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ORIGINAL ARTICLE

Ultrasonographic parameters of the liver, spleen and kidney in a healthy paediatric population in Bosnia and Herzegovina: a prospective study

Nina Mekić[1*], Nermin Salkić[2], Amela Selimović[3], Majda Mehmedović[2], Aida Brčić[4], Zlatan Mehmedović[5], Amra Šerak[1], Dijana Dugonjić[1]

[1]Paediatric Department, Health and Educational Medical Centre Tuzla, [2]Clinic for Internal Diseases Tuzla, University Clinical Centre Tuzla, [3]Clinic for Children's Diseases Tuzla, University Clinical Centre Tuzla, [4]Paediatric Practice "Dr Aida" Zavidovići, [5]Clinic for Surgery, University Clinical Centre Tuzla; Bosnia and Herzegovina

ABSTRACT

Aim To determine the normative range of ultrasound dimensions for the liver, spleen and kidneys in healthy children according to gender, age, body measurements, body surface area (BSA), and the influence of ethnicity on organ size.

Methods The prospective study included children, ranging from full-term neonates to children aged 15, with normal ultrasonographic (US) findings of the liver, spleen and kidney and no clinical evidence of a disease. Gender, age, as well as body measurements and BSA, were determined for each child along with US measurements, and normative ranges were established.

Results US images of the liver and spleen from 372 children and 366 US images of kidneys of 366 children were included. US measurements of the liver, spleen and kidney correlated well with gender, age, body weight and height, and often differed to a greater or lesser extent from the normal range of measurements (5th to 95th percentile) reported in other studies.

Conclusion Our results differed slightly from other reports conducted in Europe, but larger differences compared to measurements performed on children on other continents were found. Thus, our study confirmed that ethnically appropriate and modern tables of normal ultrasound dimensions for the liver, spleen and kidneys should be used, and that the national nomogram is justified.

Keywords: elderly children, organ size, reference values, ultrasound

INTRODUCTION

Ultrasonography (US) provides a quick assessment of visceral organ dimensions and is routinely used to evaluate organs in children. It is a real-time examination without radiation and can be safely repeated (1). Therefore, US is generally the method of choice for initial diagnostic investigation in paediatric patients and may detect organ size abnormalities that indicate disease. In clinical practice, small differences of even just one centimetre can make a difference between a result of "normal" versus "hepatomegaly" (2). The clinical assessment of hepatomegaly and splenomegaly by palpation lacks both accuracy and reliability (3,4). However, there are few studies that define the normal limits of organ dimensions determined by US examinations in healthy children (5–11). Age, body height and weight and ethnicity are known influencing factors of organ dimensions (6). Charts of normal values of ultrasound dimensions of these organs made on the basis of local, ethnically adjusted data, are considered the most appropriate to use for that population (7–10).

Changes in diet and disease profiles over time also affected children and their development. The prevalence of obesity over the past decade has rapidly increased, and severe obesity is a serious public health issue that

*** Corresponding author:** Nina Mekić
Paediatric Department, Health and Educational Medical Centre Tuzla, Albina i Franje Herljevića 1, 75000 Tuzla, Bosnia and Herzegovina
Phone: +387 35 368-411
E-mail: suzananinabrcic88@gmail.com
ORCID: https://orcid.org/0009-0004-8053-8069

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affects a large number of children in Europe (12,13). Countries from Southern Europe have the highest level of severe obesity, while in countries from Western and Northern Europe, the prevalence is lower; in countries from Central and Eastern Europe, the data are more heterogeneous (14). Multiple studies have shown a correlation of organ length with body anthropometric parameters; however, none of these studies have included Bosnian children in recent times. A meta-analysis performed in 2019 showed that data from around the globe, including children of different ethnicities, would be of international value (2). Over time, children's eating habits have changed, and their physical activity level and time of entering puberty have resulted in changes in their organ growth patterns. The average age of menarche in girls has dropped over the last century from 16-17 years to 12-13 years (15,16). Contemporary normative charts should be used in clinical practice.

The aim of this study was to establish the normal US growth patterns of liver, spleen and kidney length according to age, body measurements, body surface area (BSA), and to determine their correlation and investigate the influence of ethnicity on organ sizes. The study purpose was to provide practical and reliable charts of normal values in healthy Bosnian children of Bosnia and Herzegovina (B&H), assist in predicting changes and allow for the early identification of abnormal US findings that require further investigation.

PATIENTS AND METHODS

Patients and study design

A total of 372 children, ranging from full-term neonates to children aged 15 years were prospectively investigated. All children were examined by a paediatrician, and a detailed history was taken, with gender, age, weight, height and body surface area (BSA) determined for each child. The study was conducted in the period of 2018-2021 in the Paediatric Department of Health and Educational Medical Centre Tuzla and the Paediatric Practice in Zavidovići.

The major criteria for the selection of children included the absence of clinical (no acute or chronic disease) and US pathological findings or abnormalities related to the analysed organs, as well as history without haematological, oncological, traumatic or metabolic conditions. Given that the study was conducted in Bosnia and Herzegovina, it includes children of the ethnic structure of that area.

Exclusion criteria were children with acute and chronic diseases (infectious, oncological, metabolic diseases and traumatic events) that could affect the growth, development and size of organs (e.g. viral hepatitis, pyelonephritis, haemolytic anaemia, hypothyroidism), as well as children below the fifth and above the ninety-fifth percentile for body height and weight.

The children were divided into groups by age: 0-6 months (included new-borns and infants up to 5.9 months), 6-12 months (from 6 months to 11.9 months), 1- 2 years (full year up to 1.9 years of age), 2-4, 4-6, 6-8, 8-10, and 10-15 years.

An informed consent was obtained from all legal representatives or guardians of the children participating in the study. An ethics approval was obtained from the Ethics Committee of the Public Medical Centre Tuzla.

Methods

Only the children between the fifth and ninety-fifth percentiles were eligible for height and weight measuring. Height was measured to the nearest 0.1 cm using a height scale (Detecto, Webb City, Mo., USA). Weight was calculated to the nearest 0.1 kg with a calibrated electronic weighing scale (Bilaneia Baby, Gima, Gessate, Italy; Detecto, Webb City, Mo., USA).

Each US examination was performed using a high-resolution real-time scanner (MyLabSeven eHD/Crystal Line, Esaote S.p.A, Genova, Italy) with a multifrequency 3.5-5.0 MHz convex transducer (AC2541, Esaote S.p.A, Genova, Italy).

The liver was examined in the supine position, and after clear visualization, the longitudinal diameter (craniocaudal) was measured in the midclavicular plane with the diaphragm as the upper margin and the lowest edge as the lower margin. The transverse or ventrodorsal diameter was evaluated perpendicular to the longitudinal section, from the ventral edge of the liver to the inner dorsal edge of the diaphragm.

The spleen was examined in the supine or slightly right lateral decubitus position, starting with the subcostal sections, and by moving to the intercostal space if a part was not obtained and measuring where the widest transverse section was found. The longitudinal sections were acquired by rotating the probe 90 degrees from the transverse sections and calculating the longest diameter.

The longitudinal diameter of the right kidney was assessed while the child was in the supine and prone positions for the ventral and dorsal sections. The longest longitudinal diameter from the upper to the lower apex was measured. The longitudinal diameter of the left kidney was determined in the coronal plane passing through the renal hilum with the child in the supine or slightly right lateral decubitus position and in the dorsal section with the child in the prone position. Breathing was actively used as needed.

All measurements were carried out by a paediatrician with the cooperation of a radiologist.

Statistical analysis

Descriptive statistics were performed for each age group for liver, spleen and kidney measurements. The dependence of these measures of organ size on age and physical parameters such as height and weight were further described by Spearman's rank correlations. The results of the correlation were interpreted as follows: adjusted R^2values of 0.00−0.19 indicated a very weak correlation/no correlation; values of 0.2−0.39 indicated a weak correlation; values of 0.4−0.59 indicated a moderate correlation; and values of 0.6−0.79 indicated a strong correlation.

RESULTS

The study population consisted of 372 US images of the liver and spleen from 372 Caucasian children with a mean (standard deviation – SD) age of 7.10 (4.47) years, ranging from 0.10 to 14.02 years. There were 166 (44.6%) males and 206 (55.4%) females in the total sample of 372 children.

Six (1.6%) US images were excluded for pathological renal findings. Ultimately, the kidney study population consisted of 366 US images from 366 children, with 160 (43.7%) males and 206 (56.3%) females. Their age ranged from 0.10 to 14.02 years, with a mean (SD) age of 7.10 (4.47) years. The median height was 128 cm, and the median weight was 27 kg. The population comprised only Caucasian children (Table **1**).

The US measurements of the liver showed the highest values in the oldest group of children (12-15 years old). The percentile values of the craniocaudal diameter were assessed along the medioclavicular line and ventrodorsal diameter of the liver (Table 2). There was a strong correlation between age and body height and weight for the craniocaudal diameter of the liver (adjusted R^2=0.700; p<0.0001).

Both liver dimensions were, on average, larger in boys (by 3.7 cm for the craniocaudal diameter and 4.2 cm for the ventrodorsal diameter).

US measurements of the spleen also showed the lowest values in the youngest age group and the highest values in the oldest age group. The results obtained in this study did not show proportional longitudinal growth of the spleen by age. The largest difference was observed between the 5th and 95th percentiles in the 4–6-year-old group (Table 2).

Spleen diameters correlated more strongly with body height and weight than with age, with the highest coefficient correlation for body weight.There was a significant gender difference between in spleen size; in all age groups; girls had smaller spleens (by approximately 4.5 cm) than boys.

The dorsal diameters of both kidneys were larger than the ventral or coronal diameters. Both kidneys increased in length with age, except in the groups aged 0.5-1 years and 1-2 years (Table 3).

Table 1. Descriptive statistics pertaining to height, weight and body surface area (BSA) according to age groups

Age (years)	Variable	N	Mean (SD)	Median	Min. -Max.
<0.5	Height	57.00	66.63 (7.58)	68.00	51.00-79.00
	Weight	57.00	7.28 (2.25)	7.90	3.10-12.40
	BSA	57.00	57.00 (0.08)	0.38	0.21-0.51
0.5-1.0	Height	11.00	72.91 (6.47)	75.00	61.00-80.00
	Weight	11.00	9.65 (1.87)	9.80	6.00-12.50
	BSA	11.00	0.44 (0.06)	0.46	0.32-0.51
1-2	Height	9.00	81.11 (5.99)	83.00	74.00-88.00
	Weight	9.00	10.81 (1.08)	11.00	8.80-12.50
	BSA	9.00	0.49 (0.03)	0.50	0.43-0.54
2-4	Height	20.00	98.15 (6.43)	97.50	87.00-115.00
	Weight	20.00	15.18 (3.05)	15.00	10.00-22.00
	BSA	20.00	0.64 (0.08)	0.63	0.52-0.84
4-6	Height	23.00	111.39 (22.46)	116.00	16.00-134.00
	Weight	23.00	21.74 (4.67)	20.00	15.00-32.00
	BSA	23.00	0.81 (0.16)	0.82	0.28-1.09
6-8	Height	82.00	126.09 (5.11)	126.00	115.00-138.00
	Weight	82.00	25.96 (4.68)	25.50	18.00-40.00
	BSA	82.00	0.95 (0.10)	0.95	0.77-1.21
8-10	Height	43.00	135.14 (7.28)	134.00	120.00-153.00
	Weight	43.00	32.00 (7.20)	31.00	21.00-55.00
	BSA	43.00	1.09 (0.14)	1.08	0.84-1.53
10-12	Height	59.00	148.12 (11.73)	149.00	76.00-166.00
	Weight	59.00	41.71 (9.55)	41.00	19.70-70.00
	BSA	59.00	1.30 (0.19)	1.30	0.45-1.74
12-15	Height	68.00	160.06 (8.24)	160.00	142.00-181.00
	Weight	68.00	51.41 (16.72)	49.00	32.00-61.00
	BSA	68.00	1.50 (0.24)	1.48	1.15-2.85

N, number; SD, standard deviation; min., minimum; max., maximum;

Table 2. Percentile values for liver and spleen measurements according to age groups

Variable	Age (years)	Percentile 5	10	25	50	75	90	95
Craniocaudal diameter liver (medioclavicularline) (mm)	<0.5	61.89	62.36	70.45	76.60	84.10	86.28	92.61
	0.5-1	57.30	58.26	69.80	83.30	84.80	88.32	93.89
	1-2	69.50	69.50	70.60	73.40	80.75	94.67	97.98
	2-4	62.13	63.03	75.15	80.20	91.05	99.15	100.93
	4-6	69.48	78.16	82.10	93.30	100.00	116.20	123.80
	6-8	76.79	78.83	86.65	92.50	99.85	108.00	110.00
	8-10	77.20	79.68	85.00	93.40	100.00	110.00	113.60
	10-12	83.20	91.30	93.80	103.00	113.00	118.00	125.00
	12-15	83.91	87.53	94.83	105.00	113.75	122.10	125.10
Ventrodorsal diameter liver (medioclavicular line) (mm)	<0.5	46.90	52.22	58.05	61.10	69.20	79.82	84.35
	0.5-1	52.60	53.44	57.30	65.00	79.50	87.18	90.32
	1-2	75.90	75.90	77.35	79.80	86.20	91.12	96.23
	2-4	61.31	67.45	77.55	89.50	94.45	101.90	102.95
	4-6	79.86	81.22	86.60	92.60	99.30	106.60	109.80
	6-8	78.78	84.75	88.30	95.55	102.32	106.00	107.00
	8-10	82.18	86.20	90.90	100.00	108.00	114.00	114.80
	10-12	86.50	92.70	101.00	110.00	117.00	128.00	129.00
	12-15	97.55	100.76	108.25	116.00	122.00	128.20	135.30
Spleen longitudinal diameter (mm)	<0.5	46.17	48.40	50.15	56.10	64.85	69.68	70.29
	0.5-1.0	47.90	48.24	58.50	70.40	73.20	75.44	76.76
	1-2	50.30	50.30	55.95	58.50	62.95	79.03	81.22
	2-4	53.99	57.74	64.20	70.40	75.40	86.10	87.57
	4-6	63.88	67.64	73.00	76.70	87.30	95.38	98.78
	6-8	67.56	70.70	77.40	83.30	88.55	94.83	98.90
	8-10	69.62	74.50	79.20	85.00	90.90	97.56	99.56
	10-12	73.40	77.60	87.60	92.20	96.70	101.00	104.00
	12-15	81.48	83.32	88.65	96.65	103.00	109.02	111.55

The diameter of the right kidney measured dorsally strongly correlated with age, body height and weight, with the highest coefficient correlation for body height (Table 3) (adjusted R^2=0.91; p<0.0001). The diameter of the left kidney measured dorsally strongly correlated with age, body weight and height, with the highest coefficient correlation for body heigh (Table 3) (adjusted R^2=0.64; p<0.0001).

DISCUSSION

Our results are comparable with studies involving different ethnic groups, as well as with those conducted several decades ago. Twenty-five years ago, a study was conducted on a population of 307 Turkish children (17), followed by studies from Brazil, India, Nepal and Jordan (5,18–21). On the European continent, a German study in 1983 mainly included Caucasian children (22). Driven by the premise that comprehensive ranges of normal values need to be developed, another German study showed that Central European children had a larger liver in 2020 compared to almost 40 years before (7).

In comparison with the results from Turkey, our study showed larger liver diameter in children up to 4 years of age, smaller in children 4-12 years of age, and significantly larger in children up to 15 years of age (17). Compared to studies with children from Nepal (20,21), India (19), Brazil (18) and Germany (7), significantly larger diameters of the liver in the children up to 1 year of age were found in our study. The larger liver diameter in B&H infants can be partially explained by the lower average prevalence of low birth weight (5.2%) comparing to other countries, such as Nepal, which has the second highest prevalence of low birth weight (30%) according to the World Health Organization (23). Liver size showed the strongest correlation with body weight in our study, similarly to other studies (24); however, the strongest correlation with body height was found in other studies (17,20,25).

Studies that investigated the size of the spleen and liver together, or the spleen alone by using anthropological measurements showed a significant correlation of the ultrasound dimensions of these organs with body height and weight (26–28). Most studies showed a significant difference in spleen size between the genders (29), while one study showed no difference (27). Studies performed in children from different countries and with different ethnicities did not show a significant difference in the ultrasound size of the spleen similar to that of the liver (17,20,24). The difference between the diameter measurements of the spleen was smaller than the difference between the measurements of the liver in our study.

Table 3. Percentile values for kidney measurements according to age groups

Variable	Age (years)	Percentile 5	10	25	50	75	90	95
Right kidney length - ventral (mm)	<0.5	38.40	49.12	50,80	56.00	59.40	64.24	68.87
	0.5-1.0	47.70	48.20	52.30	60.10	70.50	71.92	74.24
	1-2	46.90	46.90	53.65	58.00	60.40	63.24	79.12
	2-4	56.22	56.64	59.15	64.70	69.43	79.93	83.64
	4-6	58.74	61.82	65.10	71.90	73.90	82.72	85.76
	6-8	61.10	65.14	69.75	74.50	77.65	81.00	83.22
	8-10	69.73	71.76	75.88	79.60	83.50	87.48	90.24
	10-12	76.86	79.44	80.90	84.10	89.05	93.04	94.25
	12-15	80.64	82.52	87.65	91.45	97.35	101.60	107.65
Right kidney length - dorsal (mm)	<0.5	45.11	49.62	54.90	57.90	60.80	66.08	69.39
	0.5-1.0	49.00	49.04	53.20	61.00	70.80	72.40	75.37
	1-2	50.30	50.30	55.30	57.00	60.35	64.22	80.02
	2-4	57.86	58.91	62.00	65.15	70.23	80.58	83.75
	4-6	63.40	64.56	68.00	72.90	78.30	80.58	87.42
	6-8	68.25	70.78	73.90	77.00	81.00	85.02	89.69
	8-10	73.45	74.50	78.88	82.55	86.98	91.70	92.63
	10-12	80.00	80.90	83.20	87.70	92.70	95.92	99.18
	12-15	83.54	84.91	91.88	94.70	101.00	104.30	106.65
Left kidney length - coronal (mm)	<0.5	47.68	50.26	53.30	57.60	60.25	67.02	69.81
	0.5-1.0	50.90	51.10	54,20	59.90	71.20	72.58	74.98
	1-2	51.30	51.30	53.35	58.60	62.50	64.04	79.26
	2-4	58.82	59.45	63.45	67.10	71.65	76.86	80.73
	4-6	59.28	65.00	69.20	74.80	80.10	91.36	93.04
	6-8	69.74	70.30	74.05	78.90	82.10	89.18	92.00
	8-10	70.85	75.35	79.48	83.80	87.35	90.29	93.40
	10-12	79.20	80.64	82.90	88.70	93.80	98.56	102.10
	12-15	81.14	84.89	89.53	94.45	100.00	104.60	107.46
Left kidney length – dorsal (mm)	<0.5	49.73	51.38	54.90	58.00	61.15	69.00	70.73
	0.5-1.0	46.40	47.28	53.80	59.60	71.90	72.86	75.23
	1-2	53.10	53.10	53.65	58.80	64.00	72.22	80.11
	2-4	60.48	62.00	65.25	68,70	73.05	79.17	81.20
	4-6	62.28	66.28	71,50	74.50	80.70	88.02	92.54
	6-8	70.21	71.50	75.40	79.10	83.40	86.34	89.70
	8-10	69.67	75.49	79.90	83.75	88.45	93.19	94.06
	10-12	78.87	81.54	87.20	91.50	96.10	101.00	104.20
	12-15	85.65	87.27	92.53	96.70	101.25	105.30	112.34

Our results are similar to those in previous European studies, but differed from studies from Nepal and India, which reported significantly smaller diameters of the spleen (19,20,29).

Many clinicians still use the normative kidney length charts from 1984 (30). More recent studies included kidney length from a Turkish (17), a Hong Kong Asian (31), an Indian (32), a Nepalese (20), a Saudi population (11), and an Australian (6) population. To our knowledge, the only European Caucasian study of children aged 0–19 years is the recent study of Polish and Lithuanian children in 2022 (33).

The reports about ethnic differences in kidney size lead us to assume that the size of the organ may be dependent on ethnicity. Ethnic differences in kidney length between African Americans and Caucasians (34), as well as between Asian and Western children (31), and between Saudi and American children (11)) were found. The results of our measurements of the right kidney were similar to the measurements of several studies (33), but they differed from the Indian and Nepalese population (20,32), having a significantly smaller kidney diameter in all age groups. The European Caucasian study showed similar results in the infant period, but in all other age groups right kidney diameters were larger (33). The most significant predictor of kidney length was stature height (33), which was found in our study too. Most of the studies presented the measurements of the right and left kidneys together or measured only the right kidney, which may affect the final results and the comparisons (18,32,33,35). Few studies, such as ours, showed the measurements of the right and left kidneys separately and concluded that the left kidney showed a larger mean diameter than the right kidney in all age groups. Similarly to the right kidney, measurements of the left kidney in our study differed most from the Indian and Nepalese populations (11,17,32). In our study, kidney measurements correlated well with body height (with a stronger correlation for the left kidney), and better correlated with body weight; the right kidney measurement had a more significant correlation with age and body parameters than the left one. Liver, spleen, and kidney measurements correlated well with body measurements.

A potential limitation of the study is its applicability only to the Bosnian Caucasian population, which could limit the generalizability of the results. However, the existence of local reference charts provides an undoubted benefit to clinicians in Bosnia, as well as countries in the region with a similar ethnic composition.

The global value of this study is in providing data for comparison and highlighting the differences that affect the measurements of these organs in children, and thus the need for local reference values.

Our results confirm the difference on the US assessment of liver, spleen and kidney size in children reported from other ethnicities, which led us to conclude that establishing a contemporary normative chart for each ethnic group will enable better interpretation of US assessments in the paediatric population.

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TRANSPARENCY DECLARATION

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REFERENCES

1 Paltiel HJ, Lee EY, editors. Pediatric Ultrasound. 2021st edition. 2021.

2 Calle-Toro JS, Back SJ, Viteri B, Andronikou S, Kaplan SL. Liver, Spleen, and Kidney Size in Children as Measured by Ultrasound: A Systematic Review. J Ultrasound Med Off J Am Inst Ultrasound Med 2020;39;(2):223–30. doi: 10.1002/jum.15114.

3 Demissie S, Mergu P, Hailu T, Abebe G, Warsa M, Fikadu T. Morphometric assessment of spleen dimensions and its determinants among individuals living in Arba Minch town, southern Ethiopia. BMC Med Imaging 2021;21:186. doi: 10.1186/s12880-021-00719-9.

4 Loloi J, Patel A, McDevitt P, Bruno MA, Riley T. How Strongly Do Physical Examination Estimates and Ultrasonographic Measurements of Liver Size Correlate? A Prospective Study. Am J Med 2019; 132;(1):103–8. doi: 10.1016/j.amjmed.2018.09.012.

5 Rousan LA, Fataftah J, Al-Omari M, Hayajneh W, Miqdady M, Khader Y. Sonographic assessment of liver and spleen size based on age, height, and weight: evaluation of Jordanian children. Minerva Pediatr 2019;71;(1):28–33. doi: 10.23736/S0026-4946.16.04433-9.

6 Coombs PR, Lavender I, Leung MYZ, Woods JC, Paul E, Webb N, et al. Normal sonographic renal length measurements in an Australian pediatric population. Pediatr Radiol 2019;49;(13):1754–61. doi: 10.1007/s00247-019-04486-2.

7 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.

8 Fatunla OAT, Olatunya OS, Ogundare EO, Fatunla TO, Olatayo AS, Taiwo AB, et al. Relationship between ultrasound-measured spleen, liver and anthropometry of children living in a rural community in southwest Nigeria: a cross-sectional study. Pediatr Radiol 2022;52;(8):1484–91. doi: 10.1007/s00247-022-05341-7.

9 Tsehay B, Shitie D, Afenigus A, Essa M. Sonographic evaluation of spleen size in apparently healthy children in north-west Ethiopia, 2020: time to define splenomegaly. BMC Pediatr 2021;21:318. doi: 10.1186/s12887-021-02792-z.

10 Akinlade FT, Asaleye CM, Ayoola OO, Aremu AA. Ultrasound assessment of normal liver, spleen, and kidney dimensions in southwest Nigerian children: a bedside formula for sonologists. Acta Radiol Stockh Swed 1987 2021;62;(7):932–9. doi: 10.1177/0284185120948488.

11 Mohtasib RS, Alshamiri KM, Jobeir AA, Saidi FMA, Masawi AM, Alabdulaziz LS, et al. Sonographic measurements for kidney length in normal Saudi children: correlation with other body parameters. Ann Saudi Med 2019;39;(3):143–54. doi: 10.5144/0256-4947.2019.143.

12 Nittari G, Scuri S, Petrelli F, Pirillo I, di Luca NM, Grappasonni I. Fighting obesity in children from European World Health Organization member states. Epidemiological data, medical-social aspects, and prevention programs. Clin Ter 2019; 170;(3):e223–30. doi: 10.7417/CT.2019.2137.

13 Hu K, Staiano AE. Trends in Obesity Prevalence Among Children and Adolescents Aged 2 to 19 Years in the US From 2011 to 2020. JAMA Pediatr 2022;176;(10):1037–9. doi: 10.1001/jamapediatrics.2022.2052.

14 Spinelli A, Buoncristiano M, Kovacs VA, Yngve A, Spiroski I, Obreja G, et al. Prevalence of Severe Obesity among Primary School Children in 21 European Countries. Obes Facts 2019;12;(2):244–58. doi: 10.1159/000500436.

15 Leone T, Brown LJ. Timing and determinants of age at menarche in low-income and middle-income countries. BMJ Glob Health 2020;5;(12):e003689. doi: 10.1136/bmjgh-2020-003689.

16 Brix N, Ernst A, Lauridsen LLB, Parner E, Støvring H, Olsen J, et al. Timing of puberty in boys and girls: A population-based study. Paediatr Perinat Epidemiol 2019;33;(1):70–8. doi: 10.1111/ppe.12507.

17 Konuş OL, Ozdemir A, Akkaya A, Erbaş G, Celik H, Işik S. Normal liver, spleen, and kidney dimensions in neonates, infants, and children: evaluation

with sonography. AJR Am J Roentgenol 1998; 171;(6):1693–8. doi: 10.2214/ajr.171.6.9843315.
18 Rocha da SMS, Ferrer APS, Oliveira de IRS, Widman A, Chammas MC, Oliveira de LAN, et al. Determinação do tamanho do fígado de crianças normais, entre 0 e 7 anos, por ultrassonografia. Radiol Bras 2009;42:7–13.
19 Dhingra B, Sharma S, Mishra D, Kumari R, Pandey RM, Aggarwal S. Normal values of liver and spleen size by ultrasonography in Indian children. Indian Pediatr 2010;47;(6):487–92. doi: 10.1007/s13312-010-0090-6.
20 Thapa NB, Shah S, Pradhan A, Rijal K, Pradhan A, Basnet S. Sonographic Assessment of the Normal Dimensions of Liver, Spleen, and Kidney in Healthy Children at Tertiary Care Hospital. Kathmandu Univ Med J KUMJ 2015;13;(52):286–91. doi: 10.3126/kumj.v13i4.16825.
21 Amatya P, Shah D, Gupta N, Bhatta NK. Clinical and ultrasonographic measurement of liver size in normal children. Indian J Pediatr 2014;81;(5):441–5. doi: 10.1007/s12098-013-1288-0.
22 Dinkel E, Ertel M, Dittrich M, Peters H, Berres M, Schulte-Wissermann H. Kidney size in childhood. Sonographical growth charts for kidney length and volume. Pediatr Radiol 1985;15;(1):38–43. doi: 10.1007/BF02387851.
23 World Health Organization. Low birthweight prevalence n.d. [Internet]. https://www.who.int/data/gho/data/indicators/indicator-details/GHO/low-birth-weight-prevalence-(-) (accessed June 19, 2024)
24 Safak AA, Simsek E, Bahcebasi T. Sonographic assessment of the normal limits and percentile curves of liver, spleen, and kidney dimensions in healthy school-aged children. J Ultrasound Med Off J Am Inst Ultrasound Med 2005;24;(10):1359–64. doi: 10.7863/jum.2005.24.10.1359.
25 Dittrich M, Milde S, Dinkel E, Baumann W, Weitzel D. Sonographic biometry of liver and spleen size in childhood. Pediatr Radiol 1983;13;(4):206–11. doi: 10.1007/BF00973157.
26 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.
27 Megremis SD, Vlachonikolis IG, Tsilimigaki AM. Spleen length in childhood with US: normal values based on age, sex, and somatometric parameters. Radiology 2004;231;(1):129–34. doi: 10.1148/radiol.2311020963.
28 Özdikici M. The relationship between splenic length in healthy children from the Eastern Anatolia Region and sex, age, body height and weight. J Ultrason 2018;18;(72):5–8. doi: 10.15557/JoU.2018.0001.
29 Mohtasib RS, Alshamiri K, Jobeir A, Ambu-Saidi FM, Masawi A, Alabdulaziz L, et al. Sonographic measurements for spleen size in healthy Saudi children and correlation with body parameters. Ann Saudi Med 2021;41;(1):14–23. doi: 10.5144/0256-4947.2021.14.
30 Rosenbaum DM, Korngold E, Teele RL. Sonographic assessment of renal length in normal children. AJR Am J Roentgenol 1984;142;(3):467–9. doi: 10.2214/ajr.142.3.467.
31 Luk WH, Lo AXN, Au-Yeung AWS, Liu KKY, Woo YH, Chiang CCL, et al. Renal length nomogram in Hong Kong Asian children: sonographic measurement and multivariable approach. J Paediatr Child Health 2010;46;(6):310–5. doi: 10.1111/j.1440-1754.2010.01714.x.
32 Otiv A, Mehta K, Ali U, Nadkarni M. Sonographic measurement of renal size in normal Indian children. Indian Pediatr 2012;49;(7):533–6. doi: 10.1007/s13312-012-0120-7.
33 Obrycki Ł, Sarnecki J, Lichosik M, Sopińska M, Placzyńska M, Stańczyk M, et al. Kidney length normative values in children aged 0–19 years — a multicenter study. Pediatr Nephrol Berl Ger 2022; 37;(5):1075–85. doi: 10.1007/s00467-021-05303-5.
34 Chen JJ, Pugach J, Patel M, Luisiri A, Steinhardt GF. The renal length nomogram: multivariable approach. J Urol 2002;168;(5):2149–52. doi: 10.1097/01.ju.0000033905.64110.91.
35 Vujic A, Kosutic J, Bogdanovic R, Prijic S, Milicic B, Igrutinovic Z. Sonographic assessment of normal kidney dimensions in the first year of life--a study of 992 healthy infants. Pediatr Nephrol Berl Ger 2007;22;(8):1143–50. doi: 10.1007/s00467-007-0478-2.

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