Original Article

Relationship between renal dimensions using ultrasonography and body mass index in apparently healthy school children in Port Harcourt, Nigeria

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Abstract

Background: Renal size is an important parameter in evaluation and management of a child with kidney disease. Establishing the normal limits of renal sizes standardized against somatometric parameters will be a useful tool in detecting probable renal diseases in children.

Aim: To determine renal sizes in relation to body mass index (BMI) in apparently healthy primary school children in Port Harcourt.

Materials and Methods: This was a cross-sectional and multi-staged study involving 450 children aged 6-12 years. Renal ultrasonography was carried out using a portable DP 1100 PLUS real time ultrasound machine fitted with 3.5MHz probe. The length, width and anteroposterior diameter of the kidneys were measured, and renal volume calculated. The BMI percentile for age and sex were obtained. The renal sizes were correlated with somatometric parameters and regression equations derived.

Results: The mean renal length and volume percentiles increased from 77.7 ± 5.6 and 49.2 ± 13.7 at 6years to 85.9 ± 5.9 and 60.4 ± 18.4 at 12years respectively. There were no significant differences in the length and volume between the right and left kidneys, and dimensions of the kidneys were not statistically different in males and females. There was a significant positive correlation between BMI and renal dimensions. The renal length and volume increased at a rate of 1.372mm and 1.951cm3 per year and at a rate of 0.067mm and 0.176cm3 per one percentile increase in BMI respectively. The regression model derived for predicting renal length in mm =65.731 + (1.372 Age X) + (0.067 BMI percentile X) while that for renal volume in cm3 =26.386 + (1.951 Age X) + (0.176 BMI percentile X), (Where X is the independent variables: age in years and BMI in percentile).

Conclusion: BMI has a significant positive linear relationship with renal dimensions. This study has provided prediction models for deriving renal length and volume from subject's BMI and age.

Keywords: Body mass index, children, renal dimensions, ultrasonography

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INTRODUCTION

Evaluation of kidney size is a valuable diagnostic parameter in clinical practice as renal measurement variations may occur in nephropathies due to hypertrophic process(es)

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and/or atrophy which may increase or decrease renal size(s).[1] A change in kidney dimension between examinations may be an indicator of the presence or progression of renal disease.[2]

Several imaging modalities have been used for the estimation of renal size in children; however, ultrasonography is widely acceptable as it is cheap, reliable, and involves no radiation exposure.[3-6] Renal dimensions may include measurement of renal length, width, depth, and cortical thickness. Renal length and volume are more clinically relevant; renal length is the most commonly used quantitative measure of renal size for ease of comparison with established or reported standards. It is more reliable, practical, and reproducible in the clinic. However, renal volume has been shown to be more accurate and correlates better with subject's anthropometry (height, weight, body surface area, and body mass index [BMI]), though is used less frequently in practice due to high interobserver variability.[7,8] Factors known to affect renal size(s) in children include age, sex, weight, height, presence of renal disease, as well as subject's nutritional status.[2,9-11]

BMI is one of the widely used measures of nutritional status of an individual. Computed BMI values can be used to classify an individual as underweight, normal weight, overweight, or obese.[12] It has been shown that malnutrition influences the growth of the kidneys, and children with undernutrition have been reported to have smaller renal size compared to normal weight children of the same age, while obese children tend to have larger renal size.[9,13-15] However, in Nigeria, there is a dearth of studies on the relationship between BMI and renal dimensions in children and every population has the need for its own renal size reference for use in clinical practice and hence the need for more population-based studies to evaluate renal dimensions and its relationship with BMI. Information obtained from this study will aid pediatricians in the management of children and hence reduce unnecessary evaluation for nephromegaly or reduced renal size in obese or undernourished children, respectively. This study aims at evaluating renal dimensions as they relate to BMI among children in Port Harcourt, and, alongside other evidence, is a step toward the development of age-, gender-, and BMI-specific nomogram for renal sizes in Nigeria.

MATERIALS AND METHODS

This was a cross-sectional, school-based study carried out over a period of 6 months (October 2015 and March 2016). A total of 450 children aged 6–12 years were selected from 18 schools in Port Harcourt, Southern Nigeria, using multistage sampling method. Subjects with existing chronic illnesses that might affect kidney sizes were excluded from participating in the study using a structured questionnaire. Children with a history of functional or structural abnormality of the kidneys (such as sickle cell anemia, human immunodeficiency virus infection, congenital heart disease, obstructive uropathy, acute kidney injury, and chronic kidney disease) were equally excluded from the study using the same structured questionnaire. Renal ultrasonography was carried out by a sonologist on all selected subjects (using a portable real-time ultrasound machine model DP-1100 PLUS MINDRAY fitted with 3.5 MHz curvilinear probe). The renal length, width, and depth (anteroposterior diameter of the kidneys) were measured and renal volume was calculated. All children with sonographically abnormal kidney(s) were excluded from the study. Obtained measures of renal dimensions were converted to percentile values for the population. Weight and height were measured using Seca model DT01 weighing scale and stadiometer model RGZ-160, respectively. BMI was calculated as weight (kg)/height^2 (m^2), and the BMI percentile for age and sex was obtained using the World Health Organization BMI chart for age and sex. Any BMI less than the 5th percentile was regarded as underweight. BMI between 5th percentile to less than the 85th percentile was regarded as normal weight, between 85th to less than the 95th percentile as overweight, and BMI equal to or greater than the 95th percentile as obese.[16]

Scanning technique

The subjects were scanned in supine position with the probe placed gently on the abdomen with coupling gel intervening at the skin–probe interphase. Longitudinal scan of the right upper abdomen was first done with the probe adjusted as necessary to obtain the best image of the right renal parenchyma using the liver as an acoustic window followed by a transverse scan of the right kidney. The left kidney was then scanned in a similar sequence. In situations where the kidneys could not be easily visualized due to excess bowel gas, the subjects were scanned in the right or left lateral decubitus position as appropriate, and if the kidneys are still not adequately visualized, the subjects were turned and scanned in the prone position.

Renal dimensions

Renal length was measured in millimeters as the longest dimension between the superior and inferior poles of the kidney, with an equal amount of cortical tissue on either side of the central renal sinus echo and with the ultrasound probe in longitudinal position.

Renal width was measured in millimeters as the maximum transverse diameter of the kidney taken from the medial to the lateral borders at the mid-point of the kidney with the ultrasound probe in longitudinal position.

Renal depth (anteroposterior diameter) was measured in millimeters as the maximum transverse diameter taken from anterior to posterior borders with the ultrasound probe in transverse position.

Renal volume was calculated using the formula:[7] renal length × renal width × renal depth × π/6, where renal depth is the anteroposterior diameter of the kidney.

Ethical considerations

Ethical clearance was obtained from the Research and Ethics Committee of the University of Port Harcourt Teaching Hospital before commencement of the study, and permission to carry out the study was also obtained from the Rivers State Ministry of Education. Written informed consent was obtained from parents/guardians of selected children prior to recruitment into the study.

Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences version 20.0 software. Descriptive statistics were presented as charts, graphs, and tables in simple proportions. Independent samples *t*-test, analysis of variance, and Pearson's correlation coefficient were used to explore differences and associations between variables where appropriate. Multiple linear regression analysis was employed in the evaluation of predictive models of renal size (length and volume respectively) from some predictors (subject's age and BMI percentile). Statistical significance was set at $P < 0.05$.

RESULTS

The data from 450 children with normal kidneys on ultrasound scan were used for analysis of renal dimensions. There were 228 (50.7%) females and 222 (49.3%) males. The age range of the study subjects was from 6 to 12 years with a mean age of 8.9 ± 1.9 years. The mean BMI percentile of the subjects was 48.2 ± 32.4. Majority (318; 70.7%) were normal weight, 41 (9.1%) were underweight, 39 (8.7%) were overweight, and 52 (11.5%) were obese [Figure 1].

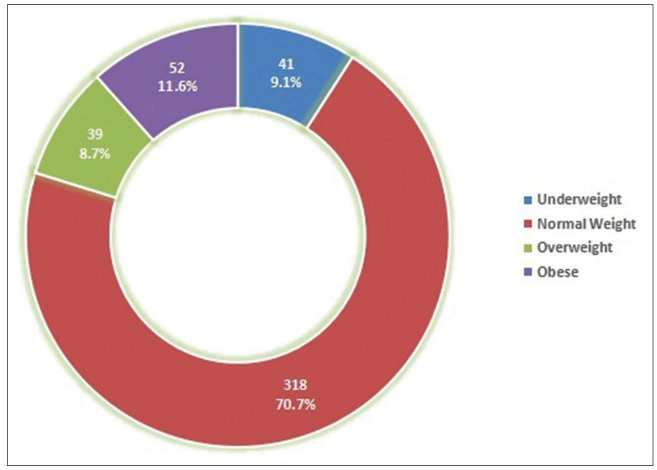

Figure 1: Distribution of nutritional status categories among subjects

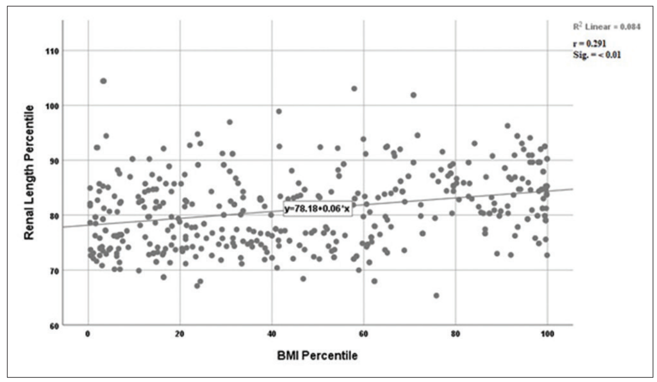

Figure 2: Scattergram of renal length percentile versus body mass index percentile of subjects

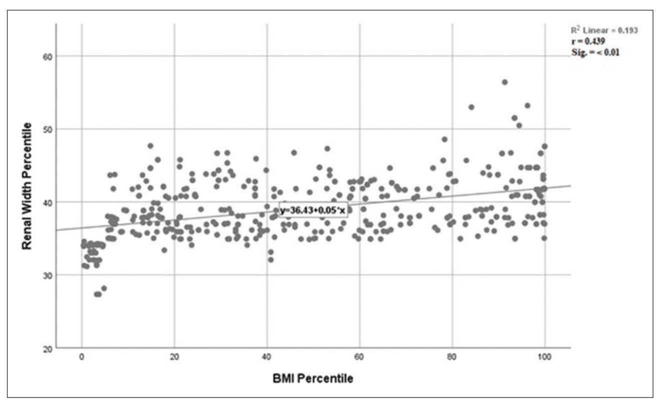

Figure 3: Scattergram of renal width percentile versus body mass index percentile of subjects

There were no significant differences in the respective pairs of right and left renal length, width, depth, and volume. The mean renal length and volume percentile increased from 77.7 ± 5.6 and 49.2 ± 13.7 at 6 years to 85.9 ± 5.9 and 60.4 ± 18.4 at 12 years, respectively [Table 1]. The renal dimensions were not statistically different in males and females [$P > 0.05$, Table 2]. There were significant differences in the renal dimensions (length, width, depth, and volume) across the nutritional status categories with progressive increase across nutritional status (from underweight to obese) as shown in Tables 3 and 4.

Renal dimensions (length, width, depth, and volume) correlated positively and significantly with BMI percentile [Figures 2-5]. Renal length and volume also correlated positively and significantly with

Table 1: Distribution of renal dimensions and body mass index percentile across age

Age in years (*n*)	95% CI for mean				
	Renal length percentile±SD	Renal width percentile±SD	Renal depth percentile±SD	Renal volume percentile±SD	BMI percentile±SD
6 (60)	77.7±5.6	38.6±3.9	30.0±3.1	49.2±13.7	55.7±36.2
	76.3, 79.2	37.6, 39.4	29.2, 30.9	45.7, 52.7	46.4, 65.1
7 (58)	79.5±7.7	39.3±3.7	31.1±3.9	51.2±13.2	46.6±31.7
	77.6, 81.5	38.3, 40.3	30.0, 32.1	47.8, 54.7	38.3, 55.0
8 (82)	80.0±6.9	38.7±4.2	31.2±4.4	51.0±14.5	50.7±33.7
	78.5, 81.5	37.7, 39.6	30.3, 32.2	47.8, 54.2	43.3, 58.1
9 (57)	79.7±5.8	40.0±3.0	30.0±3.0	52.7±15.1	47.8±29.7
	78.2, 81.2	38.8, 41.2	29.5, 31.1	48.7, 56.7	39.9, 55.6
10 (82)	82.3±6.4	38.7±3.3	30.4±4.4	53.1±14.3	48.6±33.3
	80.9, 83.7	38.0, 39.4	30.0, 32.3	50.0, 56.2	41.4, 55.7
11 (56)	84.7±6.5	39.1±3.4	30.8±3.1	52.8±12.7	46.3±29.1
	83.0, 86.5	38.1, 40.0	29.9, 31.6	49.4, 56.2	38.5, 54.1
12 (55)	85.9±5.9	40.5±4.7	31.8±3.6	60.4±18.4	49.9±33.3
	84.3, 87.5	39.2, 41.8	30.8, 32.7	55.5, 65.4	41.0, 58.9
Overall	81.2±6.9	39.1±4.0	30.9±3.8	52.4±14.8	48.2±32.4
	80.5, 81.8	38.1, 39.4	30.5, 31.2	50.4, 53.7	45.2, 51.2

n - Sample size. SD – Standard deviation; CI – Confidence interval; BMI – Body mass index

Table 2: Mean renal dimensions across gender

Renal Dimensions	Gender	Mean	SD	95% CI for mean difference	Significance
Renal length percentile	Male	80.9	7.1	−1.912-0.647	0.332
	Female	81.5	6.7		
Renal width percentile	Male	39.0	4.2	−0.906-0.558	0.674
	Female	39.1	3.9		
Renal depth percentile	Male	30.8	3.8	−0.851-0.558	0.683
	Female	31.0	3.8		
Renal volume percentile	Male	51.4	14.3	−4.624-0.841	0.174
	Female	53.3	15.2		

SD – Standard deviation; CI – Confidence interval

Table 3: Summary statistics of renal dimensions across nutritional status categories of the subjects

	Mean	SD	95% CI for mean	
			Lower bound	Upper bound
Renal length percentile				
Under weight	80.1	8.1	77.6	82.7
Normal weight	80.5	6.9	79.6	81.3
Over weight	83.5	6.0	81.6	85.5
Obese	84.3	5.4	82.8	85.8
Renal width percentile				
Under weight	32.9	1.8	32.3	33.5
Normal weight	39.2	3.3	38.8	39.5
Over weight	41.4	5.1	39.8	43.1
Obese	41.6	3.4	40.6	42.5
Renal depth percentile				
Under weight	26.1	1.0	25.7	26.4
Normal weight	30.8	3.1	30.5	31.2
Over weight	31.1	3.4	30.0	32.3
Obese	34.8	4.7	33.5	36.1
Renal volume percentile				
Under weight	34.0	3.1	33.0	35.0
Normal weight	51.9	12.7	50.5	53.3
Over weight	58.3	16.2	53.0	63.5
Obese	65.1	15.9	60.7	69.5

SD – Standard deviation; CI – Confidence interval

age [Figures 6 and 7]. However, there was no significant linear association between renal width and depth with age, respectively [Figures 8 and 9].

Both subject's age and BMI were independent predictors of renal length and renal volume, respectively, in the population. The renal length and volume increased at a rate of 1.372 mm and 1.951 cm^3/year and at a rate of 0.067 mm and 0.176 cm^3 per one percentile increase in BMI, respectively, yielding the following predictive equations: renal length (mm) = 65.731 + (1.372 age *X*) + (0.067 BMI percentile *X*), and renal volume (cm^3) = 26.386 + (1.951 age *X*) + (0.176 BMI percentile *X*), Tables 5 and 6, respectively.

DISCUSSION

The renal dimensions of children in this study were assessed using ultrasonography, although other imaging modalities such as computed tomography scan, magnetic resonance imaging, and intravenous urogram can be used, but ultrasonography is the most widely accepted technique in children because it is readily available, cost-effective, reliable, noninvasive, and free of radiation exposure.[3-6]

In this study, there were no significant differences between the right and left renal dimensions, similar to previous reports by Otiv *et al*.[10] and Eze *et al*.[17] in Indian and Nigerian populations, respectively, but contrasts with the reports by Kim *et al*.[18] and Oh *et al*.[19] in Korea who reported that the left kidney was significantly larger than the right. The reason for this observed difference may be due to interobserver differences in sonographic measurements. In the present study and the studies by Otiv *et al*.[10] and Eze *et al*. [17], one sonologist carried out the sonographic examination whereas in the studies by Kim *et al*.[18] and Oh *et al*.[19] sonographic examination was carried out by different sonologists. As ultrasonography is a subjective imaging modality, inter-observer differences in these studies may influence reported findings. Moreover,

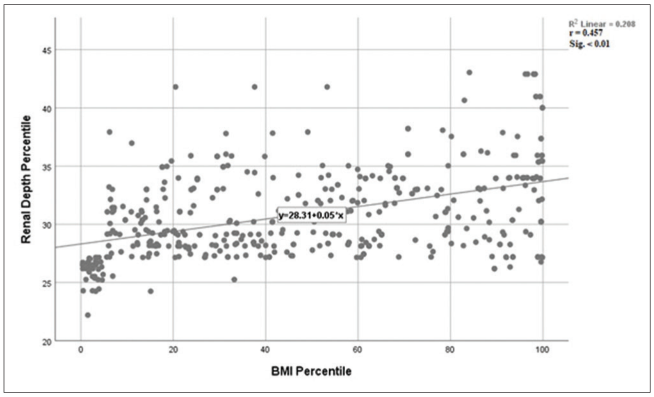

Figure 4: Scattergram of renal depth percentile versus body mass index percentile of subjects

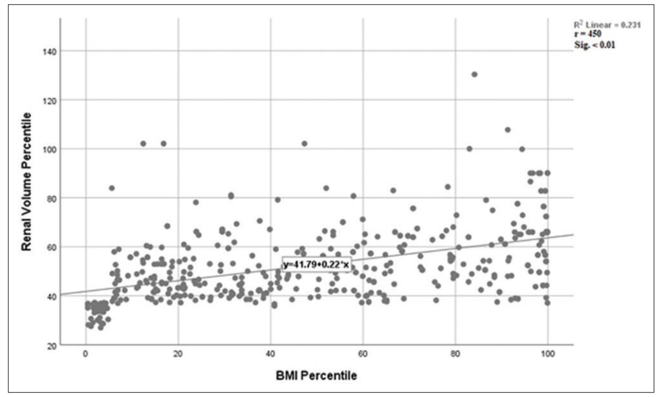

Figure 5: Scattergram of renal volume percentile versus body mass index percentile of subjects

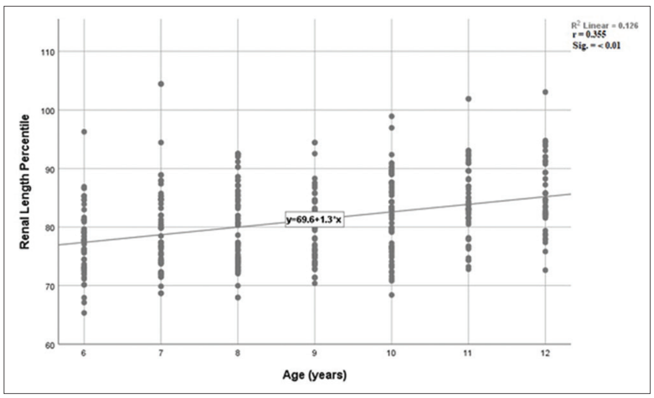

Figure 6: Scattergram of renal length percentile versus age of subjects

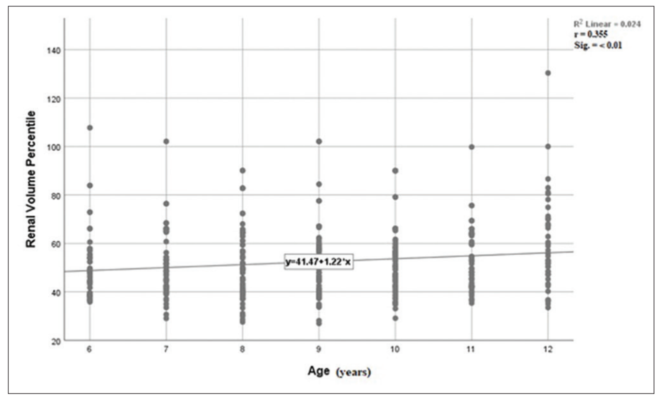

Figure 7: Scattergram of renal volume percentile versus age of subjects

differences in the imaging capabilities of the ultrasound machine (such as resolution and white balancing) can equally affect reported findings, as might have been the case in the above-referenced studies where different ultrasound machine types were employed for imaging.

This study showed that the mean renal dimensions progressively increased with age. This observed progressive increase in renal dimensions among children has been observed by several authors.[10,11,17] There are controversies on the relationship between gender and renal dimensions in children. Some studie[20-24] observed no gender differences in renal dimensions, which is consistent with the findings in this study. In contrast to these findings, however, Adeyinka and Fasan-Odunsi,[11] Ayad *et al.,*[25] and Bircan *et al*.[26] found a significant gender difference in kidney lengths. The differences in body parameters in the subjects studied could be possible explanations for the variations.

In this study, renal length and volume correlated significantly, linearly, and positively with BMI, which is similar to the findings in several studies.[14,15,17,27,28] Pantoja-Zazuarregui *et al*.[14] and Parmaksiz *et al*.[27] noted a strong and significant correlation between renal length and BMI; Eze *et al*.[17] also observed significant correlations between renal length and volume with BMI. On the other hand, Kim *et al*.[18] in their study observed a weak and inconsistent correlation with renal length and no significant correlation with renal volume, whereas Younus *et al*.[29] reported a weak and insignificant relationship between renal length and BMI in their study. The prevalence of obesity in the present study was 11.6%. Pantoja-Zazuarregui *et al*.[14] reported a higher prevalence of 28.6% whereas Kim *et al*.[18] reported a much lower prevalence of 3.7%. The prevalence of obesity in the study by Younus *et al*.[29]was however not stated. It is plausible that these differences in the compositions of the BMI categories of the subjects contributed to the differences in BMI relationship.

The renal length and volume in the present study increased with increasing BMI categories (from underweight to obesity) with significantly higher renal dimensions among the obese and overweight children than the underweight and normal weight children. This is similar to the observations by Pantoja-Zazuarregui *et al*.[14] and Soheilipour *et al*.[15] This increase in renal sizes in subjects with higher BMI may be attributed to the larger body

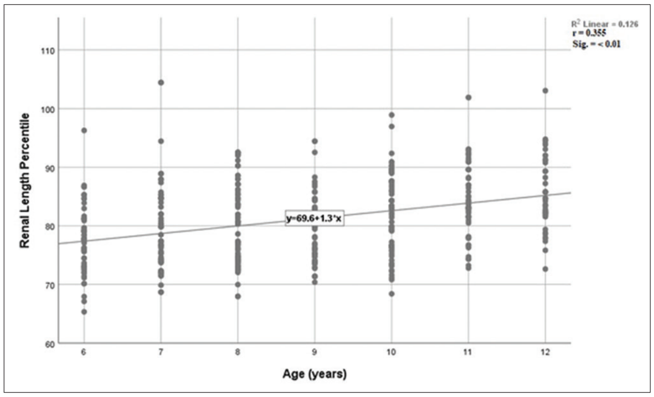

Figure 8: Scattergram of renal width percentile versus age of subjects

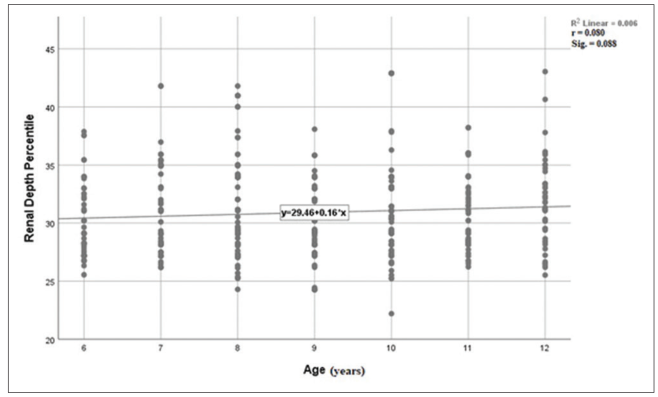

Figure 9: Scattergram of renal depth percentile versus age of subjects

Table 4: Multiple comparison of mean renal dimensions across nutritional status categories of the subjects

Renal dimensions	*F*	Significant
Renal length	6.506	0.000
Renal width	60.694	0.000
Renal depth	55.703	0.000
Renal volume	47.462	0.000

Table 5: Multiple linear regression of factors affecting renal length

Factors	*B*	95% CI for *B*	*P*
Constant	65.731	62.874-68.588	<0.01
Age (years)	1.372	1.076-1.667	<0.01
BMI percentile	0.067	0.050-0.084	<0.01

Model equation: Renal length (mm)=65.731 + (1.372 age *X*) + (0.067 BMI percentile *X*). CI – Confidence interval; BMI – Body mass index

Table 6: Multiple linear regression of factors affecting renal volume

Factors	*B*	95.0% CI for *B*	*P*
Constant	26.386	20.144–32.627	<0.01
Age (years)	1.951	1.307–2.597	<0.01
BMI percentile	0.176	0.139–0.214	<0.01

Model equation: Renal volume (cm^3)=26.386 + (1.951 age *X*) + (0.176 BMI percentile *X*). CI – Confidence interval; BMI – Body mass index

organs (including the kidneys) that are usually noted among persons with larger body size.

Prediction of renal length and volume in relation to BMI in children will facilitate clinical decision-making. The present study highlights the importance of considering the BMI of children in determining normal limits of renal dimensions as most reference charts are based on the age without adjusting for the anthropometric body indices such as BMI. The relationship between renal dimensions with age and BMI as shown in the present study is similar to those reported by Eze *et al.*[17] and Kim *et al.*[18] Furthermore, following multiple linear regression in the present study, the BMI was still significantly related to renal length and volume after adjusting for age, suggesting BMI as an independent predictor of renal length and volume. Kim *et al.*[18] in their study observed a weak and insignificant relationship between renal dimensions and BMI following multiple linear regression, while Eze *et al.*[17] did not evaluate this relationship following multiple linear regression. Few studies carried out in children have established prediction models for renal dimensions; however, the age and BMI were not included in the same formula as most were predicted using simple linear regression. The prediction model derived in this study included age and BMI: renal length (mm) = 65.731 + (1.372 age *X*) + (0.067 BMI percentile *X*) and renal volume (cm^3) = 26.386 + (1.951 age *X*) + (0.176 BMI percentile *X*). However the prediction models derived by Eze *et al.*[17] among school children aged 1-17years in Benin, Nigeria and Ayad *et al.*[25] among Sudanese children aged 7-13years did not factor age and BMI into the same regression model but had separate models for age and BMI. Another regression model established by Kim *et al.*[18] among Korean children aged 0–18 years and Eze *et al.*[23] among children aged 6–17 years in Nsukka, Nigeria, to predict renal length was done with respect to height of the children. Thus, the prediction model derived in the present study will give a better estimate of the renal dimension, considering that the age and BMI were included in the equation. Prediction of the renal length and volume can therefore be achieved by knowledge of the age and BMI, which can be used by radiologists and clinicians as reference values in clinical practice for a particular population group.

CONCLUSION

This study revealed that BMI correlated linearly and positively with the renal length and volume and has provided a prediction model for estimating renal length and volume, which can thus be used in Nigerian pediatric clinics. Multicenter studies in other regions of the country are, however, needed to establish and validate a nomogram for use in our country.

Limitations

This study did not include children under 6 years of age and those over 12 years of age and therefore may limit generalization of the findings to these age categories.

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Conflicts of interest

There are no conflicts of interest.

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