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# Anatomy, Sonographic Features, and Dimensional Variations of Spleen among Individuals with Different Sociodemographic and Anthropometric Measurement

*Solomon Demissie, Mulatie Atalay and Yonas Derso*

## Abstract

The spleen is a vital lymphoid soft organ located in the left hypochondrium region. It is a multi-dimensional organ that enlarges in all dimensions during some disease conditions. Recently, splenomegaly prevalence has been increasing throughout the world. Due to the lack of attention in clinical practice, splenomegaly has become quite a common problem in all parts of the world. The detection of the spleen by palpation is not approval of enlarged spleen because normal spleen may be palpable. A detailed knowledge of morphometric variations of the spleen is of great value in diagnosing splenomegaly clinically, radiologically, and for surgical procedures. Measurement of spleen size by sonography is important as it gives true result than splenic palpation and for identification of disorders present with enlargement or reduction of the spleen. Therefore, this study aimed to assess the anatomy, sonography, and dimensional variation of spleen among individuals with different sociodemographic and anthropometric measurements. The current study reviews different types of literature conducted on spleen all over the world. The result from overall spleen dimensions review shows measurements vary: spleen length (7–14 cm), spleen width (2–7.5 cm), spleen thickness (2–7 cm), and spleen volume (20–350 cm<sup>3</sup>). The literature revealed that spleen dimensions are affected by geographical differences, races, nutritional status, physical exercise, and anthropometric measurements. The result from reviews shows that spleen dimensions are larger in males than females. As age increases, spleen dimensions significantly decrease. Spleen dimensions positively correlate with height, weight, body mass index, and body surface of individuals. The spleen dimensions were higher in males than in females and have significant positive correlation with height, weight, body mass index, and body surface area. Clinicians, radiologists, and surgeons should confirm splenomegaly by both palpation and sonography. Spleen dimensions variation due to geographical sex, age, and other anthropometric measurements should be taken into consideration during their clinical investigation. Radiologists should measure all dimensions of spleen rather than the length to rule out splenomegaly correctly.

**Keywords:** spleen, anatomy, sonography, dimensional variation

## 1. Introduction

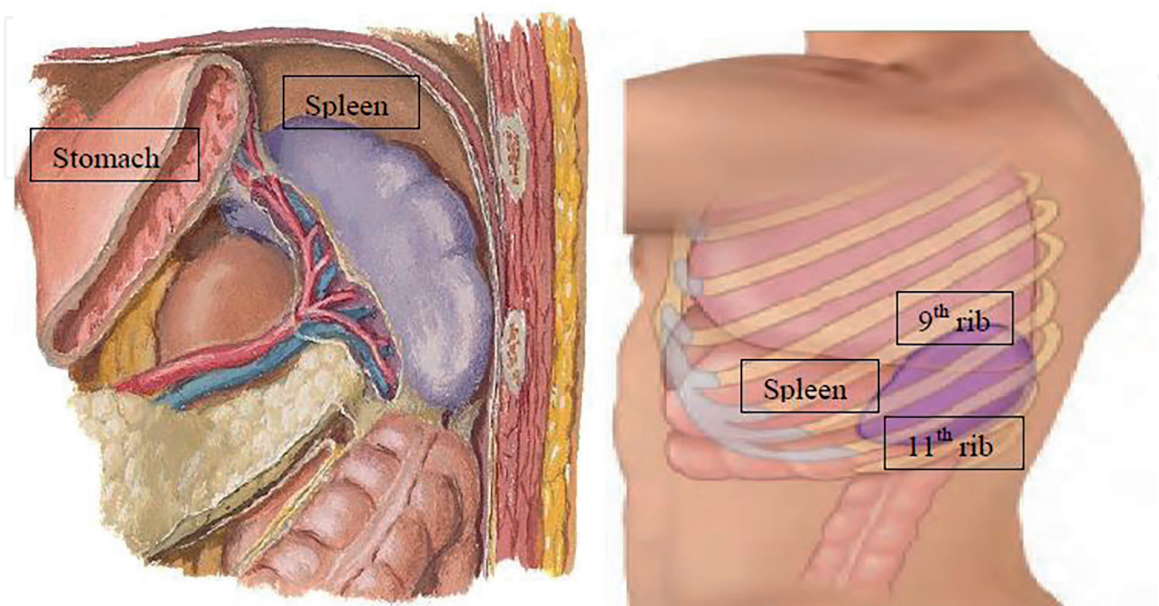
The spleen is the largest lymphoid soft organ that lies in the left hypochondrium between the fundus of the stomach and the diaphragm [1]. Its long axis extends from 9th to 11th ribs on the left side with its long axis running parallel to the 10th rib (**Figure 1**) [2].

The shape of the spleen is ovoid-like pulpy mass about the size + shape of one's fist with a convex outer diaphragmatic surface and an indented inner visceral surface [3]. The diaphragmatic surface of spleen is convex and smooth to fit the concavity of the diaphragm, while the visceral surface is irregular and related to the stomach, left kidney, left suprarenal gland, and left colic flexure [4]. The medial end (apex) lies in line with the spine of 10th thoracic vertebra about 4 cm from the midline, and the lateral end (base) does not descend beyond the midaxillary line [5].

The functions of the spleen are centered on the systemic circulation [6]. It contains two functionally and morphologically distinct compartments: the red pulp and the white pulp. The red pulp functions as a blood filter that removes foreign material and damaged erythrocytes, and the white pulp initiates immune responses to blood-borne antigens (**Figure 2**) [7].

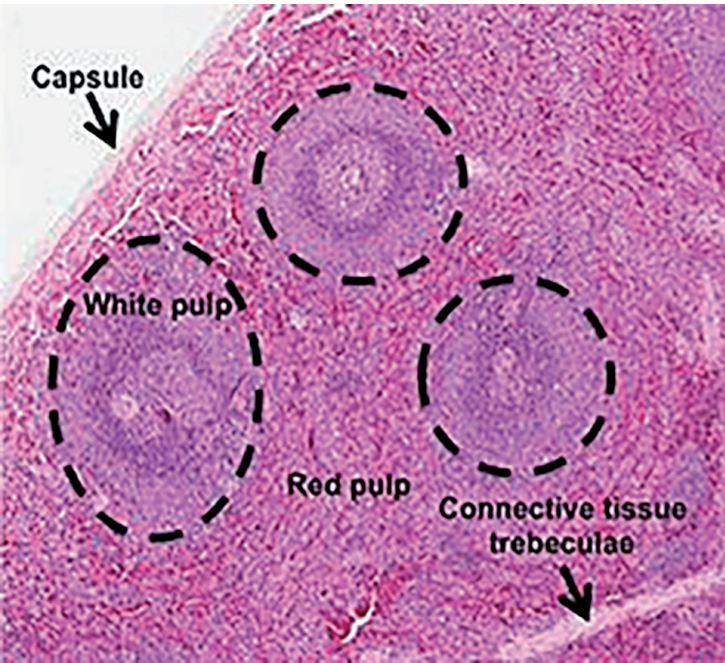
The spleen is involved and enlarged in a variety of clinical conditions. Its size is mostly affected by infections, hematological disorders, infiltrative states, and immunological and malignant diseases [8, 9]. A variety of diseases condition alters spleen dimensions, where splenomegaly and its consequence become a primary clinical concern in developing countries [10]. It is commonly seen in about 63% of patients with pulmonary arterial hypertension [11], infectious mononucleosis [12], malaria [13], lymphoma [14], kala-azar [15], typhoid fever [16], liver disease (hepatitis and cirrhosis) [17], hematological diseases, metabolism diseases, and cancer [18]. The altered splenic dimensions and structure during these diseases result in asymptomatic enlargement and complications such as hematoma formation, rupture, hypersplenism, ectopic spleen, and torsion that affect other adjacent organs [19].

Splenic atrophy is also another common problem seen in diseases like sickle cell anemia, where progressive atrophy as a result of repeated attacks of vaso-occlusion and infarction caused by these diseases leads to auto splenectomy [20].

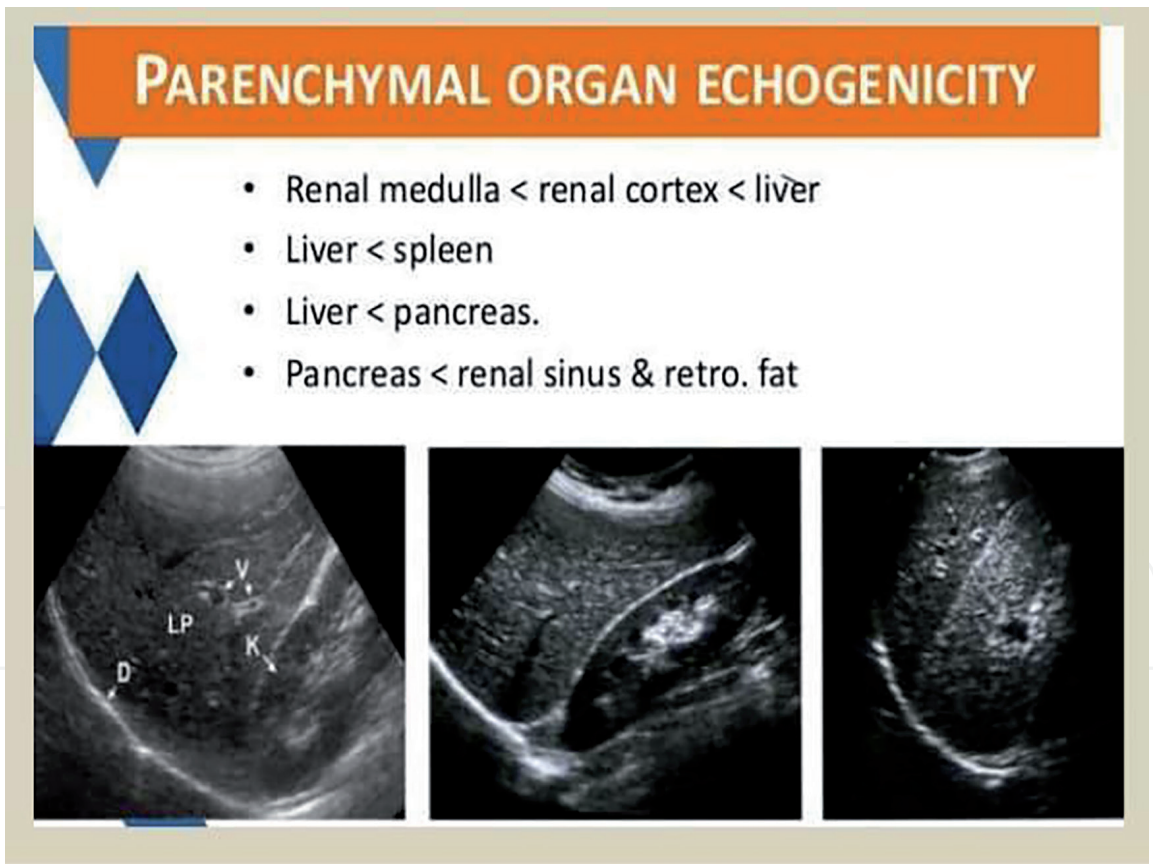


**Figure 1.**  
*Spleen anatomical location.*





**Figure 2.**  
*Spleen histological features.*



**Figure 3.**  
*Spleen sonographic comparison with kidney and liver.*

The dimension of the spleen is evaluated using conventional radiography, ultrasonography, scintigraphy, computed tomography, and magnetic resonance imaging [21]. However, ultrasonography is a non-invasive, safe, quick, and accurate method for measurement of spleen size [22]. On sonography spleen is characterized as crescent-shaped with outer convexity is smooth, whereas the inner margin is

indented. Its echo structure is homogeneous and more echogenic than healthy liver tissue and markedly hyperechoic compared to kidney tissue (**Figure 3**) [23].

The average dimensions of the spleen are 12.5 cm, 7.5 cm, and 2.5 cm in length, width, and thickness, respectively, and 150–200 g in weight, but its dimensions vary considerably [20]. The literature revealed that spleen dimensions are affected by geographical differences, races, nutritional status, and anthropometric measurements [21–23]. The following are types of literature reviewed.

## 2. Literature reviews

### 2.1 Overall morph metric evaluation of normal dimension of spleen

Average overall dimension of spleen varies from race to race and region to region. The study designed to evaluate splenic size by ultrasonography (US) of healthy Turkish men found the average splenic length to be 10.76 ( $\pm 1.84$ ) cm [24]. Study conducted in Istanbul Turkey found that the mean spleen volume (SV), splenic length (SL), width (SW), and thickness (ST) were 198 ( $\pm 88$ ) cm<sup>3</sup>, 9.96 ( $\pm 2.1$ ) cm, 8.87 ( $\pm 1.6$ ) cm, and 4.58 ( $\pm 0.8$ ) cm, respectively [25]. In another study conducted on North Indian adult population, splenic dimensions were 10.67 ( $\pm 1.62$ ) cm in length, 6.26 ( $\pm 1.66$ ) cm in width, and 4.86 ( $\pm 1.22$ ) cm in thickness [26]. Recent study conducted in North West Ethiopia also found that the mean dimensions of spleen, the mean splenic length, width, thickness, and volume with ( $\pm$ SD), were 9.95 cm ( $\pm 1.12$ ), 4.3 cm ( $\pm 0.7$ ), 3.8 cm ( $\pm 0.8$ ), and 92.0 ( $\pm 38.4$ ) cm<sup>3</sup>, respectively [27].

### 2.2 Normal spleen dimensions in correlation with sex

Different literature states that spleen dimension varies in relation to sex, with more studies indicating that males have larger spleen dimensions than females. Ultrasound assessment of spleen size in collegiate athletes conducted in Kentucky, USA, shows that spleen length and width (cm) 9.91 ( $\pm 1.27$ ) cm, 4.74 ( $\pm 0.91$ ) cm and 11.29 ( $\pm 1.49$ ) cm, 5.54 ( $\pm 1.28$ ) cm in female and male, respectively. The study concludes that men have larger spleen size than females [28].

In a study conducted on Saudi Arabian adult, the average splenic volume of males was 196.95 ( $\pm 48.70$ ) cm<sup>3</sup> and that of females was 196.95 ( $\pm 26.97$ ) cm<sup>3</sup>. The study concludes that a significant difference was found between sex [29].

In a study conducted on sonological evaluation of the spleen in an adult Southern Nigerian population, lengths of the spleen were 9.62 ( $\pm 1$ ) cm and 9.12 ( $\pm 1.22$ ) cm for the males and females, respectively. A significant difference ( $p < 0.05$ ) was found between the sex, and it is significantly larger in the males [30].

Measurement of normal spleen dimensions in adult Sudanese using ultrasonography revealed that the mean values of spleen length, width, thickness, and volume were 10.3 ( $\pm 1.2$ ), 3.3 ( $\pm 0.4$ ), 3.9 ( $\pm 0.6$ ), and 73.3 ( $\pm 23$ ) respectively for males and 9.2 ( $\pm 0.9$ ), 3.1 ( $\pm 0.3$ ), 3.6 ( $\pm 0.6$ ), and 56.5 ( $\pm 18.0$ ) respectively for female. The study concludes that men have larger spleens than females in relation of spleens to sex [31].

### 2.3 Normal spleen dimensions in correlation with age

The study conducted in Pakistan to determine the normal spleen parameters in adults shows that the mean spleen sizes of the participants were  $9.81 \pm 1.73$  cm, and a significant positive correlation was observed between age and spleen size of the individuals ( $r = 0.053$ ,  $p = 0.012$ ) [32].

The splenic dimension study conducted in Western Nepal revealed that in age groups of 16–30, 31–45, 46–60, and 61–75 years, respectively, revealed that spleen length for males ( $10.07 \pm 0.7$  cm,  $10.1 \pm 0.54$  cm,  $9.5 \pm 0.7$  cm, and  $9.0 \pm 0.43$  cm, respectively) and for the females ( $9.83 \pm 0.53$  cm,  $9.58 \pm 0.58$  cm,  $9.2 \pm 0.64$  cm, and  $8.8 \pm 0.36$  cm, respectively). The spleen thickness for males ( $4.1 \pm 0.5$  cm,  $4.05 \pm 0.58$  cm,  $3.43 \pm 0.38$  cm, and  $3.0 \pm 0.36$  cm, respectively) and for the females ( $4.06 \pm 0.47$  cm,  $3.78 \pm 0.48$  cm,  $3.38 \pm 0.35$  cm, and  $2.29 \pm 0.23$  cm, respectively). The results show that the splenic length and thickness decreased with increase in age in both males and females [33].

In a study conducted on adults of Tripura, India, with age groups of (15–30 years), (31–45 years), (46–60 years), (61–75 years), and (>75 years), the spleen lengths were  $9.00 \pm 1.07$  cm,  $8.79 \pm 1.44$ ,  $9.15 \pm 1.04$ ,  $8.63 \pm 1.55$ , and  $7.64 \pm 1.06$  cm, respectively. Correlation analysis showed that spleen length was negatively correlated with age in all adults. So, with increasing age, spleen length was found to be decreasing, which is significant ( $p < 0.05$ ) [34].

A study conducted to establish the normal range of the splenic dimensions in North Indian adult population revealed that the splenic length, width, and thickness decreased with increase in age in both males and females. The results show that in both males and females, the splenic length decreased at a slow rate up to the age of 50 years, after which it decreased rapidly; the splenic width decreased with age up to 30 years; thereafter, it remained relatively constant up to the age of 50 years and after that the splenic width decreased. It also shows that in both males and females, splenic thickness was constant up to the age of 50 years, after which there was a fall in the splenic thickness [35].

The studies from Rajasthan, India, revealed that the length was  $8.69 \pm 0.93$  cm in adults and  $9.64 \pm 0.64$  cm in older subjects. The width was  $3.59 \pm 0.55$  cm in adults, while in older subjects, the width was  $3.38 \pm 0.38$  cm [36].

## **2.4 Normal spleen dimensions in correlation with height, weight, BSA, and BMI**

In a study conducted in Saudi in Jordanian population, ultra-sonographic assessment of splenic volume revealed that splenic dimensions were  $10.72 \pm 1.37$  cm in length,  $7.40 \pm 1.52$  cm in width,  $4.40 \pm 1.47$  cm in depth, and  $184.15 \pm 79.56$  cm<sup>3</sup> in volume. Moderate positive linear relationships were found between the splenic dimension and body height, weight, BSA, and BMI ( $r > 0.3$ ). This correlation was statistically significant ( $p < 0.0001$ ) [37].

Study conducted in the United States revealed that spleen length and volume were associated with body height in which body height alone accounted for 17.3% of spleen length variability and 14.9% of spleen volume variability [38].

Sonographic evaluation of spleen size in athletes conducted in Canada revealed that the mean splenic dimensions were  $11.4 \pm 1.7$  cm length (range, 8.2–16.1 cm),  $10.8 \pm 1.4$  cm width (range, 8–14 cm),  $5.0 \pm 0.8$  cm in thickness, and  $333.6 \pm 116.1$  cm<sup>2</sup> in volume. All splenic measurements correlated better with height than weight [39].

Assessment of dimensions of spleen in normal adult Kashmiri population revealed that the mean length of the spleen was  $10.20 \pm 1.40$  cm and the width was  $8.63 \pm 1.57$  cm. The study found a statistically significant correlation of splenic dimensions with body weight and BMI [40].

## **3. Dimensional measurement on sonography**

The dimension of spleen is measured as follows.



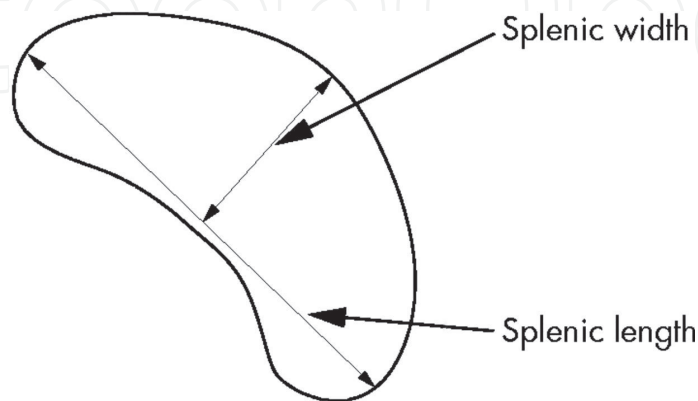
**Spleen length:** the maximum distance measured in longitudinal plane at hilum between the dome of the spleen and the splenic tip.

**Apparently healthy individual:** individuals with no signs and symptoms of disease.

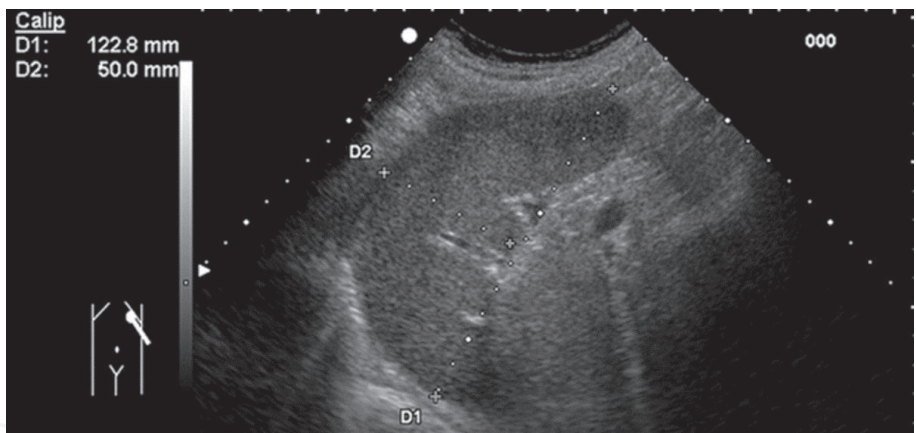
**Spleen width:** the maximum dimension measured in a plane perpendicular to the length at hilum between the medial and lateral borders of the spleen.

**Spleen thickness:** the maximum AP dimension measured on the transverse section.

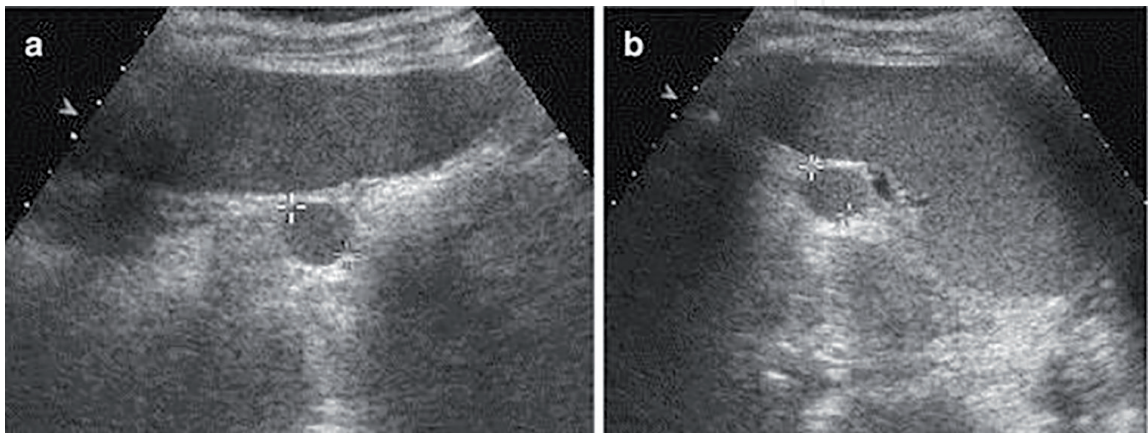
**Spleen volume:** calculated using the standard ellipsoid formula ( $\text{length} \times \text{width} \times \text{depth} \times 0.523$ ); this formula is frequently used for estimating the volume of many irregularly shaped organs (Figures 4–6) [41].



**Figure 4.**  
*Spleen length and width measurement.*



**Figure 5.**  
*Spleen sonographic length and width measurement.*



**Figure 6.**  
*Spleen thickness sonographic measurement.*

## 4. Discussion

This study describes the morphometry of spleen dimensions and compares the presence of a significant difference between sex and age as well as dimensional correlations with anthropometric measurements. The sonography assessment of spleen dimensions provides essential inputs for clinicians in daily clinical practice for the proper diagnosis of splenomegaly [33, 35, 42]. This study provides estimates of spleen to help radiologists for the diagnosis of diseases related to splenomegaly and atrophy, also used by hematologists and immunologists for the diagnosis of various gastrointestinal and hematological diseases, in addition to forensic studies [43–45].

The result from overall spleen dimensions review shows that measurements vary as follows: spleen length (7–14 cm), spleen width (2–7.5 cm), spleen thickness (2–7 cm), and spleen volume (20–350 cm<sup>3</sup>). The average dimensional difference between studies is probably due to age group differences, geographical differences, nutritional status, physical exercise, and race differences, which were stated in different literature [25, 42, 45–48].

In most of studies reviewed, the spleen dimensions were lower in females than males. This is due to histological and genetic differences of spleens between males and females. On histological studies, females have fewer total red cell mass, when compared to males [38, 49]. Studies conducted in Turkey, Saudi, Nigeria, Sudan, and Ethiopia support this idea [30, 31, 45, 50, 51]. But, one study conducted in Egypt showed the length was higher among females than males. This may be due to nutritional status where Egyptian culture recommends women to gain weight for fertility purposes [52, 53].

In most of the study reviewed, as age increases the spleen length, width, thickness, and volume are reduced. This is from the fact that as age increases, the number and size of B cell follicles of the white pulp of the spleen decrease. This implies a decrease of germinal center of spleen, which reduces overall spleen dimension [54–56]. This review is supported by the studies conducted in Iraq, Nepal, and India [33, 35, 36, 42, 57]. But, this summary of review does not agree with the studies conducted in Pakistan, Jordan, and Nigeria [32, 37, 51, 58]. The difference is maybe due to nutritional status where larger anthropometric measurements and obesity were observed in the studies of Pakistan, Jordan, and Nigeria.

Physiological studies indicate that as individual's height, weight, BMI, and BSA increase, the blood volume increases. This increase of blood volume requires larger spleens for filtration. This fact is supported by most of literature reviewed where all dimensions were positively correlated with height, weight, BMI, and BSA. The studies conducted in Jordan, the United States, India, Sudan, and Ethiopia were some of the studies that support this idea [26, 37, 38, 59].

## 5. Conclusion

This chapter gives baseline information for clinicians as well as for academicians about the morphometric variation of spleen dimensions. Hence, it helps in diagnosing pathological cases associated with spleen, both splenomegaly as well as splenic atrophy. Therefore, clinicians should consider this variation during their diagnosis. Radiology professionals also should measure all dimensions rather than the length alone to rule out splenomegaly correctly.

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## Competing interests

No competing interest.

## Consent for publication

Not applicable.

## Availability of data and materials

All relevant data are included in the article.

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