

Reference Ranges of Age-Based Liver, Spleen, Pancreas, and Kidney Size in Conjunction with Waist Circumference in Children

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What is already known on this topic?

- Most of the previous studies reported the significant positive correlations of organ length with the height of the children and organ volume/width with the weight of the children.
- The good correlation of computed tomography-based volumetric data with ultrasonography measurements to determine spleen and liver size.
- The organ size has clinical impact for management of diseases.

What this study adds on this topic?

- We provided percentile charts of multiplanar values for solid intraabdominal organ size, size equations, and constant organ size ratios for Turkish children by each age.
- Relative organ size ratios could be applied for isolated renal or portal system pathologies in a practical approach.

ABSTRACT

Objective: In the initial phases of parenchymal diseases, the only finding would be an increase in organ size. We aimed to provide percentile charts of solid intraabdominal organ sizes by age for Turkish children on contrast-enhanced computed tomography images and reveal relative size ratios.

Materials and Methods: A total of 800 abdominal computed tomography examinations of otherwise healthy children (468 males, 332 females) were enrolled. The transverse diameter and lengths of both liver lobes, the thickness of the pancreas, width and length of the spleen, and anteroposterior diameters and lengths of both kidneys were measured. Differences in mean diameters among ages were compared with the analysis of variance test. Pearson's correlation was assessed to depict the association of size with age and waist circumference.

Results: Percentile charts for all measured size parameters that presented statistically significant positive correlations with age and waist circumference were provided. There were constant ratios of the right liver lobe to the left liver lobe (1.9 ± 0.37), right liver lobe to the right kidney (1.56 ± 0.26), left to the right kidney (1.03 ± 0.09), and spleen to the left kidney (1 ± 0.2) lengths in every age groups. Age (years)-dependant regression equation for waist circumference (mm) was depicted as " $22 \times \text{age} + 408$."

Conclusion: Age-based percentile charts of solid intraabdominal organ diameters along with relative organ size ratios were provided.

Keywords: Dimension, kidney, liver, pancreas, percentiles, spleen

INTRODUCTION

The only finding would be increased size in the initial phases of parenchymal diseases. Therefore, being aware of normal organ size for each age would facilitate the management of the subjects in terms of treatment, further evaluation, or follow-up.

Most of the previous studies reported the significant positive correlations of organ length with the height of the children and organ volume/width with the weight of the children.¹ Although growth curves are dependant on multiple factors, and age is not the unique parameter determining the height and weight, age would be a reliable parameter for estimating organ size during the growth period in childhood. Age group-related data have been used to interpret normal organ lengths.² However, there has been limited data for organ diameters in healthy children for each age.

Radiation exposure limits the clinical usage of computed tomography (CT) in pediatric population. Technological developments providing CT images with lower exposure dose resulted in the frequent use of CT in pediatric evaluation after trauma and in case of acute

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abdominal pain. Therefore, CT-based data could be provided for otherwise healthy children who underwent CT only for acute pathologies.

In this study, we aimed to document abdominal solid organ size values by age based on CT-derived data of otherwise healthy children. Composing a percentile chart would help health professionals to manage children appropriately. Additionally, we aimed to compose age relative ratios to reveal organomegaly by comparison in each individual.

MATERIALS AND METHODS

Study Population

In this study, 0- to 17-year-old 800 pediatric subjects (468 males and 332 females) who admitted to the Emergency Department after high energetic trauma or acute abdominal pain and referred to the Radiology Department were enrolled. Age groups included each year of life from infant (0-12 month(s)) to 17 years old and at least 30 participants (Table 1).

Ethical Approval

This study was approved by the local ethics committee (File Number: 2019/646). We did not receive informed consent from the legal guardians of subjects because of the retrospective design and the indication of CT examination for trauma or acute abdominal pain. Abdominal intravenous contrast-enhanced CT examinations were selected from the picture archive and communication systems between December 2010 and December 2018.

Exclusion Criteria

Exclusion criteria were severe abdominal injury regarding organ laceration or parenchymal hematoma, detected signs of chronic parenchymal diseases including diabetes mellitus, hepatic or renal failure, lymphadenopathy, having solitary kidney or organ transplantation, being under follow-up for a background malignancy, venous congestion due to cardiac insufficiency or portal hypertension. Hospital records were scanned for the specified diseases.

Diagnostic Procedures

The subjects were also examined with complete blood count results because of the probability of bleeding after trauma and severe infectious or inflammatory processes. The initial diagnostic examination in most of these children was abdominal ultrasonography (US) both for the suspect of the infection/inflammation and also for trauma. The abdominal US examinations were also in the normal range, but there is no record for organ size due to the fast abdominal US procedure in acute pathologies.

Abdominal Computed Tomography Protocol

Computed tomography images had been obtained using a slice thickness of 0.5 mm with 64 detector CT scanner (Aquilion 64, Toshiba Medical Systems, Tochigi, Japan). The subjects were in a supine position. Computed tomography images were obtained with a radiation exposure range according to age, height, and weight of the subjects. The exposure protocol was 80-100 kVp up to 5 years, 110 cm and 19 kg and 100-120 kVp up to 10 years, 140 cm and 32 kg (in general 1 mAs per kg).

Image Interpretation

The included CT images were selected by consensus of 2 radiologists with 2 or more years of pediatric radiology experience. Images were assessed in the abdomen window with multiplanar reconstructions. The largest oblique transverse diameter of the liver at the level of the mean portal vein (Figure 1A) and cranio-caudal (CC) lengths of right liver lobe from dome to lowermost edge of the sixth segment at the midclavicular line with visualization of the right kidney (Figure 1B) and the left liver lobe at the fourth segment (Figure 1C) were measured. Spleen width as the largest transverse diameter on the axial section (Figure 2A) and spleen length (SL) (Figure 2B) as the largest oblique CC diameter on coronal section CT images were measured. The pancreatic head thickness was measured as the largest medio-lateral (ML) diameter perpendicular to the superior mesenteric vein (Figure 3A). Pancreatic corpus thickness (Figure 3B) and tail thickness (Figure 3C) were measured as anteroposterior (AP) diameter perpendicular to the splenic vein. Renal lengths as the largest oblique CC diameters (Figure 4A) along with the largest oblique AP (Figure 4B) dimensions of both kidneys were measured. We also measured largest AP and transverse dimensions of the abdomen at the level of the umbilicus on the axial section CT image and calculated the circumference of elliptical-shaped abdomen corresponding estimated waist circumference (WC) as an auxological data from a formula ($PI \times \text{SquareRoot of } 2 \times ((1/2 \text{ long axis})^2 + (1/2 \text{ short axis})^2)$, PI is constant and approximately equals to 3.14159).

Statistical Analysis

Statistical Package for the Statistical Package for Social Sciences version 21.0 software (IBM Corp.; Armonk, NY, USA) was used for statistical purposes. Descriptive statistics of the data were expressed as mean, standard deviation, and percentiles. The distribution of variables was tested by the Kolmogorov-Smirnov test. Differences in mean diameters among gender groups were compared with a *t*-test. Differences in mean diameters among ages were compared with analysis of variance (ANOVA) test, and comparisons among consecutive age groups were made by the *t* test. Pearson's correlation analysis was used in associations of age with diameters. We also calculated the relative ratios of left to the right kidney, spleen to the left kidney, and right liver lobe to right kidney lengths. Box-plot graphics were plotted for interquartile ranges of organ size values for each age. Scattered dot graphic was plotted for correlation of age with WC (Figure 5).

RESULTS

Demographic Parameters of the Subjects

There has been no statistically significant difference in each measured parameter among gender groups ($P = .1-.9$). Therefore, we depicted percentiles of diameters by including both males and females for each age.

Descriptive Statistics of the Organ Size Diameters

Mean diameters and standard deviations along with 5th, 50th, 90th, and 95th percentiles of the liver (Table 1), spleen (Table 2), pancreas (Table 3), left kidney (Table 4) and right kidney lengths (Table 5), and WC (Supplementary Table 1) for each age are given in tables. Interquartile ranges for lengths of the right liver lobe (Figure 5A), spleen (Figure 5B), left kidney (Figure 5C), and the right kidney (Figure 5D) are demonstrated in box-plot graphics.

Table 1. Percentiles and Mean Values of Transverse Dimension and Length of Liver Based on Ages

Age (years)	N	Liver-Transverse Diameter (mm)					Right Liver Lobe Length (mm)					Left Liver Lobe Length (mm)				
		Mean \pm Standard Deviation	Percentiles				Mean \pm Standard Deviation	Percentiles				Mean \pm Standard Deviation	Percentiles			
			5th	50th	90th	95th		5th	50th	90th	95th		5th	50th	90th	95th
0-0.59	15	96.6 \pm 16.1	63.5	92	119.1	125	65.2 \pm 11	45.5	66.3	77.2	85	30.1 \pm 5.7	21	35	41	43
0.6-0.99	17	111.4 \pm 14.2	67	103	135	155.3	70 \pm 9	60.1	70.3	85	90.4	36.2 \pm 7.1	26.1	37.2	49.3	52.4
1-1.99	52	120.3 \pm 29.5	78	119.4	152.2	182.7	84.2 \pm 14.8	64.5	80.9	108.8	114.8	43.9 \pm 8.7	30.3	42.5	55.7	59.3
2-2.99	50	124.4 \pm 15.5	101.8	122.7	146	157.4	89.9 \pm 11.8	70.3	90.4	105.6	116.1	51 \pm 9.9	34.2	47.6	55.6	62.8
3-3.99	44	130.4 \pm 14.4	109	127.6	150.8	161.3	93.6 \pm 14.1	73.9	94	114	118.7	48.6 \pm 8.2	36.4	49	58	65.8
4-4.99	47	144.5 \pm 13.8	119.2	145.2	160	173	100.3 \pm 14.5	77.8	98	121	132	54.2 \pm 6.3	43.6	55	62.8	64.9
5-5.99	51	144.6 \pm 14.2	123.5	142.7	168.3	178.9	102 \pm 15.2	68.8	104.5	117.9	125.8	61.7 \pm 10.9	42.2	58.5	71	80.8
6-6.99	36	147.9 \pm 16.4	120.5	147.7	173.8	183	108.5 \pm 17.4	78.6	107.9	130	140.7	55.2 \pm 10	40.2	55.3	66.6	75
7-7.99	38	149.6 \pm 17	106.7	149.4	167	177.5	111.5 \pm 17.3	82.25	112.6	135.25	139.2	57.7 \pm 9.5	37.3	58.3	69.5	72.5
8-8.99	45	158.5 \pm 31.2	118.1	160.6	186.5	194.5	116.4 \pm 17.9	88.9	113.5	138.8	152.4	60.3 \pm 12.5	41.6	58.9	77	87.5
9-9.99	46	159.9 \pm 24.5	116.2	156	192	201.8	114.7 \pm 15.2	89.9	118	131.1	148.7	59.6 \pm 11.1	41.4	57	72.5	76.9
10-10.99	46	165.2 \pm 21.6	133.8	166	190	214.1	123 \pm 16.7	92.6	124.5	147.3	148	61.6 \pm 11.8	40.5	62.5	73.9	78.8
11-11.99	47	171.1 \pm 28.8	140	177.7	223	237	123.7 \pm 17.5	95	124	145	163	67.1 \pm 10.2	49.1	66	80	84
12-12.99	37	176.3 \pm 24	139.6	174	210.6	225.8	123.6 \pm 17.7	92.5	124	146.6	155.5	66.7 \pm 11.7	48.7	65	81.8	87.4
13-13.99	47	181.5 \pm 18.2	154	183.5	211.8	215.4	131.2 \pm 18.6	99.2	129.9	160.9	165	70.7 \pm 12.5	46.8	68.4	86.1	99.4
14-14.99	45	188 \pm 28.5	134	186.3	222.8	243.4	130.9 \pm 16.2	90.6	132.9	149.2	154.7	69.7 \pm 11.6	55.2	68	88.8	93.8
15-15.99	52	188.4 \pm 25.1	151.1	185.3	225.5	236.2	136.8 \pm 15.5	107.5	136	159.1	164.8	74.4 \pm 14.2	55.1	71	92.4	101.6
16-16.99	36	195.3 \pm 27	152.3	191.2	236.6	249.5	139.2 \pm 19.8	96.4	141	162	166.5	73.7 \pm 14.9	51.7	73.5	91	99.5
17-17.99	49	191.9 \pm 20.8	161	192.7	217.4	234.6	141.1 \pm 11.6	89	137.7	153.9	162.1	75 \pm 16.9	50.1	71.1	101.6	117.3

numbers of subjects in age groups.

N, numbers of subjects in age groups.

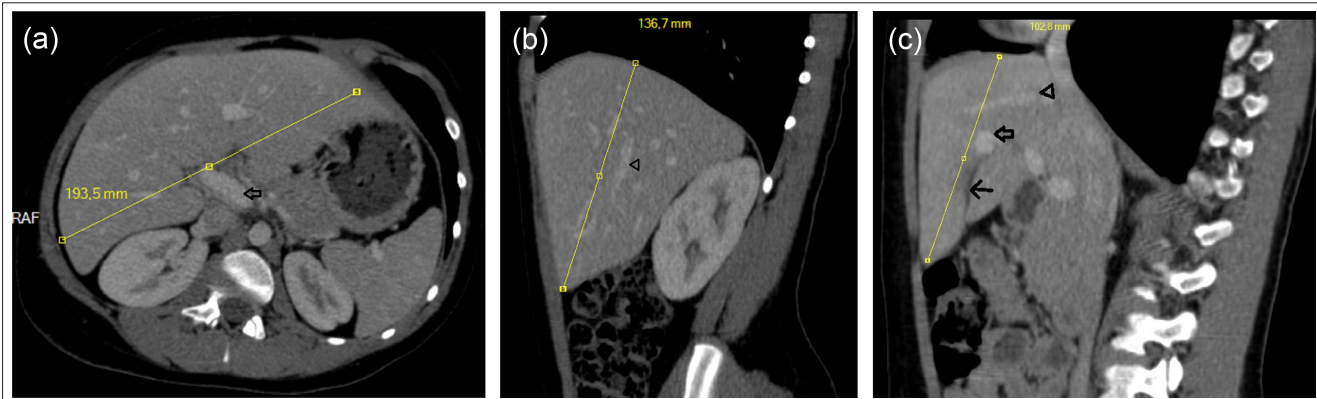


Figure 1 . Measurements of the largest transverse diameter of the whole liver (A) on an oblique axial section from the level of the mean portal vein (thick arrow: portal vein), (B) length of the right hepatic lobe at the midclavicular level (arrowhead: right hepatic vein) and length of the left hepatic lobe (C) at the level of fourth segment (arrow: falciform ligament, arrowhead: left hepatic vein, thick arrow: portal vein) were seen on sagittal sections of contrast-enhanced abdominal CT. CT, computed tomography.

Comparisons Among Age Groups

There have been statistically significant differences in mean solid organ diameters among all consecutive age groups ($P = .001$).

Correlations of the Age with Organ Dimensions

Significant positive correlations of age were found for lengths ($r = 0.83$ for left, $r = 0.82$ for right) and AP diameters of kidneys ($r = 0.77$ for left, $r = 0.78$ for right), respectively ($P = .001$). Highly significant positive correlations between lengths ($r = 0.69$ for right lobe, $r = 0.66$ for left lobe) and transverse dimension ($r = 0.72$) of the liver with age were calculated ($P = .001$). There were positive correlations of splenic width ($r = 0.72$) and length ($r = 0.69$) with age ($P = .001$). Highly significant positive correlations of age were found for pancreas thickness ($r = 0.57$ for head, $r = 0.57$ for corpus, $r = 0.53$ for tail) ($P = .001$).

Correlations of the WC with Organ Dimensions

There was a highly significant positive correlation of age with WC ($P = .001$, $r = 0.77$) (Figure 5E). Right liver lobe length ($r = 0.63$), SL ($r = 0.66$), spleen width ($r = 0.72$), right and left kidney lengths ($r = 0.75$ - 0.76), and pancreas thickness ($r = 0.52$ - 0.54) were significantly correlated with WC, respectively.

Organ Size-Based Relative Ratios

No significant difference ($P = .4$) was found for the mean ratios of the right liver lobe to right kidney (1.56 ± 0.26), left kidney to the right kidney (1.03 ± 0.09), and spleen to left kidney lengths (1 ± 0.2) among age groups. The right to left liver lobe length ratio was 1.9 ± 0.37 without significant difference among age and gender groups ($P = .18$).

Age-Dependant Regression Equation for WC

Age-dependant regression equation for WC (mm) was found as " $22 \times \text{age (years)} + 408$."

DISCUSSION

As far as we know, this has been the largest study evaluating the diameters of solid organs located at the upper abdomen in a single study for Turkish children and the first study presenting size values by percentages for each age. Additionally, relative organ size ratios could be referenced for isolated renal or portal system pathologies in a practical approach at the bedside.

Ultrasonography and computed tomography examinations are both performed in a supine position with breath-hold as far as possible, and as we composed the equations with defining US adjustable measurement protocols on CT, the equations could be used as a reference for both CT and also US-based data.

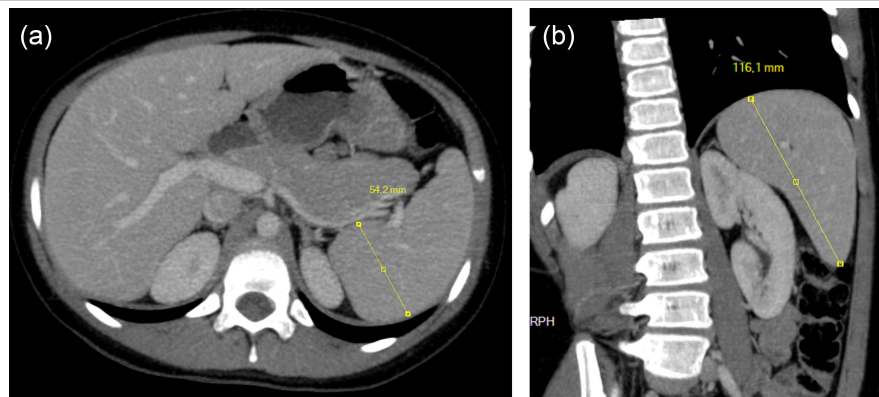


Figure 2 . Measurements of (A) spleen width on axial section CT (B) and length on the coronal section of contrast-enhanced abdominal CT images were seen. CT, computed tomography.

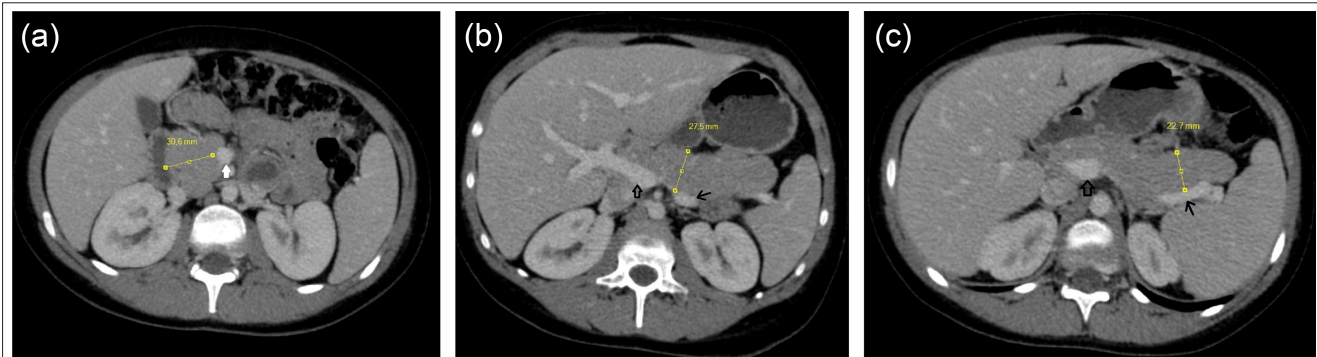


Figure 3. The largest mediolateral thickness of pancreatic head perpendicular to the superior mesenteric vein (white arrow) (A), the largest anteroposterior dimension of the pancreatic corpus (B) at the level of aortomesenteric region (thick arrow: main portal vein, arrow: splenic vein) and pancreatic tail about to splenic hilum at the distal third of the pancreas (C) perpendicular to splenic vein were measured on axial sections of contrast-enhanced abdominal CT. CT, computed tomography.

Our methods of measuring are all the achievable plans and images by US and not the standard dimensions seen on routine coronal or sagittal CT plans. Since we can measure the largest oblique CC dimensions for lengths and AP diameters for pancreas on US, all included dimensions are achievable by US examinations. Although US and CT examinations are performed in a supine position, the main issue is that this is not a synchronous correlative US and CT study and the breath-hold status may have mild effects on the lengths. A recent study revealed the good correlation of CT-based volumetric data with US measurements to determine spleen and liver size.^{3,4}

Liver size has a clinical impact for management of hepatosteatosis, portal hypertension, hematological malignancies, disorders with liver involvement, and palliation-required cardiac diseases resulting in congestive hepatopathy. The liver length was measured on the sagittal section by providing the midclavicular line and visualization of the right kidney in the same plan as a previously determined standard method for the US.⁵ We applied the same method to the study protocol to facilitate the adaptation of US-based data for the percentile charts we provided on CT. The liver size of the Turkish children regarding only length or 2 dimensions for the liver has been determined in a few studies by US.^{1,6,7} A recent study revealed significantly larger liver length in males when compared to females.⁷ However, we did not found a significant difference in mean values of

transverse liver diameter and liver length as well as all measured size parameters of other organs among gender groups. Hepatic, splenic, and renal diameters have been reported in 506 children aged 0-14 by using US in Turkish pediatric population.⁸ The largest study investigating organ dimensions by using US included 712 children, aged 7-15 years.⁶ A recent study investigating hepatic and splenic diameters in infancy to pre-adolescence subdivided the children to only 9 age groups, and age groups covered 2 years of life.⁹ In the current study, all ages with a considerable number of participants in each age group were included, which were insufficient in the previous US-based studies. Additionally, age and WC were found to be independent and strong estimators for liver and other organ sizes. Waist circumference is an auxological parameter that has a clinical impact on metabolic syndrome predicting cardiovascular risk. Since body mass index (BMI) could not reflect abdominal obesity alone, WC would be more valuable than BMI to predict hepatic steatosis and therefore liver size. We thought that the circumference of the ellipsoidal-shaped abdomen can be calculated approximately by CT examination, taking into account the abdominal AP and ML diameters. The median WC values were higher than 400 mm in 1-4 years of children, higher than 500 mm in 5-11 years of children, higher than 600 mm in 12-14 years of children, and higher than 700 mm in 15-17 years of children with this calculated method. Normative values of WC in children in conjunction with age have been recently

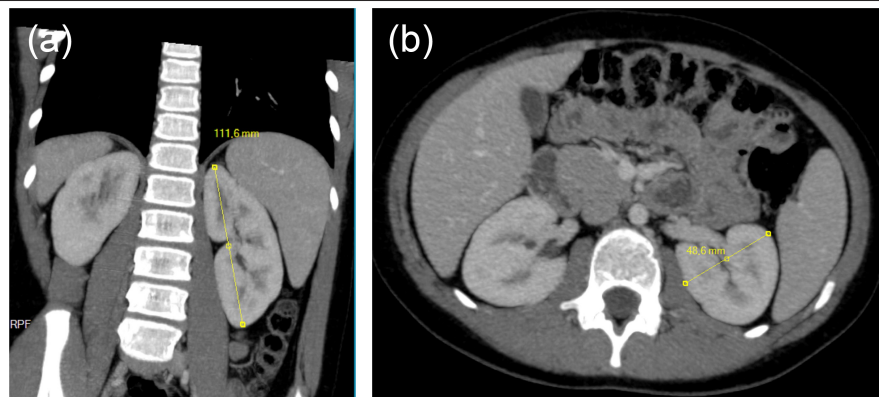


Figure 4. Measurements of (A) length of left kidney on an oblique coronal section and (B) oblique axial diameter of left kidney on an axial section of contrast-enhanced abdominal CT were shown. CT, computed tomography.

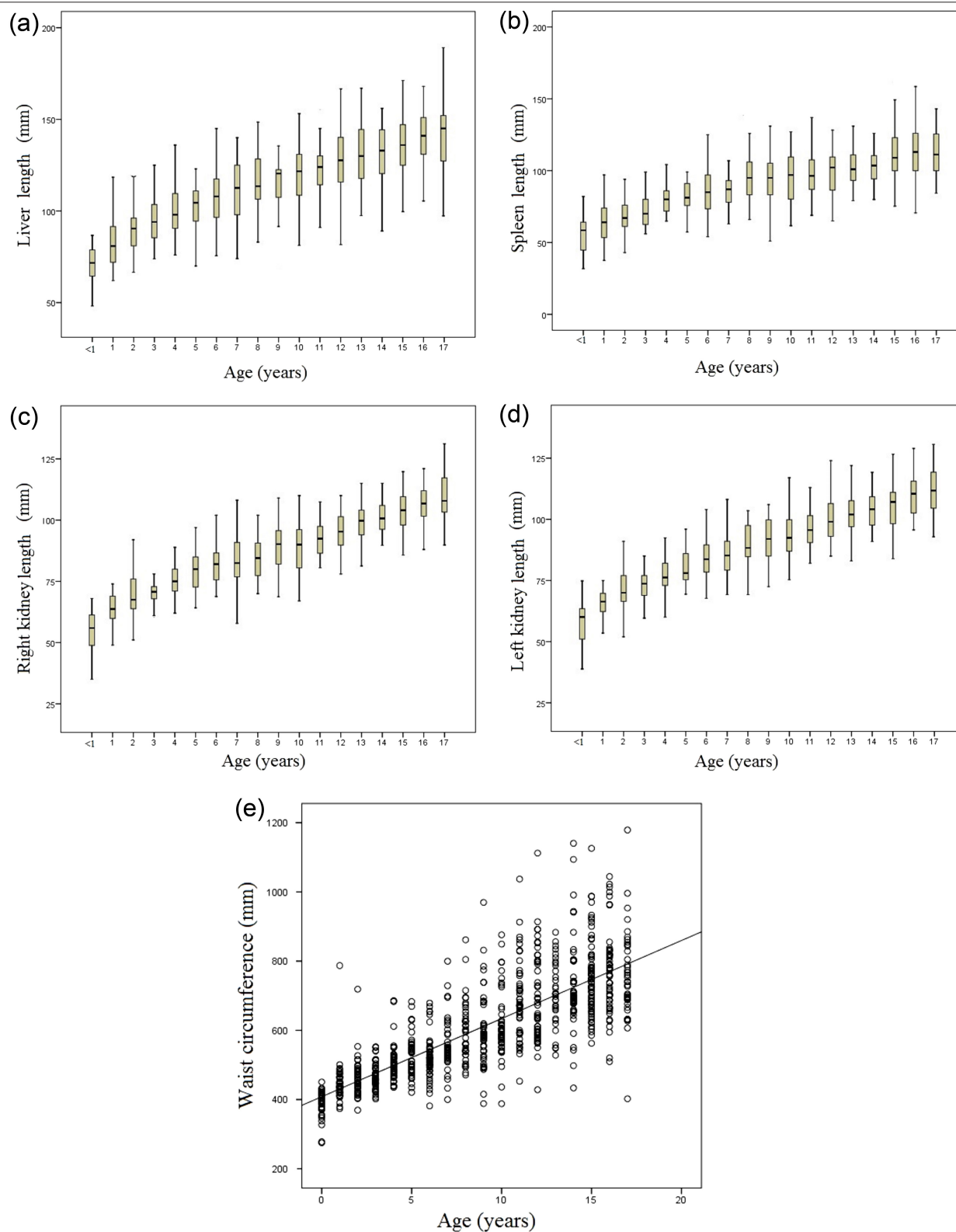


Figure 5. Box-plot graphics show liver (A), spleen (B), right (C), and left kidney (D) lengths according to age. Boxes indicate 25th-75th percentile ranges. Scattered dot graphic (E) shows a positive correlation of age with waist circumference.

Table 2. Percentiles and Mean Values of Width and Length of Spleen Based on Ages

Age (Years)	Spleen Length (mm)					Spleen Width (mm)				
	Mean \pm Standard Deviation	Percentiles				Mean \pm Standard Deviation	Percentiles			
		5th	50th	90th	95th		5th	50th	90th	95th
0-0.59	54 \pm 10	30.8	54.5	73	78.3	22 \pm 7.1	14	22	31.3	36.7
0.6-0.99	58 \pm 3	34.5	60	84.5	88.4	27 \pm 4	18.1	26.9	33.9	38.2
1-1.99	54.9 \pm 6.1	40.7	64.1	87.2	100.8	28.1 \pm 4.9	19.6	28	33.7	38.4
2-2.99	67.7 \pm 10.8	48.9	67	80	91.2	29 \pm 4.5	22	28	35.2	38.4
3-3.99	72.6 \pm 13.1	56.1	70	88.7	97.5	29.5 \pm 4.8	22.2	30	35.6	36.7
4-4.99	80.5 \pm 10.7	65.2	80	94.4	105.1	31 \pm 5.3	21.6	30	38.4	41.3
5-5.99	82.4 \pm 10.2	62.1	81.2	96.6	99	33.6 \pm 5.6	22.7	34.5	40	43.4
6-6.99	85.4 \pm 16.2	62.1	85	106	118.4	34.7 \pm 5.6	27	34	40.9	46.6
7-7.99	87.5 \pm 14.5	61	87	105.6	124.1	35.6 \pm 6.3	24.5	35.5	43.9	45.8
8-8.99	94.9 \pm 15.3	67.1	95	118.2	121.7	38.8 \pm 6.1	27.5	39.5	45.5	50.3
9-9.99	93.1 \pm 20.7	52.3	95	113.2	122.8	39.1 \pm 7.2	29	39.6	49.2	50
10-10.99	95.5 \pm 20.1	62.3	97	119.7	126.9	39.3 \pm 7	28.9	39	49.8	52.2
11-11.99	98.2 \pm 16.5	70.4	96.4	120.7	128.5	41.8 \pm 6.8	31	40.1	51.1	55
12-12.99	99.5 \pm 16.1	75.1	102.2	119.6	127.1	42.4 \pm 6.9	32.6	41.4	51.8	52.3
13-13.99	102.1 \pm 21.3	60.5	101	125.4	141.1	43.8 \pm 8.4	24.2	44.7	53.7	55.6
14-14.99	102.2 \pm 17	70.2	103.5	115.9	125.7	44 \pm 6.2	31.1	43.5	53.8	54.2
15-15.99	110.4 \pm 18.2	77.5	109	133	144.1	45.6 \pm 6.8	33.6	45	55	56.9
16-16.99	112.6 \pm 18	84.4	113	136.5	148.9	48 \pm 7.8	35.3	47.8	58.4	62.7
17-17.99	112.2 \pm 15.4	86	111.2	135.6	147.6	45.5 \pm 6.1	32.6	46	55	56.2

published.^{10,11} Our WC centiles were similar to the recently published results, especially in pre-school children. Comparative studies with actual and calculated values are needed to reveal actual deviations for abdominal circumference due to breath-hold or calculation method.

Splenomegaly plays a pivotal role in infectious, immunological, and hematological disorders. A recent study depicted spleen size ranges as 11-13 cm in adults higher than 150 cm in height with the men having larger and longer spleen than the woman.¹² A previous study presented splenic length of caucasian children among wide age groups¹³ but not for each age. A strongest correlation of height with the splenic length of the subjects was found in Turkish children.¹⁴ Percentile graphs for lengths of the liver, spleen, and kidneys have been formed according to the body weights that have been a reliable predictor for the dimensions of all organs.¹⁵ Because of insufficient data for the height or weight parameters, we investigated the association of CT-based WC values with organ sizes. Age ($r = 0.72$) and WC ($r = 0.72$) were significantly correlated with spleen width, which is similar to the study investigating the association of body weight and SL ($r = 0.74-0.63$).¹⁵ Splenic width has presented the best correlation with splenic volume followed by the splenic length and a good correlation of 3D reconstruction of the CT image-based data with US measurements.³ Spleen width was strongly correlated with splenic volume and would be more valuable than the SL in decision making of splenomegaly. Our correlation coefficients of both age and WC parameters were higher for splenic width when compared to splenic length. The values of 95th percentiles of spleen width were over 4, 5, 6 cm in children older than 4, 8, 16 years, respectively. Otherwise, the constant ratios of the spleen to the left kidney length were similar for each age and would be a practical tool to achieve relative length estimations. Therefore, in the case of portal system pathologies without additional renal diseases, the

splenic length would be compared with the left kidney length to achieve the decision of splenomegaly.

Normal size ranges for the pancreas have been investigated in a few studies by measuring the vertical length and parenchymal thickness from the head, neck, body, and tail of the pancreas (aged 3-17 years) and anteroposterior dimensions of the pancreas in 150 subjects (aged 10-60 years).¹⁶⁻¹⁸ We measured AP diameter of the pancreas that is sonographically achievable rather than vertical length. We depicted median thickness values up to 30 mm, 25 mm, and 20 mm for the pancreatic head, corpus, and tail in children up to 17 years of age, respectively. Thickness would be a predictive value of hypoplasia and atrophy. The thickness exceeding the specified values may indicate edematous expansion and pancreatitis. Similarly, values below 1 cm at any age may suggest parenchymal atrophy. In the study, the presented concordant CT- and US-based data demonstrated positive correlations of pancreatic body thickness with age, height, and weight and pancreatic thickness around 16-17 mm in the pediatric population.¹⁷ They included a limited sample size ($n = 140$) and our thickness values were higher than this study.¹⁷ This variation may be due to the limited sample size or ethnicity. Pancreatic thickness correlations were slightly higher with age than WC in our study. Waist circumference presented a significant positive correlation with pancreas thickness ($r = 0.52$) similar to results that were obtained by height ($r = 0.44$) and weight ($r = 0.53$).¹⁷ Although pancreas head or body thickness has revealed higher correlations with age or WC than pancreatic tail presented, these levels failed to reach the degree that other organ size parameters achieve. Clinical significance of pancreatic head size includes type 1 diabetes mellitus,¹⁸ protein energy malnutrition,¹⁹ and eating disorders.²⁰ The decision making for pancreatic atrophy due to chronic pancreatitis, cystic fibrosis, or diabetes mellitus requires normative comparable data for children.

Table 3. Percentiles and Mean Values of Pancreas Thickness Based on Ages

Age (Years)	Pancreas Head Thickness (mm)					Pancreas Corpus Thickness (mm)					Pancreas Tail Thickness (mm)							
	Mean ± Standard Deviation		Percentiles			Mean± Standard Deviation		Percentiles			Mean± Standard Deviation		Percentiles					
			5th	50th	90th			95th	5th	50th			90th	95th	5th	50th	90th	95th
0-0.59	12 ± 2		8	12	14.7	15.3	9.2 ± 1.8		6.3	9.1	12.6	12	7.6 ± 2.4		4.0	8	9	11
0.6-0.99	14.4 ± 1.9		9.1	14.4	18	18.1	12.1 ± 1.7		7.9	13.5	14.4	16.7	10.4 ± 1.8		6.2	10.5	11.6	15
1-1.99	15.4 ± 3.1		10.2	15.0	19.5	21.7	13.1 ± 2.9		8.4	13.0	17.4	18.0	10.6 ± 3.4		5.3	10.7	15.4	16.0
2-2.99	17.5 ± 3.3		12.3	17.0	21.6	23.7	14.8 ± 2.9		9.9	15.0	18.6	20.0	12.8 ± 3.3		7.0	13.0	17.3	18.8
3-3.99	18.6 ± 3.2		12.7	19.0	22.4	23.5	15.3 ± 3.5		8.9	16.0	19.0	19.4	12.6 ± 3.3		6.9	12.2	17.0	17.2
4-4.99	19.5 ± 4.0		12.5	19.9	25.2	26.2	16.4 ± 3.6		9.4	16.0	20.4	23.6	14.1 ± 4.2		5.5	14.0	20.4	21.2
5-5.99	21.4 ± 3.4		15.8	21.8	25.2	26.5	18.1 ± 3.6		11.6	18.5	23.0	25.0	14.9 ± 4.1		7.9	15.5	20.0	21.0
6-6.99	21.2 ± 3.7		16.0	20.5	27.0	28.0	17.5 ± 3.2		12.7	17.0	22.4	23.0	14.1 ± 4.1		8.0	13.2	19.2	21.2
7-7.99	20.2 ± 3.2		13.9	20.3	24.4	25.1	16.9 ± 2.6		12.0	18.0	20.0	20.5	14.0 ± 3.7		7.7	14.0	19.0	19.3
8-8.99	22.2 ± 4.5		14.7	22.0	28.0	29.3	18.4 ± 3.3		13.6	18.0	23.5	26.0	15.4 ± 2.8		11.2	15.0	20.0	21.2
9-9.99	22.4 ± 4.4		15.0	23.0	27.2	30.0	18.1 ± 4.1		12.0	18.0	24.0	26.8	14.1 ± 4.1		9.1	14.0	20.0	22.8
10-10.99	22.5 ± 4.0		15.0	23.7	27.0	29.0	18.8 ± 3.4		11.6	19.0	22.9	25.9	15.4 ± 3.5		9.6	15.3	20.0	21.9
11-11.99	23.7 ± 3.9		16.5	23.2	29.5	30.0	20.5 ± 3.3		15.9	20.0	25.0	26.0	16.3 ± 3.6		10.1	16.0	21.0	24.0
12-12.99	23.0 ± 4.8		14.4	22.0	29.6	33.0	19.6 ± 3.8		12.6	20.0	24.7	26.6	16.7 ± 4.2		9.2	17.3	22.0	23.8
13-13.99	24.0 ± 5.0		13.5	24.8	29.7	32.8	19.4 ± 4.0		11.1	19.0	24.4	26.8	15.5 ± 4.4		8.2	15.1	21.4	23.7
14-14.99	24.4 ± 4.8		17.0	23.4	31.2	33.0	19.2 ± 3.6		13.5	18.5	24.8	26.0	16.1 ± 4.3		9.7	15.8	22.9	23.9
15-15.99	24.9 ± 4.5		17.2	24.1	32.0	33.5	20.8 ± 4.1		13.0	21.0	26.6	28.7	16.9 ± 5.1		8.5	16.9	24.0	25.9
16-16.99	26.3 ± 4.5		19.0	26.0	32.6	34.6	21.0 ± 3.5		14.9	20.8	25.0	26.6	17.4 ± 4.2		11.0	17.0	23.0	24.5
17-17.99	28.2 ± 4.6		18.7	29.1	34.2	35.1	23.3 ± 4.5		16.0	24.0	29.8	32.1	17.9 ± 5.1		10.4	18.2	25.0	25.2

Table 4. Percentiles and Mean Values for Anteroposterior Dimension and Length of Left Kidney Based on Ages

Age (Years)	Left Kidney Length (mm)					Left Kidney Anteroposterior Diameter (mm)				
	Mean \pm Standard Deviation	Percentiles				Mean \pm Standard Deviation	Percentiles			
		5th	50th	90th	95th		5th	50th	90th	95th
0-0.59	54 \pm 9.9	37.2	57.3	66	71.6	27 \pm 3.4	20	27.4	33.5	43.7
0.6-0.99	58 \pm 10.24	39.1	62.8	68.3	75.4	35.4 \pm 11.3	23.7	30.5	36.2	46.9
1-1.99	66.1 \pm 9.0	47.0	66.4	74.4	88.4	32.5 \pm 5.2	25.7	31.9	37.0	47.4
2-2.99	70.7 \pm 8.9	54.4	70.0	82.8	87.2	33.2 \pm 3.8	26.2	34.0	37.8	38.0
3-3.99	72.8 \pm 7.2	60.1	73.7	80.9	84.1	33.8 \pm 4.4	29.0	32.7	38.2	39.5
4-4.99	76.6 \pm 10.6	56.0	76.0	90.6	94.6	37.6 \pm 5.8	31.0	37.0	42.4	51.2
5-5.99	80.7 \pm 6.7	70.8	78.0	90.0	92.6	38.2 \pm 4.1	30.4	38.5	42.1	45.2
6-6.99	84.4 \pm 10.4	69.1	83.7	98.3	105.8	38.7 \pm 4.7	30.1	38.6	44.7	46.0
7-7.99	83.2 \pm 11.1	56.5	84.0	97.3	103.2	39.3 \pm 5.0	31.0	39.1	46.5	49.1
8-8.99	87.9 \pm 8.9	70.7	87.1	100.0	100.6	40.9 \pm 4.5	32.7	41.0	46.3	48.5
9-9.99	91.5 \pm 10.1	73.0	92.0	103.6	104.9	40.9 \pm 4.9	34.1	40.0	47.6	52.7
10-10.99	93.1 \pm 8.8	78.4	92.5	104.0	106.0	42.0 \pm 5.1	35.1	41.0	49.2	52.9
11-11.99	96.7 \pm 8.6	83.1	95.6	111.0	113.0	45.1 \pm 4.4	38.5	45.0	53.0	54.0
12-12.99	98.8 \pm 11.5	85.4	99.0	111.6	114.0	46.3 \pm 6.4	36.5	46.0	54.0	56.4
13-13.99	103.5 \pm 9.6	90.0	102.0	119.5	126.7	48.3 \pm 3.9	41.8	48.0	53.5	57.8
14-14.99	102.4 \pm 9.5	89.7	102.9	114.8	117.0	48.1 \pm 4.5	37.2	48.3	53.6	55.2
15-15.99	105.8 \pm 9.6	86.8	107.1	116.3	123.3	49.6 \pm 5.3	40.4	48.9	56.7	58.0
16-16.99	110.0 \pm 9.7	95.9	110.5	121.9	126.6	50.7 \pm 6.3	40.0	50.1	59.1	62.3
17-17.99	109.2 \pm 9.5	92.4	109.0	123.1	125.7	49.1 \pm 6.0	39.3	48.3	59.1	60.5

The renal size has been an important factor for diagnosing renal parenchymal diseases associated with increased cardiovascular risk in prepubertal children.²¹ The renal size is a predictor for reduced glomerular filtration rate levels in late life when the newborns are with a solitary kidney.²² Besides, lower birth weights reduce kidney size and function and obese children have larger kidneys.^{23,24} Also, size is important in case of pyelonephritis, renal ischemia, and hematological malignancies.

Hydration has been reported to have a considerable effect on the renal size.²⁵ We excluded children with solitary kidneys and the children whose hydration status was unknown. We demonstrated the constant ratios revealing similar sizes of left kidney and spleen which were greater than the right kidney. Considering the maximum kidney size and the constant ratio from our results, it is understood that the size difference between the 2 kidneys will not exceed 1 cm. Renal lengths in

Table 5. Percentiles and Mean Values for Anteroposterior Dimension and Length of Right Kidney Based on Ages

Age (Years)	Right Kidney Length (mm)					Right Kidney Anteroposterior Diameter (mm)				
	Mean \pm Standard Deviation	Percentiles				Mean \pm Standard Deviation	Percentiles			
		5th	50th	90th	95th		5th	50th	90th	95th
0-0.59	53 \pm 10.46	34.9	54.9	65.1	65	27.6 \pm 6	20.5	27	32	38.7
0.6-0.99	55.7 \pm 9.9	38.4	57.3	68	71.3	29.75 \pm 5.54	23.1	29.5	36.5	42.6
1-1.99	64.6 \pm 7.7	52.7	63.7	73.1	80.2	31 \pm 5.1	25.1	30	37.6	46.2
2-2.99	69.6 \pm 9.1	52.6	67.5	81	85.1	31.8 \pm 3.9	25.3	32	37	39.6
3-3.99	70.2 \pm 5.9	58.4	70.7	77.7	80.8	32.7 \pm 4.2	26.3	32	38	39.7
4-4.99	74.2 \pm 9.2	56.6	75	83.8	86.3	36.4 \pm 6	30.8	36	40.1	46.4
5-5.99	79.2 \pm 8	66.5	80	91	95.3	37.1 \pm 4.6	29.3	37	42.2	44.3
6-6.99	82.5 \pm 10	69.7	82	96	101.2	36.8 \pm 4.9	29	36.3	42.1	47.8
7-7.99	81.6 \pm 9.9	59	80.6	92	99.3	37.8 \pm 4.8	29	37.2	44	45
8-8.99	84.4 \pm 8.9	70.4	84.5	98	100.3	40.2 \pm 5.1	32	40	47.3	49.1
9-9.99	88.6 \pm 10	69.4	90.2	99.8	104.5	39.3 \pm 4.9	30.3	38.6	46	47.9
10-10.99	89.2 \pm 10.3	73.5	90	101.9	107.4	40.9 \pm 5.3	32.1	40.1	47.6	52.8
11-11.99	91.2 \pm 8.9	80	90	102.1	116	44 \pm 4.8	38	43	51.1	53
12-12.99	94.7 \pm 11.9	78.4	95.3	108.1	109.8	44.7 \pm 5.9	35.2	43.8	52.4	56.4
13-13.99	99.3 \pm 8.5	81.7	99.7	108	117.5	45.6 \pm 4.3	37.3	45.3	50.6	52.6
14-14.99	100.7 \pm 8.6	89.7	100.7	112	113	47.1 \pm 5.6	36	47.2	56.6	57.9
15-15.99	102.9 \pm 8.4	86.5	104	113	115.2	47 \pm 7.9	37.2	48.4	53.2	58.6
16-16.99	106.1 \pm 8.7	90.7	106.7	114.7	120.5	47.9 \pm 6.3	39	47.1	57.5	59.1
17-17.99	105.4 \pm 9.9	89.7	103.6	119.6	121.6	48.1 \pm 6.5	39.3	46.2	55.6	65.5

Turkish children alone has been investigated in a recent study by US,²⁶ and our results were similar to these US-based data. Kidney lengths in Saudi children (n = 950) revealed a significantly larger left kidney compared to the right one similar to our results, and height was the most correlated parameter with the renal length.²⁷ In the current study, we depicted the highest positive correlations of age and WC with renal lengths. Age depicted the similar correlation power with the height parallel to the previous study.²⁷ Park et al²⁸ revealed that renal length presented greatest correlation with height, body surface area, and renal volume on a CT study enrolling 272 pediatric subjects.²⁸ The correlations of AP renal diameters with WC were slightly higher than renal lengths in our study.

There are some shortcomings in our study. First of all, we could not obtain height, weight, and BMI of the subjects because of the retrospective design. We provided estimated WC values by formula as an auxological parameter closed to real WC values depicted in children. Second, the dimensions were measured by 2 radiologists, and we did not evaluate interobserver variability owing to the lack of dynamic evaluation and presence of fixed measurement protocols. Third, these reference data could be considered comparable when subjects underwent diagnostic CT and also US examinations since our measurement protocols are adjustable to US examinations. Fourth, we included a relatively smaller sample size regarding infants whose birth data either as term or preterm were unknown due to limited CT examinations in very younger children. Finally, exclusion criteria solely rely on imaging findings. As several studies stated the significant correlations of solid abdominal organ sizes with age, we documented age- and also WC-based measurements of abdominal solid organs. But it should be kept in mind that BMI and height of the participants should also be evaluated before decision making about hypoplasia or organomegaly especially in children presenting upper and lower borders of auxological parameters. Further studies are needed to investigate the correlation of real and CT-based WC values, the impact of height, weight, BMI, WC, and age parameters on organ size values in a single and larger study.

CONCLUSION

In conclusion, we provided reference values for solid abdominal organ diameters from CT-based data. In this large-scale study, the distribution of organ sizes according to percentiles for all ages in healthy children was reported. In order to predict the upper limit of the values that can be considered normal without being dependent on the scale, interconnected size ratios of organs have been put forward. Age and WC are independent predictors for organ size estimation. There is a constant ratio between the CC lengths of intraabdominal solid organs, which does not change with age.

Ethics Committee Approval: This study was approved by Ethics committee of Istanbul University, (Approval No: 2019/646).

Informed Consent: Verbal/Written informed consent was obtained from the patients who agreed to take part in the study.

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Supplementary Table 1. Percentiles of Waist Circumference Based on Ages								
Age (Years)	Waist Circumference (mm)							
	Mean \pm Standard Deviation	Percentiles						
		5th	10th	25th	50th	75th	90th	95th
<1	384.2 \pm 41.4	276.55	328.00	367.27	392.20	415.20	429.05	440.75
1-1.99	450.3 \pm 65.3	378.20	401.62	419.50	439.25	465.17	487.69	543.74
2-2.99	460.4 \pm 53.4	403.23	412.47	430.50	447.25	480.95	514.99	544.06
3-3.99	468 \pm 36.42	409.94	424.00	446.72	460.60	490.52	515.85	545.43
4-4.99	505.9 \pm 55.2	438.70	451.00	471.40	496.80	522.80	555.30	683.10
5-5.99	527 \pm 59.6	435.85	461.48	483.47	523.00	558.90	624.15	663.56
6-6.99	522.3 \pm 62.3	424.60	449.46	484.20	516.30	545.60	641.40	660.44
7-7.99	560.6 \pm 80.6	427.69	464.52	520.62	545.35	599.70	695.95	739.52
8-8.99	598 \pm 86.9	476.89	494.79	536.22	597.20	646.35	697.48	807.63
9-9.99	601 \pm 106.9	436.85	492.04	540.60	584.70	646.75	753.02	817.69
10-10.99	615.4 \pm 98.9	456.78	528.43	563.72	591.70	649.70	779.47	831.07
11-11.99	688.9 \pm 114	535.73	551.26	594.15	673.50	759.42	853.44	897.54
12-12.99	694 \pm 131	533.52	564.52	592.70	648.50	799.70	876.74	905.00
13-13.99	708 \pm 96	540.87	552.14	639.70	705.00	792.07	840.66	865.55
14-14.99	731 \pm 134	515.72	582.82	676.50	699.30	801.00	941.56	1052.78
15-15.99	756 \pm 112	597.46	622.14	675.60	747.70	812.10	923.98	983.62
16-16.99	766 \pm 121	568.49	628.24	686.72	759.70	819.85	980.66	1016.83
17-17.99	756 \pm 130	606.50	630.20	688.20	740.60	843.80	920.30	996.00