A Systematic Review on Sonographic Evaluation of Renal Size in Apparently Healthy Adults

Firdausi Ukashah Uthman [1], *Anas Ya'u[1], Sidi Mohammed[1],
Aminu Abubakar Abubakar[1], Umar Mansur[1], Aliyu Hassan Abdullahi[2]

[1]Department of Medical Radiography,
Faculty of Allied Health Sciences,
Bayero University, Kano Nigeria.

[2]Radiology Department,
Aminu Kano Teaching Hospital,
Kano Nigeria.
*Email: ayau.radg@buk.edu.ng

Abstract

The normal size of a kidney is variable and is affected by both physiologic and pathological conditions. Since renal size is affected by various factors, it is necessary to establish population specific normative values. Ultrasonography has shown its usefulness as an essential tool in the evaluation of renal size. The study aimed at reviewing published articles in the evaluation of renal size and identifying gaps in order to make recommendation for further studies. All articles included in this review are prospective in design with the smallest sample size used being 100 participants and the largest 4,035 participants. The age of the participants ranged from 13 to 80 years. The overall mean renal size reported in this review ranged from 63 ± 18.1 cm³ to 164.3 ± 38 cm³ for the right kidney and 69.1 ± 25.1 cm³ to 183.3 ± 48.9 cm³ for the left kidney. Six of the reviewed articles reported a statistical significant difference between male and female mean renal size (p<0.05), while two articles revealed no statistical significant difference between male and female mean renal sizes (p>0.05). However, the remaining seven articles did not compare the mean renal size between male and female participants. Seven out of the articles reported a significant positive correlation between kidney dimensions and BMI, while other eight articles did not check the association between kidney dimensions and anthropometric parameters. This review showed only one article out of fifteen used a probability sampling method and only two articles used larger sample size. Eight of the reviewed articles did not perform creatinine clearance test before recruitment of their participants.

Keywords: Systematic review, Sonography, Renal size, Adults.

INTRODUCTION

Kidneys are a pair of excretory organs one on each side of the vertebral column, situated on the posterior abdominal wall, behind the peritoneum(Chaurasia, 2019). Each kidney features a light brown inner medulla and a dark brown outer cortex. The medulla is composed of about a dozen renal pyramids, each having its base oriented toward the cortex and its apex, the renal papilla, projecting medially (Snell, 2012). The cortex extends into the medulla between adjacent pyramids as the renal columns (Snell, 2012). At the concave medial margin of every kidney maybe a vertical cleft, the renal hilum which serves as an entrance to a space within

the kidney(Moore *et al.*, 2017).Structures that serve and drain urine from the kidneys enter and exit the renal sinus through the renal hilum (Moore *et al.*, 2017).

Kidneys perform several vital functions besides formation of urine which includes but not limited to waste products excretion, regulation of water, electrolyte and acid-base balance (Sembulingam&Sembulingam, 2013).They also function in production of erythrocytes by secreting erythropoietin, hormone secretion and also regulation of blood pressure by regulating the volume of extracellular fluid via rennin angiotensin mechanism (Sembulingam&Sembulingam, 2013).

Sizes of the kidneys are important diagnostic concern in nephrologic and urological practice when evaluating patients with possible renal disease (Yadav *et al.*, 2017). Renal size can be affected by various disease conditions such as; renal inflammatory conditions, diabetes mellitus, chronic renal failure and hypertension. Anthropometric parameters such as age, height, weight, geographical location and gender, some physiological processes like pregnancy, hydration, hypoxia, physical activities and socioeconomic factors can also affect renal size (Buchholz *et al.*, 2000; Sabanayagam *et al.*, 2010; Musa & Abukonna, 2017; Johnson *et al.*, 2019). It is necessary to first establish normal values of renal size since it is affected by various factors, for comparison when evaluating renal diseases. Renal size can be determined by measuring renal length, renal volume and cortical volume or thickness (Raza *et al.*, 2011).

Imaging methods used for assessing renal size includes ultrasonography, computed tomography (CT) and magnetic resonance imaging (MRI). In the case of CT the necessity of radiation and eventually nephrotoxic contrast media restricts its utilization as a routine imaging method for assessing kidney volume. Though MRI has the potential of obtaining true tomographic images without the need for radiation and nephrotoxic contrast burden, it is however, very expensive, not readily available, time consuming and requires more expertise to be operated (Gavela *et al.*, 2006).Ultrasonography is the first line imaging modality of choice for the estimation of renal size because of it availability, affordability, non-invasiveness and doesn't use ionizing radiation(Gavela *et al.*, 2006, Anibor, 2019, Nazma *et al.*, 2021).In adults, a curved array transducer with center frequency of 3-6MHz is used in Ultrasonic renal exams (Hansen *et al.* 2015). The study is aimed at reviewing published articles on renal size determination in apparently healthy adults using ultrasound and identify areas that need to be address in subsequent studies.

METHODOLOGY
This is a retrospective study that focused on published literature on the topic. A secondary source of data was employed, with references obtained using GOOGLE SCHOLAR and PUBMED data bases. An extensive search was performed using the following search terms; "Determination of renal size on healthy adult using ultrasound, Sonographic determination of renal dimension, Sonographic evaluation of renal size, and Sonographic assessment of renal size in healthy adults". Original research articles that were conducted on the determination of renal size in apparently healthy adults using Ultrasonography, and were published in English language were included in this review. Articles excluded from this review include those that assessed the renal size in children and geriatric patients, articles considering patients with known renal disease, and those that used other imaging modalities than Ultrasonography. Eligibility of each article was assessed by carefully screening the title, abstract and results. Then the full text of the articles was thoroughly screened. Additional searches of their reference lists were made for the retrieval of other related articles. After the review of the relevant articles author(s), publication year, design of the study, location,

population, sampling method, instrument of data collection, statistical tool for data analysis and findings from each study were extracted from each article.

A total number of 37 articles were retrieved through electronic database search, 10 articles were excluded due to title and 5 based on abstract. Consequently, 7 articles were removed based on content and due lack of enough information, leaving 15 articles for the review.

RESULTS

A prospective study was conducted by Nazma *et al.* (2021) on assessment of kidney size using ultrasound and its correlation with body mass index in healthy subjects in India. A consecutive sampling method was used to select 499 healthy normotensive subjects both male and female, with an age range of 18 to 80 years. Subjects having urinary calculi, renal cysts, past history of renal surgeries, existence of acute or chronic disease capable of causing damage to renal function and pregnancy were excluded from the study. Renal length, width and cortical thickness, were measured using standard protocol. Maximum accuracy of the dimensions obtained through a single observer cross checking the measurements. Supplementary information noted were - age, gender, height, weight, BMI and history of established hypertension and diabetes mellitus. Of the 499 volunteers included in the study, 327 were males and 172were females. The mean BMI in males and females was 25.20 ± 3.96 and 24.08 ± 3.28 respectively. In males the mean cortical thickness(CT) in right and left kidney was 13.68 ± 2.47 mm and 13.94 ± 2.6 mm respectively. While in females right and left kidney cortical thickness was 12.63 ± 1.91 mm and 13.40 ± 2.37 mm respectively. The right and left mean renal length was also reported to be 9.9 ± 40 mm and 10.19 ± 0.978 mm respectively. A positive correlation was observed between BMI and right renal length, left renal length, right cortical thickness and left cortical thickness in males (r=.040; p=.476), (r=.043; p=.433), (r=.047; p=.402) and (r=.079; p=.154) respectively. Similarly, a positive correlation between BMI and right renal length, right breadth, left renal length and right cortical thickness in females was reported (r= .026; p= .733), (r= .015; p= .846), (r= .014; p= .858) and (r= .059; p= .442) respectively.

In the prospective study conducted by Yau *et al.* (2020) on normative values of renal volume, renal sinus volume, and renal parenchymal volume among normal adults in Kaduna. Simple random sampling method was used to select 792 participants (396 male and 396 female). Subjects with kidney diseases, underlying disease condition such as diabetes mellitus, pyelonephritis, HIV, or hypertension, pregnancy, pediatrics and patients above 65years of age were excluded from the study. Images of the kidneys were acquired using Nortek CS 3 digital ultrasound machine equipped with electronic caliper and a 3.5MHz curvilinear probe. IBM SPSS Version 22.0 was used to perform all statistical analysis with a statistical level of significance was set at p<0.05. The age range of the participants was 18 to 65 years for both males and females, with mean age of 37.37 ± 11.99 (years); 36.64 ± 12.2 years for males and 38.09 ± 11.71 years for females. The mean height of the participants was 1.65 ± 0.09m and 1.70 ± 0.07m for males and females respectively. The average weight of the participant was 66.34 ± 12.51kg; 67.72 ± 11.89kg and 64.97 ± 12.96kg for males and females respectively. Participant's body mass index (BMI) and body surface area (BSA) were 24.37 ± 4.44kg/m^2 and 1.73 ± 0.17m^2; mean BMI values for males are 23.37 ± 3.98kg/m^2 and 25.38 ± 4.79 kg/m^2 for females, while 1.78 ± 0.16m^2 and 1.67 ± 0.16m^2 are the mean values for BSA of males and females respectively. The mean value of renal volume, renal sinus volume, and renal parenchymal volume was found to be 109.56 ± 13.52 cm^3, 9.50 ± 2.87 cm^3, and 99.98 ± 12.53 cm^3 for the right kidneys, 123.03 ± 13.88cm^3, 11.30 ± 3.92cm^3, and 111.62 ± 12.84cm^3 for the left kidneys respectively. There was a statistical significant difference of the right and left mean values of renal volume, sinus volume and parenchymal volume between male and female (p=.000). BMI had a positive correlation with the right and left renal volume, right and left renal sinus

volume, right and left renal parenchymal volume in males (r=.058, p=.251 ; r=.057, p=.260), (r=.123, p=.014; r=.136, p=.007) and (r=.038, p=.457 ; r=.017, p=.737) respectively, also BMI had a positive correlation with the right and left renal volume, right and left renal sinus volume, right and left renal parenchymal volume in females (r=.0109, p=.031 ; r=.090, p=.075), (r=.176, p=.000; r=.165, p=.001 and (r=.079, p=.118 ; r=.034, p=.494) respectively.

A prospective study was conducted by Yadav *et al*. (2017) on measurement of renal length and width in healthy adults in Nepal. Here, a consecutive sampling method was used to select 110 healthy persons (15-80) years, out of which 57 were males and 53 females. Participants in the study were asymptomatic patients having normal serum creatinine level and normal calculated creatinine clearance while individuals having any disease that could affect renal length and width were excluded from the study. The weight and height of the participants were taken and used to calculate the body mass index (BMI). Digital renal ultrasound was performed using a "SIEMENS ACUSON X 300 Ultrasound System" with 7MHzcurved linear array probe and the data obtained was analyzed using SPSS® Version 17.0. The mean age for males and females were 37.66 ± 17.44 years and 33.33 ± 12.76 years respectively. The mean right and left kidney lengths were 9.77 ± 0.98 cm and 9.94 ± 0.86 cm respectively. The mean right and left kidney widths were 4.08 ± 0.63 cm and 4.18±0.86 cm respectively. When compared between males and females, the only parameters that show significant differences were weight and height. A significant correlation was reported between BMI and renal length (p < 0.05). A significant positive correlation was also observed between right and left renal length and weight (for right kidney r = 0.32, p < 0.01; for left kidney r= 0.81, p < 0.01) but not with height (r= 0.18, p = 0.059) and age (r= 0.02, p = 0.86).

In the prospective study conducted by Yunusa *et al*. (2017) on ultrasonographic measurement of renal size among normal adults in Abuja, Nigeria, consecutive sampling method was used to select 390 adults, of which 155 were males and 197 were females. The study was carried out on normal adult patients with age range18-70 years and no history of renal pathology while individuals that were pregnant, had diabetes, hypertension, previous surgical operation or trauma to the kidneys, and any renal congenital anomalies and other pathology observed during ultrasound examination were excluded. All renal scans were done using an EMP G70, China ultrasound scanner with a 3.5 MHZ curvilinear probe. On suspended breathing, images were obtained in longitudinal and transverse view with the participants in supine and prone positions. Renal dimensions measured included length, width, depth, volume, cortical thickness and parenchymal thickness of both kidneys and renal size was obtained using the formula: - length x breath x depth. The age, sex, body surface area and body mass index were further recorded and all data obtained were analyzed using SPSS 19.0 software. The mean age for the subjects was 37.1±12.6 with the mean age of females and males to be 39±12.9 and 35±11.9 respectively. The mean renal length, renal width, renal volume, cortical thickness and parenchymal thickness were found to be 10.4cm, 4.6cm, 156.6cm^3, 7.5mm and 16.0mm respectively. For the right kidney, mean renal length, renal width, renal volume, cortical thickness and parenchymal thickness were found to be 10.1±0.8cm, 4.1±0.6cm, 6.4±0.9, 7.2±2.7mm and 15.2±3.6mm respectively and for the left kidney to be 10.7± 6.0cm, 4.7±0.8cm, 6.5±0.8 cm, 7.7±2.6mm and 16.8±4.1mm respectively. Mean renal volume was 139±34.2cm^3 and 173.7±13.5cm^3 for the right and left kidneys respectively. The measured renal dimensions among the subjects were higher on the left side than the right side which was statistically significant (p<0.05) for measured volume, width, cortical thickness and parenchymal thickness but not statistically significant for the measured length and depth (p=0.45 and p= 0.38) respectively. A significant positive correlation of renal size with BMI and BSA in the right kidney(r= 0.37; p= 0.02) and (r= 0.72; p= 0.02) respectively, as well as a significant

positive correlation of renal size with BMI and BSA in the left kidney (r= 0.52; p= 0.01) and (r=0.90; p= 0.03) respectively was also reported.

In a similar study conducted prospectively by Musa & Abukonna, (2017) on measurement of renal size using ultrasound in normal high altitude populations in Saudi Arabia, consecutive sampling method was used to select 171 subjects of which 46 subjects were excluded due to the presence of renal multiple cyst, unilateral nephroctomy, diabetes mellitus, hypertension, hydronephrosis, pregnancy, ectopic kidney and renal parenchymal diseases leaving a total number of 125 participants (70 male, 55 women aged between 20-70 years) for the study. Ultrasound scan was performed using logic 3, LSD 30269WS5, General electric, USA system with 3.5 MHZ curvelinear transducer. Renal dimensions measured were length, width, thickness and cortical size. Height and weight for each subject was measured and this was used to calculate the body mass index (BMI). All statistical analysis was performed using SPSS. The body mass index (BMI) ranged between 15.84 to35.8 kg/m². The right mean kidney length was found to be 9.8 ± 0.9 cm, width was .9 ± 0.7 cm and thickness 4 ± 0.7 cm while the left mean kidney length, width and thickness were 10.7 ± 0.3, 3.5 ± 0.7 cm and 4.3 ± 0.7 cm respectively. The range of renal volume for the left kidney and right kidney was found to be 57.46 cm³ - 147.83 cm³ and 57.10cm³- 147.78cm³respectively. The mean right and left renal volume was found to be90.84 ± 1.1cm³and 93.35 ± 1.5cm³respectively. A significant negative correlation between age and renal volume with r= -0.83 and r= -0.9; (p=0.000 and 0.000) for right and left kidney respectively was observed while a significant positive correlation between renal volume and BMI, in both kidneys was reported.

In the prospective study conducted by Jabbari et al. (2016) on ultrasound measurement of renal dimensions in Iranian adults, consecutive sampling method was used to select103 individuals. Individuals with serum creatinine≤1.5 mg/dL, glycaemia≤110 z mg/dL in patients aged over 40 years or with BMI>30 kg/m2, arterial normotensive, no existence of acute or chronic disease capable of causing damage to renal function, and normal appearance of the kidneys by ultrasound were included in the study while individuals with history of hemodialysis or peritoneal dialysis, renal morphologic anomalies, unilateral or partial nephrectomy, renal parenchymal diseases, polycystic kidneys, multiple bilateral cysts, a solitary cyst larger than 1 cm, hydronephrosis, renal transplantation, renal tumors, pregnancy, or extreme obesity were excluded. Images of the kidney was obtained using RT-X200; GE Medical Systems with a 3.5 MHz transducer. All data were analyzed using SPSS version 16.0. The anthropometric measurements, including height, weight, and body mass index (BMI) were also recorded in all subjects. Right and left mean kidney length was found to be 104.96mm and 106.22mm respectively (p=0.02). Right and left mean parenchymal thickness was found to be 16.9mm and 18.2mm respectively (P<0.001). There was a significant positive correlation between renal size and parenchymal thickness with weight, height and BMI in the right kidney (r= 0.306 , p= 0.002 ; r= 0.222, p= 0.024 ; r= 0.185, p= 0.062) and (r= 0.498, p= 0.000 ; r= 0.113, p= 0.257 ; r= 0.459, p= 0.000) respectively, as well as a significant positive correlation between renal size and parenchymal thickness with weight, height and BMI in the left kidney (r= 0.325, p= 0.001 ; r= 0.211, p= 0.032 ; r= 0.210, p= 0.033) and (r= 0.235, p= 0.017 ; r= 0.089, p= 0.372 ; r= 0.195, p= 0.048) respectively.

A prospective study was conducted by Maaji et al. (2015) on sonographic measurement of renal dimensions in northwestern Nigeria. Renal ultrasound measurements were performed on104 (50 females and 54 males) consecutive volunteers without known kidney pathology or any systemic diseases. With the subjects holding their breath images were obtained in supine, left and right lateral positions. All renal scans were done using a dynamic ultrasound scanner with a 3.5 MHZ curvilinear probe. Additional information recorded where age, sex, weight,

body mass index, and height. Mean age was 30.4 ± 19 years (18-70). The mean kidney length for right kidney was 11.3 ± 8.8 and for left kidney was 11.6 ± 9.8. The mean height was 1.67 ± 0.85 and mean and weight was 70.9 ± 11.2. Right mean kidney width was 4.4 ± 0.71 and the left mean kidney width was 5.2 ± 5.26. Right mean renal thickness was 4.7 ± 0.67 and the left mean renal thickness was 4.5 ± 0.68. The right renal volume was 109.6 ± 29.3 and the left renal volume was 119.7 ± 32.8. The body mass index for females was calculated to be 25.1 ± 3.96 (16.18) and for males to be 26.0 ± 5.36 (24.7).

In the prospective study conducted by El-Reshaid & Abdul-Fattah (2014) on "sonographic assessment of renal size in healthy adults" in Kuwait, consecutive sampling method was used to select 252 healthy subjects (111 males and 141 females). Diabetic patients, hypertensive patients, patients with renal stones, renal scars, multiple cortical cysts, single kidney, poor cortical visualization, increased cortical echogenicity and primary renal disease were all excluded from the study. Ultrasound scan was performed using a LOGIQ C8 device. Ultrasonographic measurements obtained included the longest longitudinal diameter and the cortical thickness of the kidney. Analysis of the data was performed using the SPSS 17.0. The Pearson correlation coefficient was used to test the significance of linear association between variables, and $P < 0.05$ was considered significant. The mean right renal length was 10.68 ± 1.4 and the left renal length was 10.71 ± 1.0 cm, which had a significant correlation with weight (r: 0.67, $p < 0.001$). The mean cortical thickness was 1.1 ± 0.53 cm. Renal length correlated significantly with weight (r= 0.57, $p < 0.01$). Renal length, however, had no statistical correlation with height (r= 0.23, $p = 0.46$). There was a significant correlation between BSA and renal length (r= 0.71, $p = 0.02$) which was higher in males than in females ($p < 0.001$). BMI was also significantly correlated with renal length ($p < 0.005$). Cortical thickness, however, didn't show any correlation with weight or BMI ($p = 0.49$ and 0.94, respectively).

A prospective study was conducted by Okur *et al.* (2014) on ultrasonographic determination of the relationship between kidney volume and body indexes in Turkey. Consecutive sampling was used to recruit 152 subjects (79 men and 72 women). Additional information such as patients' age, sex, weight, height and body mass index (BMI) was recorded. Individuals with hypertension, diabetes mellitus and heart disease or other findings at ultrasound were excluded from the study. Sonographic examination was performed using a 4.5-5 MHz transducer with the subject in supine and prone positions. Kidney dimensions measured were length, width and thickness. Kidney volume and parenchymal volume were obtained. Statistical analysis was performed using SPSS 18.0. Mean kidney length, mean volume and mean parenchymal volume for the right kidney were 10.3±7.8cm, 158±39cm³, and 126±34cm³ respectively, and for the left kidney; 10.4±9cm, 168±40cm³, and 133±35cm³ respectively. There was a positive correlation between body height, kidney length, and width (p=0.005) as well as between body weight, kidney length and width (p<0.001). A significant correlation with total kidney volume and kidney measurements was observed for body weight in both kidneys (p<0.001, r: 0.32-0.44). There was a weak correlation between left kidney volume and BMI (p<0.05, r: 0.20) and a mild correlation between parenchymal volume and total volume with BMI for both right and left kidneys (p<0.05).

In another prospective study conducted by Gupta *et al.* (2013) on "ultrasonographic renal dimensions in normal adult population of north-east India", consecutive sampling method was used to select 340 normotensive subjects both males and females with an age range of 18 to 50 years. Individuals with urinary calculi, renal cysts, history of renal surgeries, acute or chronic disease capable of causing damage to renal function and pregnancy were excluded from the study. Renal length, width and cortical thickness were all measured. The kidney size was estimated, which corresponds closely to the renal volume. All ultrasound scans were

performed using a single ultrasound machine. Additional data recorded include age, gender, height, weight, BMI and history of established hypertension and diabetes mellitus. Data obtained were analysed using SPSS Version-16. Comparative analyses were done by means of a student's "t" test, Pearson's correlation co-efficient and ANOVA tests with a p-value <0.05 regarded as statistically significant. Of the 340 subjects included in the study, 236 were males and 104 were females with a mean age of 28.37 ± 7.3 years and 29.23 ± 9 years for males and females respectively. The mean body weight for males and females was 60.5 ± 9.5 and 52.2 ± 8.4 respectively. The mean height for males and females was 162.9 ± 8cm and 152.9 ± 6.1cm respectively. In males, right mean kidney length was 8.9±0.9cm, mean kidney width was 4.7±0.8cm and mean cortical thickness was 1.8 ± 0.4 cm. Right kidney size was 76.5 ± 30.1 cm³. Similarly, the mean length, mean width, mean cortical thickness and size for the left kidney was 9.1±0.9cm,4.7±0.6cm,1.8 ± 0.3 cm and 80.7 ± 26 cm³ respectively. In females, the mean length, mean width, mean cortical thickness and size for the right kidney were8.9±1.1cm, 4.3±0.9cm, 1.8 ± 0.3 cm and 69.2 ± 28.1 cm³respectively. While for the left kidney, mean length, width, cortical thickness and size were 8.8±0.9cm,4.2±0.7cm, 1.8 ± 0.3 cm and 69.1 ± 25.1 cm³ respectively. A significant difference (P<0.01) was reported in the width of both the kidneys when compared between males and females. The Pearson's correlation coefficient between renal size and BMI of the right and left kidneys in females and males were (RT kidney p=0.290, r=0.039, LT kidney p=0.379, r=0.006) and (RT kidney p=0.424, r=0.000, LT kidney p=0.257, r=0.005) respectively.

In the prospective study conducted by Hammad (2012) on sonographic study of kidney dimensions in Saudi Arabia, a consecutive sampling method was used to select 100 students (50 males and 50 females). Individuals with active urinary tract infection, poly cystic kidneys, and congenital abnormalities of the urinary system, hypertension, pregnancy, diabetes, heart diseases, cancer, other terminal illness and abnormal serum creatinine level were excluded from the study. Paired sample t-test was used to examine differences in kidney dimensions between both sides. Two sample t-test was used to compare the two means comparisons of kidney dimensions among sex while Pearson correlation coefficient was used to examine the presence of a dependence of kidney dimensions on height, weight and BMI in both groups and in each group. Ultrasound scan was performed using a Convex probe 2 – 5 MHz and a Phased array probe 6 -13 MHz Hitachi EUB- 6500 (Hitachi, Japan). The mean and standard deviation (SD) for age, height, weight and BMI for male (n=50) were 22.06 (1.08), 1.72 (0.06), 63.76 (9.13), 21.69 (3.04) respectively and for females (n=48) it was 21.7 (2.64), 1.57 (0.06), 60.31 (10.21), 24.43 (4.33) respectively. The mean and SD for kidney dimensions in centimeters (cm) and in cm³ for kidney volume, for the right kidney were length- 10.32(0.69), width- 5.07(0.68), cortical thickness- 4.94(0.84), and kidney volume-130.82(36.64). The mean and SD for kidney dimensions in centimeters (cm) and in cm³ for kidney volume, for the left kidney were length- 10.77 (0.87), width- 5.16 (0.90), cortical thickness- 4.46 (0.69), and kidney volume 127.56 (32.46). A significant difference was reported between the right and left kidneys length and thickness, cortical thickness and echogenic area thickness (p= 0.000), and a positive correlation between width, volume and cortical thickness with weight in the right kidney (r= 0.550, r= 0.577 and r= 0.580) respectively, and also positive correlation between length, volume and cortical thickness with weight in the left kidney (r= 0.505, r= 0.552 and r= 0.519) respectively was observed. A positive correlation was also found between right kidney volume, right cortical thickness and left kidney length with BMI (r= 0.539, r= 0.638, and r= 0.520 respectively).

Saeed *et al*. (2012) conducted a similar study prospectively on sonographic measurement of renal dimensions in adults and its correlates in Pakistan. A probability sampling method was used to select225 healthy subjects (30-80 years) with no history of renal disease and normal calculated GFR. Individuals with congenital kidney anomalies, kidney stones, chronic kidney

disease and malignancy were excluded from the study. All renal ultrasound scans were done using a real-time ultrasound scanner with a 3.5-MHz curvilinear probe. Body mass index (BMI), total body surface area, renal volume, and absolute renal size were all estimated and the data obtained was analyzed using SPSSv.17.0. Pearson correlation was used to record any significant correlations between renal length and anthropometric parameters of subjects with a p-value of <0.05 considered as statistically significant. The mean height for males and females was 174 ± 6.6 cm and 161 ± 7.0 cm respectively. The results obtained showed that the mean kidney length was 9.90 cm, mean kidney width was 4.61cm, cortical thickness 1.46 cm, kidney size and volume was 68.3 cm^3 and 35.7 cm^3 respectively. While renal length was similar for both genders (9.82 cm in men and 9.88 cm in females), males had larger kidney sizes than females (71.3 cm^3; 60.1 cm^3 p<0.001), due to both larger width and parenchymal thickness. A significant correlation was reported between renal measurements of subjects' height, weight, total body area, and body mass index with the strongest correlation being with renal volume and total body surface area r= 0.576 (p <0.001). Also, renal length positively correlated best with body weight r= 0.384 (p <0.001).

In a prospective study conducted by Arooj *et al*. (2011) on comparison of renal size among different ethnicities in Malaysia, a consecutive sampling method was used to select 100 students (49 males and 51 females). Study inclusion criteria were absence of prior history of any pathology and a valid consent for the study. Other information recorded were height and weight of the subjects. Images were obtained with patients in prone position and holding their breath for a while. Parameters measured include longitudinal length, width, thickness and kidney volume. The mean body weight was 57.42±10.94kg with a range of40kg to 110kg. The mean body height was 163.34 ±9.13cm with a range of 140cm to 180cm. Mean kidney length for the right and left kidney was found to be 8.91- 10.49cm and 8.94 – 10.86cm respectively. For males, mean length for the left and right kidney was 10.04±0.88cm and 9.67±0.77cmrespectively. While for females, mean length for the left and right kidney was 9.8±1.03cm and 9.7±0.84cm respectively. A significant positive correlation was reported between renal size and body weight p<0.05.

Another prospective study was conducted by Raza *et al*. (2011) on assessment of renal size and its correlation with body mass index in adults by ultrasound in Pakistan. Consecutive sampling method was used to select 4,035 adults with no history of renal pathology and a normal serum creatinine. Individuals with pregnancy, diabetes, hypertension and inability to change posture for accurate assessment of kidneys at time of scan were excluded from the study. Renal ultrasound scans were performed with a real time ultrasound machine and a 3.5–6 MHz transducer. Renal length, width, depth and parenchymal thickness were all measured. The volume was calculated as: Length (cm) × width (cm) × depth (cm)\2. Correlation of renal length and volume with BMI and also with age, gender, height and weight of the subjects were determined. Data was analysed using SPSS-version 11. Descriptive statistics were applied on the available data. Out of the 4,035 subjects, 1,961 were male and 2,074 females. Mean age was 44.4±15.2 years. Mean height for males and females was 172.6±6.9 cm and 155.2±5.9 cm respectively (range 120–192 cm). Mean weight for males and females was 76.3±14.4 Kg and 67.1±13.9 Kg respectively (range 36–137 Kg). Mean renal length, width, parenchymal thickness for right kidney were 101.6±8.9 mm, 42.7±7.1 mm and 14.4±3.0 mm respectively and for the left kidney 102.7±9.2 mm, 47.6±7 mm and 15.1±3.1 mm. Right and left mean renal volume was 99.8±37.2 m^3 and 124.4±41.3 cm^{3}respectively. There was a statistically significant difference between dimensions of right and left kidneys (p<0.01) which were all statistically higher in males than females (p<0.01). Correlation coefficients between BMI and renal lengths, volume and parenchymal thickness in the right and left kidneys were

RT kidney (r= 0.19, r= 0.11 and r= 0.36) and LT kidney (r= 0.21, r= 0.19 and r= 0.38) respectively.

Buchholz *et al.* (2000) conducted a prospective study on "ultrasonographic renal size in individuals without known renal disease" in Karachi. Consecutive sampling was employed to select 194 patients (13 to 80 years). Pregnant individuals and those with kidney stones were excluded from the study. The kidney dimensions measured were length, width, and cortical thickness. The kidney size was obtained using the measured length, width and cortical thickness. Additional data recorded include age, gender, height, weight, BMI and history of established hypertension and diabetes mellitus. Data were analysed using SPSS-8. Comparative analyses were done by means of a student's "t" test. A p-value <0.05 was regarded as statistically significant. Of the total 194 patients, 98 were males and 96 females. The mean age was 44.7 ± 14 years, with 46.1 ±, 15.4 years and 43.3 ± 13.2 years for males and for females respectively. Mean kidney length, width, cortical thickness and size was 10.4 ± 0.8 cm, 4.5±0.6cm, 1.6 ± 0.2 cm and 76.16 ± 21.7 cm^3 respectively. There was no significant difference in kidney length between right and left side (P=0.469). However; differences in width, cortical thickness and size were all significant (P<0.05). Furthermore, a positive significant correlation was reported between renal size and BMI (p<0.05).

Table 1: Characteristics of the reviewed articles

S/N	Author/year	Location	Design	Sampling	Sample size	Age range	Mean age	Laboratory investigation	Probe/approach
1	Nazma *et al.* (2021)	India	Prospective	Consecutive	499	18-80	-	-	-
2	Yau *el al.*(2020)	Nigeria	Prospective	Simple random	792	18-65	37.37±11.99	-	3.5MHz/Supine-Prone
3	Yadav *et al.* (2017)	Nepal	Prospective	Consecutive	110	15-80	35.58±15.45	Creatinine	7MHz/-
4	Yunusa *et al.* (2017)	Nigeria	Prospective	Consecutive	390	18-70	37.1±12.6	-	3.5MHz/Supine-Prone
5	Musa and Abukonna (2017)	Saudi Arabia	Prospective	Consecutive	171	20-70	-	-	3.5MHz/Supine
6	Jabbari *et al.* (2016)	Iran	Prospective	Consecutive	103	18-70	-	Creatinine	3.5MHz/Supine-Prone
7	Ma'aji *et al.* 2015)	Nigeria	Prospective	Consecutive	104	18-70	30.4±19	Creatinine&FBS	3.5MHz/Supine
8	El-Reshaid and Abdul-Fattah (2014)	Kuwait	Prospective	Consecutive	252	18-80	-	Urinalysis/Creatinine	-
9	Okur *et al.* (2014)	Turkey	Prospective	Consecutive	152	25-65	42±13.7	-	4.5-5MHz/ Supine-Prone
10	Gupta *et al.* (2013)	India	Prospective	Consecutive	340	18-50	28.37±7.3	-	-
11	Hammad (2012)	Saudi Arabia	Prospective	Consecutive	100		-	Creatinine	2-5MHz/-
12	Saeed *et al.* (2012)	Pakistan	Prospective	Consecutive	225	30-80	47.0±10.1	Creatinine	3.5MHz/Supine
13	Arooj *et al.* (2011)	Malaysia	Prospective	Consecutive	100	-	-	-	Supine/Recumbent
14	Raza *et al.* (2011)	Pakistan	Prospective	Consecutive	4,035	>18	44.4±15.5	Creatinine	3.5-6MHz/-
15	Buchholz *et al.* (2000)	Karachi	Prospective	Consecutive	194	13-80	44.7±14	-	-

Key: FBS= Fasting blood sugar; MHz= Mega hertz

Table 2: Summary of the results

S/n	Authors/year	Findings								P-value	Correlation of RV with BMI	
		RK(mean±SD)				LK(mean±SD)						
		L	T	W	V	L	T	W	V		RK	LK
1	Nazma et al. (2021)	10.27±4.29	13.15±2.2	4.56±.44		10.1±1.0	13.67±2.49	4.6±.59		-	-	-
2	Yau et al. (2020)	-	-	-	109.56±13.52	-	-	-	123.03±13.88	p<0.05	.058	.057
3	Yadav et al. (2017)	9.77±0.98	-	4.08±0.63	-	9.94±0.86	-	4.18±0.86	-	p>0.05	-	-
4	Yunusa et al. (2017)	10.1±0.8	7.72±2.7	4.1±0.6	139.5±34.2	10.7±6.0	7.7±2.6	4.7±0.8	173.7±130.5	p<0.05	.37	.52
5	Musa and Abukonna (2017)	9.8 ± 0.9	4 ± 0.7	4.9 ± 0.7	90.84 ± 1.1	10.7 ± 0.3	4.3 ± 0.7	3.5 ± 0.7	93.35 ± 1.5	-	-	-
6	Jabbari et al. (2016)	10.50±0.7	1.69±0.12	-	-	10.62±0.62	1.82±0.17	-	-	p<0.05	-	-
7	Ma'aji et al. (2015)	11.3 ± 8.8	4.7 ± 0.67	4.4 ± 0.71	109.6 ± 29.3	11.6 ± 9.8	4.5 ± 0.68	5.2 ± 5.26	119.7 ± 32.8	-	-	-
8	El-Reshaid and Abdul-Fattah (2014)	10.68 ± 1.4		0.98±0.5		10.71 ± 1.0		1.02±0.4		p>0.05	-	-
9	Okur et al. (2014)	10.3±7.8			158±39	10.4±9			168±40	p<0.05	.12	.17
10	Gupta et al. (2013)	8.9±1.0	1.8 ± 0.35	4.5±0.85	72.85 ± 29.1	9.0±0.9	1.83 ± 0.3	4.43±0.65	75±23.55	p>0.05	.424	.257
11	Hammad (2012)	10.32 ± 0.69	4.94±0.84	5.07 ±0.68	130.82 ± 36.64	10.77±0.87	4.46 ± 0.69	5.16 ±0.90	127.56 ±32.46	p>0.05	.539	-
12	Saeed et al. (2012)	9.85	1.43	4.53	65.3	10.00	1.49	4.68	69.9	-	-	-
13	Arooj et al. (2011)	9.7±0.79	3.8±0.57	3.8±.52	71.5±18.84	9.9±0.96	4.3±0.79	4.4±0.59	93.6±27.7	-	-	-
14	Raza et al. (2011)	10.16±0.89	1.44±0.29	4.27±0.71	99.8±37.2	10.27±0.92	1.51±0.31	4.76±0.70	124.4±41.3	-	.11	.19
15	Buchholz et al., 2000	10.4±0.9	1.5±0.2	4.2±0.7	70±22	10.5±0.9	1.6±0.2	4.8±0.7	82±24	p<0.05	-	-

Key words: L=Length (cm), W=Width(cm), T=Thickness(cm), V=Volume (cm³), RK= Right kidney, LK= Left kidney, RV=Renal volume, S.D=Standard deviation, BMI= Body mass index

DISCUSSION

Many organs within the abdomen can be evaluated using ultrasound and kidneys are one of those structures that can be evaluated right from intra-uterine life through all age groups after delivery (Sidi & Umar, 2020). Renal size can be affected by various disease conditions, anthropometric parameters and physiological processes. Changes in renal sizes can be consider to be a sign of kidney disease as renal size can be influenced by several renal diseases (Raza et al., 2011). The information available for one population might not be the same to other population due to different reasons which include gender, body size, body mass index and ethnic differences (Yunusa et al., 2017; Kelly et al., 2016; Okur et al., 2014).

All studies included in this review were conducted prospectively; therefore, in terms of study design, will be considered as the same.
Studies included in this review were conducted using a non-probability sampling method except that of Yau et al. (2020) who adopted the probability sampling method. Studies that used probability sampling had more strength over those that used non-probability sampling because probability sampling is done based on randomization where every element of the population gets an equal chance of being selected for the study which reduces the chances of sampling selection bias thus, having the greatest freedom from bias (Taherdoost, 2016).

Based on this review, the study conducted by Raza et al. (2011) used the highest sample size of 4,035 participants hence; it is considered to have more strength when compared to other reviewed articles. Meanwhile studies by Hammad (2012) and Arooj et al. (2011) used the lowest sample sizes of 100 participants each and that serve as a weakness of their study in respect of sample size. Studies with larger sample size tends to give results that are more accurate and reliable because the likelihood of the results to represent the population is higher, also the greater the sample size the smaller the margin of error and the better the precision especially when establishing a normative value of an organ (Sidi & Umar, 2020; Biau et al., 2008).

The study of Yau *et al*. (2020) has more strength than all other studies in this review in view of the studied subject's age bracket which ranges between 18 to 65 years of age, because it is considered to be the idle age bracket for establishing normative values of the kidneys. The ages of the participants in this review ranged from 13 to 80 years. However, participants below 18 years of age were within the pediatric age group while those above 65 years fall within geriatric age group and renal size may not represent adult population renal size due to physiological changes such as atrophy.

Seven of the reviewed articles Yadav *et al*. (2017); Jabbari *et al*. (2016); Ma'aji *et al*. (2015); El-Reshaid and Abdul-Fattah (2014); Hammad (2012); Saeed *et al*. (2012); Buchholz *et al*. (2000) perform creatinine test which placed them above other studies. A measurement of creatinine in the blood or urine provides clues about how healthy the kidneys are. Therefore studies that perform laboratory test to ensure they are dealing with a normal kidney have more strength than the studies that did not perform laboratory test.

Estimation of renal size can be performed using either linear or volumetric measurement. The latter is considered to be the most appropriate as it take account of the whole kidney size irrespective of renal morphology unlike single linear measurements. Therefore, studies conducted by Nazma *et al*. (2021); Yadav *et al*. (2017); Jabbari *et al*. (2016); El-Reshaid and Abdul-Fattah (2014) have less strength than other studies that determine the renal size using volumetric method.

The overall mean renal size reported in this review ranged from 63±18.1 cm³ to 164.3±38cm³ for the right kidney and 69.1±25.1cm³ to 183.3±48.9cm³ for the left kidney respectively. Mean renal size in male subjects for right and left kidneys were 70.74±19.24cm³ to 164.3±38cm³ and 80.7±28cm³ to 183.3±48.9cm³ respectively while that of female subjects ranged from 63±18.1cm³ to 151.8±39cm³ and 69.1±25.1cm³ to 164.3±47.7cm³ for the right and left kidneys respectively. The lowest renal size for the right and left kidneys was reported by Gupta *et al*. (2013) and Buchholz et al. (2000), and both studies were conducted in Asia. This is not surprising considering Walpole *et al*. (2012) reported an average body mass for Asian population to be 57.7Kg and a world value of 62.0Kg respectively in their study. This may be the reason why the Asian populace has small renal size.

Studies conducted by Yau *et al*. (2020), Yunusa *et al*. (2016), Jabbari *et al*. (2016), Okur *et al*. (2014) and Buchholz *et al*. (2000) reported a significant statistical difference in renal size between males and females, while studies conducted by Yadav *et al*. (2017), El-Reshaid and Abdul-Fattah (2014), Gupta *et al*. (2013) and Hammad (2012) shows no significant statistical difference in renal size between the male and female gender. However, studies conducted by Nazma *et al*. (2021), Musa and Abukonna (2017), Ma'aji *et al*. (2015), Saeed *et al*. (2012), Raza *et al*. (2011) and Arooj *et al*. (2011) did not compare between male and female renal size which is considered as the weakness of their studies.

Furthermore, studies conducted by Nazma *et al*. (2021), Yau *et al*. (2020), Yunusa *et al*. (2017), Okur *et al*. (2014), Gupta *et al*. (2013), Hammad (2012) and Raza *et al*. (2011) reported a positive correlation between renal size and body mass index (BMI) while the rest of the studies did not perform correlational analysis between renal size and anthropometric parameters which serves as the weakness of their study.

CONCLUSION
This review showed only one article out of fifteen used a probability sampling method and only two articles used a large sample size. Eight of the reviewed articles did not perform

creatinine clearance test before recruitment of their participants. Similar studies should be replicated for each population and the use of ideal sampling technique, large sample size and relevant laboratory investigations should be considered before recruitment of participants.

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