Sonographic Assessment of the Normal Limits and Percentile Curves of Liver, Spleen, and Kidney Dimensions in Healthy School-Aged Children

Alp Alper Safak, MD, Enver Simsek, MD, Talat Bahcebasi, MD

Objective. The purpose of this study was to determine the normal standards of liver, spleen, and kidney dimensions and the relationship of each with sex, age, body weight, height, body mass index, and body surface area in healthy school-aged children. ***Methods.*** Seven hundred twelve healthy school-aged children (7–15 years) in 2 neighboring cities, including rural areas and city centers, were evaluated prospectively. Sex, age, weight, height, body mass index, and body surface area were determined for each case. Organ dimensions were measured 3 times, and the mean values were recorded. All measured organs had a normal position, shape, and echo texture. The children were separated into 5 groups according to body weight. ***Results.*** There were no significant differences in organ dimensions with respect to sex ($P > .05$). The mean right kidney length was shorter than the left kidney length, and the difference was significant ($P = .009$). Body weight showed the best correlation with liver, spleen, and kidney dimensions. The results were also supported by the variance and covariance of the correlation coefficients. ***Conclusions.*** The normal limits of the liver, spleen, and kidneys are important parameters during a sonographic examination. This study revealed that organ dimensions showed the best correlation with body weight. To our knowledge, in clinical practice there are no pediatric organ dimension percentile graphs for interpretation of sonographic examinations. We hope this study contributes to daily practice in radiology clinics. ***Key words:*** dimensions; kidney; liver; spleen; sonography.

Abbreviations
BMI, body mass index; BSA, body surface area

Received February 23, 2005, from the Departments of Radiology (A.A.S.), Pediatrics (E.S.), and Public Health (T.B.), Duzce School of Medicine, Abant Izzet Baysal University, Duzce, Turkey. Revision requested March 28, 2005. Revised manuscript accepted for publication May 6, 2005.

Address correspondence and reprint requests to Alp Alper Safak, MD, Department of Radiology, Duzce School of Medicine, Abant Izzet Baysal University, Konuralp 81620, Duzce, Turkey.
E-mail: alpalpersafak@yahoo.com

Sonography is routinely used to evaluate visceral organs in children because it offers numerous advantages; there is no radiation; furthermore, the examination is real time, tridimensional, and independent of organ function. Sonography can be repeated safely during the examination. However, there are few studies to define the normal limits of organ dimensions in healthy children, especially school-aged children.[1–17] Our purpose was to determine the normal standards of liver, spleen, and kidney dimensions and the relationship of each with sex, age, body weight, height, body surface area (BSA), and body mass index (BMI) in healthy school-aged children.

Materials and Methods

Clinical and Imaging Procedures

Seven hundred twelve school-aged children (7–15 years) in 2 neighboring cities, including rural areas and city centers, were evaluated prospectively. Sex, age, weight, height, BSA, and BMI were determined for each child.

All children were examined by a pediatrician, and only healthy subjects were included in this study. Clinical exclusion criteria were chronic renal failure, acute or chronic hepatitis, jaundice, fever, macular or maculopapular rash, and lymphadenopathy. Imaging exclusion criteria were parenchymal mass lesions, cysts, accessory spleens, hydronephrosis, and calyectasis. Weight and height were noted to the nearest 0.1 cm with the use of a height scale and to the nearest 0.1 kg with the use of an electronic weighing scale (Seca, Hamburg, Germany).

The sonographic examinations were performed with a high-resolution real-time scanner (SSA-270A; Toshiba Medical Systems Co, Ltd, Tokyo, Japan) with a 3.5-MHz convex transducer. The measurements of organ dimensions were made during deep inspiration. Liver measurements were performed in a supine position. The longitudinal axis was measured after clear visualization of the liver in the midclavicular plane. The uppermost edge under the dome of the diaphragm was defined as the upper margin, whereas the lowermost edge was defined as the lower margin. Spleen measurements were performed in a lateral decubitus position. Longitudinal size measurement of the spleen was performed between the most superomedial and the most inferolateral margins. Kidney measurements were performed in a lateral decubitus position. The renal hilum was visualized to get the optimum longitudinal dimension.

Each organ was measured 3 times, and the mean value was recorded as the absolute length. All measured organs had a normal position, shape, and echo texture. All the measurements were classified into 5 groups according to body weights.

This study was approved by Turkish Ministry of Health and the Ethics Committee of the Abant Izzet Baysal University School of Medicine. Informed consent was obtained from the parents of all children involved in this study.

Statistical Methods

The differences among the groups were determined by a paired samples t test. The relationships of all dimensions with sex, age, height, weight, BSA, and BMI were statistically analyzed. Correlation coefficients were derived by the Pearson coefficient of correlation. Analysis of variance (polynomial linear) and minimum norm quadratic unbiased estimation methods were used to calculate the variance and covariance of the correlation estimates. Linear regression analysis was carried out for age, sex, weight, height, BSA, BMI, and all dimensions. Descriptive statistical methods were used when appropriate. Statistical analysis was carried out with SPSS/PC version 12.0 (SPSS Inc, Chicago, IL).

Results

Seven hundred twelve school-aged children (357 boys [50.1%] and 355 girls [49.9%]) in the age group from 7 to 15 years were screened. The descriptive analysis of the organ dimensions (mean, minimum, and maximum values, SD, and lower and upper bounds) are shown in Tables 1–4. There were no significant differences in organ dimensions with respect to sex ($P > .05$). The mean right kidney length was shorter than the left kidney length, and the difference was significant ($P = .009$). Longitudinal dimensions of the liver, spleen, and right and left kidneys showed a statistically significant correlation with the measured BSA (Table 5). Body weight showed the best correlation with liver, spleen, and left kidney dimensions, whereas height showed the best correlation with right kidney dimensions (Table 5). Body mass index and age showed the weakest correlations with all the organ dimensions (Table 5). These results were also supported by the variance and covariance of the correlation coefficients (Table 6). Therefore, the children were separated into 5 groups according to body weight. The percentile curves of mentioned organs are shown according to body weight in Figures 1–3.

Discussion

In the literature, there are few detailed studies to interpret the organ dimensions in school-aged children.[1–9] However, sonography is one of the most common imaging methods used in routine

Table 1. Longitudinal Lengths of Liver Versus Body Weight

Body Weight, kg	Length, mm				95% CIM	
	Mean	Minimum	Maximum	SD	Lower Bound	Upper Bound
20	105	76	164	14	103	108
30	112	84	146	13	110	114
40	116	83	149	12	114	118
50	119	83	161	15	116	121
60	123	95	165	14	120	126

CIM indicates 95% confidence interval for mean.

Table 2. Longitudinal Lengths of Spleen Versus Body Weight

Body Weight, kg	Length, mm				95% CIM	
	Mean	Minimum	Maximum	SD	Lower Bound	Upper Bound
20	78	52	100	9	76	77
30	80	52	110	9	78	87
40	83	50	135	18	81	83
50	86	61	130	13	86	83
60	91	71	114	12	89	94

CIM indicates 95% confidence interval for mean.

Table 3. Longitudinal Lengths of Right Kidney Versus Body Weight

Body Weight, kg	Length, mm				95% CIM	
	Mean	Minimum	Maximum	SD	Lower Bound	Upper Bound
20	81	64	121	8	80	83
30	87	68	111	7	86	88
40	89	72	106	6	88	90
50	93	60	130	8	91	94
60	98	82	115	7	96	100

CIM indicates 95% confidence interval for mean.

Table 4. Longitudinal Lengths of Left Kidney Versus Body Weight

Body Weight, kg	Length, mm				95% CIM	
	Mean	Minimum	Maximum	SD	Lower Bound	Upper Bound
20	83	62	119	8	81	84
30	86	67	110	8	85	88
40	90	69	120	8	89	92
50	93	64	131	9	92	95
60	98	80	123	9	96	100

CIM indicates 95% confidence interval for mean.

Table 5. Correlations of Organ Dimensions With Body Mass Index, Body Surface Area, Weight, Height, and Age

Parameter	Age	Liver	Spleen	Right Kidney	Left Kidney
BSA	0.820*	0.351*	0.341*	0.582*	0.500*
BMI	0.268*	0.278*	0.277*	0.277*	0.301*
Weight	0.678*	0.388*	0.390*	0.552*	0.511*
Height	0.828*	0.351*	0.338*	0.581*	0.498*
Age		0.255*	0.314*	0.488*	0.415*
Liver				0.385*	0.293*
Spleen				0.325*	0.355*
Right kidney					0.703*

*Statistically significant at $P < .001$.

Table 6. Covariance and Variance of the Correlation Estimates of Organ Dimensions With the Body Parameters

	Estimate*				ANOVA†	
Parameter	Liver	Spleen	Right Kidney	Left Kidney	F	*P*
BSA	0.000	0.000	0.000	0.000	101.855	<.001
BMI	12.177	–2.707	9.034	10.351	58.403	<.001
Weight	65.814	20.057	10.069	18.514	125.374	<.001
Height	12.597	–2.151	12.927	11.033	102.506	<.001
Age	17.229	5.504	2.861	0.361	51.874	<.001
Variance (error)	183.978	114.191	50.144	67.585		

*Covariance method: minimum norm quadratic unbiased estimation (weight = 1 for random effects and residual).
†Analysis of variance (polynomial linear).

Figure 1. Percentile curves of longitudinal length of the liver versus body weight.

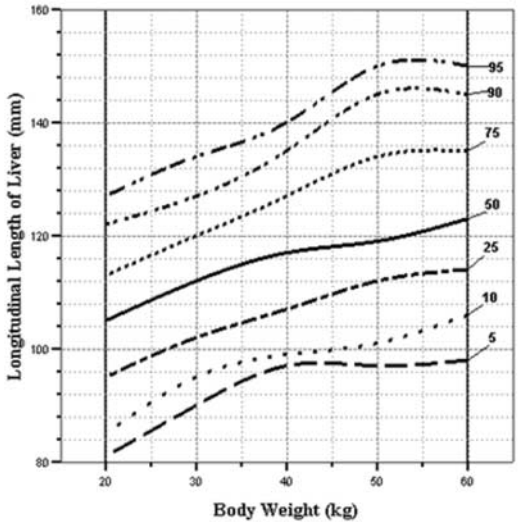
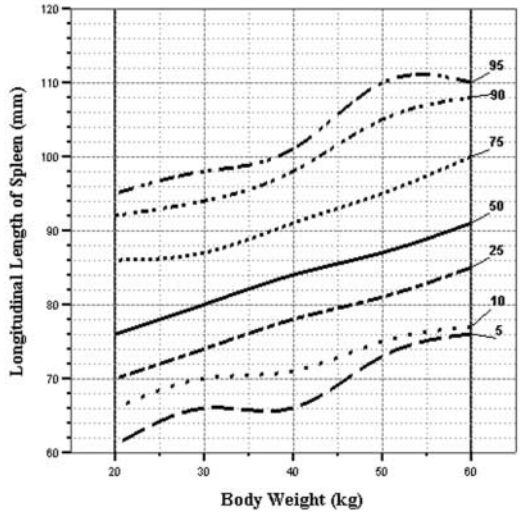
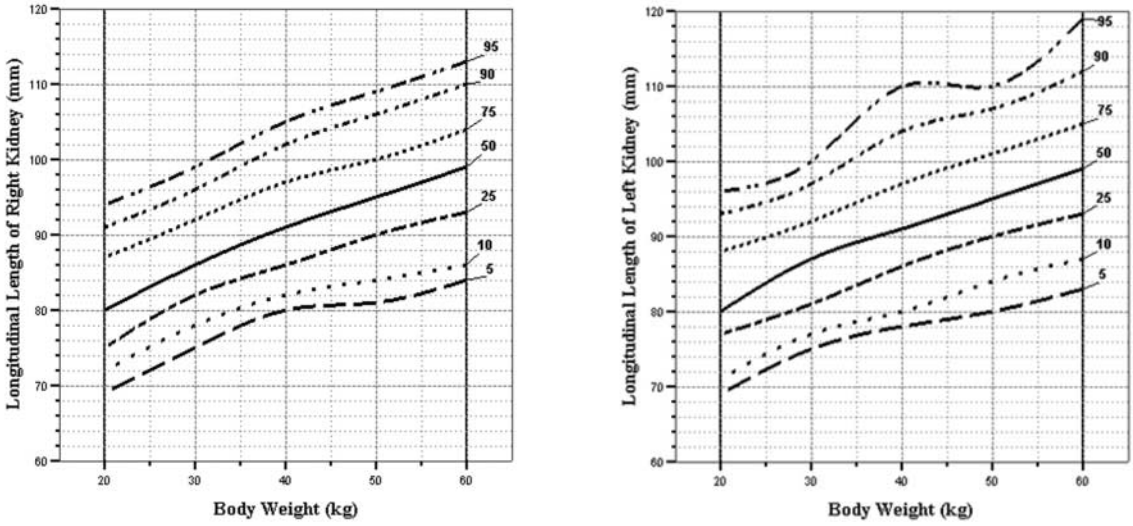


Figure 2. Percentile curves of longitudinal length of the spleen versus body weight.





A B

Figure 3. A, Percentile curves of longitudinal length of the right kidney versus body weight. **B**, Percentile curves of longitudinal length of the left kidney versus body weight.

practice. Our objective in this study was to define the normal limits of organ dimensions in a large group of school-aged children. To the best of our knowledge, our study, which aimed to investigate the normal limits of the liver, spleen, and kidneys, comprises one of the largest series in the literature, including the age group of 7 to 15 years.

There is no consensus on which measurement parameter is most sensitive for investigating the normal limits of organ dimensions. It is not practical to use the volumes of the liver and spleen.[3,10–12] Previous studies showed that the longitudinal measurements of the liver, spleen, and kidneys were best correlated with body parameters.[1–4,12–18] The results of our study were in accordance with the findings of those studies. In many studies, the lengths of the liver in the midclavicular and midsagittal planes were both measured, but they found better correlation between the measurement of the midclavicular plane and the body parameters.[2–6] In our study, only midclavicular measurements of the liver were used, and strong correlations were found with the body parameters. This result indicates that midclavicular measurement of the liver is practical and yields reliable information. There are different methods for evaluating the kidneys by sonography, such as lateral decubitus, supine, and prone positions. A lateral decubitus position was mostly preferred in previous studies.[11,12,14,16] Accordingly, we used a lateral decubitus position for the measurements. Kidney dimensions in pediatric age groups have been studied relatively more frequently by many authors than liver and spleen dimensions. In this study, the longitudinal length of the left kidney was greater than that of the right kidney, as shown in previous studies.[13–17] However, Christophe et al[18] found a slight difference between kidney lengths and considered it negligible.

Previous studies described normal percentiles of the liver and spleen according to age.[1–4,7] However, our study showed that liver and spleen dimensions showed weak correlations with age. Spleen dimensions showed the best correlation with body weight, as did liver dimensions. Soyupak et al[4] and Dinkel et al[13] also reported that liver, spleen, and kidney dimensions showed the best correlation with body weight. In our study, longitudinal lengths of the right kidney showed the best correlation with height. This finding was consistent with those of many previous studies.[13,15,17,18] In this study, the percentile curves and normal limits of the liver, spleen, and kidneys were defined according to body weight, which showed the most important correlation with organ dimensions. The body weight might show variations in different ethnic origins.

We have not found a sex-related difference in the sizes of the organs. This was concordant with the findings of the other authors.[1,3,4,13–16]

Also, we have built the following prediction models of the longitudinal lengths of the measured organs, in millimeters, according to body weight as an alternative method for the examiners: liver, 96.063 + (body weight [kilograms] × 0.509); spleen, 69.875 + (body weight [kilograms] × 0.371); right kidney, 73.636 + (body weight [kilograms] × 0.426); and left kidney, 74.565 + (body weight [kilograms] × 0.421).

In conclusion, the normal limits of the liver, spleen, and kidneys are important parameters during a sonographic examination. This study revealed that organ dimensions showed the best correlation with body weight. To our knowledge, in clinical practice there are no pediatric organ dimension percentile graphs for interpretation of sonographic examination. We hope this study contributes to daily practice in radiology clinics.

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; 157:119–121.
2. Carpentieri U, Gustavson LP, Leach TM, Bunce H. Liver size in normal infants and children. South Med J 1977; 70:1096–1097.
3. Konus OL, Ozdemir A, Akkaya A, Erbas G, Celik H, Isik S. Normal liver, spleen and kidney dimensions in neonates, infants and children: evaluation with sonography. AJR Am J Roentgenol 1998; 171:1693–1698.
4. Soyupak SK, Narli N, Yapicioglu H, Satar M, Sungur EH. Sonographic measurements of the liver, spleen and kidney dimensions in the healthy term and preterm newborns. Eur J Radiol 2002; 43:73–78.
5. Holder L, Strife J, Padikal TN, Perkins PJ, Kerelakes JG. Liver size determination in pediatrics using sonographic and scintigraphic techniques. Radiology 1975; 117:349–353.
6. Dittrich M, Milde S, Dinkel E, Baumann W, Weitzel D. Sonographic biometry of liver and spleen size in childhood. Pediatr Radiol 1983; 13:206–211.
7. Megremis SD, Vlachonikolis IG, Tsilimigaki AM. Spleen length in childhood with US: normal values based on age, sex, and somatometric parameters. Radiology 2004; 231:129–134.
8. Ishibashi H, Higuchi N, Shimamura R, Hirata Y, Kudo J, Niho Y. Sonographic assessment and grading of spleen size. J Clin Ultrasound 1991; 19:21–25.
9. Perlmutter GS. Ultrasound measurement of the spleen. In: Goldberg BB, Kurtz AB (eds). Atlas of Ultrasound Measurements. Chicago, IL: Year Book Medical Publishers; 1990:126–138.
10. Rosenbaum DM, Korngold E, Teele RL. Sonographic assessment of renal length in normal children. AJR Am J Roentgenol 1984; 142:467–469.
11. De Sanctis JT, Connoly SA, Bramson RT. Effect of patient position on sonographically measured renal length in neonates, infants and children. AJR Am J Roentgenol 1998; 170:1381–1383.
12. Zerin JM, Blane CE. Sonographic assessment of renal length in children: a reappraisal. Pediatr Radiol 1994; 24:101–106.
13. 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; 15:38–43.
14. Han BK, Babcock DS. Sonographic measurements and appearance of normal kidneys in children. AJR Am J Roentgenol 1985; 145:611–616.
15. Dremsek PA, Kritscher H, Böhm G, Hochberger O. Kidney dimensions in ultrasound compared to somatometric parameters in normal children. Pediatr Radiol 1987; 17:285–290.
16. Carrico CW, Zerin JM. Sonographic measurement of renal length in children: does the position of the patient matter? Pediatr Radiol 1996; 26:553–555.
17. Mathur S, Chandra J, Mittal KP, Mittal SK, Khurana A. Sonographic renal length in Indian children. Indian J Pediatr 1996; 63:553–557.
18. Christophe C, Cantraine F, Bogaert B, et al. Ultrasound: a method for kidney size monitoring in children. Eur J Pediatr 1986; 145:532–538.