subjects into nine age groups at ten-year intervals. Spleen weights were assessed for all sudden deaths in all age groups during the specified period. The spleen was separated from the organ complex at autopsy and weighed and measured for each of the deceased. The exclusion criterion was the presence of advanced putrefaction - autolysis. Such cases were excluded from the sample.

The collected data was processed using R software. The Shapiro-Wilk test was used to determine whether the data was normally distributed. The Student's t-test was used to assess the statistical significance of differences in continuous variables between the study groups. Spearman's correlation coefficients were assessed. A weak correlation was defined as R-values  $< 0.39$ ; a moderate correlation with R-values from 0.40 to 0.69; and a strong correlation with R-values  $> 0.70$ . Additionally, 95% confidence intervals were calculated. Differences with p values less than 0.05 were considered significant.

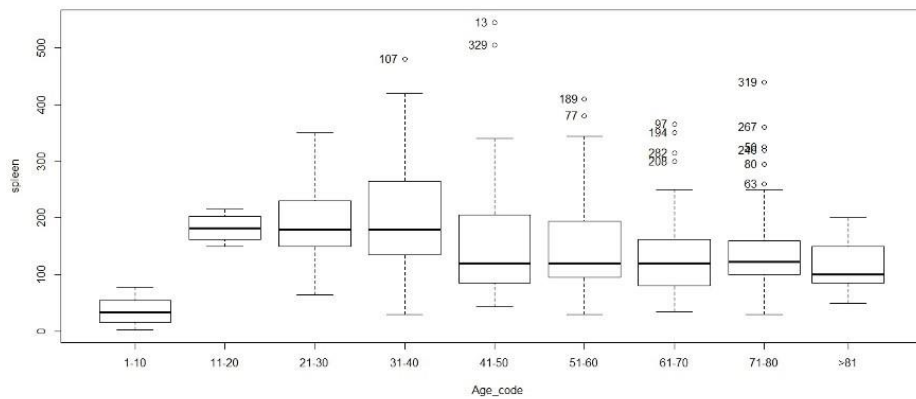
In all cases, the deceased were subjected to full autopsies with tests for ethyl alcohol and its surrogates, as well as toxicological tests for the detection of drugs and other potent substances in the blood and urine.

Histological sections were cut and prepared for routine light microscopy. Histomorphological features of the sample were examined using hematoxylin and eosin (H&E) staining. Perls' Prussian blue reaction was used to detect ferric iron, and Masson's trichrome staining was used for collagen fibers. The H&E staining process consists of several stages: the removal of paraffin, staining, and dehydration. Sections are deparaffinated by keeping them sequentially in absolute alcohol, 96% and 70% ethanol, and distilled water for a certain time. After that, specimens are stained with a hematoxylin solution and then continuously irrigated with flowing water. Afterward, an eosin-floxin solution is applied. Finally, specimens are quickly sequentially dehydrated in 70%, 90%, and absolute alcohol and enclosed with covering material. The nucleus and other DNA/RNA-containing structures are dyed blue-violet, whereas the cytoplasm and matrix have different pink tints.

### **3. Results**

Of the 371 individuals in the sample (278 male and 93 female), the mean age with standard deviation was  $57 \pm 17.01$  years. The mean age of male in the whole sample was  $55.31 \pm 15.02$  years, and that was statistically significantly different from the mean age of female  $62.09 \pm 21.19$  years (two-sample t-test),  $p = 0.005$ . The youngest was 1 year old, and the oldest was 97 years old.

In the entire sample (n = 371), the mean weight of the spleen was 149.7 g, the median was 125.0 g, the lowest weight was 2.5 g (1-year-old child) and the highest weight was 545 g (Fig. 1). The mean spleen weight of male (151.45±83.94 g) was not statistically significantly different from the mean spleen weight of female (144.52±85.26 g) (Two Sample t-test, p = 0.49).



**Fig. 1.** The mean spleen weight of the different age groups

Based on the literature, liver and spleen weights correlate with height. Thus, we assessed the height of the deceased in the sample, which differed significantly. Of the entire male sample, the mean height of 175±12 cm was statistically significantly different from the female mean height of 160±17 cm (Two Sample t-test, p < 0.05). Meanwhile, the mean height of the entire sample was 171 cm, the median was 173 cm, the lowest height was 48 cm, and the highest height was 198 cm. Spearman's correlation coefficient was calculated to see how spleen weight correlates with the height of the deceased. There was a statistically significant but weak correlation between the spleen weight and height of the deceased (r = 0.2; p < 0.05).

Also, Spearman's correlation coefficient was calculated to see how spleen weight correlates with the age of the deceased. A weak negative correlation was found between

spleen weight and the age of the deceased ( $r = -0.14$ ;  $p = 0.007$ ). This indicates a trend towards lower spleen weight with increasing age (Table 1).

	<b>Male (n=278)</b>	<b>Female (n=93)</b>	<b>p</b>
Mean age	55.31±15.02	62.09±21.19	$p < 0.05$
Mean height of individuals (cm)	175±12	160±17	$p < 0.05$
Mean weight of spleen (g)	151.45±83.94	144.52±85.26	$p > 0.05$

**Table. 1** The spleen weight of male and female

The spleen weight of the age group 1–10 years was statistically significantly different from the spleen weight of all other age groups (Paired t-test,  $p < 0.05$ ).

The spleen weight of the group's 11–20 years old, 21–30 years old, and 31–40 years old differed significantly from the spleen weight of the 71–80 years old and >81 years old age groups ( $p < 0.05$ ).

There was a significant difference in the spleen weight in the groups of 41–50 years old and 51–60 years old deceased comparing with a group of >81 years old ( $p = 0.02$ ).

The spleen weight of the age group 71–80 years differed insignificantly from the age group >81 years ( $p = 0.08$ ) (Table 2).

<b>Age groups</b>	<b>Mean weight of spleen (g)</b>	<b>n</b>
1–10	36.58 ± 28.75	6
11–20	182.50 ± 27.23	4
21–30	187.69 ± 83.56	13

31–40	202.23 ± 113.68	31
41–50	158.45 ± 99.29	66
51–60	152.99 ± 74.11	85
61–70	132.91 ± 68.04	91
71–80	148.44 ± 82.99	50
>81	116.20 ± 43.26	25

**Table 2.** The mean spleen weight of the age group

During the toxicological testing in 166 cases out of 371, ethyl alcohol was detected in the blood. The mean age of the alcohol users was  $54.3 \pm 13.4$  years, while the mean age of the control group (no alcohol detected) was  $59.56 \pm 20.11$  years. The mean age was statistically significantly different in these groups ( $p = 0.005$ ). A mean concentration with a standard deviation of  $1.86 \pm 1.21$  promille (‰). The mean concentration of ethyl alcohol in the blood of male ( $1.89 \pm 1.23$  promille) was not statistically significantly different from the mean concentration in the blood of female ( $1.70 \pm 1.12$  promille), ( $p = 0.43$ ). The groups of alcohol users were compared with the corresponding groups of non-drinkers. Each age group was compared separately. No statistically significant difference in spleen weight was observed in all groups ( $p > 0.05$ ). The weight of the spleen in the group where ethyl alcohol was found did not show a statistically significant difference between the group in which ethyl alcohol was not found ( $p = 0.34$ ).

### 3.1 Clinical Cases



### **3.1.1 Case 1**

A forensic autopsy of a 69-year-old male of medium build, 174 cm tall was conducted. He was found suddenly dead at home. An external examination revealed no mechanical injuries of the body. The autopsy revealed marked atherosclerotic lesions to the cardiovascular system with arterial stenosis of more than 75% and ischemic changes in myocardial. Fatty liver, esophageal mucosal erosions and pancreatic fibrosis have been observed. Hypertrophy of the spleen was documented. The measures of the spleen were 29x19x8 cm and the weight was 2410 g (Fig. 2). In the incision the spleen was dark red-purple and histologically showed perivascular fibrosis, sclerotic foci and focal fibrosis in the capsule of the spleen.

Toxicological tests did not reveal the presence of toxic substances or ethyl alcohol.

The cause of death was ischemic heart disease. Splenic hypertrophy was found incidentally as a concomitant pathology. The cause of splenomegaly while the person was alive has not been identified.



**Fig. 2.** Macroscopic view of the spleen hypertrophy

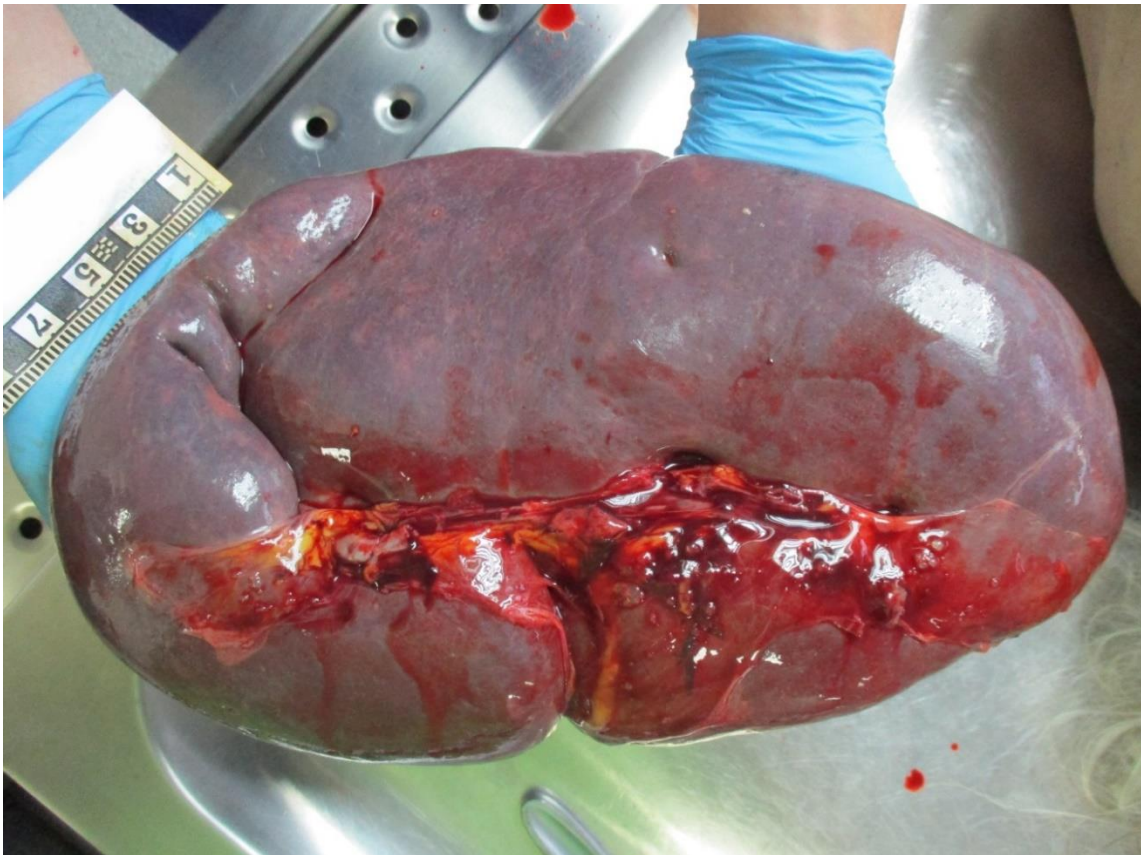
### **3.1.2 Case 2**

A corpse of a 76 year-old female, 167 cm tall, with a medium build, was examined. She died as a result of multiple pelvic fractures during a fall, leading to complications such as pulmonary embolism, pneumonia and sepsis. An external examination showed injuries on the pelvic area. During the autopsy, multiple pelvic fractures, atherosclerotic lesions of the cardiovascular system with arterial stenosis of more than 75%, and a scar from myocardial infarction was established. Bilateral pneumonia, fatty liver, esophageal erosions, pancreatic fibrosis and severe renal sclerosis were also observed. Splenic hypertrophy was found (Fig. 3). The measures of the spleen were 32x19x8 cm and the weight was 2660 g (Fig. 4). The spleen was dark red-purple in the incision. Histologically,

the spleen was full-blooded and hyperplastic. Clinically determined polycythemia and thrombocytosis.

Toxicological tests did not reveal the presence of toxic substances or ethyl alcohol.

The cause of death was trauma and splenic hypertrophy was found as an incidental finding. The cause of splenomegaly remains unknown.



**Fig. 3.** Macroscopic view of the spleen hypertrophy. Visceral surface.



**Fig. 4.** Macroscopic view of the spleen hypertrophy. Diaphragm surface.

### **3.1.3 Case 3**

An autopsy of a 57 year-old male, 171 cm tall, with a hypersthenic build was performed. He was found suddenly dead at home. An external examination revealed no mechanical injuries on the body. The autopsy revealed a heart weighing 915 g, hypertrophy of the heart muscle, marked atherosclerotic lesions of the cardiovascular system with arterial stenosis of more than 95%, up to a punctate radius, ischemic changes in the myocardium and a wide myocardial infarction scar of 12x10x1.8 cm in the anterior wall of the left ventricle extending into the septum. It also revealed fatty liver, esophageal erosions, pancreatic fibrosis, renal sclerosis and splenic hypertrophy. The measure of the spleen was 20x12x7 cm and the weight was 875 g. Histologically, the spleen was full-blooded

and capsule fibrosis was found. Clinical findings included primary arterial hypertension, arterial hypertension, left ventricular hypertrophy, hypertrophic cardiomyopathy, heart failure and type 2 diabetes mellitus.

Toxicological tests did not reveal the presence of toxic substances or ethyl alcohol.

The cause of death was ischemic heart disease. Splenic hypertrophy was found incidentally as a concomitant pathology. The cause of splenomegaly while the person was alive has not been identified.

### **3.2 Discussion and research comparison with literature**

In literature, much attention is paid to the correlation between spleen size and anthropometric data. Height is one of the most important factors determining the size of an individual's spleen. A larger height is associated with a larger spleen (6–9, 12, 13, 15, 17). Our study also showed a statistically significant but weak correlation.

The size of the spleen can also be affected by various diseases: cardiovascular, hepatic, hematological, oncological, infectious, metabolic and storage diseases, diabetes mellitus and traumas (3, 4, 6, 7, 10, 16). This is also illustrated by the exceptional cases we have described in which splenic hypertrophy was found as an incidental finding in deceased patients suffering from various diseases mentioned in the literature. Although the cause of the splenic enlargement remained unknown, all three patients had significant medical conditions that could have contributed to the splenic hypertrophy. It is important to pay attention to the enlargement of the spleen because of possible connections with serious pathologies (18,19). When the spleen crosses the midline, reaches the iliac crest, or weighs more than 1500 g, it is classified as large splenomegaly by most writers. While splenomegaly is a common observation in many disorders, only a few conditions result

in severe enlargement of the spleen. For significant splenomegaly, a bone marrow biopsy and flow cytometry are the suggested tests (20). The spleen may grow dramatically as a result of melanoma metastases. A splenectomy is recommended to stop the spleen from rupturing on its own if the patient's overall health is good (21).

The negative correlation of spleen weight with age obtained in our study is also described in the literature. This means that the spleen decreases as a person ages (9, 15, 16,). However, until a certain age, the spleen, like other internal organs, tends to increase. It has to do with the individual's own growth. Studies in children and adolescents have described spleen growth (4–8, 11, 12, 14). The most significant changes in spleen size were observed in children aged 0–3 years and 4–10 years (6, 11, 14). Our research showed similar results. There was a significant difference in spleen weight (lowest weight) in the 1–10 years age group compared to all other groups. There was also an increase in spleen weight in the adolescent group.

In studies that did not only include children, the results showed that the spleen still enlarges in adults to certain age. From age 20 to age 39, the spleen was enlarging (15). In one study, the highest spleen weight was reported in the 36–45 age group and the lowest in the 66–75 age group (9). Another study distinguished between the sexes: men had the largest spleen at 39 years and women at 44 years (11). The results are presented slightly differently, but the ages in the two studies do not contradict each other. Our study showed that spleen weight was lower in the age groups 41–50 years and older. These results confirm what has been described in the literature.

Spleen length was greater at 31–40 years compared to younger and older age groups. Width was greater in the 31–40 age group than in the older age groups. Thickness changes were also more pronounced in the 31–40 age group than in the older age groups, and more

pronounced in the 11–20 age group than in the >50 age group. Changes in spleen volume were greater in the 21–30 age group than in the >50 age group, and more pronounced in the 31–40 age group than in the 41–50 age group (19). We have only assessed the weight of the spleen among all the spleen parameters, so we cannot confidently compare our results with those described in this study, which assessed other spleen parameters (length, width, volume and thickness). Nevertheless, we can assume that the results for weight would have been similar to those we obtained in our study.

Publications describing post-mortem studies have found that spleen weight correlates poorly with a person's height, body weight and BMI. In men, there was no significant difference in spleen weight between underweight, normal weight and overweight groups; a significant difference between normal weight deceased and obese (22). In the women's group, the results were slightly different. There was a weak correlation between height, weight and BMI; no difference between normal weight, overweight and obesity; the spleen is lighter in underweight (23). Another study, which did not differentiate between groups in terms of the weight of the deceased, generally found that in both men and women, a higher weight of internal organs was associated with a higher body weight. However, it is recommended that normal viscera sizes are based on sex (24). A significant positive correlation between spleen weight and BMI of the deceased was observed in the Malay, Chinese and Indian populations, but only in men (25). Post-mortem studies have further shown that blood loss leads to a lower spleen weight in men, while congestion of internal organs leads to an increase in spleen weight. This was observed in a group of men (22). In women, the differences are not significant (23).

In the field of forensic pathology, organ weight is typically used as a determinant of disease processes or pathologic states. However, the ability to predict organ weights is

important in medical fields that rely on that data to evaluate the effects of radiation exposure or to determine radiation doses for therapeutic purposes (22). As bleeding and visceral overload affect spleen weight in the literature analysed (22, 23) and our study has shown that differences in spleen weight are also observed in different age groups, it is important to know the limits of the normal range in order to make it easier for clinicians to assess the presence of a pathology, and also to serve as one of the criteria to be used by forensic doctors when they suspect haemorrhage.

#### **4. Conclusions**

A negative weak statistically reliable correlation was obtained when spleen weight was compared with the age of the deceased. The spleen weight of the age group 1–10 years was statistically significantly different from the spleen weight of all other age groups.

As the weight of the spleen can vary between age groups, it is important to know the normal parameters of this organ in order to suspect and correctly diagnose pathology. If a larger than normal spleen is detected, it is worth assessing whether the patient has any comorbidities or accompanying significant pathology.

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