

NORMATIVE VALUES OF RENAL VOLUME, RENAL SINUS VOLUME AND RENAL PARENCHYMAL VOLUME AMONG APPARENTLY NORMAL ADULTS IN KADUNA, NIGERIA

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ABSTRACT

Background: Diseases of the kidneys may affect both morphology and size of the kidney due to an overall reduction or increase of renal size. Renal size measurement is valuable in diagnosis and treatment of renal diseases.

Objective: The study was aimed at establishing the normative values of renal volume among apparently normal adults in Kaduna, Nigeria

Materials and Method: The prospective and cross-sectional study was conducted on 792 apparently normal adult. Nortek CS 3 ultrasound machine equipped with 3.5MHz curvilinear probe was used. The maximum length, width and thickness of the kidneys and central renal echoes were measured. The machine displayed the renal size in volume automatically. Heights and weights of the participants were measured using stadiometer and balance scale. Student *t*-test was used to compare the mean value of right and left renal volumes between males and females, Pearson's correlation was employed to assess the relationship between anthropometric indices and renal parameters $p < 0.05$.

Results: The mean value of renal volume was found to be $109.56 \pm 13.52 \text{ cm}^3$ for the right kidney and $123.03 \pm 13.88 \text{ cm}^3$ for the left kidney. There was statistically significant difference between male and female renal volume ($p = .000$). BSA showed better relationship with renal volume in both genders; $r = .208^{**}$ and $.193^{**}$ for RRV and LRV in male, and $r = .240^{**}$ and $.223^{**}$ for RRV and LRV in female

Conclusion: There was statistically significant difference between male and female renal size, so also between right and left renal size of same individual.

Introduction

The kidneys are a pair of excretory organs situated on the posterior abdominal wall, one on each side of the vertebral column, behind the peritoneum.[1] They are both measuring about 9-15cm in length,

4-7cm wide and its thickness is about 3cm with the left being commonly longer than the right.[2-4] It consist of three distinct regions, the outer cortex, under the cortex is internal structure termed the medulla, which composed of 8 to 18 conical masses

known as renal pyramids and the more central area the renal sinus.[5,6] Renal parenchyma consists of the renal cortex and medullary pyramid.[7] It has been observed that the measurement of renal parenchyma thickness provides a more accurate estimation of renal function compared to the one dimensional measurement of renal length. The thickness of the renal parenchyma is related to the volume of renal mass which contain millions of nephrons in the renal parenchyma.[8] Egberongbe et al.[9] reveals that the normal adult kidney volume ranges from 65.51-200.72 cm³ for the left kidney and 64.38-163.96 cm³ for the right kidney respectively. Kidneys are the primary means for eliminating waste products of metabolism.[1,10,11] They play a dominant role in regulation of arterial blood pressure, excreting sodium and water, help in acid-base regulation, secrete erythropoietin and produce an active form of vitamin D.[10]

Renal volume and renal parenchyma volume can be assessed using computed tomography (CT), magnetic resonance imaging (MRI) and ultrasonography. However, sonography remains the modality of first choice because it is a simple and non-invasive method for estimating renal volume in vivo. It is also readily available, cost-effective, easily reproducible and requires no special patient preparation or contrast media administration.[8,9] Normal kidney size depends on several factors such as age, sex, height, weight and pregnancy.[12,13] Many renal disorders are associated with changes in the sizes of the kidneys such as pyelonephritis, HIV-associated nephropathy and diabetes mellitus.[14-17]

Musa and Abukonna.[18] found the renal size in normal adult that leaves in a high altitude area to be 90.8±1.1cm³ and 93.5±0.15cm³ for the right and left kidney respectively. Yunusa et al.[13] revealed the mean right and left normal adult renal size to be 139±34.2cm³ and 173±13.5cm³ in there study respectively. In a similar study conducted by Maaji et al.[15] revealed the mean right renal volume as 109.6±29.3cm³ and left mean renal volume as 119.7±32.8cm³. There is paucity of data on the renal nomogram among normal adult Kaduna populace and to the best of researcher's knowledge there is no published work on normative renal volume in Kaduna state. The findings of the study are expected to serve as a guide to sonographers, radiologist and physicians in diagnosis and

management of patients with renal diseases. The study was aimed at sonographically establishing the renal volume, renal sinus volume and renal parenchyma volume among apparently normal adult residents of Kaduna state.

Materials and Methods

The study design was prospective and cross-sectional conducted on apparently normal adult residence of Kaduna state from October 2018 to April 2019. An ethical approval was obtained from the Human Research and Ethics Committee of the Kaduna State Ministry of Health and Human Services, also an informed consent was obtained from each participant before commencement of data collection. Simple random sampling technique was used to select 792 participants (396 male and 396 female) from nine different state own hospitals across Kaduna state; three from each senatorial zone. Participants with current or previous history of kidney disease, underlying disease condition such as diabetes mellitus, pyelonephritis, HIV, or hypertension, pregnant woman, pediatrics and those above 65 years of age were all exclude from the study. Nortek CS 3 digital ultrasound machine equipped with electronic caliper and a 3.5MHz curvilinear probe was used to acquire images of the kidneys. Inter and intra observer variability was assessed before the commencement of data collection. Survey scan was performed to rule out renal abnormality; the right kidney was examined in the supine position through the liver by angling the transducer obliquely. With the patients in the right decubitus, the arm extended over the head, and using a coronal approach, the left kidney was visualized through the spleen. The kidneys were best measured in a prone position; the images of both kidneys were acquired with the patient in a prone position for measurements.[17] The machine automatically displayed the value of the renal volume and renal sinus volume whenever the length, width, and thickness of kidney and central echoes were measured respectively. The right and left renal volume and renal sinus volume were recorded on the data capture sheet.

Renal parenchyma volume was obtained by subtracting the renal sinus volume from the total renal volume.[19] Test for normality was carried out on the data using Shapiro Wilk test. Both descriptive and inferential statistics were applied to the data. Means ± standard deviations (SD) of the

renal volume, renal sinus volume, renal parenchyma volume and range were obtained using descriptive statistics. Student *t*-test was used to compare the mean value of the right and left kidney between male and female. Pearson's correlation was used to determine the relationship of anthropometric (age, height, weight, BMI and BSA) with the right and left renal volume, renal

sinus volume and renal parenchyma volume of male and female respectively. Scatter-Dot Graph was used to plot the relationship between body surface areas with right and left renal volume for both genders. All statistical analysis was performed using the Statistical Package for the Social Sciences (IBM SPSS) Version 22.0 software. Statistical level of significance was set at $p < 0.05$.



Figure 3.1: Grey scale Ultrasound image showing measurements of maximum length, width and thickness of the right kidney



Figure 3.2: Grey scale Ultrasound image showing measurements of maximum length, width and thickness of the central echoes of the right kidney

Results

Table 1: Demographic characteristics of the selected subjects.

Variables	Male (N=396)	Female (N=396)	Total (N=792)
Mean age (years)±SD (range)	36.64±12.25 (18-65)	38.09±11.71 (18-65)	37.37±11.99 (18-65)
Mean height (m)±SD (range)	1.70±0.07 (1.25-1.88)	1.60±0.066 (1.24-1.86)	1.65±0.09 (1.24-1.28)
Mean weight (Kg)±SD (range)	67.72±11.89 (50.50-118.50)	64.97±12.97 (46.00-110.50)	66.34±12.51 (46-118.5)
Mean BMI (Kgm ²)±SD (range)	23.37±3.98 (16.65-38.92)	25.38±4.79 (16.88-39.35)	24.37±4.44 (16.65-39.35)
Mean BSA (m ²)±SD (range)	1.78±0.16 (1.28-2.31)	1.67±0.16 (1.35-2.22)	1.73±0.17 (1.28-2.31)

SD = standard deviation

Table 2: The right and left renal volume, renal sinus volume and renal parenchyma volume of the selected subjects

Variables	Male(N=396)	Female(N=396)	Total (N=792)
Mean RRV (cm ³)±SD (range)	114.59±11.73 (100.78-169.11)	104.52±13.33 (92.02-152.90)	109.56±13.52 (92.02-169.11)
Mean RRSV(cm ³)±SD (range)	10.76±2.56 (6.76-20.13)	8.24±2.60 (5.01-15.88)	9.50±2.87 (5.01-20.13)

Mean RRPV (cm³)±SD (range)	103.68±11.32 (72.30-158.58)	96.28±12.60 (79.83-143.98)	99.98±12.53 (72-158.58)
Mean LRV (cm³)±SD (range)	128.56±12.23 (105.48-183.37)	117.50±13.23 (99.05-175.56)	123.03±13.88 (99.05-183.37)
Mean LRSV (cm³)±SD (range)	12.97±3.62 (8.04-25.40)	9.62±3.46 (3.99-26.58)	11.30±3.92 (3.99-26.58)
Mean LRPV (cm³)±SD (range)	115.58±11.80 (92.17-166.84)	107.65±12.62 (68.30-155.18)	111.62±12.84 (68.3-166.84)

SD = standard deviation **RRV** = Right Renal Volume; **RRSV** = Right Renal Sinus Volume; **RRPV** = Right Renal Parenchyma Volume; **LRV** = Left Renal Volume; **LRSV** = Left Renal Sinus Volume; **LRPV** = Left Renal Parenchyma Volume

Table 3: Comparison of right and left renal volume, renal sinus volume and renal parenchyma volume between male and female subjects

Variables	Male (N=396)	Female (N=396)	Total (N=792)	p-value
Mean RRV (cm³)±SD (range)	114.59±11.73	104.52±13.33	109.56±13.52	.000
Mean RRSV (cm³)±SD (range)	10.76±2.56	8.24±2.60	9.50±2.87	.000
Mean RRPV (cm³)±SD (range)	103.68±11.32	96.28±12.60	99.98±12.53	.000
Mean LRV (cm³)±SD (range)	128.56±12.23	117.50±13.23	123.03±13.88	.000
Mean LRSV (cm³)±SD (range)	12.97±3.62	9.62±3.46	11.30±3.92	.000
Mean LRPV (cm³)±SD (range)	115.58±11.80	107.65±12.62	111.62±12.84	.000

SD = standard deviation **RRV** = Right Renal Volume; **RRSV** = Right Renal Sinus Volume; **RRPV** = Right Renal Parenchyma Volume; **LRV** = Left Renal Volume; **LRSV** = Left Renal Sinus Volume; **LRPV** = Left Renal Parenchyma Volume

Table 4: Correlation of right and left renal volume, renal sinus volume, and renal parenchyma volume with anthropometric variables of the male subjects

Variables	RRV		RRSV		RRPV		LRV		LRSV		LRPV	
	r	p	r	p	r	p	r	p	r	p	r	p
Age (years)	-.077	.127	.064	.205	-.082	.104	-.050	.318	.096	.056	-.082	.105
Height (m)	.215**	.000	.063	.211	.213**	.000	.190**	.000	.085	.090	.170**	.001
Weight (Kg)	.155**	.002	.138**	.006	.136**	.007	.146**	.004	.167**	.001	.100*	.047
BMI (Kg/m²)	.058	.251	.123*	.014	.038	.457	.057	.260	.136**	.007	.017	.737
BSA (m²)	.208**	.000	.141**	.005	.192**	.000	.193**	.000	.171**	.001	.148**	.003

** : Correlation is significant at the 0.01 level (2-tailed), **r** = correlation coefficient, **p** = p-value, * : Correlation is significant at the 0.05 level (2-tailed).

Table 5: Correlation of right and left renal volume, renal sinus volume, and renal parenchyma volume with anthropometric variables of the female subjects

Variables	RRV		RRSV		RRPV		LRV		LRSV		LRPV	
	r	p	r	p	r	p	r	p	r	p	r	p
Age (years)	-.155*	.022	-.021	.677	-.118*	.019	-.098	.052	-.100*	.046	-.069	.169
Height (m)	.228**	.000	.121*	.016	.217**	.000	.225**	.000	.174**	.001	.191**	.000
Weight (Kg)	.198**	.000	.223**	.000	.163**	.001	.180**	.000	.231**	.000	.112*	.026
BMI (Kgm ²)	.0109*	.031	.176**	.000	.079	.118	.090	.075	.165**	.001	.034	.494
BSA (m ²)	.240**	.000	.225**	.000	.208**	.000	.223**	.000	.248**	.000	.156**	.002

** : Correlation is significant at the 0.01 level (2-tailed), r = correlation coefficient, p = p-value,
 * : Correlation is significant at the 0.05 level (2-tailed).

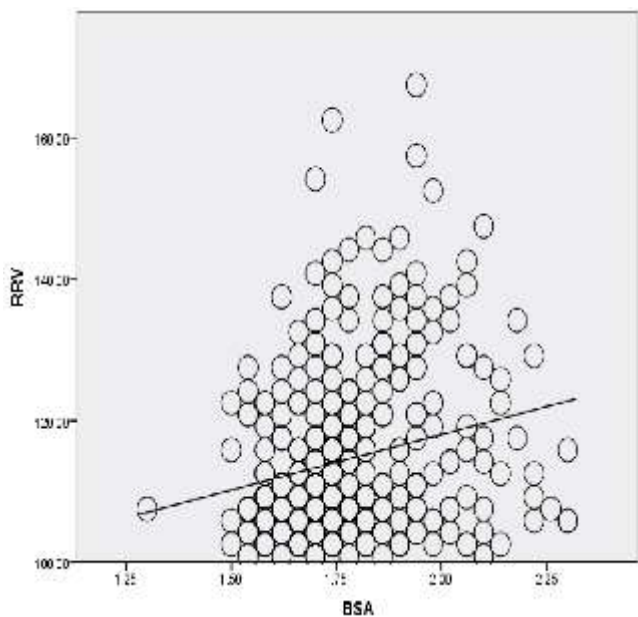


Figure 1: Scatter- Dot Graph showing relationship between body surface area BSA (m²) and right renal volume RRV (cm³) in male

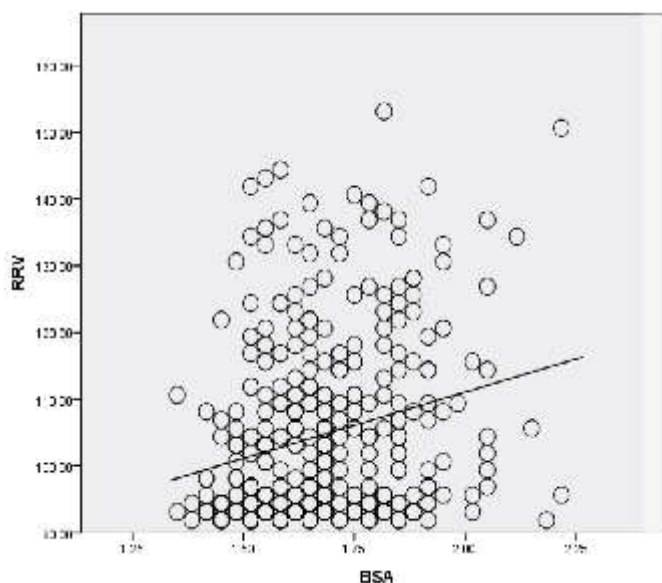


Figure 3: Scatter- Dot Graph showing relationship between body surface area BSA (m²) and right renal volume RRV (cm³) in female

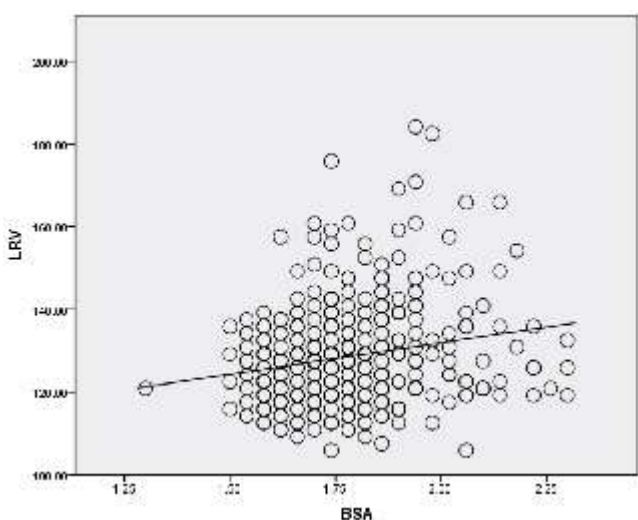


Figure 2: Scatter- Dot Graph showing relationship between body surface area (BSA) m² and right renal volume (LRV) cm³ in male

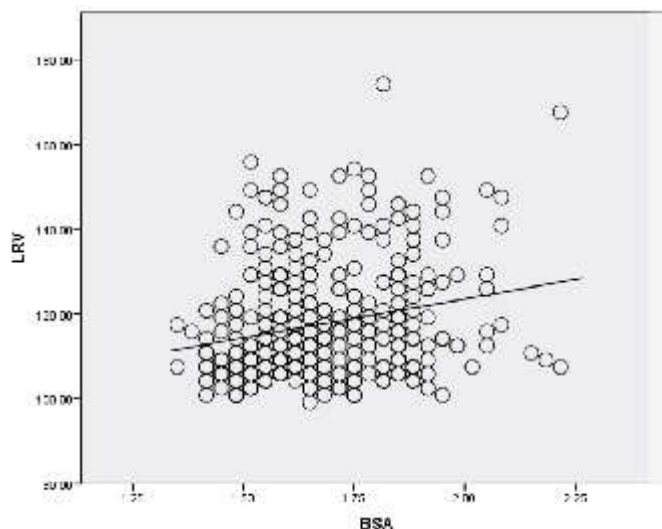


Figure 4: Scatter- Dot Graph showing relationship between body surface area BSA (m²) and right renal volume LRV (cm³) in female

DISCUSSION

Seven hundred and ninety two (792) subjects participated in the study; comprising of three hundred and ninety six (396) males and three hundred and ninety six (396) females. The ages of the participants ranged from 18 years to 65 years for both males and females, with mean age of 37.37 ± 11.99 (years); 36.64 ± 12.25 (years) for male and 38.09 ± 11.71 (years) for females. It is in agreement with the findings of Yunusa et al.[13] that reported mean age of 37.1 ± 12.6 ; 35 ± 11.9 for males and 39 ± 12.9 for females. It however disagree with the findings of Okur et al.[21] that reported 44 ± 14 and 41 ± 13 as the mean ages for males and females respectively. The mean height of the participant was 1.65 ± 0.09 m; 1.70 ± 0.07 m and 1.60 ± 0.07 m for males and females respectively. The average weight of the participant was 66.34 ± 12.51 Kg; 67.72 ± 11.89 Kg and 64.97 ± 12.97 Kg for males and females respectively. Participant's body mass index (BMI) and body surface area (BSA) were 24.37 ± 4.44 Kg/m² and 1.73 ± 0.17 m²; mean BMI values for males are 23.37 ± 3.98 Kg/m² and 25.38 ± 4.79 Kg/m² for females, while 1.78 ± 0.16 m² and 1.67 ± 0.16 m² are the mean values for BSA of males and females respectively as shown in Table 1. The overall values of mean height, weight, BMI and BSA found in the current study agrees with findings of Yunusa et al.[13] that reported The mean height, weight, BMI, and BSA as 1.6 ± 0.09 m, 67.1 ± 15 Kg, 24.7 ± 5.5 Kg/m², and 1.7 ± 0.2 m² respectively. However Okur et al.[21] revealed mean values of weight and BMI to be 77 ± 11 Kg and 28 ± 5 Kg/m² for males and 71 ± 12 Kg and 27 ± 6 Kg/m² for females respectively.

The mean value of renal volume, renal sinus volume, and renal parenchyma volume found in the current study are 109.56 ± 13.52 cm³, 9.50 ± 2.87 cm³, and 99.98 ± 12.53 cm³ for the right kidneys, 123.03 ± 13.88 cm³, 11.30 ± 3.92 cm³, and 111.62 ± 12.84 cm³ for the left kidneys respectively as shown in Table 2. The findings of the study are in agreement with the findings of the studies conducted by Maaji et al.[15]; Raza et al.[7] that reported mean renal volume to be 109.6 ± 29.3 and 119.7 ± 32.8 for right and left kidneys and 99.8 ± 37.2 cm³ for the right kidney and 124.4 ± 41.3 cm³ for the left kidney respectively. The possible explanation of the agreement with Maaji et al.[15] is that, both studies were conducted in the same geo-political region of the country (North

western Nigeria), however the previous published work did not determine the renal sinus volume and renal parenchyma volume. The possible reason of the agreement with Raza et al.[7] might be link with the similarities in subject's mean height and weight with that of the current study. Renal volume range was found to be (92.02-183.37 cm³) as shown in Table 2, the values are almost similar to what was reported by Cheong et al.[20] (90-190cm³). However, the findings are contrary to the findings of the studies conducted by Okur et al.[21]; Musa & Abukunna.[18] that reported the mean value of the right renal volume and left renal volume to be 158 ± 39 cm³ and 168 ± 40 cm³, and 90.84 ± 1.1 cm³ and 93.35 ± 1.5 cm³ for the right and left kidney respectively, the values reported by the former published article are higher than the values reported in the current study and the value reported by the later published article is lower. The possible reason of the disagreement between Okur et al.[21] and the current study might be because of higher mean weight of the participants in the study 74 ± 11.5 when compared to 66.34 ± 12.51 Kg of the current study or due to races difference. Furthermore, the possible reason of the disagreement between Musa & Abukunna.[18] and the current study might be the previous published work was conducted among normal populations leaving in high altitude 2200m above the sea level, this probably explain the reason behind small renal size. These differences in renal dimensions showed that renal size could be different among people of different geographical location, races, ethnicity, and even economical status. The implication of this is that; normative renal reference value for one population may not be appropriate for used as reference in making diagnosis of another population. The findings of the study also show that, the mean value of the left kidney volume to be larger than the mean value of right kidney volume; 123.03 ± 13.88 cm³ and 109.56 ± 13.52 cm³ for the left and right kidneys respectively. The findings of the study are in agreement with the findings of many other studies.[7,12,13,15,19] The differences in size between right and left kidneys may be because the left kidney has more space to grow than the right kidney. The presence of the liver on the right may have more impact on renal growth when compared to the spleen on the left. Greater blood flow to the left kidney on account of a shorter and straighter left renal artery is the plausible explanations hypothesized.[15,19,22]

Furthermore, the findings of the study show that, there is statistical significant difference of the right and left mean values of renal volume, renal sinus volume and renal parenchyma volume between male and female ($p = .000$) as shown in Table 3. The findings of the study are in agreement with the findings of several other studies.[13,15,22-24] Gender differences in renal size can be accounted for by the disparity in anthropometric indices which are independent predictors of renal size or might be link with the influence of sex steroid hormones or physical activities. However, the findings of the study are contrary to the findings of the study conducted by El-Rashaid & Abdul-Fatah,[25] that reported no statistical significant difference between males and females in terms of renal length or cortical thickness.

The findings of the current study also show a weak negative correlation between age and right renal volume, right renal parenchyma volume, left renal volume, and left renal parenchyma volume but, there is a weak positive correlation with right renal sinus volume and left renal sinus volume among male subjects. However, there is a weak negative correlation between age and right renal volume, right renal sinus volume, right renal parenchyma volume, left renal volume, left renal sinus volume, and left parenchyma volume among female subjects. The findings of the study show a weak correlation between the age and the renal volume in both male and female subjects as shown in Tables 4 and 5. The findings of the study are in agreement with the findings of the study conducted by Raza et al.[7] that reported a statistical significant negative weak linear correlation when age was correlated with left renal volume and right renal volume with correlation coefficient of -0.221 and -0.210 respectively and ($p < 0.01$) however, bilateral parenchyma thicknesses did not show significant correlation with age ($p > 0.01$). The findings of the study are contrary to the findings of the study conducted by Johnson et al.[26] that reported no relationship between age and renal parenchyma volume. The findings of the study also show positive weak correlation between height and right renal volume, right renal sinus volume, right renal parenchyma volume, left renal volume, left renal sinus volume, and left parenchyma volume among both gender ($r = .215^{**}$; $p = .000$) and RRPV ($r = .213^{**}$; $p = .000$) among male subjects while RRSV ($r = .223^{**}$; $p = .000$) and LRSV ($r = .231^{**}$; $p = .000$) among female subjects as shown in Tables 4 and 5.

The findings of the study are in agreement with the findings of the study conducted by Johnson et al.[26] that reported body surface area and body weight correlated best with renal parenchyma volume. The findings of the study also show positive weak correlation between weight and right renal volume, right renal sinus volume, right renal parenchyma volume, left renal volume, left renal sinus volume, and left parenchyma volume in both male and female subjects. The correlation coefficient and p-value for weight and right renal parenchyma volume and left renal sinus volume in male are ($r = .155^{**}$; $p = .002$), and ($r = .167^{**}$; $p = .001$), and right renal sinus volume and left renal sinus volume in female are ($r = .223^{**}$; $p = .000$) and ($r = .231^{**}$; $p = .000$). Body mass index shows positive weak correlation with the right renal volume, right renal sinus volume, right renal parenchyma volume, left renal volume, left renal sinus volume, and left parenchyma volume in both male and female subjects also revealed a statistically significant positive weak correlation ($r = .208^{**}$ $p = .000$; $r = .193^{**}$ $p = .000$) for male right and left kidneys respectively as shown in Table 4. Right renal volume and left renal sinus volume also show a weak positive correlation with body surface area among female subjects $r = .240^{**}$ $p = .000$ and $r = .248^{**}$ $p = .000$ respectively as shown in Table 5. The results of this study showed body surface area as the most sensitive indicator for renal size determination, this finding agrees both with literature and logic since organ size is unquestionably related to body size.[12,19]

Conclusion

The results of this study shows significant difference in renal size of adult residence of Kaduna and other part of the world, it also showed significant difference between the right and left kidney as well as male and female kidneys. These differences suggest the need for establishing reference value for renal size among different group and also put side and gender into consideration when dealing with particular kidney disease that has to do with change in renal size.

Recommendation

- The variations in renal size between different populations reiterate the need for establishing local reference value for different populations.
- Further study shall evaluate the renal functions test and correlate it with sonographic findings.

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