ORIGINAL ARTICLE

Sonographic Determination of Renal Volume and its Correlation with Body Mass Index Among Healthy Adults in Kano, Nigeria

Saleh MK, Danbatta AH

ABSTRACT

Background: Kidney dimensions, including volume, of a patient is a valuable diagnostic parameter in nephrology and urologic practice and vary with age, gender, body mass index, pregnancy and co-morbid conditions. Congenital and some important morbid conditions affect renal dimensions and some of these pathologic conditions have close relationship with BMI. **Aim and Objectives**: To determine the normal ultrasound volume in healthy adults and to correlate it with the Body Mass Index (BMI). **Materials and Methods:** This was a descriptive cross-sectional study in which kidney dimensions were acquired and from which the volumes were determined using the ellipsoid formula. The anthropometric variables of the patients were documented, and the BMI calculated. Variations of the renal volume with sex and age, and the relationship of the renal volumes with BMI were determined. **Results:** A total number of 400 adult subjects were recruited for the study, with a M:F ratio of 3:1. The mean age was 39±13.2 years. The mean BMI was 22.95±3.20kg/m^2. The mean renal volumes were 140.0±30.5cm^3 and 149.5±34.6cm^3 on the right and left sides respectively. There was a positive correlation between the BMI and right renal volume ($p<0.01$; $r= 0.188$) and BMI with left renal volume ($p<0.01$; $r= 0.218$). There was also positive correlation between the right and left renal volumes and age ($P<0.01$) and gender ($P<0.01$; $P<0.05$). **Conclusion:** Positive correlations were noted between the renal volumes and body mass index, age, sex and sides.

Key words: Sonography, Renal volumes, BMI, Sonography, Healthy adults, Kano.

[1]Department of Radiology,
Aminu Kano Teaching Hospital, Kano

Corresponding Author
Dr Mohammed Kabir Saleh
Department of Radiology Bayero University/Aminu Kano Teaching Hospital, Kano, Nigeria
Email: mk_saleh@yahoo.com
Phone number: +2348037872982

Access this article online	
Quick Response Code	
	website: www.bornomedicaljournal.com
	DOI: 10.31173/bomj.bomj_126_16

Introduction

Renal size and function reflect the health of the kidney and changes in renal size may occur as a consequence of aging or diseases such as congenital anomalies, urinary tract diseases, systemic diseases, micro and macrovasular diseases and neoplasia.[1,2] Since the renal size is affected by various factors, it is necessary to first establish the normal values. For determining the renal size, the length, width and cortical thickness are to be measured. However, the most useful measurement of renal size is the total renal volume, which is correlated with body mass index (BMI).[3]

Ultrasound scan (US), computed tomography (CT) and magnetic resonance imaging (MRI) are the imaging modalities that evaluate the anatomical structure of the kidneys, while intravenous urography (IVU) and nuclear medicine are used primarily for physiology of the kidney.[4] CT scan, MRI, IVU and nuclear medicine have their limitations which include either non-availability or affordability by our patients and the use of ionizing radiations or nephrotoxic contrast agents. As such they are not routinely employed for the assessment of renal size. Ultrasound scan on the other hand, is a safe, easily available, inexpensive, fast, non-invasive and radiation-free imaging modality that made it become an indispensable modality over the other modalities.[5]

Among the various studies carried out in Nigeria only few correlated renal size with BMI. Therefore, the aim of this study was to determine the renal volume and to correlate it with BMI using ultrasound scan among healthy adults in Kano, Nigeria.[6-10]

Materials and methods

The study was a descriptive, cross-sectional type carried out in the department of Radiology, Aminu Kano Teaching Hospital (AKTH), Kano, Nigeria with the study population randomly recruited from General outpatient department (GOPD) and Medical outpatient clinics in AKTH and other referral hospitals. Only subjects that do not have symptoms and signs or laboratory diagnosis of kidney disease that could interfere with the outcome of the renal ultrasound scan were included in the study.

Approval to carry out the study was sought and obtained from the ethics and research committee of the AKTH. Informed verbal and written consents were also obtained from the subjects before they were recruited into the study.

The Sample size of 400 subjects was determined using Fisher's statistical formula ($n=Z^2pq/d^2$).

The height and weight of the subjects were measured and recorded using Stadiometer ZT-120 Metlar, (China) which is a weighing scale equipped with height measuring capability.

Ultrasound scanning was done in supine and prone positions after the application of adequate amount of water-soluble coupling gel and the general architecture of the kidneys noted to exclude any form of kidney disorder. Subjects were scanned using two-dimensional Mindray Digiprince DP8500 (Shenton, China) ultrasound machine with 3.5 – 5.0MHz curvilinear transducer equipped with electronic callipers. The kidney was located and the transducer rotated slightly to determine the longest renal axis. The renal length was measured as the maximum bipolar dimension in longitudinal plane which showed central sinus echoes the best with the renal parenchyma evenly distributed all around the central sinus (Figure 1). In the same plane, renal thickness or depth was also measured as the distance between ventral and dorsal surfaces of the kidney (antero-posterior diameter). (Figures 1 & 2). The transducer was then rotated 90 degrees to the longitudinal axis and the transverse section is obtained at the level of the renal hilum (Figure 2). Renal width was measured as the maximum distance between medial and lateral borders of kidney in this view.

Renal volumes were then calculated using the following formula: Kidney volume = L (cm) x W (cm) x D (cm) x constant (0.523) where L is renal length; W is renal width; and D is renal depth as measured from the ultrasound scan images. All measurements were obtained

while patient was instructed to stop breathing
for a while.

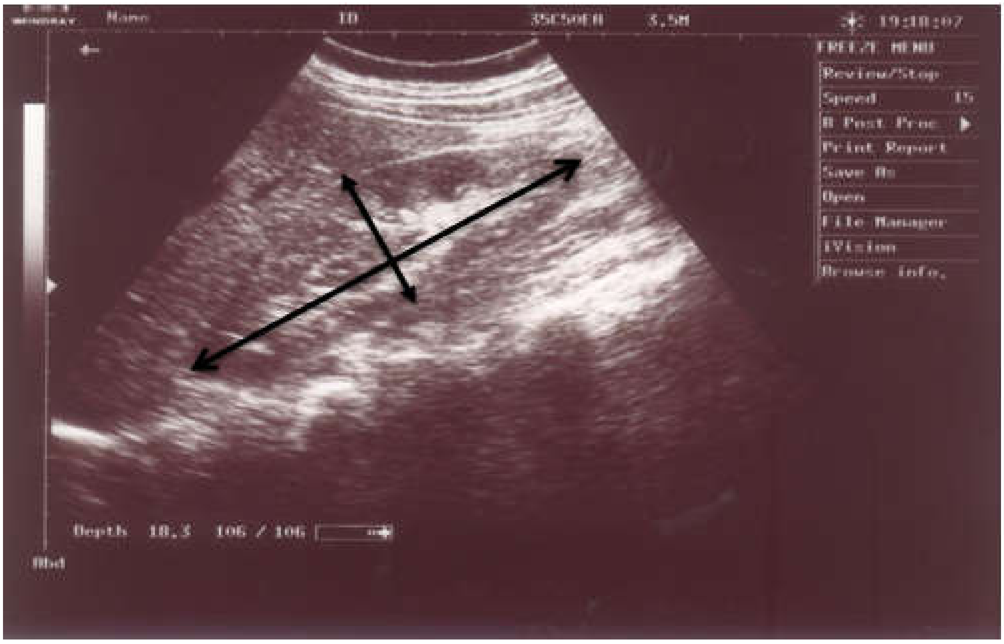

Figure 1: Longitudinal image of the right kidney and liver, showing its bipolar length and the A.P. diameter (thick black arrows) and echogenicity in relation to the adjacent liver.

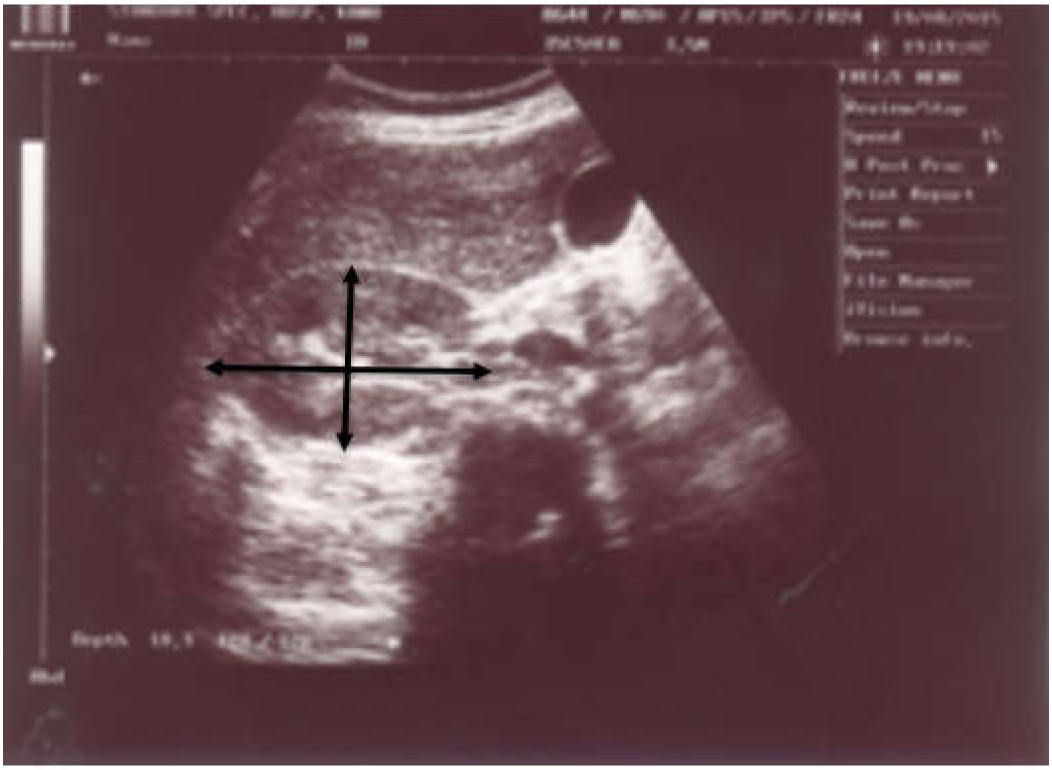

Figure 2: Transverse image of the right kidney showing transverse dimension/width of the right kidney (thick black arrow) and cortico-medullary differentiation.

Data Analysis

The data collected was analysed using Statistical Package for Social Sciences (SPSS) version-20 (SPSS Inc. IL, USA). The mean heights and weights of the subjects were calculated from which the mean BMIs of these subjects were also calculated using the formula; Weight (kg)/Height² (m²). The mean renal dimensions and volumes of the kidneys for the subjects were calculated. These mean dimensions including volumes were correlated to gender, age and sides. The relationships of the kidney dimensions and volumes with the BMI in males and females were examined using regression and correlation coefficients. Comparative analyses were carried out by means of a Pearson's correlation coefficient and ANOVA tests. P-values <0.01 and <0.05 were regarded as statistically significant.

Results

Of the 400 apparently healthy subjects included in the study, 303 (75.8%) were males and 97 (24.2%) were females (M: F= 3:1). The minimum age was 18 years and the maximum age was 65 years (Table 1). The modal age group was 34-41 (Table 1).

Table 1: Age group and gender Distribution

Age Group, years	**Sex**		**Frequency**	**Percent**
	Male	**Female**		
18-25	57	16	73	18.3
26-33	55	14	69	17.3
34-41	69	23	92	23.0
42-49	50	21	71	17.8
50-57	39	11	50	12.5
58-65	33	12	45	11.3
Total	303	97	400	100

Table 2: General Descriptive Statistics

Variables	**N**	**Minimum**	**Maximum**	**Mean**	**Std deviation**
Age (Years)	400	18	65	39	13.2
Height (m)	400	1.55	1.87	1.7	0.07
Weight (kg)	400	47	93	65.7	8.2
BMI (kg/m²)	400	17.2	22.2	22.9	3.20
RRL (cm)	400	9.0	11.2	10.4	0.58
LRL (cm)	400	9.3	12.0	10.9	0.68
RRV (cm³)	400	52.8	206.66	140.0	30.5
LRV (cm³)	400	64.25	218.32	149.5	34.6

NB: RRL= Right Renal Length, LRL= Left Renal Length, RRV = Right Renal Volume, LRV=Left Renal Volume, Std = Standard

Table 3: Mean Kidney Volume, Height and Weight in Males and Females

Gender	RR Vol. (cm^3)	LR Vol. (cm^3)	HT (m)	WT (kg)
Males	134.65±32.71	141.77±29.65	1.71±0.65	66.29±8.37
Females	143.57±38.72	151.84±33.04	1.66±0.68	63.93±7.55

HT = Body Height, WT = Body Weight

Table 4: Mean BMI, Kidney length and Volume in Males and Females

Gender	BMI (kg/m^2)	Mean RRL (m)	Mean LRL (m)	Mean RR Vol. (cm^3)	Mean LR Vol. (cm^3)
Males	22.846±3.30	10.6±0.62	11.1±0.63	141.77±29.65	151.84±33.04
Females	23.274±2.88	10.3±0.59	10.9±0.65	134.65±32.71	143.57±38.72

RRL= Right Renal Length, LRL= Left Renal Length

Table 5: Pearson's correlation coefficients between renal volumes and BMIs in Males and Females

Renal Volumes	Correlation Coefficient 'r'	p- value
RRV in males	0.197	0.001
LRV in males	0.225	0.000
RRV in females	0.194	0.057
LRV in females	0.235	0.002

RRV= Right Renal Volume, LRV= Left Renal Volume

Table 6: Pearson's correlation coefficients between renal volumes and age in Males and Females

Renal Volumes	Correlation Coefficient 'r'	p- value
RRV in males	0.361	0.000
LRV in males	0.441	0.000
RRV in females	0.315	0.002
LRV in females	0.291	0.004

RRV= Right Renal Volume, LRV= Left Renal Volume

Table 7: Pearson's correlation coefficients between renal volumes, heights and weights of the Subjects

Renal Volumes in cm³	Height (cm)		Weight (kg)	
	Correlation Coefficient 'r'	p-value	Correlation Coefficient 'r'	p-value
RRV	0.033	0.512	0.229	0.000
LRV	0.067	0.184	0.284	0.000
RRL	0.184	0.000	-0.030	0.554
LRL	0.150	0.003	-0.034	0.496

RRV= Right Renal Volume, LRV= Left Renal Volume, RRL=Right Renal Length, LRL= Left Renal Length

Discussion

Normal renal measurements are important factors in studying renal function and its disorders and it is also important in making a primary diagnosis as well as during the subsequent follow-up of patients with renal diseases, in order to monitor the progress of the disease.[5]

Of all the imaging modalities, ultrasound scan has been considered and preferred as an imaging modality of choice in most clinical studies for being non-invasive, safe, reliable, cost effective and readily available.[11] It is one of the most common imaging methods used in the demonstration of normal anatomy of the internal abdominal organs and reliable in visualizing pathological changes in abdominal organs including the kidneys.[12] Many congenital and acquired diseases directly or indirectly affect renal dimensions in all age groups.

There may be an increased or decreased renal size, which may or may not be accompanied by changes in the normal organ structure.[13]

Standard parameters used in routine ultrasound renal examinations are longitudinal renal length, renal width and renal parenchymal thickness in mm or cm. Additional measurements acquired using these three parameters include renal volume, based upon its correlation with subject's height, weight, BMI, age etc. Even the most precise assessment of abnormalities in renal size would require measurement of renal volume or even parenchymal volume in relation to sex, weight, or total body area, but such calculations are not clinically practical.[14]

In this study mean renal volumes, calculated from renal length and width, were 140.0±30.5cm3 and 149.8±34.6cm3 on the right and left sides respectively (range; 64.2 to 218.3cm3 on the left and 59.5 to 206.6cm3 on the right sides respectively and the length was 9.3 to 12.0cm on the left and 9.0 to 11.2cm on the right respectively). These were correlated with the patient's BMI, weight and height and also with the genders and the sides.

A significant positive correlation ($p<0.01$) was found with the BMIs and weights and between the right and left renal volumes of the subjects in this study.

One of the very important and easily reproducible parameters, which also acts as an indicator of renal function, is renal volume that shows variations with age, gender, ethnic backgrounds, height, weight and BMI.[11]

Renal volume correlated significantly with BSA and BMI, but decreased with age.[22]

The present study concurred with that as is shown that the calculated renal volumes correlated significantly with the BMIs of the subjects. The minimal size of a fully functional adult healthy kidney has been quoted to be 9cm in length.[23] This is similar to the current study in which 9.0cm and 9.3cm were found as the mean renal length on the right and left sides respectively.

In this study, measurements of renal volume were performed to find normal values for our population to help standardize criteria to be used in clinical assessment of certain disease processes largely relying on renal dimensions especially volume and thus to reduce any missed or over-diagnosis of a disease in practice. Renal volume shows variations with age, gender, height, weight and BMI.[11] The first major objective was to show that BMI had direct relationship with renal volume, as proved in few of previous comparable studies.[14,15]

In a study by Emamian *et al*[14] it was shown that the length and renal volume in subjects aged between 30 to 50 years showed slight differences and a clear decrease in both parameters. An increase in the renal volumes is noted in the middle ages and with a gradual decrease of these in the older ages likely from the same reason above. Increase in the renal volumes with increase in the subject's age was noted in this study and this is observed to be stronger in the middle ages. In this context, the changes in renal structure and shape that take place in human beings with age, decreased renal mass and renal weight and size, are well known.[24]

Rasmussen *et al.*[25] has reported the total renal volume to be the most accurate when correlated with the body weight. This is also observed in this study where the renal volume in both kidneys is seen to significantly and positively correlate with the subject's body weights and their BMIs. In normal subjects, the smallest kidney's volume should not be less than 37% of the total renal volume[25]. There appears to be an exponential increase in renal volumes and significant positive correlation between the right and left renal volumes in males and females that constitutes the study population in this study as opposed to the above assertion. This could be attributed to the genetic and environmental influences in the present study environment.

The significant correlation between renal volume and body weight and between renal volume and BMI was established in this study. A probable explanation is based on Brenner's principle of right renal dosing which states that larger body size requires a larger nephron dose to meet its metabolic demands.[16,17] Correlation was also noted between renal volume with height, gender and the side. Renal volume showed a significant decrease with age which probably was totally due to reduction in parenchymal volume.[3, 14] Similar trend was observed in this study.

In studies by Emamian *et al.*[14] and Fernandes *et al.*[19] a significant positive correlation was seen between renal length and height bilaterally; while Okoye *et al.*[26] concluded that renal length is not associated with body's height, but with subject's weight. Barton *et al.*[27] believed that lengths and widths of kidneys were not associated with height in either gender. A positive correlation was however seen in this study, between renal volumes and weight and between renal lengths and heights and no relationship was noted between renal volumes and heights and renal lengths and weights of the subjects studied. This correlation was comparatively stronger between renal volume and subject's weights and BMIs bilaterally. This finding has been supported by previous workers.[11]

The renal length and renal volume have been found to show a good correlation with BMI.[3] This was shown in this study as well where the renal weight and volume showed a stronger correlation with BMI than with renal length.

In this study it was observed that the values for renal volume of male subjects were higher than those of female subjects in all ages studied.

This could be due to the higher body weights of the males compared to the females.

This study also showed that the left kidney is larger in volume than the right kidney in both genders within the age ranges studied agreeing with previous studies of Carrasco *et al*[18], Fernandes *et al*[19] and Mazzotta *et al.*[20]

A theory postulated for this is that the left renal artery is shorter in length and straighter, which increases blood flow to the left kidney, with the corresponding increase in volume of the left kidney.[14, 21]

Also, it could be due to the fact that the liver is bigger than the spleen, which means that the right kidney has less space to grow.[14]

The significant positive correlation found in this study, between BMI and weight of individuals and the kidney volumes suggest that the growth of each individual is usually associated with increase in the kidney size.

In conclusion, positive correlations were noted between the determined renal volumes with body mass index, age, sex and sides, with which one can possibly predict changes in renal volume when there is variation in the anthropometric characteristics of the individuals.

References

1. Bax L, Van der Graaf Y, Rabelink AJ, Algra A, Beutler JJ, Mali WP. Second Manifestation of ARTerial disease (SMART) Study Group. Influence of atherosclerosis on age related changes in renal size and function. Eur J Clin Invest. 2003; 33(1):34-40.
2. Agnes DM, Danny Y, Virginia QB, Rafael S, Arlene CC, et al. Kidney measurements by sonography on normal Filipino adults influence of age, sex and habitus. Philipines J Int Med. 2013; 51(1):1-5
3. Buchholz NP, Abbas F, Biyabani SR, Afzal M, Javed Q, Rizvi I, et al., Ultrasonographic renal size in individuals without known renal disease. J Pak Med Assoc 2000; 50:12-16.
4. Ryan S, McNicholas M, Eustace S. Anatomy for Diagnostic Imaging. 2nd edition. Saunders. Philadelphia; 2004. Pp 189-194.
5. Adeela A, Jostinah L, Yeoh JW, Eko S. Comparison of renal size among different ethnicities. Intl J Biol Biomed Eng. 2011; 4(5):221-228.
6. Ma'aji SM, Daniel O, Adamu B. Sonographic Measurement of renal dimensions of adults in Northwestern Nigeria: A preliminary report. Sub-Saharan Afr J Med. 2015; 2:123-127.
7. Yahuza MA, Isyaku K, Idris SK, Saleh MK, Suwaid MA, Umar MU, Shehi AA, Nura I, Naimatu AT. Sonographic measurement of kidney dimensions in healthy adults in Northwestern Nigeria. West Afr J Ultrasound. 2016; 17:28-35
8. Isyaku, K, Dambatta, AH, Umar, UM. Sonographic evaluation of the relationship between renal bipolar length and the height of the individual in healthy adults in Northwestern Nigeria. West Afr J Ultrasound. 2017; 18:19-26

9. Kolade-Yunusa HO, Mamven MH. Ultrasonographic measurement of renal size among normal adults in Abuja, Northcentral, Nigeria. Int Inv J Med Med Sci. 2017; 4(1):6-11
10. Ogbeide, OU, Ohikhokhai, WI. Sonographic assessment of renal size and its correlation with age and gender in apparently healthy adults in Benin City, Nigeria. Nig Hosp Pract. 2016; 17:3-11
11. Mujahid, R, Hameed, A, Imran Khan, M. Ultrasonographic assessment of renal size and its correlation with body mass index in adults without known renal disease. J Ayub Med Coll Abbottabad 2000; 23:64-68.
12. Udoaka, AI, Enyi C, Agi CE. Sonological evaluation of the liver, spleen and the kidneys in an adult Southern Nigerian population. Asian J Med Sci. 2013; 5(2):33-36.
13. Sanusi AA, Arogundade FA, Famurewa OC, Akintomide AO, Soyinka FO, Ojo OE *et.al*. Relationship of ultrasonographically determined kidney volume with measured glomerular filtration rate (GFR), calculated creatinine clearance and other parameters in chronic kidney disease (CKD). Nephrol Dial Transplant. 2009; 24:1690-1694.
14. Emamian SA, Nielsen MB, Pedersen JF, Ytte L. Kidney dimensions at sonography: Correlation with age, sex and habitus in 665 adult volunteers. AJR 1993; 160:83-86.
15. Kang KY, Lee YJ, Park SC, Yang CW, Kim YS, Moon IS, et al. A comparative study of methods of estimating kidney length in kidney transplantation donors. Nephrol Dial Transplant. 2007; 22:2322-2327
16. Luyckx VA, Brenner BM. The clinical importance of nephron mass. J Am Soc Nephrol. 2010; 21:898-910.
17. Mehta K, Ali U, Otiv A. Sonographic measurement of renal size in normal Indian children. Indian Ped. 2012; 49:533-536.
18. Carrasco, JO, Castellanos FR, Kimura E, Hernandez RD, Felix H. Renal Length measured by ultrasound in adult Mexican population. Nefrologia. 2009; 29(1):30-34.
19. Fernandes MM, Lemos CC, Lopes GS, Madeira EP, Santos OR, Dorigo D et al. Normal renal dimensions in a specific population. Int Braz J Urol. 2002; 28:510-515.
20. Mazzotta L, Sarteschi LM, Carlini A, Antonelli A. Comparison of renal ultrasonographic and functional biometry in healthy patients and in patients with chronic renal failure. Arch Ital Urol Androl. 2002; 74(4):206-209.
21. Wing HL, Adrian XN, Andrea WS, Karen KY, Yip HW, Chilene CC et al. Renal length nomogram in Hong Kong Asian children: Sonographic measurement and multivariable approach. J Paediatr Child Health. 2010; 46(6):310-315.
22. Adedeji AE, Victor AA, Abiodun OA, Olusegun TA, Anthony OA, Olugbenga OA. Evaluation of renal volume by ultrasonography in patients with essential hypertension in Ile-Ife, south western Nigeria. Lib J of Med. 2010; 25:5
23. Shcherbak AI. Angiographic criteria in the determination of indications for organ preserving surgery in renal artery occlusion. Klin Khir 1989; 12:15-17.
24. Chaudhury D, Levi M, Tuncel M. Ageing and Kidney Disease. In: Brenner BM (editor). The Kidney. 2012; 9th ed. Vol 1. Philadelphia: Elsevier Saunders; pp. 809-841.
25. Rasmussen SN, Haase L, Kjeldsen H, Hancke S. Determination of renal volume by ultrasound scanning. J Clin Ultrasound. 1978; 6:160-164.

26. Okoye IJ, Agwu KK, Idigo FU. Normal Sonographic Renal length in adult Southeast Nigerians. Afr J Med Sci. 2005; 34:129-131.

27. Barton EN, West WM, Saegeant LA, Lindo JF, Iheonunekwu NC. A Sonographic study of kidney dimensions in a sample of healthy Jamaicans. West Ind Med J 2000; 49(2):154-157.

Cite this Article as: Saleh MK, Danbatta AH. Sonographic Determination of Renal Volume and its Correlation with Body Mass Index Among Healthy Adults in Kano, Nigeria**. Bo Med J 2019;16(1): Source of Support:** Nil**, Conflict of Interest:** None declare