Sonographic Biometry of Normal Kidney Dimensions among School-age Children in Nsukka, Southeast Nigeria

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ABSTRACT

Background: *Some kidney diseases are usually associated with changes in kidney size.*
Objective: *To determine sonographically the normal limits and percentile curves of the kidney dimensions according to age, gender and somatometric parameters among school-age children.*
Methods: *A prospective cross-sectional research design and convenience sampling method were utilized. Participants included 947 normal subjects (496 boys and 451 girls) aged 6–17 years old. The sonographic examination was performed on a Shenzhen DP-1100 machine with 3.5 MHz convex transducer. Longitudinal and transverse dimensions of the kidneys were obtained in coronal plane with the subject in the supine or left lateral decubitus position.*
Results: *The means of right and left kidney lengths in mm were 79.6 ± 8.1 and 81.6 ± 8.3, respectively while those of the right and left kidney widths in mm were 35.03 ± 3.6 and 35.09 ± 3.6, respectively. Dimensions of the kidneys were not statistically different in boys and girls ($p > 0.05$). There was a statistically significant difference between right and left kidney length ($p < 0.05$). Height correlated best with both kidney lengths. Thus the normal limits, prediction models and percentile curves of kidney lengths were established with respect to height.*
Conclusion: *Sonographic determination of pathologic changes in the size of the kidney necessitates knowing the normal ranges of its length especially with respect to height in school-age children.*

Keywords: Measurements, renal size, school-age children, sonography

Biometría Sonográfica de las Dimensiones Normales del Riñón entre Niños de Edad Escolar en Nsukka, Sureste de Nigeria

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RESUMEN

Antecedentes: *Algunas enfermedades renales se asocian generalmente a cambios en el tamaño del riñón.*
Objetivo: *Determinar sonográficamente los límites normales y las curvas percentiles de las dimensiones del riñón según edad, género y parámetros somatométricos entre niños en edad escolar.*
Métodos: *Se utilizó un diseño de investigación transversal prospectivo y un método de muestreo de conveniencia. Los participantes incluyeron 947 sujetos normales (496 niños y 451 niñas) de 6–17 años de edad. El examen sonográfico fue realizado con un equipo Shenzhen DP-1100 con transductor convexo de 3.5 MHz. Las dimensiones longitudinales y transversales de los riñones fueron obtenidas en el plano coronal con el sujeto en posición supina o decúbito lateral izquierdo.*
Resultados: *Los promedios de las longitudes de los riñones derechos e izquierdos en mm fueron 79.6 ± 8.1 and 81.6 ± 8.3, respectivamente, mientras que los de las anchuras de los riñones derechos e izquierdos en mm fueron 35.03 ± 3.6 and 35.09 ± 3.6, respectivamente. Las dimensiones de los riñones no fueron estadísticamente diferentes en los niños y las niñas ($p > 0.05$). Hubo una diferencia estadísticamente*

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DOI: 10.7727/wimj.2013.010

*significativa entre la longitud del riñón derecho y el izquierdo (*p *< 0.05). La altura guardó una mejor correlación con ambas longitudes del riñón. Así los límites normales, los modelos de predicción y las curvas percentiles de las longitudes del riñón, fueron establecidas con respecto a la altura.*

Conclusión: *La determinación sonográfica de los cambios patológicos en el tamaño del riñón requiere que se conozcan los rangos normales de su longitud, especialmente con respecto a la altura, en los niños en edad escolar.*

Palabras claves: Mediciones, tamaño renal, niños en edad escolar, sonografía

West Indian Med J 2014; 63 (1): 47

INTRODUCTION

Measurement of renal size is important because many disorders present with enlargement or reduction of the kidneys. Serial size measurements may be used in tracking normal growth pattern of the kidneys and in the follow-up of known pathology of the kidneys in children. Establishment of normal values of the kidneys in routine sonographic examinations can serve as a baseline for diagnosis of renal diseases associated with changes in their size such as acute or chronic pyelonephritis.

Clinical assessment of changes in visceral organ size is difficult and unreliable (1). Radiography, computed tomography and radionuclide imaging expose the patients to ionizing radiation while magnetic resonance imaging is expensive and is not readily available (2). Sonography is a simple and reliable way to visualize and measure abdominal visceral organs without the risk of ionizing radiation. Sonographic measurement is non-invasive and does not have the problem of magnification but is less reproducible compared to urographic measurement (3). Refinements in ultrasound technology have advanced the use of this modality beyond the simple display of anatomy, anatomic relationships and spatial localization of lesions. Sonography is also useful in the determination of agenesis, hypertrophy, atrophy and ectopic location of the kidneys. In cases of gross enlargement of the kidneys, confirmation by sonography is easy. However, where there is only mild enlargement as a result of disease processes, making decision about the size can be difficult. Therefore, it is very important to have a set of standard normal sonographic values showing upper and lower limits. Prediction model of kidney size estimation according to the parameter that shows the best correlation with the kidney size is also important to be built as an alternative method for examiners in remote locations where ultrasound facility is not readily available.

Organ volumes obtained by using various organ dimensions and body surface areas are already used in correlation with body parameters to describe the normal dimensions and to measure the degree of pathologic deviation from normal (4−6). However, these volume measurement techniques are time consuming and impractical in daily use. Therefore, use of one or more of length, antero-posterior and width dimensions seem more practical for the purpose of establishing normograms. Any other data, like age, body weight and height which are easily obtainable can be combined with the above measurements when necessary.

In clinico-radiological practice, there is a paucity of data on normal kidney dimensions and its variants for the interpretation of sonographic examinations in school-age children in the Nigerian population. Moreover, racial differences in the normal kidney dimensions have been shown to exist (7).

The main purpose of the present study is to determine the normal limits and variants of the kidney dimensions in relation to age, gender, height, weight, body surface area (BSA) and body mass index (BMI) among healthy school-age children in a Nigerian population. The provision of these data in the present study will enable a more practical and objective evaluation during a sonographic examination involving the kidneys of school-age children.

SUBJECTS AND METHODS

The study was carried out using a prospective cross-sectional research design and convenience sampling method at the University of Nigeria Medical Centre, Nsukka, between January 2011 and May 2011.

The sample group included school-age children between six and 17 years. The age of each subject was obtained from his/her hospital birth certificate. Some of the children recruited into the study attended hospital for clinical reasons unrelated to kidney and for routine medical examinations at the study centre while the majority of them attended hospital just as volunteers for the study. The volunteer children were recruited from some primary and secondary schools within Nsukka metropolis in Southeast Nigeria.

The apparently normal subjects were examined by a paediatrician and those who met the selection criteria were enlisted in the study. Subjects with acute or chronic renal failure, renal parenchymal mass lesion, cysts, hydronephrosis or caliectasis were excluded. Apparently healthy subjects and subjects with normal sonographic appearances of the kidneys were included.

Ethical approval was obtained from the ethics committee of the University of Nigeria, Nsukka Medical Centre. In addition, informed consent was obtained from each participant's parent and the school authorities. A chaperone was available during data collection for female subjects.

The sonographic examinations were performed with high resolution real time scanner (DP-1100, Shenzhen Mindray Biomedical Electronics Co. Ltd, China) made in 2008 with 3.5 MHz convex transducer. Demographic data were collected from each participant at the time of their pre-participation physical examination. This information included age, gender, height, BSA and BMI. Anthropometric measurements were obtained from the participants wearing lightweight street clothes without shoes. Weight was measured on a calibrated portable Salter scale (BR 9011; Hana Co. Ltd, China) to the nearest 0.1 kg. Height was measured with a metal tape measure to the nearest 0.5 cm with the participants standing upright with the head in the Frankfurt position (8).

Scanning technique

Kidney size (length and width) measurements (Fig. 1) were obtained in the coronal plane passing through the renal hilum

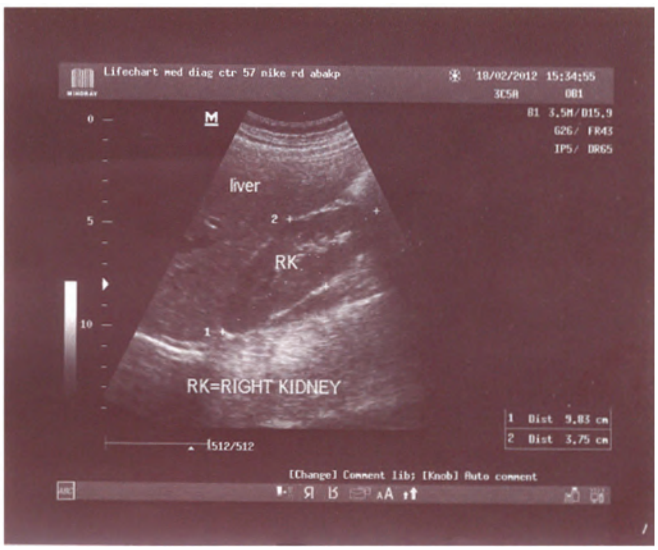

Fig. 1: Normal right kidney demonstrated on supine longitudinal view showing measurement of length (1) and width (2).

with the subjects in the supine or slightly right or left lateral decubitus positions. This technique was adopted because of the superior advantage of obtaining easily the longest dimension of the kidneys and reproducibility of measurements as shown by previous authors (9−11).

A single sonographer with 14 years of experience in abdominal sonography performed the scan for data collection in this study. This sonographer is also one of the two sonographers that did the pilot study to determine the intra- and inter-rater reliability of kidney size measurements. The second sonographer who participated in the pilot study had 13 years of experience in abdominal sonography.

Organ dimension was measured three times, and the mean values were recorded. All measured organs for normal subjects had normal position, shape and echotexture. The measurement of organ dimensions was made during deep inspiration.

Statistical analysis

Body mass index was calculated as weight (Kg)/height (m^2) while BSA was calculated as √weight x height/3600 (11). The association between kidney dimensions and gender, age, height, weight, BSA and BMI was assessed with Pearson's correlation coefficient; to determine the exact pattern of the relationship, non-linear regression analysis was performed. Analysis of variance (polynomial linear) and minimum norm quadratic unbiased estimation methods were used to calculate the variance and co-variance of the correlation estimates. Linear regression analysis was used to create models for calculating normative values. Difference of continuous variables between two independent groups was assessed with the Student's *t*-test while more than two groups were assessed with analysis of variance (ANOVA). Intra-class correlation coefficients (ICCS) were calculated to assess inter- and intra-rater reliability for ultrasound measurements, using SPSS statistical package version 10.14 (SPSS Chicago, Illinois, USA).

RESULTS

Table 1 is the result of the pilot study which shows high and moderate intra- and inter-rater reliability in the measurement of

Table 1: Intra- and inter-rater reliability of sonographic measurement of kidney dimensions

Observer	Intra- and inter-rater reliability
Intra-observer,	Intra- rater reliability
	RKL, ICC (2, 1) = 0.921
Sonographer 1	RKW, ICC (2, 1) = 0.624
	LKL, ICC (2, 1) = 0.901
	LKW, ICC (2, 1) = 0.523
Intra-observer,	Intra- rater reliability
	RKL, ICC (2, 1) = 0.897
Sonographer 2	RKW, ICC (2, 1) = 0.620
	LKL, ICC (2, 1) = 0.880
	LKW, ICC (2, 1) = 0.681
Inter observer,	
	Inter-rater reliability
Both sonographers	RKL, ICC (2, 1) = 0.852
	RKW, ICC (2, 1) = 0.641
	LKL, ICC (2, 1) = 0.842
	LKW, ICC (2, 1) = 0.602

ICC = Intra-class correlation coefficient, ICC (2, 1) = Intra-class correlation coefficient between the first and second measurements obtained by each sonographer (intra-observer) and between the first measurements obtained by both sonographers (inter-observer), RKL = right kidney length, RKW = right kidney width, LKL = left kidney length, LKW = left kidney width.

kidney length and width, respectively. The age *versus* gender distribution of the subjects is shown in Table 2. There were 496 (52.4%) males and 451 (47.6%) females. No statistically significant differences were found in the kidney dimensions between males and females ($p > 0.05$). Figure 1 shows how the sonographic measurements of the kidney dimensions during inspiration in a supine subject were obtained.

Table 2: Age and gender distribution of the subjects

S/N	Age (years)	Gender		Total
		Male	Female	
1	6	43	31	74
2	7	39	26	65
3	8	27	45	72
4	9	39	26	65
5	10	70	24	94
6	11	62	23	85
7	12	25	47	72
8	13	43	64	107
9	14	38	49	87
10	15	38	32	70
11	16	47	20	67
12	17	25	64	89
Total		**496**	**451**	**947**

There was a statistically significant difference between right and left kidney lengths ($p < 0.05$) and none for both kidney widths ($p > 0.05$). For this reason, data on kidney widths were not included in tables and graphs. The mean values of the kidney lengths are 79.56 ± 8.10 mm for the right kidney and 81.61 ± 8.32 mm for the left kidney while that of kidney widths are 35.03 ± 3.55 mm for right kidney and 35.09 ± 3.57 mm for left kidney. The mean values of the body parameters include: age = 11.66 ± 3.37 years, height = 140.24 ± 17.93 cm, weight = 34.88 ± 12.23 kg, BSA = 1.16 ± 0.28 cm^2 and BMI = 17.10 ± 2.06 kg/m^2.

Table 3 shows Pearson's correlation coefficient of kidney lengths with body parameters. Height was the parameter best correlated with the kidney lengths, followed by BSA, weight, age, BMI and gender. Thus the normal limits, percentile curves and prediction models of the kidney lengths were established with respect to height. Height, weight, BSA and age correlated strongly with kidney lengths while BMI and gender showed moderate and negative correlations, respectively.

Table 3: Pearson's correlation coefficient of kidney length with body parameters

Body parameter	Right kidney length correlation coefficient	Left kidney length correlation coefficient
Age	r = 0.879	r = 0.882
Gender	r = -0.162	r = -0.159
Height	r = 0.899	r = 0.901
Weight	r = 0.889	r = 0.891
BMI	r = 0.688	r = 0.690
BSA	r = 0.893	r = 0.895

BMI – body mass index, BSA – body surface area

Tables 4 and 5 show normal limits of kidney lengths with respect to height of the school-age children studied. The 3rd percentile values represent the range of borderline lower limit of normal; the 3rd–97th percentile values represent the range of normal values, whereas the 97th percentile values represent the range of borderline upper limit of normal. Figures 2 and 3 are percentile curves of kidney lengths *versus* height. Figures 4 and 5 show scatter diagrams of the kidney lengths plotted against height of subjects. These show positive linear relationship between height and renal lengths.

The equations of the prediction model of normal kidney size estimation with respect to height in the studied population include: right kidney length (mm) = 0.406 x height (cm) + 22.61 and left kidney length (mm) = 0.407 x height (cm) + 23.41.

Table 4: Normal limits of right kidney length with height

Subjects	Longitudinal length (mm) of right kidney								
Body height (cm)	n	Minimum	Maximum	Mean	SD	3%	97%	Suggested limits of normal Lowermost	Uppermost
102−107	14	63	67	35.9	1.1	63.0	67.0	60	72
108−113	46	63	74	40.4	3	63.4	72.8	60	77
114−119	80	64	74	41.7	3.3	65.0	74.0	62	80
120−125	70	65	80	42.5	3.7	66.1	78.0	63	85
126−131	105	67	84	45.9	2.5	68.0	83.0	65	90
132−137	134	67	85	46.9	4.4	73.0	83.0	65	90
138−143	106	68	86	48.2	3	72.0	85.0	66	94
144−149	91	69	89	48.1	2.3	70.0	87.2	66	95
150−155	66	74	91	50.8	2	75.0	91.0	71	100
156−161	89	81	95	50.8	3.4	81.0	94.0	75	105
162−167	66	83	94	54.4	2.9	83.0	94.0	76	106
168−173	74	86	96	54.3	2.5	87.0	94.8	78	106
174−179	11	88	105	57.6	2.4	88.0	97.0	83	110

Table 5: Normal limit of left kidney length with height

Subjects	Longitudinal length (mm) of left kidney								
Body height (cm)	n	Minimum	Maximum	Mean	SD	3%	97%	Suggested limits of normal Lowermost	Uppermost
102−107	14	64	68	65.1	1.3	64.0	67.0	60	70
108−113	46	64	83	67.3	3.1	64.4	79.7	61	85
114−119	80	65	75	70.4	2.8	66.0	75.0	62	85
120−125	70	67	81	73.9	3.1	67.1	79.0	62	86
126−131	105	68	85	76.5	4	69.0	84.0	64	88
132−137	134	71	85	79.3	3.3	74.0	84.0	66	90
138−143	106	69	87	80	4.4	73.0	86.0	67	92
144−149	91	71	90	82.8	4.6	71.0	88.0	68	94
150−155	66	75	92	85.3	4.5	76.0	92.0	70	98
156−161	89	82	96	87.4	3.2	82.0	95.3	75	102
162−167	66	84	96	91.2	2.8	86.0	95.0	80	102
168−173	74	87	97	91.9	2.2	88.0	95.8	82	103
174−179	11	89	106	95.5	4.5	89.0	98.0	85	110

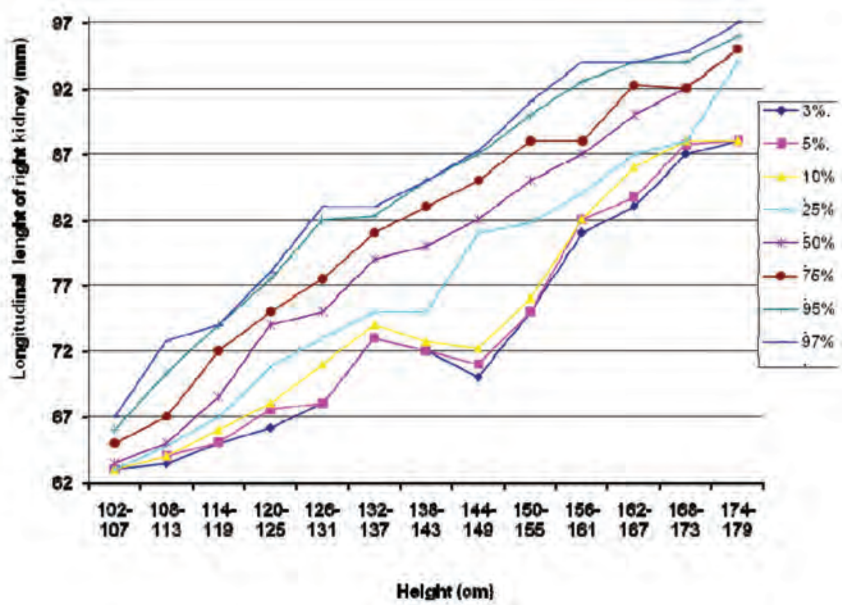

Fig. 2: Percentile curve of longitudinal length of right kidney *versus* height.

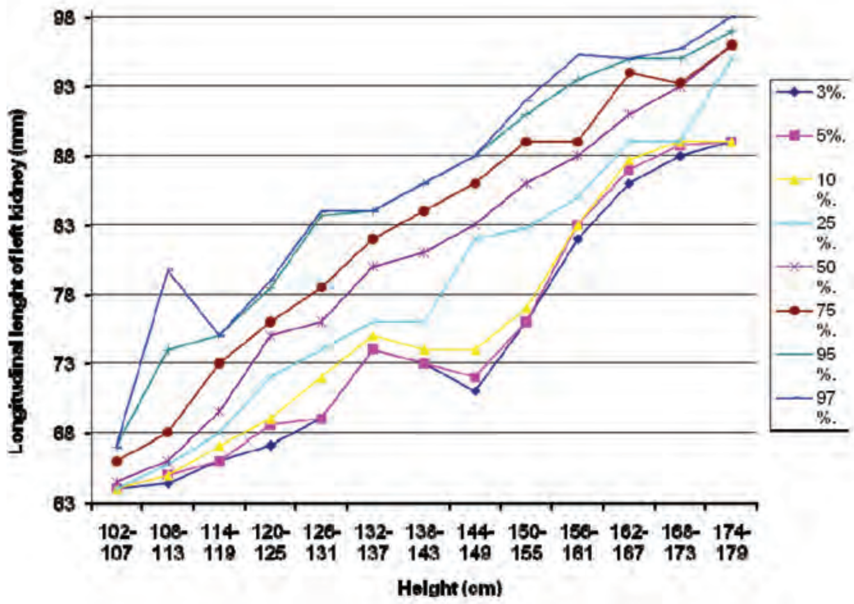

Fig. 3: Percentile curve of longitudinal length of left kidney *versus* height.

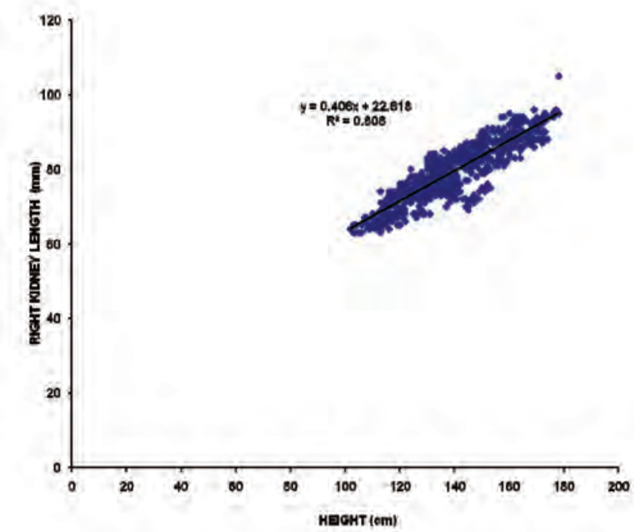

Fig. 4: Scatter diagram of right kidney length *versus* height.

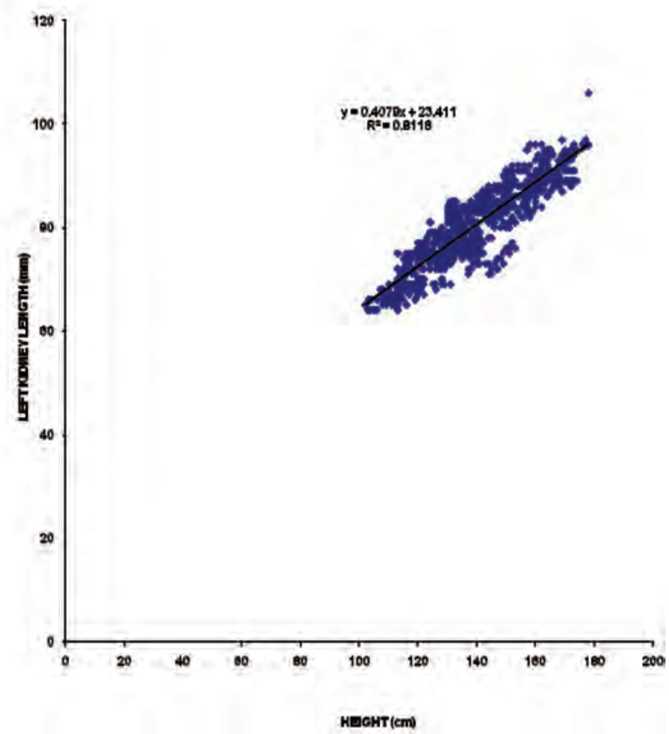

Fig. 5: Scatter diagram of left kidney length *versus* height.

DISCUSSION

The normal values of visceral organ dimensions are important parameters during sonographic examinations (12). In the present study, kidney dimensions were analysed in terms of length and width which are simple, reproducible, reliable and objective measurements. Measurements of both kidney lengths are reliable within and between sonographers as shown by high intra and inter-rater reliability in the pilot study. Measurements of both kidney widths, however, are less reliable as evidenced by only moderate intra and inter-rater reliability in the pilot study. These findings support the historical assessment of visceral organ size based on longitudinal length measurement. Because the measurements of both kidney widths are less reliable, defining renomegaly on the basis of renal volumes may be more uncertain.

The scan and measurements in this study were performed by a certified sonographer with 14 years of experience to reduce inter-observer error. A previous study has shown that experience has an influence on measurement accuracy during ultrasound scanning (13).

In this study, school-age children ranging from 6−17 years were studied. This age range of 6−17 years of the studied subjects is in keeping with school-age children in Nigeria (14). To the best of the authors' knowledge, literature reviewed showed that this study covers the largest series of paediatric kidney dimensions by sonography involving the age range of 6−17 years in any Nigerian population. The present study has shown that there were no significant differences in measured organ size with respect to gender ($p > 0.05$). This finding is similar to the findings of other previous authors (5, 10, 15, 16). Therefore, gender certainly is not a determining factor for kidney dimensions in school-age children in this population. This suggests that special tables based on gender are not necessary.

The morphology of visceral organs varies from person to person. During the maturation process from infancy through adolescence, growth of visceral organs shows a high correlation with gains in height, weight and BSA (5, 17). Among the body parameters, height was the one best correlated with the kidney dimensions followed by BSA, weight, age, BMI and gender. These results were also supported by the variance and covariance of the correlation coefficients. This observation probably results from rapid body growth that occurs before the attainment of mature body morphology at adult stage. Thus it is easy to predict renal size reliably on the basis of these variables, especially height, in this population. Konus *et al* (5) also reported that kidney dimensions showed the best correlation with body height in a Caucasian children population. Soyupak *et al* (15) and Safak *et al* (10), however, reported that kidney dimensions showed the best correlation with body weight among the children population they studied. These differences with the present study may be due to variations in race or different ethnic origins. The normal limits of the kidneys were, therefore, defined according to height in the present study.

The present study preferred to define the lowermost and uppermost longitudinal and transverse dimensions of the kidneys using the 3^{rd} and 97^{th} percentile values, respectively as a guide. In most other studies, sizes between the 5^{th} and 95^{th} percentiles were the accepted normal limits (18, 19). However, this practice results in approximately 10% of children with normal visceral organs falling outside these limits (20). Besides, although plus or minus two standard deviations are the accepted equivalents of the 5^{th} and 95^{th} percentile values statistically (21), some studies were based on plus or minus one standard deviation (22).

The prediction models of the lengths of the kidneys, in millimeters, were built according to height in this study as an alternative method for the examiners. Thus, if the height is obtained in a busy practice or in remote locations where ultrasound facility is not readily available, the normal kidney size for children aged 6−17 years in Southeast Nigeria can be estimated from these equations.

The implication from our study for the Nigerian ultrasound community is obvious because of possible variations in the anthropometric parameters of various populations, races and regions. It is important for Nigerians to have their own population specific normograms of the kidneys in the studied age group as American and European population data cannot be used as universal patterns. Our results could be extrapolated to the wider international community where there is need for each country to establish their own specific normograms of kidney size in school-age children with reference to the body parameter that shows the best correlation with kidney dimensions as height might show variation in different ethnic origins or races.

The limitations of this study include the fact that it was done in the Southeast geopolitical region of Nigeria of Igbo ethnic background. A multicentre study in other regions of the country might improve the precision of the estimates and also the generalizability of the data. The socio-economic status of children estimated was not recorded, although some of them belonged to lower middle and lower income groups. It is hoped that further studies will address these limitations.

RECOMMENDATIONS

- The established normal parameters can be used to determine the pathologic changes in the size of the kidneys in routine sonographic examination of school-age children in this population.
- The prediction model of the normal kidney dimensions can serve as an alternative method for sonographers assessing organ size in a busy practice setting or in remote locations in the studied population.
- Any specific longitudinal dimension of the kidney should primarily be correlated with patient height and findings should be compared with tables of normal parameters.

CONCLUSION

Sonographic determination of pathologic changes in the size of the kidneys necessitates knowing the normal ranges of their lengths, especially with respect to height in this population.

ACKNOWLEDGEMENTS

Many thanks to the director, medical and paramedical staff of University of Nigeria, Medical Centre, Nsukka, for providing the enabling support for the study. There is no conflict of interest to declare.

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