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Establishing CT-based reference ranges for liver and spleen sizes in the Pakistani pediatric population

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ABSTRACT

Background: Accurate liver and spleen reference ranges are essential for diagnosing pediatric abnormalities. Most existing data rely on ultrasound, while CT offers greater measurement precision, yet age-specific CT-based norms remain limited. This study aims to establish CT based reference values for liver and spleen sizes based on age, gender and anthropometric parameters in Pakistani pediatric population.

Methods: This study analyzed CT scans of 772 children aged 0 to 16 years, selected from 7,000 records from January 2010 to December 2024 at Aga khan University hospital Karachi. The participants were grouped into 19 age categories ranging from 0-1 week to 15-16 years. At least four liver measurements and three spleen measurements were taken on axial and coronal images for every case. Mean and standard deviation were calculated, and variations between age groups and genders were evaluated.

Results: Liver and spleen sizes increased significantly with age ($p < 0.001$). The mean liver anteroposterior (AP) diameter taken at mid-clavicular increased from 76.59 ± 15.25 mm in the youngest age group to 129.49 ± 14.05 mm in the older children. Similarly, the liver's transverse diameter increased from 85.76 ± 22.03 mm to 154.14 ± 26.20 mm ($p < 0.001$). Spleen dimensions also displayed consistent age-dependent growth ($p < 0.001$). Although males had marginally higher mean values, the differences were statistically insignificant. Furthermore, height and BMI were found to be the strongest independent predictors overall through the regression analysis.

Conclusion: Both liver and spleen dimensions showed a steady increase with age, with no significant differences between boys and girls. These CT-based reference ranges provide valuable benchmarks to distinguish normal organ growth from pathological enlargement in children.

Keywords: Computed Tomography, Liver, Organ Dimensions, Spleen

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Introduction

Measuring liver and spleen size in children is clinically important because deviations from normal dimensions may signal early disease, including infections, hematologic disorders, metabolic conditions, and malignancies (1,2). Establishing accurate normative values is therefore essential for distinguishing physiological growth from pathological enlargement. Ultrasonography is commonly used for this purpose due to its safety, accessibility, and lack of radiation; however, its accuracy is operator-dependent and frequently affected by intestinal gas, patient habitus, and variable image quality (3,4).

In contrast, computed tomography (CT) provides highly consistent imaging with excellent spatial resolution, enabling precise organ measurements and minimal interobserver variability (5). With advancements in low-dose pediatric CT protocols and enhanced image-processing techniques, CT has become a dependable modality for generating normative organ size data (6). Despite this, CT-based reference values for pediatric liver and spleen dimensions remain limited, particularly for South Asian populations (5).

Organ size is influenced by multiple factors including age, sex, height, weight, body surface area, nutritional status, and ethnicity (7,8). Studies have demonstrated considerable variation in liver and spleen size among children of the same age, shaped by genetic, dietary, and environmental determinants (9,10). Prior research consistently shows strong associations between organ size and anthropometric measures such as height, weight, and overall body habitus (11,12). Metabolic variables, including body fat composition or conditions like fatty liver disease, may further contribute to organ enlargement (13).

Evidence from other regions supports the need for population-specific reference charts. Waelti and colleagues emphasized this for Central European children (9), while de Padua et al. demonstrated the importance of tailored CT-derived ranges for accurate interpretation in pediatric populations (5). Given the rapid somatic growth in early childhood and adolescence, stratification into narrower age groups further refines assessment accuracy (8).

For Pakistani children, reliable CT-based normative measurements for the liver and spleen are lacking. Ultrasound-derived reference values from other populations may not be applicable due to ethnic and anthropometric differences. To date, no CT-based study has established normal pediatric organ dimensions in Pakistan. The present study aims to generate CT-derived reference ranges for liver and spleen size in Pakistani children and assess their associations with age, sex, height, weight, and body surface area.

Methods

This is a cross-sectional study carried out at the Radiology Department of Aga Khan University Hospital in Pakistan. CT scans done over a 14-year period from January 2010 to December 2024 were reviewed. All available pediatric CT scans in which liver and spleen were imaged due to any reason, were evaluated for eligibility. A total of 7,000 pediatric CT records were screened from the hospital database, and 772 scans met the inclusion criteria. Children aged 0 to 16 years who underwent unenhanced or contrast-enhanced CT scans for indications unrelated to hepatic or splenic pathology were included in this study. Only CT examinations demonstrating normal liver and spleen morphology, without evidence of structural or congenital abnormalities, were considered eligible

Demographic information including age, sex, height, weight, and BMI was mandatory for inclusion), and these data were accepted only if recorded within one month of the CT examination. Data was extracted from electronic medical records. Children were excluded if they had known or suspected hepatic, splenic, or systemic conditions that could influence organ size, such as hepatitis, storage disorders, anemia, portal hypertension, malignancy, or infection. CT scans showing evidence of trauma, congenital anomalies, venous congestion, sepsis, significant ascites, pleural effusion, or post-surgical abdominal changes were also excluded. In addition, cases with incomplete clinical information or missing anthropometric records were omitted from analysis.

The final sample had a mean age of 6.78 ± 4.78 years (range: newborn to 16 years), with approximately 60% males. The age groups with the highest representation were 1–2 years and 4–5 years (each 9.2%), followed by 13–14 years (8.0%), while the 15–16-year group had the lowest representation (0.5%). Mean weight, height, and BMI were 22.66 ± 15.69 kg, 112.39 ± 34.42 cm, and 15.78 ± 4.35, respectively. For age-specific analysis of liver and spleen dimensions, participants were categorized into predefined age groups: 0–1 week, 1 week–4 months, 4–8 months, 8–12 months, 1–2 years, 2–3 years, 3–4 years, 4–5 years, 5–6 years, 6–7 years, 7–8 years, 8–9 years, 9–10 years, 10–11 years, 11–12 years, 12–13 years, 13–14 years, 14–15 years, and 15–16 years.

All examinations were performed on either multidetector CT scanners GE-Health Care (Revolution 128-slice systems) or Toshiba (Aquilion 640-slice systems) using a standardized pediatric abdominal imaging protocol. Tube voltage (80–120 kVp) and current were adjusted according to patient body weight following ALARA (As Low as Reasonably Achievable) principles. All images were reviewed on dedicated radiology workstations (PACS viewer) with standardized display settings for measurement consistency. Organ measurements were obtained using electronic calipers on axial and coronal reformatted CT images.

The maximum craniocaudal length of the right hepatic lobe was measured on coronal images at the level of the main portal vein, from the dome to the inferior margin. Another craniocaudal length was measured in midclavicular line at the level of portal vein. The anteroposterior (AP) diameter and maximum transverse diameter were recorded on axial images at the same level, measured in the midclavicular line and between the right and left hepatic margins, respectively (figure 1).

Splenic length was measured along its longest axis on coronal images. The maximum oblique transverse diameter was obtained on axial images, and splenic thickness was measured at the hilum perpendicular to the transverse axis (figure 1)

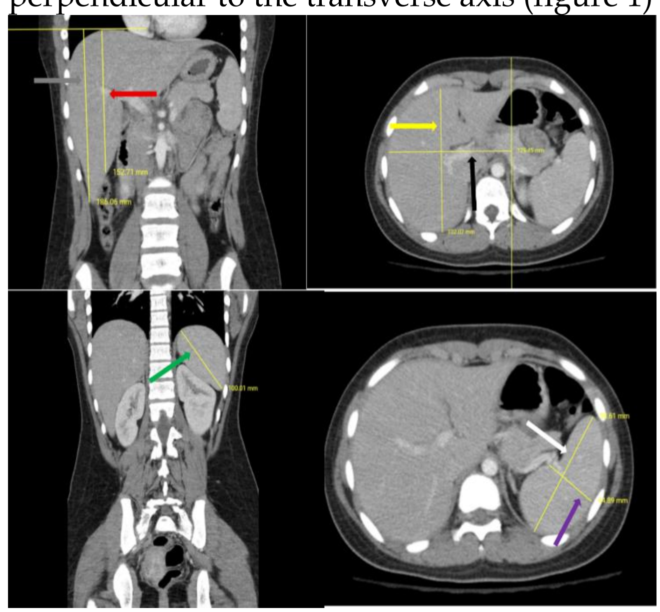

Figure 1: Picture Liver and Spleen measurement methods used in this study.

The liver measurements included the maximum coronal dimension at the level of the portal vein (grey arrow), the coronal dimension in the midclavicular line at the same level (red arrow), the anteroposterior dimension in the midclavicular line (yellow arrow), and the maximum transverse diameter at the portal vein level (black arrow). For the spleen, the maximum oblique coronal dimension was recorded (green arrow), along with the long-axis measurement at the level of the hilum on the axial plane (white arrow).

SPSS version 27 was used for data analysis. Numeric data (like age, weight, BSA, height, liver, and spleen sizes) were summarized as mean ± SD or median (IQR), based on the normal distribution. Nominal variables were expressed as frequency and percentages. Numeric data differences were calculated using student independent t-test or Mann–Whitney U test. Correlation between organ size and somatic variables were determined using Pearson's or Spearman's tests. Independent predictors of liver and spleen dimensions were determined using linear regressions model. A p-value below 0.05 was considered statistically significant.

This study was approved by the Ethics Review Committee (ERC) of Aga Khan University hospital prior to data collection and retrieval. Keeping in view the retrospective nature of the study, informed consent was waived (2025-11363-34324

Results

A total of 772 children were included in the final analysis. Comparison between male and female participants showed that girls were slightly older on average (7.28 ± 4.79 years) than boys (6.42 ± 4.75 years), and this difference was statistically significant (p = 0.014), reflecting small age variations between sexes in the sample. A similar trend was observed for height, which was also significantly higher in girls (p = 0.031). Mean BMI was slightly higher in girls (15.89 ± 4.78) than boys (15.70 ± 4.04), although this difference was not statistically significant (p = 0.540). Body surface area (BSA) was significantly higher in girls (0.85 ± 0.40) compared to boys (0.79 ± 0.40, p = 0.046), suggesting modest sex-related differences in body size. These findings provide important context for interpreting organ size measurements. Detailed demographic and anthropometric data are presented in Table1.

Table 1: Demographic and anthropometric parameters based on gender

Parameters		Total	Gender		P-value
			Male, n=457	Female, n=314	
Age (mean ± SD)		6.78±4.78	6.42±4.75	7.28±4.79	0.014
Age groups	0 - 1 wk	13 (1.7)	9 (2.0)	4 (1.3)	0.214
	1 wk - 4 mo	43 (5.6)	29 (6.3)	14 (4.5)	
	4 - 8 mo	31 (4.0)	21 (4.6)	10 (3.2)	
	8 - 12 mo	47 (6.1)	24 (5.3)	23 (7.3)	
	1 - 2 y	71 (9.2)	46 (10.1)	25 (8.0)	
	2 - 3 y	49 (6.3)	38 (8.3)	11 (3.5)	
	3 - 4 y	7 (0.9)	3 (0.7)	4 (1.3)	
	4 - 5 y	72 (9.3)	42 (9.2)	30 (9.6)	
	5 - 6 y	50 (6.5)	29 (6.3)	21 (6.7)	
	6 - 7 y	46 (6.0)	26 (5.7)	20 (6.4)	
	7 - 8 y	39 (5.1)	25 (5.5)	14 (4.5)	
	8 - 9 y	43 (5.6)	24 (5.3)	19 (6.1)	
	9 - 10 y	43 (5.6)	27 (5.9)	16 (5.1)	
	10 - 11 y	46 (6.0)	25 (5.5)	21 (6.7)	
	11 - 12 y	39 (5.1)	17 (3.7)	22 (7.0)	
	12 - 13 y	50 (6.5)	29 (6.3)	21 (6.7)	
	13 - 14 y	62 (8.0)	29 (6.3)	32 (10.2)	
	14 - 15 y	17 (2.2)	12 (2.6)	5 (1.6)	
	15 - 16 y	4 (0.5)	2 (0.4)	2 (0.6)	
Weight (mean ± SD)		22.66± 15.69	21.76 ± 15.40	23.90± 16.04	0.063
Height (mean ± SD)		112.39± 34.42	110.11± 34.90	115.57± 33.41	0.031
BMI		15.78± 4.35	15.70 ±	15.89	0.540

(mean ± SD)		4.04	±4.78	
BSA (mean ± SD)	0.82± 0.40	0.79 ± 0.40	0.85 ±0.40	0.046

Statistically significant gender differences were observed only in the liver mid-clavicular coronal dimension (p = 0.016), with females showing a slightly higher mean value (100.40 ± 49.58 mm) compared to males (93.74 ± 25.59 mm).No statistically significant differences were found in the other CT dimensions, including liver maximal AP mid-clavicular (p = 0.773), maximal transverse (p = 0.338), maximal coronal (p = 0.724), spleen axial long axis (p = 0.583), spleen axial short axis (p = 0.478), and spleen maximal coronal oblique (p = 0.887).These results provide evidence that sex has a limited impact on overall organ size in the studied pediatric population (Table 2).

Table 2: Gender differences in liver and spleen CT measurements

Liver and sleep dimensions	Gender												p-value
	Male						Female						
	Mean± SD	Min	Max	Median	Percentile		Mean±SD	Min	Max	Median	Percentile		
					75	25					75	25	
Liver maximal AP mid-clavicular (axial)	106.98± 23.25	11.50	170.00	108.00	123.00	92.60	107.46±21.39	28.00	161.00	110.15	123.00	94.00	0.773
Liver maximal transverse (axial)	122.82± 33.31	46.00	220.00	124.00	144.00	98.00	125.15±32.26	50.00	205.00	125.00	149.00	103.00	0.338
Liver maximal coronal	121.17± 29.73	44.00	207.00	121.00	142.00	100.00	121.95±30.17	42.90	192.00	123.00	142.00	101.00	0.724
Liver mid-clavicular line coronal	93.74± 25.59	32.00	178.00	93.90	111.00	73.66	100.40±49.58	28.10	820.00	97.00	116.00	77.21	0.016
Spleen axial long axis	72.39± 19.86	19.40	133.00	73.30	85.90	58.60	71.58±19.87	6.80	119.00	72.70	85.00	57.90	0.583
Spleen axial short axis	30.63± 10.23	9.40	101.10	29.70	35.50	25.00	30.09±10.16	11.00	87.82	29.50	35.00	24.00	0.478
Spleen maximal coronal oblique	76.14± 19.19	24.20	130.00	77.00	89.50	63.90	75.93±20.08	28.00	128.00	75.50	90.00	64.00	0.887

Both liver maximal antero-posterior (AP) and transverse dimensions established statistically significant differences across pediatric age groups (p = 0.001). The mean liver maximal AP dimension progressively increased from 67.45 ± 20.37 mm in neonates (0–1 week) to 136.25 ± 10.34 mm among adolescents aged 15–16 years.

Table 3: Differences of axial Liver CT measurements across age groups

Age groups	Liver maximal AP					Liver maximal transverse				
	Mean ± SD	Min	Max	Percentile		Mean ± SD	Min	Max	Percentile	
				05	95				05	95
0 - 1 wk	67.45±20.37	49.00	116.00	49.00	116.00	75.74±30.45	46.00	158.00	46.00	158.00
1 wk - 4 mo	67.47±10.25	40.50	104.00	53.90	79.00	76.12±18.27	47.00	118.00	50.20	110.00
4 - 8 mo	79.08±16.68	28.00	117.00	51.00	117.00	87.06±15.81	58.00	113.00	60.00	112.00
8 - 12 mo	85.61±9.84	66.00	110.00	68.00	98.00	96.29±21.52	62.00	145.00	69.00	137.00
1 - 2 y	91.14±9.93	70.00	113.00	70.30	109.00	102.63±23.22	63.50	157.00	72.00	145.00
2 - 3 y	98.82±10.05	75.00	123.00	85.70	117.00	110.27±18.48	79.40	152.00	84.60	138.00
3 - 4 y	103.53±6.19	97.00	113.00	97.00	113.00	116.34±22.66	84.00	153.00	84.00	153.00
4 - 5 y	102.74±12.36	56.00	128.00	82.00	122.00	119.49±21.46	63.60	164.00	79.00	155.00
5 - 6 y	110.13±11.02	91.00	153.00	93.30	125.00	125.06±22.09	89.00	177.00	93.00	165.00
6 - 7 y	111.66±20.50	11.50	141.00	85.00	136.00	132.94±29.13	62.00	196.00	96.00	182.00
7 - 8 y	112.24±9.34	92.60	132.00	96.00	131.00	136.05±25.39	82.60	186.00	85.00	184.00
8 - 9 y	121.22±15.89	93.00	163.00	99.50	146.00	135.10±24.82	99.00	193.00	104.00	175.00
9 - 10 y	121.80±11.95	100.00	147.00	103.00	143.00	137.26±25.33	63.00	183.00	102.00	179.00
10 - 11 y	123.73±10.91	107.00	161.00	108.00	138.00	145.00±23.25	100.00	203.00	115.00	190.00
11 - 12 y	120.1311.91±	96.30	150.00	99.00	148.00	140.08±18.87	104.00	175.00	104.00	174.00
12 - 13 y	127.43±14.23	95.00	160.00	105.00	152.00	153.68±24.96	114.00	205.00	118.00	194.00
13 - 14 y	130.14±14.08	100.00	160.00	106.50	153.50	151.21±25.13	101.00	203.00	116.50	199.00
14 - 15 y	131.71±14.22	105.00	170.00	105.00	170.00	164.59±31.39	122.00	220.00	122.00	220.00
15 - 16 y	136.2510.34±	125.00	146.00	125.00	146.00	159.50±32.56	126.00	199.00	126.00	199.00

Table 3 presents the mean liver maximal transverse dimension showed a consistent rise from 75.74 ± 30.45 mm to 159.50 ± 32.56 mm over the same age range.

Table 4: Differences of coronal liver CT measurements based on age groups

Age groups	Liver maximal coronal dimensions					Liver mild-clavicular line coronal dimensions				
	Mean ± SD	Min	Max	Percentile		Mean ± SD	Min	Max	Percentile	
				05	95				05	95
0 - 1 wk	74.35±24.06	53.40	135.00	53.40	135.00	59.34±19.78	38.00	118.00	38.00	118.00
1 wk-4 mo	73.43±14.28	42.90	116.00	50.10	88.60	58.86±11.38	32.00	89.00	39.40	72.80
4 - 8 mo	84.95±15.38	51.00	110.00	56.60	105.00	64.80±15.64	28.10	92.00	36.00	90.00
8 - 12 mo	92.60±12.44	71.00	121.00	74.30	109.00	91.82±109.25	46.00	820.00	59.00	97.00
1 - 2 y	101.11±15.84	64.00	137.00	76.20	130.00	81.87±16.24	41.20	111.00	53.00	108.00
2 - 3 y	105.50±12.31	81.90	133.00	87.00	128.00	86.06±12.97	62.00	108.00	66.00	105.00
3 - 4 y	105.40±21.47	80.00	141.00	80.00	141.00	88.87±16.58	65.70	110.00	65.70	110.00
4 - 5 y	112.67±17.24	59.40	157.00	79.00	142.00	89.16±18.81	45.30	132.00	50.00	120.00
5 - 6 y	121.29±13.64	92.00	153.00	98.00	139.00	90.02±17.47	52.00	128.00	59.00	113.00
6 - 7 y	124.70±18.84	86.00	171.00	92.30	160.00	98.66±20.98	48.00	148.00	68.00	141.00
7 - 8 y	129.59±17.83	93.00	175.00	105.00	169.00	100.76±19.83	54.20	137.00	60.00	135.00
8 - 9 y	137.43±23.59	101.00	207.00	109.40	175.00	110.23±21.37	75.00	178.00	83.00	139.00
9 - 10 y	140.55±13.98	101.00	167.70	115.00	159.00	109.66±22.12	58.00	143.50	64.00	142.00

10 - 11 y	143.84±16.33	111.00	179.00	116.00	178.00	112.18±25.70	52.80	171.00	65.00	163.00
11 - 12 y	143.07±16.75	105.00	186.00	112.00	170.00	110.82±21.40	59.40	157.00	60.50	150.00
12 - 13 y	148.65±19.00	85.50	192.00	122.00	179.00	118.45±20.68	69.00	180.00	75.70	148.00
13 - 14 y	156.69±19.14	109.00	199.00	125.50	193.50	121.40±24.49	66.30	176.00	74.00	164.00
14 - 15 y	160.24±18.21	131.00	186.00	131.00	186.00	117.53±22.83	75.00	152.00	75.00	152.00
15 - 16 y	163.25±8.14	154.00	173.00	154.00	173.00	109.15±35.54	64.60	150.00	64.60	150.00

Similarly, liver's maximal coronal and mid-clavicular line coronal dimensions exhibited differences among various pediatric age groups (p = 0.001). The mean maximal coronal liver size increased from 74.35 ± 24.06 mm in newborns (0–1 week) to 163.25 ± 8.14 mm in adolescents aged 15–16 years. The mean liver mid-clavicular coronal length grew from 59.34 ± 19.78 mm in the youngest group to 109.15 ± 35.54 mm in the oldest [table 4]. All the three spleen sizes including axial long axis, axial short axis and maximal oblique dimension exhibited statistically significant differences across pediatric age groups (p = 0.001). The mean axial long axis of the spleen grew from 44.54 ± 18.05 mm in newborns (0–1 week) to 115.25 ± 14.38 mm in teens aged 15–16 years. Likewise, the axial short axis increased from 16.51 ± 6.71 mm to 40.40 ± 6.38 mm, and the largest oblique coronal length rose from 42.95 ± 17.56 mm to 98.05 ± 13.54 mm as illustrated in Table 5.

Table 5: Spleen measurements comparison across age groups

Age groups	Spleen axial long axis					Spleen axial short axis					Spleen maximal Oblique				
	Mean ± SD	Min	Max	Percentile		Mean ± SD	Min	Max	Percentile		Mean ± SD	Min	Max	Percentile	
				05	95				05	95				05	95
0 - 1 wk	44.54±18.05	29.30	93.50	29.30	93.50	16.51±6.71	12.00	38.00	12.00	38.00	42.95±17.56	29.00	94.90	29.00	94.90
1 wk-4 mo	42.19±9.10	20.50	59.70	27.30	56.00	18.45±6.23	9.40	49.60	12.40	26.00	44.83±9.65	24.20	70.00	29.30	58.00
4 - 8 mo	47.34±9.49	29.20	69.00	29.30	60.20	22.06±7.81	11.00	57.31	15.00	31.10	52.68±14.54	29.00	85.50	29.40	85.50
8 - 12 mo	53.00±8.19	37.50	77.70	41.00	67.00	21.23±4.10	12.00	30.00	16.00	29.00	55.36±9.07	40.00	85.00	42.40	68.40
1 - 2 y	61.76±11.15	39.90	93.70	44.00	79.60	25.51±5.27	11.80	40.80	18.00	33.50	64.10±11.53	36.90	92.00	40.40	84.90
2 - 3 y	64.89±10.75	28.90	85.90	47.70	81.60	27.36±7.92	17.00	74.50	20.80	33.00	70.57±9.53	50.00	94.80	57.00	87.00
3 - 4 y	68.24±4.16	60.00	72.00	60.00	72.00	28.01±4.07	23.00	33.20	23.00	33.20	75.20±10.46	57.20	88.20	57.20	88.20
4 - 5 y	67.64±13.32	19.40	98.30	48.00	91.50	29.25±6.48	16.30	61.40	21.90	37.40	72.70±9.65	42.40	98.60	55.60	87.70
5 - 6 y	72.89±15.36	20.00	99.00	54.00	95.00	31.70±9.88	20.00	86.60	22.90	42.20	75.39±11.99	45.00	112.00	58.00	97.00
6 - 7 y	74.49±15.95	6.80	102.00	50.00	99.00	32.15±6.80	20.00	46.70	22.00	44.90	82.07±14.08	44.00	119.00	64.00	106.00
7 - 8 y	77.76±10.02	59.50	96.00	61.00	95.00	31.39±5.22	20.90	50.30	25.00	40.00	78.76±12.08	52.40	99.40	53.00	94.70
8 - 9 y	81.69±13.34	44.20	108.00	65.30	106.00	33.31±7.98	23.00	72.00	26.00	41.70	85.19±16.17	26.00	107.00	61.00	105.00
9 - 10 y	80.10±13.40	29.59	107.00	60.00	102.00	34.52±9.30	21.00	82.29	27.20	41.30	86.43±13.29	60.50	128.00	69.90	106.00
10 - 11 y	85.67±15.03	27.63	110.00	67.00	109.00	36.01±9.33	25.00	87.82	26.90	44.00	89.15±11.44	71.60	117.00	72.20	110.00
11 - 12 y	81.82±14.65	35.40	111.00	55.00	104.00	35.65±12.06	20.20	97.90	25.00	47.30	89.11±13.36	62.40	111.50	63.40	111.00
12 - 13 y	87.48±17.13	32.00	130.00	65.00	115.00	38.51±10.85	20.00	91.00	28.00	51.90	92.46±12.97	37.00	116.00	74.70	110.00
13 - 14 y	93.30±15.62	37.70	132.00	70.35	118.50	38.31±11.53	20.00	101.10	27.35	56.60	96.22±13.20	70.00	126.00	75.55	117.50
14 - 15 y	92.80±12.61	68.30	114.00	68.30	114.00	37.09±4.86	30.00	52.00	30.00	52.00	99.78±13.89	75.00	130.00	75.00	130.00
15 - 16 y	115.25±14.38	99.00	133.00	99.00	133.00	40.40±6.38	33.00	48.00	33.00	48.00	98.05±13.54	82.00	115.00	82.00	115.00

Spearman's rank correlation showed strong positive relationship between anthropometric profile (age, weight, height, BMI, BSA) and liver and spleen dimensions. BSA correlated with liver maximal AP mid-clavicular (ρ = 0.847), liver maximal coronal (ρ = 0.841), and spleen maximal coronal oblique (ρ = 0.792). Age, weight, and height also correlated (ρ > 0.70), while BMI showed weaker yet significant correlations (ρ = 0.22–0.045) as shown in **Figure 2**.

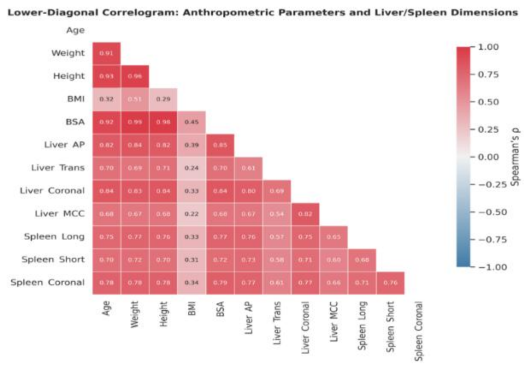

Figure 2: Liver/Spleen measurement correlation with anthropometric parameters

A positive linear relationship between liver size and BSA was observed. Liver maximal AP mid-clavicular diameter correlated strongly with BSA (R^2 = 0.665), while liver transverse diameter showed a moderate correlation with body weight (R^2 = 0.366) as depicted in figure 3.

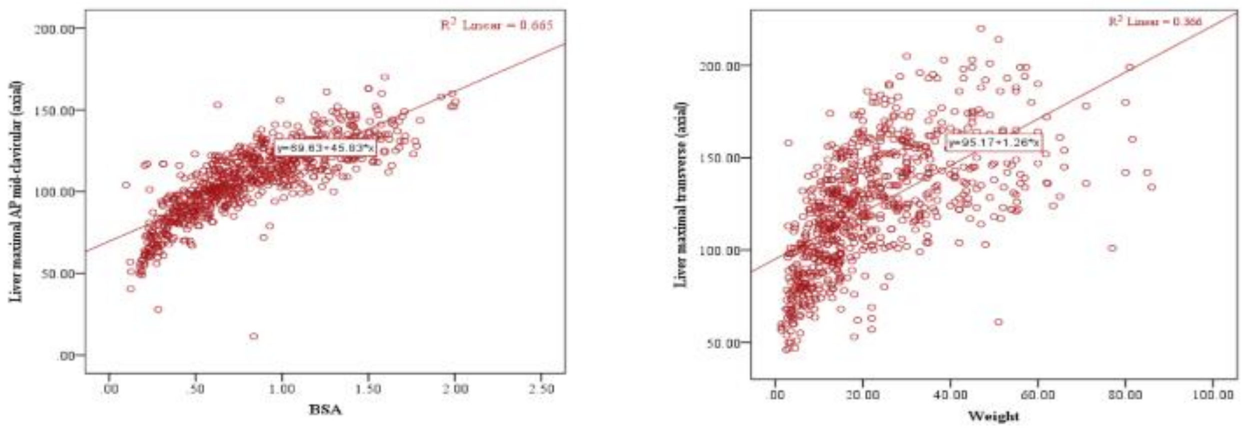

Figure 3: Correlation of liver dimensions with BSA and body weight

The scatter plot displays how BSA relates to spleen size (Axial long axis, Axial short axis, and oblique coronal axis) in males. A positive relationship was observed in Figure 4.

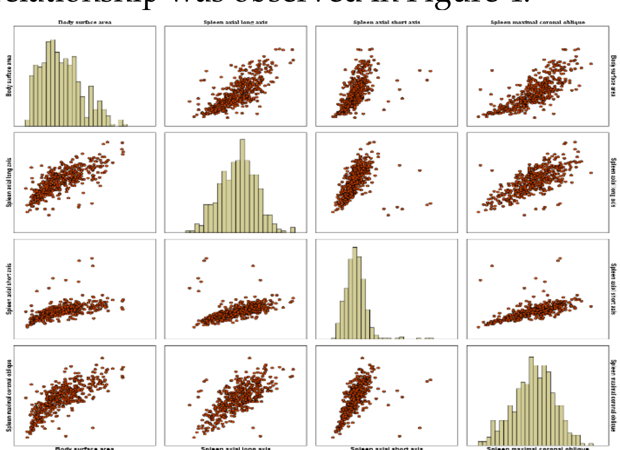

Figure 4: Correlation between BSA and spleen dimensions in male

Similarly, in female the scatter plot shows how body surface area relates to spleen size (long, short, and oblique axes). The graphs depict a strong positive relation as shown in figure 5.

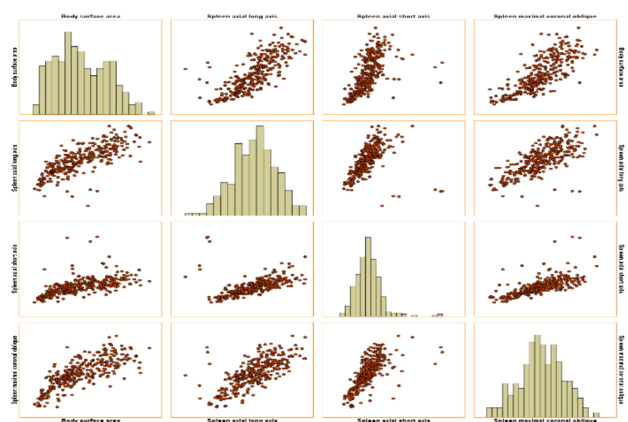

Figure 5: Correlation between BSA and spleen dimensions in female.

Multiple linear regression analysis was run to see the independent predictor's liver and spleen sizes. The models showed best fit (adjusted R^2 = 0.367–0.718), body measurements explained a great differences in organ size. Height and BMI were found to be strong predictors for the liver sizes. For spleen, BMI was main factor for all measurements, showing it has a significant effect. Gender showed that male generally having larger organs. BSA had some positive effect, but it was statistically insignificant. Overall, height and BMI were the most reliable predictors, while age and gender had more mixed effects.

Table 6 : Multiple Linear Regression Analysis for independent factors of Liver and Spleen Dimensions

Predictors	Liver Max. AP Mid-Clavicular	Liver Max. Transverse (Axial)	Spleen Axial Long Axis	Spleen Axial Short Axis	Spleen Maximal Coronal Oblique
Model Fit (R/R^2/Adj R^2)	0.85/0.72/0.72	0.73/0.53/0.53	0.77/0.60/0.59	0.61/0.37/0.37	0.80/0.64/0.64
Age (years)	β = 0.35, p = 0.151	β = 1.26, p = 0.006	β = 0.31, p = 0.230	β = 0.31, p = 0.062	β = 0.50, p = 0.039
Gender (female)	β = -1.99, p = 0.026	β = -1.25, p = 0.462	β = -2.88, p = 0.002	β = -1.38, p =0 .024	β = -2.28, p = 0.010
Weight (kg)	β = -0.09, p = 0.848	β = -0.48, p = 0.582	β = 0.15, p = 0.766	β = -0.27, p = 0.402	β = -0.82, p = 0.075
Height (cm)	β = 0.70, p < 0.001	β = 0.87, p = 0.009	β = 0.38, p = 0.043	β = 0.12, p = 0.303	β = 0.18, p = 0.306
BMI (kg/m^2)	β = 1.57, p < 0.001	β = 1.36, p = 0.001	β = 0.60, p = 0.009	β = 0.32, p = 0.031	β = 0.55, p = 0.011
BSA (m^2)	β = -18.78, p = 0.558	β = -16.33, p = 0.788	β = -4.61, p = 0.892	β = 10.31, p = 0.637	β = 47.02, p = 0.138

Discussion

The study findings revealed a clear age-related growth pattern and determine consistent pediatric CT reference ranges for liver and spleen dimensions. The study population with a mean age of 6.78 ± 4.78 years, all liver and splenic dimensions increased significantly. Somatic variables such as BSA, height, and BMI strongly correlated with organ size, with height and BMI as significant independent predictors.

A study by Yang et al. acknowledged height and weight as leading factors of liver size, our findings endorse height as a significant predictor for liver dimensions through CT (14). A study by Waelti et al. estimated ultrasonographic liver and spleen dimensions in a Central European pediatric population and established that height or BSA indexing reduces inter-ethnic variation (9). Our study results show BSA correlations with liver maximal AP and coronal dimension; age-specific percentiles align with Bayramoğlu et al., confirming steady growth patterns (6).

Another study by Toro et al. described that liver and spleen dimensions increase with age, with height and weight as potential factors. This study results support this trend, but they also show that BSA is not a significant factor after inclusion of height and BMI. Conversely, the most significant predictors are height and BMI with there being some overlap between the predictors (15).

The growth patterns correlating with age, height, weight, and BMI are indicative of normal biological organ growth. The different measurement results in various studies could be attributed to the differences in imaging methods, the nature of the populations studied, or their nutritional levels. The careful division into different age groups in this research may have led to a more precise detection of the phases of rapid growth. The more significant link between BMI and spleen size could be a sign of the effect of fat on measurements made by CT. Suttorp et al (16) and Alves et al (5) found that sex had a relatively small adolescent effect, in accordance with prepubertal growth trends.

The reference ranges based on CT in the pediatric population have given reliable directions for the liver and spleen sizes and have provided reliable directions in situations like trauma, organ enlargement or malignancies. Height and BMI appeared as strong predictors of organ size which means that these parameters are more reliable for the estimation than age alone. Using BMI in assessments may help in early detection of organ enlargement in children with metabolic risk. The regression models (adjusted $R^2 \approx 0.72$) further emphasize the need of interpreting organ measurements by taking into account the wider clinical context (17,18). By incorporating anthropometric data into the regression models, this study provides valuable reference information for interpreting pediatric CT scans, indicating that a more detailed size specification can be produced and comprehended.

These CT-derived normative ranges enable clinicians to reliably differentiate normal organ growth from early pathological enlargement, improving diagnostic accuracy and guiding timely clinical management in pediatric patients. CT imaging provides highly reproducible and precise organ measurements, minimizing operator-dependent variability seen with ultrasound. These normative ranges help clinicians distinguish normal growth patterns from early organ enlargement, supporting more accurate decision-making in pediatric evaluation.

Limitation of the study

The worth mentioning limitation is the lack of longitudinal growth patterns evaluated because this study was conducted at single time point. Because of concerns about radiation exposure, the sample size was also constrained using CT imaging. Therefore, future studies should compare results with larger cohorts. The study's unexplained variation highlights the need for additional studies on variables like body composition, nutrition, ethnic background, and puberty ideally through multicenter studies to improve generalizability.

Conclusion

This study offers CT-derived reference data for the dimensions of the liver and spleen in pediatric populations. Both organs showed considerable increases in size with age, which is normal for growth. The liver showed a steady linear increase, while the spleen expanded proportionally in all directions at the same rate. These results provide reliable baseline data that aid in differentiation between normal organ development and pathological enlargement in pediatric imaging.

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References

1. Rosenberg HK, Markowitz RI, Kolberg H, Park C, Hubbard A, Bellah RD. Normal splenic size in infants and children: sonographic measurements. AJR Am J Roentgenol. 1991;157(1):119-21.doi: 10.2214/ajr.157.1.2048509.
2. Poddar U, Jagadisan B. Measuring liver and spleen by ultrasonography. Indian Pediatr. 2010;47(6):475-6.doi: 10.1007/s13312-010-0086-2.
3. Prassopoulos P, Cavouras D. CT assessment of normal splenic size in children. Acta Radiol. 1994;35(2):152-4
4. Wood L, Baker PM, Martindale A, Jacobs P. Splenectomy in haematology--a 5-year single centre experience. nt J Hematol. 2005;10(6):505-9.doi: 10.1080/10245330500183418.
5. de Padua VAV, Dillman JR. Computed tomography-based measurements of normative liver and spleen volumes in

children. Pediatric radiology. 2023;53(3):378-86.doi: 10.1007/s00247-022-05551-z.
6. Bayramoğlu Z, Ayyıldız H, Ersoy B. Reference Ranges of Age-Based Liver, Spleen, Pancreas, and Kidney Size in Conjunction with Waist Circumference in Children. Turkish archives of pediatrics. 2022;57(2):175-85.doi: 10.5152/TurkArchPediatr.2022.21097
7. El-Shafie AM, Bahbah WA, Zefzaf HMSE, Mousa WA, Abdellatif HA, El-Hossary RH, et al. Establishment of Z score reference of liver, spleen, and kidney parameters for Egyptian children and adolescents: a cross-sectional randomized study. Gaz Egypt Paediatr Assoc. 2024;72(1):75.doi: 10.1186/s43054-024-00313-y.
8. Ünlü S, Ilgar M. Measurement of normal spleen volume and dimensions in all child age groups by abdominal computed tomography. Eur Rev Med Pharmacol Sci. 2022;26(14):5128-35.doi: 10.26355/eurrev_202207_29301.
9. Waelti S, Fischer T, Wildermuth S, Leschka S, Dietrich T, Guesewell S, et al. Normal sonographic liver and spleen dimensions in a central European pediatric population. BMC Pediatr. 2021;21(1):276.doi: 10.1186/s12887-021-02756-3.
10. Schlesinger AE, Edgar KA, Boxer LA. Volume of the spleen in children as measured on CT scans: normal standards as a function of body weight. AJR Am J Roentgenol. 1993;160(5):1107-9.doi: 10.2214/ajr.160.5.8470587.
11. Debnath P, Tkach JA, Saad M, Vitale DS, Abu-El-Haija M, Trout AT. Magnetic resonance imaging T1 mapping of the liver, pancreas and spleen in children. Abdominal Radiology. 2024;49(11):3963-74.doi: 10.1007/s00261-024-04428-z.
12. Khan SA, Yasmeen S, Adel H, Adil SO, Huda F, Khan S. Sonographic Evaluation of Normal Liver, Spleen, and Renal Parameters in Adult Population: A Multicenter Study. Journal of the College of Physicians and Surgeons--Pakistan : JCPSP. 2018;28(11):834-9.doi: 10.29271/jcpsp.2018.11.834.
13. Ezenwuba BN, Hynes CM. Ultrasound screening of paediatric non-alcoholic fatty liver disease (NAFLD): A critical literature review. Radiography. 2024;30(5):1317-25.doi: 10.1016/j.radi.2024.07.006.
14. Yang X, Wang H, Dong B, Hu B, Hao X, Chen X, et al. Standard Liver Volume-Predicting Formulae Derived From Normal Liver Volume in Children Under 18 Years of Age. Frontiers in pediatrics. 2021;9:629645.doi: 10.3389/fped.2021.629645.
15. Calle-Toro JS, Back SJ. Liver, Spleen, and Kidney Size in Children as Measured by Ultrasound: A Systematic Review. J Ultrasound Med. 2020;39(2):223-30.doi: 10.1002/jum.15114.
16. Suttorp M, Classen CF. Splenomegaly in Children and Adolescents. Frontiers in pediatrics. 2021;Volume 9 - 2021.doi: 10.3389/fped.2021.704635.
17. Barr RG, Wilson SR, Rubens D, Garcia-Tsao G, Ferraioli G. Update to the Society of Radiologists in Ultrasound Liver Elastography Consensus Statement. Radiology. 2020;296(2):263-74.doi: 10.1148/radiol.2020192437.
18. Kim DW, Ha J, Lee SS, Kwon JH, Kim NY, Sung YS, et al. Population-based and Personalized Reference Intervals for Liver and Spleen Volumes in Healthy Individuals and Those with Viral Hepatitis. Radiology. 2021;301(2):339-47.doi: 10.1148/radiol.2021204183.

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