

# Ultrasound quantification of kidneys length and width to establish normal values in healthy Sudanese school aged children

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**Abstract:** Changes in renal morphology are apparent by many pathologies. The objectives of this study were to characterize the kidneys of Sudanese school aged children sonographically, and correlate with their demographic indices, as well as to establish a local reference of normal values. A total of 215 healthy children were included, 104 (48.4%) were males and 111 (51.6%) were females. All children underwent ultrasound examination for abdomen, coupling gel was used and longitudinal and transverse scans were obtained. The study showed that the normal Left Kidney Length was  $7.9 \pm 0.8$ ,  $8.1 \pm 0.7$ . Left Kidney Width  $3.9 \pm 0.5$ ,  $3.9 \pm 0.5$  and Right Kidney Length  $8.0 \pm 0.8$ ,  $8.3 \pm 0.8$ , Right Kidney Width  $3.4 \pm 0.4$ ,  $3.4 \pm 0.4$  for males and females respectively. Significant differences were noticed between two genders for left and right lengths ( $p$ -values = 0.017, 0.037). A significant relationship at  $p$ -value 0.000 was detected between the kidneys measurements and children age, weight, height, abdomen circumference (AC) and Body mass index (BMI). The Left Kidney Length/spleen length ratio was found to be decreased in the ages of 9 and 10 years for females and Right Kidney Length/liver length ratio was increased in the ages 8, 10 years for females. This study revealed that the kidneys measurements for Sudanese school aged children differed from what was mentioned in the previous studies in the same age groups. To the best of our knowledge, in clinical practice there are no pediatric kidneys length and width equations for interpretation of sonographic examinations. Reference values were established. We hope this study contributes to daily practice in ultrasound clinics. These measurements can be considered as typical, and should be used for adequate comparison in evaluation of children kidney diseases.

**Keywords:** Ultrasonography, Kidneys Measurements, Children

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## 1. Introduction

Characterization of kidneys is very important to the clinician to determine the health of the individuals and diagnose any presence of abnormalities. [1] Renal length is the most frequently used quantitative calculation of renal size for comparison with documented standards. [2, 3] Many studies have revealed that the kidney measurements are predisposed by many factors including: age, ethnicity, gender, and other factors. [4, 5] There are few studies to define the normal limits of organ dimensions in healthy children, especially school-aged children. [6, 7] Ultrasonography is one of the most widespread imaging modalities used in everyday practice for visualizing the normal anatomy and is also easy and dependable to visualize pathological changes in the abdominal organs. [8] Ultrasound measurement of renal length is frequently

used as an indicator of the chronicity of renal disease, with a value of 9 cm or less considered indicating irreversible disease. [9] As youth is an important period of growth for many organs, therefore, having a reliable reference for kidney length and width in children is valuable in evaluation of renal growth. The Sudanese population has immigrants from many different countries, resulting in a mixed population. Therefore the normal pattern of renal length and width should be established for this population considering its characteristics and demographic indices. The aims of this study were to establish a local reference of the right and left kidneys length, width and renal/liver and renal/spleen length ratios, and to find out correlations with the age, gender, body mass index, height, weight, abdominal circumference.

To the best of our knowledge no study was done in the open literature regarding the renal sonographic measurements of the Sudanese Healthy school aged children.

## 2. Materials and Methods

### 2.1. Materials

This study was done in Alsidigah School and Hamza Ebn Abdmutalib School- Bhary City during the period from February to June 2012.

This study dealt with the normal kidney measurements in healthy school aged children and correlates them with gender, age, height, weight and body mass index (BMI), as well as the left kidney/spleen ratio and right kidney/liver ratio in both genders for evaluation of their growth.

A number of 215 healthy Sudanese school aged-children, 104(48.4%) were males and 111(51.6%) were females .Their ages were between (7-13) years old .All the children were with normal organ position, shape and echo texture. Children with paraenchymal mass lesions, cysts, hydronephrosis, splenomegaly ,hepatomegally, renal disease were excluded.

The sonographic examinations were performed with a high resolution real time scanner (SSD-500 Aloka Medical System Co, Ltd, Tokyo, Japan) with a 3.5MHz convex transducer.

### 2.2. Methods

The examination was done with the children in the supine position, left lateral decubitus, lateral oblique positions for the right kidney and right lateral decubitus or lateral oblique positions for the left kidney.

Scans are performed in the sagittal and transverse planes from the anterior approach using the liver and spleen as acoustic windows.

For measurements of length: the maximal longitudinal axes were evaluated from the ventral side. The calipers were placed on the outer edges of the caudal and cranial side in a sagittal plane to obtain the maximum longitudinal renal length .The width was measured from the ventral ultrasonographic section of the kidney, the width that is perpendicular to the longitudinal length was obtained.

The spleen and liver length was also measured using computer cursor. The children weight, height, abdomen circumference and BMI were measured and recorded in a master data sheet.

For statistical analyses Excel 2007 and SPSS program version 16 were used. Data were expressed as mean values and standard deviation; equations were created from the relationship regressions.

## 3. Results

The children demographic data were evaluated and classified into classes and signified in percentages (%).

Children Body Mass index (BMI) were: 10-14.9 representing (34.9%), 15-19.9(51.6%), 20-24.9(9.8%), 25-29.9 (3.3%) and the BMI of 30-34.9 representing (0.5%).

Children weights were: 16-26 representing (33.5%) 27-37(42.3%), 38-48(14.4%), 49-59(7.4%), and  $\geq 60$

representing(2.3%).

Abdominal circumferences were: 40-49 constituting (5.6%), 50-59(60.9%), 60-69(25.1%), and  $\geq 70$  constituting (8.4%).

Children Heights were: 110-129representing (24.2%), 130-149(60.0%), and 150-169 representing(15.8%).

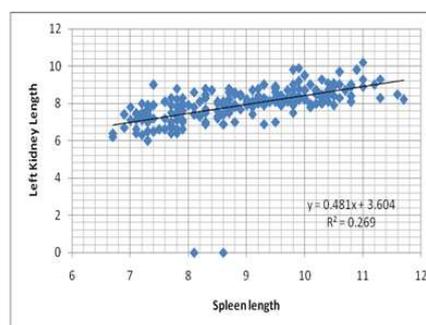
**Table(1).** Compare mean of Kidneys length and width, Children Demographic Indices, Spleen and Liver Length according to gender.

Variables	Gender		Total	P-value
	Male	Female		
BMI*	16.6 ± 2.3	16.9 ± 4.2	16.8 ± 3.4	0.58
LKL*	7.9 ± 0.8	8.1 ± 0.7	8.0 ± 0.8	0.02*
LKW*	3.9 ± 0.5	3.9 ± 0.5	3.9 ± 0.5	0.22
RKW*	3.4 ± 0.4	3.4 ± 0.4	3.4 ± 0.4	0.59
RKL*	8.0 ± 0.8	8.3 ± 0.8	8.1 ± 0.8	0.04*
Spleen Length	8.7 ± 1.1	9.3 ± 1.1	9.0 ± 1.2	0.00*
Liver Length	12.5 ± 1.1	12.8 ± 1.4	12.7 ± 1.3	0.13
Weight (AC)*	31.6 ± 7.8	33.4 ± 11.8	32.5 ± 10.1	0.19
Height	57.2 ± 5.6	59.3 ± 8.1	58.2 ± 7.1	0.03*
	136.9 ± 0.5	138.8 ± 11.4	137.9 ± 1.0	0.20

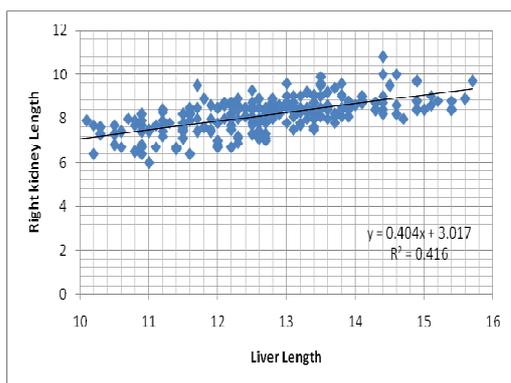
\*BMI=Body Mass Index, LKL=Left Kidney Length, LKW= Left Kidney Width, RKW= Right Kidney Width, RKL= Right Kidney Length, Abdominal Circumferences=AC. Values are expressed as Mean ± SD; \* Significant at P-value < 0.05.

**Table (2).** Compare left kidney length/spleen ratio and right kidney /liver ratio according to age and gender.

Age/years	Gender	Left Kidney Length/spleen	Right Kidney Length/liver
7 years	Male	0.95	0.64
	Female	0.94	0.64
8 years	Male	0.95	0.63
	Female	0.97	0.69
9 years	Male	0.92	0.63
	Female	0.82	0.64
10 years	Male	0.95	0.64
	Female	0.83	0.68
11 years	Male	0.90	0.66
	Female	0.86	0.64
12 years	Male	0.86	0.64
	Female	0.87	0.64
13 years	Male	0.86	0.66
	Female	0.85	0.62



**Figure [1].** A scatter plot diagram showed a linear relationship between children Spleen Length and left kidney length, as the spleen length increased the left kidney length is also increased by 0.48 , $R^2=0.269$



**Figure [2].** A scatter plot diagram showed a linear relationship between children Liver Length and right kidney length, as the liver length increased the right kidney length is also increased by 0.40  $R^2=0.416$ .

**Table (3).** Shows Proximity Matrix of correlations between kidneys length and width and body demographic indices, spleen length and liver length.

	Correlations	LKL*	LKW*	RKW*	RKL*
BMI*	PC	0.37	0.16	0.26	0.37
	P-value	0.000	0.021	0.000	0.000
LKL*	PC	1.00	0.24	0.43	0.68
	P-value	.	0.000	0.000	0.000
LKW*	PC	0.24	1.00	0.19	0.27
	P-value	0.000	.	0.006	0.000
RKW*	PC	0.43	0.19	1.00	0.46
	P-value	0.000	0.006	.	0.000
RKL*	PC	0.68	0.27	0.46	1.00
	P-value	0.000	0.000	0.000	.
Spleen length	PC	0.69	0.21	0.33	0.66
	P-value	0.000	0.002	0.000	0.000
Liver length	PC	0.56	0.23	0.38	0.65
	P-value	0.000	0.001	0.000	0.000
Weight	PC	0.55	0.27	0.40	0.58
	P-value	0.000	0.000	0.000	0.000
AC*	PC	0.46	0.23	0.35	0.40
	P-value	0.000	0.001	0.000	0.000
Height.	PC	0.61	0.33	0.41	0.68
	P-value	0.000	0.000	0.000	0.000

\*BMI=Body Mass Index, LKL=Left Kidney Length, LKW= Left Kidney Width, RKW= Right Kidney Width, RKL= Right Kidney Length, Abdominal Circumferences=AC. The Pearson Correlation (PC) denotes value of the correlation either positive (+) or negative (-) as the follow: 0.90 – 1.00 very strong relationship, 0.70 – 0.89 strong relationship, 0.50 – 0.69 middle relationship, 0.00 – 0.49 weak relationship.

### 4. Discussion

There are few detailed studies to interpret the organ dimensions in school-aged children. [10] Ultrasonography is one of the most common imaging methods used in routine practice. Comparing the variables means according to gender, were presented in table [1].A significant difference between males and females in Left Kidney Length, Right Kidney Length, Spleen length and AC, were noticed, because P-value is  $\leq 0.05$  (0.017, 0.037, 0.000 and 0.029) respectively, that means the means of Left Kidney Length, Right Kidney Length, Spleen and AC in females are more than means in males, respectively. But in the other variables there is no significant difference concerning gender. Previous studies showed that the longitudinal measurements

of the children livers, spleens, and kidneys were best correlated with body parameters.[11-18]The results of our study were in accordance with the findings of those studies. Comparing variables means according to different age classes and gender were presented in table [4].The body demographic indices including children height, weight, BMI, AC, age and gender, which were presented in table [3] showed significant relations with the kidneys length and width as well as Liver and Spleen length .The age is an important factor affecting the organs measurements, because in childhood period of life, there is a full maturation of all renal structures. The cortex: medulla ratio increases in the newborn infants, due to cortical immaturity till it reaches its normal values in adults.[19] The glomeruli begin to degenerate as early as the seventh month of the intrauterine life ,and by the seventh year of life there are clearly visible degenerated juxtamedullary glomeruli .[11]Similar studies regarding the kidney dimensions showed that there is a prominent correlation between the kidney length and the age of children, their height, and weight and body surface. But no gender differences were recognized. [20, 21]

Studies established normal limits of the liver, spleen, and kidneys and defined them according to body weight, which showed the most important correlation with organ dimensions. [22]The bodyweight might show variations in different ethnic origins. [22]Therefore we correlated the kidneys measurements with the children weights. The study showed significant relations with children weight at p-value 0.000.Normal Renal Measurements in Children were studied in similar group of age [23], it was found to be greater to what was found in our study.

Also, our study has built the following prediction models of the lengths and width of the measured Right and left kidneys in millimeters, according to BMI, AC and children ages as an established method for the clinicians.

$$\text{Left Kidney length} = 0.19X\text{Child age} + 6.02 \quad r^2 = 0.13$$

$$\text{Right Kidney length} = 0.25X\text{Child age} + 5.66 \quad r^2 = 0.42$$

$$\text{Left Kidney length} = 0.01X\text{Child BMI} + 6.72 \quad r^2 = 0.05$$

$$\text{Right Kidney length} = 0.08X\text{Child BMI} + 6.72 \quad r^2 = 0.13$$

$$\text{Left Kidney Length} = 0.048x\text{Child (AC)} + 5.08 \quad r^2 = 0.10$$

$$\text{Right Kidney length} = 0.044X\text{Child (AC)} + 5.54 \quad r^2 = 0.16$$

$$\text{Left Kidney Width} = 0.022X\text{Child (BMI)} + 3.51 \quad r^2 = 0.02$$

$$\text{Right Kidney Width} = 0.027X\text{Child (BMI)} + 2.96 \quad r^2 = 0.07$$

$$\text{Left Kidney Width} = 0.070X\text{Child (age)} + 3.19 \quad r^2 = 0.09$$

$$\text{Right Kidney Width} = 0.070X\text{Child (age)} + 2.73 \quad r^2 = 0.15$$

$$\text{Left Kidney Width} = 0.015X\text{Child (AC)} + 2.96 \quad r^2 = 0.05$$

$$\text{Right Kidney Width} = 0.018X\text{Child (Ac)} + 2.38 \quad r^2 = 0.12$$

One sonographic study measured the annual increase in length of the kidneys during childhood. [24] Therefore correlations between the right and left kidneys with other adjacent organs including the liver and spleen were also studied. Comparing left kidney length/spleen ratio and right kidney /liver ratio according to age and gender were

presented in table [4]. The results showed that the Left Kidney Length/spleen length ratio in the ages 9 and 10 years (0.82, 0.83) decreases for females and Right Kidney Length/liver length ratio in the ages 8, 10 years (0.69, 0.68) increases for females. A linear relationship between children Spleen Length and left kidney length, was presented in figure [1], and as the Spleen length increased the kidney length is also increased by 0.48mm  $r^2=0.269$ . A linear relationship between child Liver Length and left kidney length, was also demonstrated in figure [2], as the Liver length increased the kidney length is also increased by 0.40mm.  $r^2=0.416$ . Equations were established to estimate the kidneys length when the normal spleen and liver length were known in the age group of (7-13) years old.

$$\{Left\ Kidney\ length = 0.481 \times Child\ spleen\ length + 3.604\}$$

$$\{Right\ Kidney\ length = 0.404 \times Child\ Liver\ length + 3.017\}$$

### 5. Conclusion

This study revealed that kidneys length and width showed correlation with body demographic indices as well as liver and spleen length. The Sudanese measurements are different from what was mentioned in previous studies in the same age groups. To the best of our knowledge, in clinical practice there are no pediatric organ length graphs and equations for interpretation of sonographic examination. We hope this study contributes to daily practice in radiology and ultrasound clinics. These measurements can be considered as typical, and should be used for adequate comparison in evaluation of children kidney diseases.

Table (4). Compare mean of variables according to age and gender.

Age	Gender	BMI*	LKL*	LKW*	RKW*	RKL*	Spleen Length	Liver Length	Weight	AC*	Height
7 years	Male	15.6± 1.8	7.6 ± 0.6	3.5± 0.5	3.2 ± 0.3	7.3± 0.7	8.0± 0.8	11.4±0.9	23.7± 3.4	53.5±4.1	123.7 ± 6.9
	Female	13.6± 1.7	7.4 ± 0.7	3.7± 0.4	3.3 ± 0.5	7.4 ± 0.8	7.9 ± 0.5	11.5±0.8	22.3 ± 3.7	54.3± 4.2	127.9 ± 3.5
8 years	Male	15.7± 1.6	7.1 ± 0.6	3.8± 0.5	3.2 ± 0.2	7.4± 0.6	7.5± 0.6	11.8±1.1	26.0± 3.7	54.3 ± 3.1	128.4 ± 5.7
	Female	13.7± 2.3	7.6 ± 0.6	3.8± 0.4	3.3 ± 0.2	7.9± 0.4	7.8± 0.5	11.4±0.9	22.1 ± 5.2	52.7± 6.8	126.8± 5.1
9 years	Male	16.5± 1.6	7.3 ± 0.7	3.7± 0.5	3.3 ± 0.3	7.6± 0.7	7.9± 0.7	12.0±0.8	29.5± 3.9	57.1 ± 4.9	133.7± 4.5
	Female	19.6± 5.9	8.1 ± 0.5	4.0± 0.5	3.4 ± 0.2	8.2± 0.5	9.9± 0.9	12.9±1.1	36.3± 11.8	63.3±10.3	135.7± 4.1
10 years	Male	16.7± 2.2	8.2 ± 0.4	4.0± 0.6	3.5 ± 0.4	8.4± 0.5	8.6± 0.4	13.2± 0.9	31.9± 4.3	58.7 ± 4.3	138.1± 5.8
	Female	17.3± 3.3	8.3 ± 0.3	3.9± 0.5	3.4 ± 0.3	8.4± 0.5	10.0±0.3	12.7± 0.9	34.2± 9.7	59.9± 8.1	140.0± 8.9
11 years	Male	16.1± 2.2	8.3 ± 0.6	4.1± 0.5	3.5 ± 0.4	8.4± 0.4	9.2± 0.7	12.8± 0.9	32.3 ± 5.5	57.3 ± 4.5	141.3± 5.8
	Female	17.3± 3.0	8.2 ± 0.3	3.9± 0.4	3.5± 0.4	8.5± 0.3	9.5± 0.3	13.2± 0.6	34.7 ± 6.4	60.4 ± 5.7	141.5± 4.6
12 years	Male	18.3± 3.2	8.3 ± 0.4	3.9± 0.5	3.5 ± 0.3	8.5± 0.4	9.7± 1.0	13.3±0.8	37.8 ± 8.3	57.8± 6.8	143.2± 4.4
	Female	18.0± 2.7	8.7 ± 0.6	4.1± 0.5	3.6 ± 0.4	8.9± 0.6	10.0±0.3	14.0±0.6	39.8± 7.2	60.3± 6.8	148.6± 7.2
13 years	Male	17.7± 2.4	8.4 ± 0.7	4.0± 0.4	3.6 ± 0.4	8.6± 0.8	9.8 ± 0.7	13.1± .9	40.3 ± 8.5	61.5 ± 7.0	150.3± 9.7
	Female	20.2± 4.3	8.9 ± 0.5	4.2± 0.4	3.7 ± 0.3	8.9± 0.7	10.5± .5	14.4± .9	48.6± 10.3	66.1± 6.6	155.3± 7.5

\*BMI=Body Mass Index, LKL=Left Kidney Length, LKW= Left Kidney Width, RKW= Right Kidney Width, RKL= Right Kidney Length, Abdominal Circumferences=AC. Values are expressed as Mean ± SD.

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