

**A Study of Anatomical Dimensions of Spleen in Population of Eastern Bihar: A Sonological Study**Parijat Mukherjee\*<sup>1</sup>, Sayantan Das<sup>2</sup>, Anupam Khalkho<sup>3</sup>, Avinash Kumar<sup>4</sup><sup>1\*</sup> Assistant Professor, Department of Anatomy, Mata Gujri Memorial Medical College & LSK Hospital, Kishanganj<sup>2,3</sup> Associate Professor, Department of Anatomy, Mata Gujri Memorial Medical College & LSK Hospital, Kishanganj<sup>4</sup> Assistant Professor, Department of Orthopaedics, Mata Gujri Memorial Medical College & LSK Hospital, Kishanganj

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Conflict of interest: Nil

**Abstract:****Background:** Accurate knowledge of normal splenic dimensions is important for diagnosing clinical conditions associated with altered spleen size. A descriptive cross sectional study was conducted with the aim to determine normal splenic measurements in the Eastern Bihar population and to compare them with body parameters such as height, weight, age and sex.**Methods:** 78 females and 32 male adult participants underwent abdominal ultrasound in Kishanganj, Bihar, India. Participants were taken after they met with inclusion criteria and gave informed consent for the study. The splenic length, breadth and thickness were measured, and their height, weight and age were also recorded. The analysis was done using SPSS version 26.**Results:** The study included 110 subjects (78 females, 32 males). Average splenic dimensions were: length 97.05 mm, breadth 60.50 mm, thickness 34.82 mm, volume 111.53 cm<sup>3</sup>. No significant differences were found between males and females. A negative correlation with age with splenic parameters except thickness was also found. No significant correlation was found between splenic parameters with other body parameters such as height or weight.**Conclusion:** The study indicated no significant correlation of splenic parameters with height and weight, and indicated difference between male and female splenic parameters to be insignificant. This might reflect the population variations found in other studies. The findings emphasize the need for population-specific reference ranges and suggest a potential age-associated shrinkage effect on splenic dimensions. Further research with larger sample sizes is recommended.**Keywords:** Splenic length, splenic breadth, splenic thickness, normal dimensions of spleen, population variation, Ultrasonography, Age related shrinkage.

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**Introduction**

Spleen is an organ located in the left hypochondrium, working as a filter for the old and diseased RBCs. As the largest lymphoid organ of the human body and part of the reticuloendothelial system, spleen also has function related to immunology. Size of spleen can change in various disease processes such as Malaria, Leishmaniasis, various leukaemias and malignancies, storage diseases and other metabolic diseases, resulting in splenomegaly and processes such as Sick cell anaemia that cause shrinkage of spleen when sufficiently advanced. [1,2] Thus, knowing the normal dimensions of spleen holds importance in proper diagnosis of the clinical conditions where splenic dimensions are altered. In textbooks the

splenic length is shown to be ranging from 9 to 15 cms, breadth to be 5 to 7 and thickness 3 to 5 cms. However, it is seen in various studies that the size of the spleen can differ between population, and is variable according to sex, height, age, weight and other parameters. [3–5] A review of present literature indicates a paucity of data in reference to India [6–9], and particularly in the Eastern Bihar population [10], where many diseases such as Malaria and Kala zar are endemic. [11] Therefore, we have conducted this descriptive study to ascertain the normal splenic dimensions in this population, and to observe which parameters influence the different splenic measurements. Changes in the size of spleen is hard to determine

clinically[12]. It is seen that most of the studies that measure the spleen do so through either sonologically[3–10,13], direct cadaveric measurement[14–16], and Helical CT scan[17,18]. Among these, sonology was taken as the preferred method as it is non-invasive, has no hazard to the patient, relatively inexpensive and widely available, and has the benefit of measuring the spleen in a live patient [12]. Cadaveric measurements can differ from their living counterpart due to embalming and preservation methods [19], So it was not utilized in our study. Helical CT, while can directly determine splenic volume, is not widely available, subjects patients to ionizing radiation, and is costlier [12]. Studies conducted to correlate the splenic volume measured through the Helical CT with the splenic measurements through prolate ellipsoid formula ( $0.524 \times \text{length} \times \text{maximum width} \times \text{thickness}$ ) have good correlation [7,20], and most of the studies thus have used sonology as the preferred method of splenic measurement. This supported our choosing of the method of splenic measurement to be sonological.

## Methods/Methodology

### Type of Study

**Study design:** Descriptive cross sectional study

**Study samples:** Adult population (greater than 18 year of age) of Kishanganj undergoing diagnostic ultrasonography of abdomen/ routine ultrasonography

**Duration of study:** Study period from 06.04.23 to 30.05.23, data collection period from 20.04.2023 to 20.05.2023.

### Inclusion criteria

1. Patients above 18 year age
2. Resident of District of Kishanganj
3. Undergoing routine ultrasonography or ultrasonography for suspected disease in organs other than spleen, patients with normal ultrasonographic study as final diagnosis.

### Exclusion criteria

1. Patients with history of splenectomy, or splenic trauma leading to rupture of spleen at any point of life.
2. Known case of malaria, kala azar, malignancy involving spleen including leukaemia, sickle cell anaemia, liver disease, renal failure. Medical documentation or laboratory reports were checked for detection of it, and history was taken.
3. Documentation of previous ultrasonography with diagnosed splenomegaly or splenic anomalies.
4. Patients below 18 year age

5. Present history of fever
6. Patients from other localities beyond district of Kishanganj

## Materials

1. Ultrasonography machine for obtaining the measurements: Sonoscape S11 plus ultrasound system was used for the study with curvilinear probe (2-5Mhz) was used for the purpose of the study.
2. Measuring tape and stadiometer
3. Computer with windows operating system equipped with the following software.
  - a. IBM SPSS version 26 for statistics
  - b. Microsoft excel 2019
4. Proforma for data collection (Annexure 1)
5. Consent form (Annexure 2)

## Methods:

A diagnostic centre situated within Kishanganj equipped with ultrasonographic facilities available to the researchers was selected for the data collection based on feasibility of data collection.

Patients visiting the diagnostic centre for ultrasonography of abdomen were approached by the researchers and the study was explained to them in layman terms in detail so that they can understand the procedure and purpose of study. Only the patients undergoing ultrasonography of abdomen for diagnostic reasons were approached for this and no patients were pressured in undergoing procedures if they were not already medically advised.

After explaining the premises of research, the agreed patients were questioned about their medical history and their medical and laboratory records (if any) checked to ascertain that they fit our criteria for inclusion and exclusion. A consent form was used to take their consent along with ample verbal explanation.

The consenting patients who fit the inclusion criteria were asked about their age and sex, which were noted in the data collection format, and then they were taken for abdominal ultrasonography. The measurements were taken keeping the patient supine and right lateral decubitus for better visualization. The parameters of the spleen according to the operational definitions were noted in the data collection format. After this, their height and weight were measured, and noted in the proforma along with rest of the data. The data was entered into an excel sheet first to compile and prepare for analysis. Later the data was analyzed using SPSS version 20 for Windows and appropriate statistical tests were conducted.

**Operational definitions:** Length, Breadth, Width, Volume

**Splenic Length:** The maximum length between the upper pole and lower pole of the spleen as visualized during ultrasonography was taken as the splenic length.

**Splenic Breadth:** The maximum anteroposterior breadth was taken as the breadth, as visualized during ultrasonography.

**Splenic width:** The splenic width was taken as the maximum distance between medial and lateral

surfaces of the spleen on a plane perpendicular to the plane of the length.

**Results**

A total of 110 subjects were assessed during the study, of which 78 were females and 32 were males. The age ranged from 18 to 73 years with the mean age being 30.6 years for the total population. The age ranges and other parameters for the males and females are shown in the Table 1.

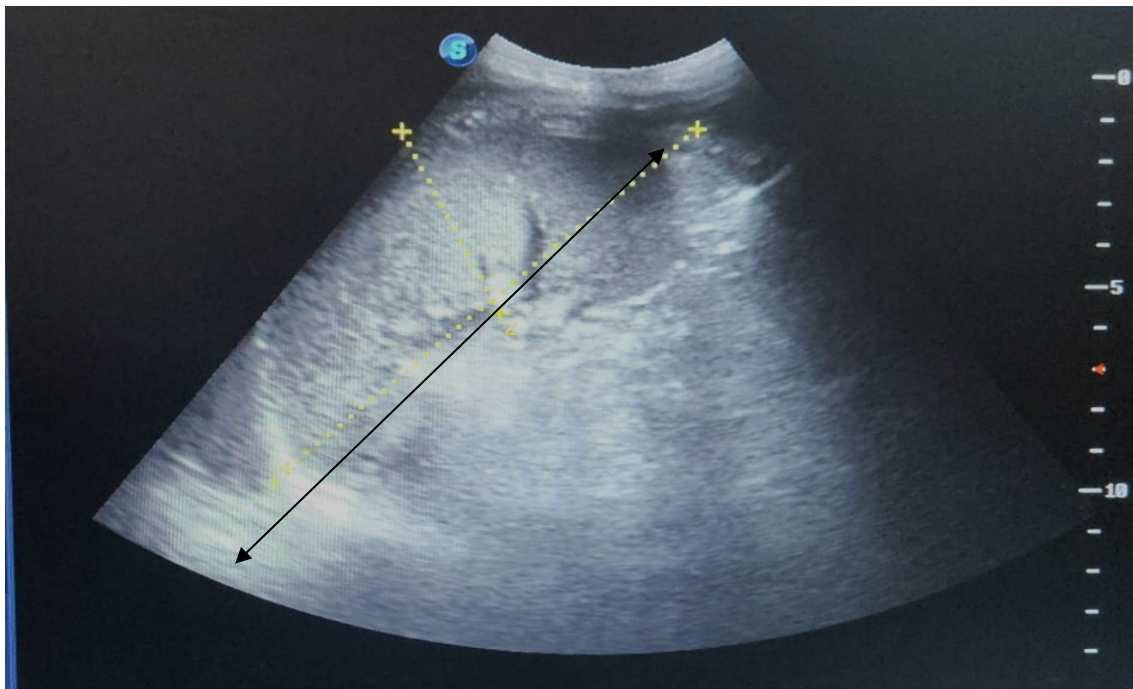
**Table 1: Summarizing the demographic distribution of the population with their age, height, weight**

	Age(years)			Height (cms)			Weight (kgs)		
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Female (n=78)	65	18	28.24	168	133	146.40	67	30	47.79
Male (n= 32)	73	18	36.34	168	138	153.63	70	34	53.88
Total (n= 110)	73	18	30.6	168	133	148.5	70	30	49.56

The splenic measurements for length ranged from a maximum of 125mm to a minimum of 70 mm, with the average being 97.054mm; the breadth (Max: 79, Min 47, Mean:60.5 mm), thickness (Max: 50, Min:25, mean: 34.818 mm), were also calculated. Volume was calculated through the splenic length, breadth and thickness with the help of Prolate ellipsoid formula (volume= l x b x t x 0.524), the volume ranged from 49.8717 cm<sup>3</sup> to 235.9572 cm<sup>3</sup> and the average being 111.53 cm<sup>3</sup>. The various splenic parameters can be seen in table 2.

**Table 2: Various Splenic Parameters**

	Splenic Length			Splenic Breadth			Splenic Thickness			Volume		
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Female	125	70	97.34	78	47	60.67	48	25	34.93	227.5753	49.8717	112.5737
Male	116	82	96.38	79	48	60.1	50	25	34.57	235.9572a	53.448	108.985
Total	125	70	97.06	79	47	60.5	50	25	34.82	235.9572	49.8717	111.53



**Figure 1: Measurement of splenic length through ultrasonography. The length has been highlighted with black double sided arrow in the figure**

The data was subjected to statistical testing using IBM SPSS version 26. The values of the measurements are as follows:

**Table 3: Measurements of spleen, height, weight and volume**

	Sex	Mean	Std. Deviation	Std. Error Mean
Splenic Length mm	female	97.33	11.520	1.304
	male	96.38	8.095	1.431
	Total	97.05	10.611	1.012
Spl Breadth mm	female	60.67	7.548	.855
	male	60.09	7.450	1.317
	total	60.50	7.490	.714
Spl Thickness mm	female	34.92	5.707	.646
	male	34.56	6.460	1.142
	Total	34.82	5.908	.563
Spl Volume mm cube	female	112573.67	42138.025	4771.192
	male	108985.04	42111.450	7444.323
	Total	111529.41	41968.646	4001.553
Spl Volume in cm <sup>3</sup>	female	112.57367	42.138025	4.771192
	male	108.98504	42.111450	7.444323
	Total	222.52971	41.968646	4.001553
Height in cm (roundup)	female	146.40	6.908	.782
	Male	153.63	6.927	1.225
		148.50	7.631	.728
Weight in kgs	female	47.78	7.972	.903
	Male	53.88	9.520	1.683
	Total	49.55	8.854	.844

To detect any significant difference between the values of the males and females of the sample, independent sample t test was done with the help of spss version 26. Prior to doing t test, Levene's test was done to test the homogeneity of variance, which showed an insignificant value in all parameters except the splenic length. Due to this, Student's independent sample t test was conducted for all parameters except splenic length, for which Welch's independent sample t test was conducted at 95% confidence interval. The values were all found to be statistically insignificant for splenic length ( $p = 0.622$ , CI 95% alpha 0.05), splenic breadth ( $p=0.717$ , CI 95%, alpha 0.05), splenic thickness ( $p = 0.773$ , CI 95%, alpha=0.05) and splenic volume ( $p = 0.686$ , CI 95%, alpha 0.05); while values for weight and height showed significant difference between males and females, at 95% confidence limit.

The values for height and weight by conducting independent sample Student's t test was found to be

( $p<0.001$ , CI 95%, alpha 0.05) for height, and ( $p=0.001$ , CI =95%, alpha 0.05), respectively.

The values for this calculation are shown in Table 4 below:

Correlation was done between the variables using Pearson's R, at 95% confidence limit. The results were insignificant except for correlation between height and weight. There was significant correlation between splenic parameters themselves, viz. Splenic length, breadth, thickness and volume showed correlation between each other. However correlation of body parameters such as height, weight and splenic parameters were insignificant. Age was found to be a factor with significant correlation with that of splenic length, breadth and volume at 95% confidence limit (alpha =0.05). It appeared that the splenic parameters correlated negatively with increasing age, indicating a shrinking effect on the splenic parameters with increasing age.

**Table 4: Independent sample t test to test significant difference between males and females (CI 95%, alpha 0.05, df 108)**

Independent Samples Test									
		Levene's Test for Equality of Variances	t-test for Equality of Means						
			Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Splenic Length mm	Equal variances not assumed (As Levene's test yields significant (p= 0.027) at alpha (0.05))	0.027	0.495	0.622	0.958	1.936	-2.894	4.811	
Spl Breadth mm	Equal variances assumed as Levene's test shows (p>0.05) at alpha 0.05	0.903	0.363	0.717	0.573	1.579	-2.556	3.702	
Spl Thickness mm	Equal variances assumed	0.277	0.29	0.773	0.361	1.245	-2.108	2.829	
Spl Volume mm cube	Equal variances assumed	0.923	0.406	0.686	3588.634	8844.425	-13942.552	21119.819	
Spl Volume in cm <sup>3</sup>	Equal variances assumed	0.923	0.406	0.686	3.588634	8.844425	-13.942552	21.119819	
Height in cm (roundup)	Equal variances assumed	0.668	-4.98	0	-7.228	1.451	-10.104	-4.351	
Weight in kgs	Equal variances assumed	0.294	-3.437	0.001	-6.093	1.773	-9.607	-2.579	

**Table 4: Correlations between splenic parameters (length, breadth, thickness, volume) with height, weight and age**

		Correlations					
		Height in cm (roundup)	Weight in kgs	Splenic Length mm	Spl Breadth mm	Spl Thickness mm	Spl Volume mm cube
Height in cm (roundup)	Pearson Correlation	1	0.227*	0.082	0.004	-0.047	-0.009
	Sig. (2-tailed)		0.017	0.396	0.970	0.627	0.926
	N	110	110	110	110	110	110
Weight in kgs	Pearson Correlation	0.227*	1	0.141	0.185	0.182	0.159
	Sig. (2-tailed)	0.017		0.142	0.052	0.057	0.096
	N	110	110	110	110	110	110
Splenic Length mm	Pearson Correlation	0.082	0.141	1	0.819**	0.557**	0.811**
	Sig. (2-tailed)	0.396	0.142		0.000	0.000	0.000
	N	110	110	110	110	110	110
Spl Breadth mm	Pearson Correlation	0.004	0.185	0.819**	1	0.932**	0.990**
	Sig. (2-tailed)	0.970	0.052	0.000		0.000	0.000
	N	110	110	110	110	110	110
Spl Thickness mm	Pearson Correlation	-0.047	0.182	0.557**	0.932**	1	0.924**
	Sig. (2-tailed)	0.627	0.057	0.000	0.000		0.000
	N	110	110	110	110	110	110
Spl Volume mm cube	Pearson Correlation	-0.009	0.159	0.811**	0.990**	0.924**	1
	Sig. (2-tailed)	0.926	0.096	0.000	0.000	0.000	
	N	110	110	110	110	110	110
Age	Pearson Correlation	-0.071	.033	-0.330**	-0.249**	-0.147	-0.242*
	Sig. (2-tailed)	0.461	0.729	0.000	0.009	0.125	0.011
	N	110	110	110	110	110	110
*. Correlation is significant at the 0.05 level (2-tailed) (95% CI)							
**. Correlation is significant at the 0.01 level (2-tailed) (99% CI)							

**Discussion**

The review of literatures suggest that the splenic dimensions differ between populations (3–6,8–10). Our study found the average splenic parameters for splenic length, breadth, width and volume to be 9.733 ± 1.152 cm, 6.067 ± 0.7548 cm, 3.492 ± .5707cm, 112.573 ± 42.138 cm<sup>3</sup> for females, and 9.638 ± 0.8095cm, 6.009 ± .745cm, 3.456 ± .6460cm, 108.985 ±42.111 cm<sup>3</sup> for males; and 9.7054 ± 1.061cm, 6.05 ± 0.7490cm, 3.4818 ± 0.5907cm, 111.529 ± 41.968 cm<sup>3</sup> for the total sample population. The other parameters such as height, weight had no significant correlation with the splenic parameters at 95% CI, but the age had a negative correlation with the splenic length, breadth and volume significant at 95% CI, indicating a shrinking effect with age. In our study no significant difference was found between males and females.

In the 1993 study by Suh J and Lee M (published online on 2015), it was found that the average splenic dimensions for splenic length, breadth and thickness were 6.33 ± 1.46 cm, 6.85 ± 1.31 cm, 4.93 ± 1.27 cm for the males and for females it was 6.33 ± 1.42cm, 5.17 ± 1.25cm, 6.61 ± 1.23cm; and on average it was 6.33 ± 1.39cm,

5.05 ± 1.27cm, 6.73 ± 1.27cm.[21] This study was done in a Korean adult population. Here the splenic length was shorter than what most other studies have found. But other parameters seem to be within the limit of other existing literature. This study found no significant difference between males and females, as well as age groups.

In the 2005 study by Spielmann A, DeLong D et al. it was found that average splenic length, breadth and thickness(width) were 11.4±1.7, 10.8 ±1.4, 5.0±0.8 cm and 333.6 ±116.1 cm<sup>3</sup>, respectively. This is more than what our study has found, which might have been attributed by the difference in the average height and weight. The study by Speilmann A had an average population height 189cm ± 9cm for men and 176cm ± 9cm for women, and concluded the height has a correlation with the splenic parameters, specially in taller individuals. However this study was conducted on tall athletes, and the height ranges differ from our population (153.63 ± 6.9cm for males, 146.4 ± 6.9 for females) which might be the reason for significant correlation found in their study, or otherwise can indicate an inherent difference between populations.[4]

The 2010 study by Mustapha Z et al. indicated that the difference of splenic parameters can be the result of different ethnicities, and discussed the smaller values observed in African population than their western counterparts. They found their average splenic volume to be 120 cm<sup>3</sup> which differed from the western sources with a range of 209-215 cm<sup>3</sup>[3]. This study also did not find any significant correlation of splenic volume with that of age, weight, height and BMI. However, they have found a significant difference of splenic volume between males and females, which was not found in our study. This can be due to a difference inherent to population. [5]

The studies done in Asia tended to have a smaller size of spleen as already indicated in the study of Suh J and Lee M [21] in the Korean population, and a similar trend of smaller spleen size can be observed in the 2002 study by Kaneko J et al. [22]. This study found a 112 cm<sup>3</sup> spleen size, with a wide range (32 to 209 cm<sup>3</sup>), which is closer to the values of our study. They also found the splenic volume to correlate with age, but not with body weight and surface area. Similar to our study, a difference between genders was not found to be significant. In a 2018 cadaveric study done in Ethiopia by Bahiru T, and Muche A; the splenic length, breadth and width was found to be 11.2, 6.6 and 5cm respectively. This value is closer to our values of 9.7, 6.05 and 3.48 cms (average values) respectively. They also found a wide variation between splenic weight(45.72 to 331.61gms), which indicates a similar difference to exist in their volumes which was found in our study as well as other studies done in Asia and Africa. The height and weight of the cadavers were not measured in their study, hence the correlation with the height cannot be ascertained.[15]

Badran D et al. in their 2015 study in Jordanian population found the splenic parameters to be 10.72±1.37 cm in length, 7.40±1.52 cm in breadth, 4.40±1.47 cm in depth, and 184.15±79.56 cm<sup>3</sup> in volume. Other than splenic breadth and volume, rest of the parameters are closer to the values of our study.

Among more recent studies, a 2022 study by Gariballah A found mean splenic length, width, thickness, and volume to be 9.32±1.23, 8.64±1.24, 3.86±0.79 cm, and 170.64±72.89cm<sup>3</sup>, respectively for a Sudanese population. This study also found a significant difference between males and females, and stated that height, weight and BMI had a weak positive with splenic volume, while age had a weak negative correlation.[23]

In a 2023 study in a Kurdish population, Fateh M et al. had found the splenic parameters for splenic length, breadth, thickness and volume to

be 10.68±1.28 cm, 4.1±0.58 cm, 7.3±0.9 cm and 174.4±52.4 ml, respectively. Males had larger parameters than females in this study as well. They also found a significant positive correlation with splenic length and height as well as weight, and a significant negative correlation with age. [24] These recent studies are consistent with studies from the past.

These studies indicate a wide variation between splenic parameters normal level between populations, and different degrees of correlation with the other parameters such as age, height, weight and difference between males and females.

Among the Indian studies, the 2010 study by Aurora N et al. among North Indian adults, the mean splenic length ranged from 107.24 to 97.09 mms for males and females in 21-30 year age group, while at 51-60 years they found the splenic length to be 87.85 to 85.06 mms for males and females respectively. For the splenic width of males and females, the 21-30 year showed an average of 55.07 to 47.27 mms, and 51-60 years showed a 42.64 to 38.65 mms respectively. The thickness of spleen for the 21 - 30 years showed a 39.60 and 35.45 mms average values for males and females, and at 51-60 it was 34.41 to 30.90 mms respectively. This value appears closer to our study (and 9.7054 ± 1.061cm, 6.05 ± 0.7490cm, 3.4818 ± 0.5907cm for the average of entire sample). They also concluded the effect of age leading to a decrease in the splenic parameters, but have found a significant difference between males and females.[6]

The 2013 study by the same authors on a North Indian population further explored the correlation of the splenic parameters with the height and weight. They concluded that splenic length had a positive correlation with that of height, weight and body surface area; and that splenic length differed between males and females. This effect was not found in our study. However, Aurora N et al. also found a negative correlation of splenic length with age, which was consistent with our study.[9]

In 2016, Chakraborti S et al. found that in a population from Tripura, India splenic length decreased with increase in age in both males and females. They found the splenic length to be increasing with height, weight and surface area in both males and females. They also found a difference between males and females for the splenic length, however such differences for other splenic parameters were not stated. This finding did not match with finding of the present study. However, Chakraborti S et al. also found a negative correlation of splenic length with age, which matches with the findings of present study.

Singh A et al. in their 2016 study in Bihar has found that the splenic length correlated positively with that of height, and found a significant difference between males and females.[10] This study did not correlate the age with splenic parameters.

From reviewing the existing literature it was found that in our study the positive correlation with splenic length with height and significant difference between males and females were absent. This might be due to the fact that our study population had a significantly (on conducting one sample t test to compare our mean values of height with national average  $t = -10.514$ ,  $p < 0.0001$ , CI 95% for males and  $t = -11.228$ ,  $p < 0.0001$ , CI 95% for females respectively) lower average height comparing to the national average (166.50 for Indian average male and 155.18 cm for Indian average female, comparative to  $153.63 \pm 6.92$  cm for males and  $146.40 \pm 6.9$  cm for females respectively. Also, the parameters vary widely between studies, which are done in distinct populations. It shows that different studies have found different types of correlation of body parameters with splenic parameters.

#### Study Limitations

The study was done in a limited sample size, and due to variations in different population may not be applicable to all. Present study also had more females than males, and the sample did not have a diverse age range with sufficient quantities. Subclinical undiagnosed diseases that have no documentation may also influence the results. The effect of nutrition on height can also have lead to the lower average height of the participants, which might have reflected in splenic parameters. Some women had pregnancy, which might also influence the splenic volume to some extent. A larger study involving more samples might help explore the statistical difference and significance better.

#### Conclusion

This study had sought to explore the normal splenic dimensions in an Eastern Bihar population and compared the values to that of other studies. Our study indicates a negative correlation of splenic parameters including length, breadth and volume with age, but not thickness (insignificant). There was no significant difference between males and females, and no significant correlation was found between splenic parameters with that of the height and weight of the individuals. Review of existing literature suggested a wide variation between splenic dimensions of population of different countries as well as within India. The findings of this study are consistent with the rest in this regard.

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