

Sonographic Measurement of Renal Dimensions in Adults and its Correlates

Zeb Saeed ¹, Waseem Mirza ², Raza Sayani ³, Adil Sheikh ⁴, Iffat Yazdani ⁵, Syed Ather Hussain ^{6*}

¹ Medical Student, Aga Khan University, Karachi, Pakistan

² Department of Radiology, Aga Khan University, Karachi, Pakistan

³ Department of Radiology, Aga Khan University, Karachi, Pakistan

⁴ Medical Student, Aga Khan University, Karachi, Pakistan

⁵ Department of Nephrology, Aga Khan University Hospital, Karachi, Pakistan

⁶ Department of Nephrology, Aga Khan University Hospital, Karachi, Pakistan

* **Corresponding Author:** Syed Ather Hussain;

Section Head of Nephrology, Associate Professor & Consultant Nephrologist

Aga Khan University Hospital, Pakistan

Phone: 922134864572 | Fax No: 922134934294 | Email: ather.hussain@aku.edu

Abstract

Background: Unilateral or bilateral changes in kidney size are manifested by many renal diseases and to recognize these anatomical deviations, it is important to have standard sonographic measurements for appropriate comparison. Our primary aim was to determine a normal range of values for renal dimensions in our asymptomatic adult population and to correlate renal length with measures of renal function as a secondary objective.

Methods: A cross-sectional population survey was conducted at two spaced-out densely populated areas in the city of Karachi, Pakistan. Ultrasound was performed and blood samples collected from 225 healthy individuals with no known renal pathology and with normal calculated GFR.

Results: Mean kidney lengths were 9.85cm (95% CI: 9.74-9.95 cm) on right side and 10.0 cm (9.85-10.1 cm) on left. The mean width was 4.61cm (95%CI: 4.53 – 4.68cm), cortical thickness 1.46 cm (CI 1.43-1.49cm) with estimated average kidney volume 35.7 cm³ (CI: 34.1-36.5 cm³). Males had larger kidney sizes than females (p < 0.001); age however was only associated with a decrease in renal length after ages 70 and above.(p=0.001) Renal length best correlated with body weight (correlation coefficient 0.384) .eGFR, representative of renal function also positively correlated with renal length (Coefficient 0.415). A multivariate analysis showed male gender (OR 1.60), age (OR 0.89), weight (OR 1.02) and height (OR 7.77) to be significant independent predictors of renal length.

Conclusion: We established the normal values for renal dimensions in our adult population. Our study signifies the potential of ultrasound as a useful tool for diagnostic and follow-up purposes of kidney-associated diseases. By extending this research and including data from other parts of the country; we can formulate a gender and age specific nomogram for kidney dimensions for adequate comparison in evaluation of kidney diseases.

Key words: ultrasound, kidney size, epidemiology, demographics, anatomy

Running title: *Ultrasound Renal Dimensions in Adults*

Introduction

Unilateral or bilateral changes in kidney size and/or morphology are manifested by many renal pathologies and are important parameters in clinical evaluation and management of patients with kidney diseases. Renal ultrasonography provides a safe, reliable, widely accessible and affordable way of imaging the kidneys. The modality is currently in use for the evaluation and follow-up of patients with congenital anomalies of the kidney, renal cystic diseases, kidney stones, renal arterial stenosis, recurrent urinary tract infections, vesicoureteral reflux, chronic kidney disease, kidney tumors and kidney transplants, both in the pediatric and adult population.¹⁻⁴ Being quicker, convenient and more accurate at visualizing the kidney anatomy and estimating its dimensions, it has largely replaced conventional radiography as an important tool in clinical evaluation of kidney diseases.⁵

Estimation of renal size by sonography can be performed by measuring renal length, renal volume, cortical volume or thickness. The most accurate of these is provided by the renal volume.^{6,7} However due to its low inter-observer variation and better reproducibility, renal length; as measured in the longitudinal plane parallel to the longest renal axis, is the most clinically useful parameter.⁶ Renal length as well as renal cortical thickness has been closely related to creatinine clearance in patients with chronic kidney disease.⁸ Similarly, medullary parenchymal thickness is pivotal for grading hydronephrosis especially in the pediatric age group and ultrasound remains the mainstay for diagnosis of hydronephrosis in adults.⁹

To recognize anatomical deviations in individuals with renal diseases, it is important to have a set of standard sonographic measurements for appropriate comparison. Extensive data on these biometric measurements in infants and children has been published in literature; however there is paucity of adult statistics on renal measurements. Among the first such studies conducted on fifty-two patients with normal renal function was by Brandt et.al in 1982.¹⁰ Since then countries with multiple ethnic backgrounds have sought after finding the average normal sonographic renal length in their populations, looking for potential associations with age, height, sex and body weight of individuals.^{11,12} Despite having a large burden of kidney diseases with the incidence of end-stage renal disease

(ESRD) estimated to be about 100 patients/million population, there is dearth of normal data on renal anatomy in the Pakistani population.¹³

Our primary aim was to establish a normal range of values for kidney length and volume in our adult population with normal renal function, recognizing individual variations observed with anthropometric parameters of subjects. Renal length was correlated with measures of renal function in this sample of individuals as a secondary objective.

Subjects and Methods

A cross sectional, descriptive study was conducted in the urban metropolis of Karachi, Pakistan during the period of January 2011. The survey was performed by establishing medical camps ,in a time span of three weeks, at two city shopping centers-Defence Sunday Market and Gulshan-e-Iqbal Friday market. These centers were identified due to their central location and variability of attendees from various socioeconomic backgrounds. Information of camps was disseminated in the vicinity for verbally motivating people and pamphlets briefly describing study objectives were distributed in the area.

Data Collection

The initial stage of assessment involved administration of an interview based questionnaire conducted by two medical students who were trained and briefed prior to taking these interviews, for the purpose of consistency in data collection. The questionnaire recorded information on age, level of education, monthly gross income, and co-morbidity status. All individuals with any known renal pathology including congenital kidney anomalies, kidney stones, chronic kidney disease, or malignancy were excluded. The physical assessment performed by the same interviewer included a blood pressure check and anthropometric measurements with a balance scale and stadiometre. Venous blood samples of 5 cm³ were collected by two expert phlebotomists to measure serum creatinine which was measured by the Jaffe method.

All renal ultrasound scans were done by using a single real-time ultrasound scanner using a 3.5-MHz curvilinear probe in supine and oblique positions with deep inspiration. Measurements were done in longitudinal as well as axial image at the level of hilum in static image. Additional findings like renal cyst, stone or hydronephrosis were also recorded. Hard copy images were taken for documentation. All examinations were performed by two credentialed consultant radiologists. In order to reduce inter and intra-observer variability, hard copy images were reviewed by a third sonographer to validate the measured renal dimensions.

Renal estimated Glomerular Filtration Rate (eGFR) in ml/min per1.73m² was calculated by the four variable MDRD formula using the investigated level of serum creatinine and

patient anthropometric measurements as taken during the physical assessment where $GFR (mL/min/1.73 m^2) = 186 \times (Cr)^{-1.154} \times (Age)^{-0.203} \times (0.742 \text{ if female})$ where Cr is serum creatinine.

CKD stages were defined, following the National Kidney Foundation clinical practice guidelines.

Body Mass Index (BMI) was calculated as $BMI (kg/m^2) = \text{weight (kg)} / \text{height (m)}^2$

Total body surface area was calculated using the Dubois & Dubois formula, $\text{Total body area (m}^2) = \text{weight (kg)}^{0.425} \times \text{height (cm)}^{0.725} \times 0.007184$.¹⁴

Renal volume (cm^3) was calculated as : $0.523 \times \text{length (cm)} \times \text{width (cm)} \times \text{depth (cm)}$.¹⁵

Absolute Renal Size (cm^3) was calculated as: $\text{length (cm)} \times \text{width (cm)} \times \text{depth (cm)}$.

Data Entry and Analysis

The data was entered into a pre-designed data base by two individuals separately using Epi Data Version 3.6.1. Both data sets were then checked to detect any errors in data entry and the data was analyzed using Statistical Package for Social Sciences version 17 (SPSS v.17.0®).

Descriptive statistics were used to look at the spread of data with respect to the age, education and economic status. Proportion & percentages were computed for categorical variables. Tests for normality, including the Shapiro Wilk test, were used to check for normality assumption for continuous variables. With symmetric distribution of the outcome variable of renal sonographic dimensions, mean and corresponding 95% confidence interval for continuous variables was computed. The Pearson correlation was used to highlight any significant correlations between renal length and anthropometric parameters of subjects. Parametric tests of independent sample t-test and ANOVA were used to find any significant difference in renal dimensions between different sexes and age groups. These statistical tests were also used to assess for difference in renal dimensions between healthy individuals and those with $GFR < 60$ (excluded initially from the study). A multivariate regression model was applied to identify various factors predicting renal length in our study population. A p-value of < 0.05 was taken to be statistically significant.

Ethics Statement

Study methodology was approved by the Ethical review committee of the Aga Khan University (ERC protocol-1628) while study grant was approved by the University Research Council (EGC-020910 MC-P). Written consent was sorted prior to participation from respondents by means of an informed consent. Participants were informed regarding their laboratory and ultrasound results with appropriate follow up recommendations by means of postal service.

Results

Initial screening for eligibility into the study was done on 255 individuals who approached our study centers. Of these, 2 volunteers were excluded due to pre-existing diagnosed chronic kidney disease and 2 due to prior history of recurrent kidney stones. Ultrasound was thus performed on 251 healthy individuals with no known renal disease. Based on the sonographic findings, nine individuals were excluded for the following reasons: solitary cysts larger than 2 cm in diameter (four cases), hydronephrosis (two cases), unilateral kidney (two cases) and a hypoechoic kidney mass (one case). eGFR was calculated for all these 242 individuals using their serum creatinine values obtained after which 17 individuals were further excluded due to renal impairment with eGFR <60. Thus, the analyses of normal sonographic renal measurements included 225 subjects (147 males and 78 females) without renal impairment who were 30–80 years old [mean \pm standard deviation (SD), 47.0 \pm 10.1 years]. The mean height was 174 \pm 6.6 cm (range, 155–190cm) for men and 161 \pm 7.0 cm (range, 150–174 cm) for women. The respondents came from diverse educational backgrounds with 34.4% holding a graduate degree and 14.7% having no formal education at all. The mean gross monthly income was USD \$379 (range \$ 11-833). A quarter of our study sample had hypertension and 13.3% were diabetics. The demographic data of our study population has been summarized in Table 1 and a flow sheet demonstrating our selection method in Diagram Flow Sheet.

The mean kidney length was 9.90 cm (95% CI: 9.80-10.0 cm). Mean kidney lengths were 9.85 cm (95% CI: 9.74 - 9.95cm) on the right side and 10.00 cm (CI 9.89-10.13 cm) on the left side ($p=0.028$). The mean kidney width was 4.61cm (95%CI:4.53 – 4.68cm), cortical thickness 1.46 cm (CI 1.43-1.49cm) making the estimated average kidney size and volume to be 68.3 cm³ (CI: 65.3- 69.9 cm³) and 35.7 cm³ (CI:34.1-36.5) respectively. Table 2 gives renal lengths and widths by age, sex, and side.

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 cm³; 60.1 cm³ $p<0.001$), due to both larger width and parenchymal thickness. Renal length and renal volume showed only slight differences between volunteers 30 to 69 years old and were distinctly decreased in volunteers 70 years old and above ($p\leq 0.01$). All renal measurements were significantly reduced in individuals over 70. (Figure 1)

Renal measurements were correlated with the subjects' height, weight, total body area, and body mass index using the Pearson's correlation. The strongest correlation with renal volume was found for total body surface area; the correlation coefficient was 0.576 ($p<0.001$). Average renal length positively correlated best with body weight; the correlation coefficient was 0.384 ($p<0.001$). (Figures 2, 3) To illustrate the independent effects of sex, age, height, weight, history of diabetes mellitus, and hypertension on renal length, a multivariate regression was applied. All the above factors except hypertension and diabetes had independent significant impact on renal length; and being young, male and of a bigger body habitus predicted to having the largest kidney size. (Table 3)

Nearly one fourth of our study sample had pre-existing hypertension and/or diabetes and this subset of the population was compared with the remaining study sample for possible differences. It was observed that both hypertensives and diabetics had larger kidney sizes than the healthy subset; only diabetes was associated with statistically significant increase in kidney length of 10.2 ± 0.76 cm when compared to 9.90 ± 0.80 cm of the remaining individuals ($p = 0.019$).

Renal dimensions were correlated with eGFR. The mean serum creatinine was 0.78 ± 0.17 mg/dL and mean eGFR was 119 ± 34 ml/min/1.73m². eGFR showed a significant ($p < 0.001$) positive correlation with kidney length; correlation coefficient of 0.415 (Figure 4). Renal width and parenchyma thickness failed to show significant correlation with eGFR as calculated from the serum creatinine values. Since we had the sonographic findings of the excluded individuals with renal impairment such as eGFR < 60 ml/min/1.73m², we compared those with rest of our study population. The average kidney length of these 17 individuals was 9.1 ± 0.8 cm which was significantly lesser than our study population ($p < 0.001$). Other kidney dimensions were also diminished with average kidney width at 4.50 ± 0.71 cm and parenchymal thickness at 1.38 ± 0.24 cm; however, this difference was not statistically significant.

Discussion

The average kidney size in Pakistani population was estimated by Buchholz et.al in 2000 by determining sonographic kidney measurements in 194 patients without evident renal disease.¹⁶ However, it was a hospital-based study conducted on patients undergoing diagnostic abdominal ultrasound which introduced a major selection bias. Our study looked at healthy volunteers recruited from the community itself. Catering to a diverse population and being the most populous city, Karachi seemed ideal for conducting our study. We targeted those places in the city which are frequented by men and women of all ages, different ethnicities, socio-economic status and educational accomplishments to get an adequate representation of our study population; our demographic data reflecting the diversity which we were hoping to achieve. By further calculating the estimated glomerular filtration rate and excluding those with renal impairment, we tried to have a true representation for establishing normal renal dimensions in our adult population.

The average renal length observed by Buccholz et al was 10.4 ± 0.8 cm and is probably a reflection of the relatively small body size of South East Asians. Autopsy findings of renal biometry in Indian population yielded comparable results with kidney length ranging between 9.1-9.9cm.¹⁷ Our average kidney length was similar to above findings. In contrast, Nigerians have been reported to have larger kidney lengths averaging 10.3 – 10.6 cm, with likewise results seen in the Mexican population, a depiction of different body habitus.^{11,12} Kidney length was normally distributed; the left kidney was significantly larger than the right, which is consistent with medical knowledge and previous studies in literature.

Presence of liver on right side with less spatial growth of the corresponding kidney and greater blood flow to the left kidney on account of a shorter left renal artery are the plausible explanations hypothesized.¹⁸

The finding that males have larger kidney sizes was consistent with most studies; however surprisingly there were no gender-related differences in renal length.^{11,19} Gender differences in renal size can be accounted for by the disparity in body sizes as height and weight were independent predictors of renal size. Body surface area was the most sensitive indicator of renal size in our study, a finding which agrees both with literature and logic since organ size is unquestionably related to body size.¹⁸ Similarly renal length, considered the single most important renal parameter significantly correlated with both body weight and height; weight however showed a stronger correlation. Both these variables were identified as independent predictors of renal length in our multivariate model. We infer from these findings that body habitus and built is a major predictor of renal size in healthy adults; some parameters may have greater impact than others but it is the amalgam of these anthropometric measurements which determines kidney size in a healthy individual.

Age also has an essential bearing as both physiology and anatomy of the human body alters with age. It is well established that by 70 years, as much as 30 -50% of cortical glomeruli atrophy; manifested by a progressive loss in renal mass.²⁰ While renal dimensions remained essentially unchanged in our study group between the decades of 30 to 60 years, a statistically significant decrease in all kidney measurements was observed in individuals over 70. This seems to suggest fairly rapid and accelerated decline in renal dimensions after 70 years of age with otherwise relative homogeneity throughout adult life. Post mortem studies have shown that the weight of kidney is up to 19% lower in elderly compared with young adults.²¹ Different mechanisms including cellular senescence, glomerulosclerosis, tubulointerstitial fibrosis, vascular collapse and thickening, oxidative stress and alterations in cytokines and growth factors have been implicated in literature.^{22,23}

Kidney is one of the main organs affected by both hypertension and diabetes. A quarter of our population was hypertensive and had larger kidney sizes albeit the difference was not a significant one. Further analyses showed that these individuals had a statistically significant higher mean BMI of 29.8 ($p=0.002$) which may have accounted for the above disparity in kidney size; a finding consistent with Egberongbe, A.A., et al where the authors looked at effect on kidney volume in individuals with essential hypertension and no underlying kidney disease.²⁴ Larger body habitus with mean BMI of 28.9 in our diabetic population as compared to mean BMI 27.7 in healthy individuals could also, at least partially, explain for larger kidney dimensions in this subgroup of population. Abnormal glucose tolerance in itself has been associated with larger kidneys in literature; however, whether it does so in the setting of normal renal function is not established.²⁵ Our multivariate analysis failed to show either hypertension or diabetes as significant predictors of renal length which suggests increased weight and BMI to be confounding factors for the observed effect on univariate analyses.

As a secondary objective, we attempted to relate renal dimensions with its physiology as the major excretory organ. A significant positive correlation was observed to exist between kidney length and estimated GFR suggesting kidney dimensions to be reflective of functional renal capacity. Individuals with creatinine clearance less than 60 had 9% smaller kidney length and diminished volume signifying underlying total nephron loss. Studies comparing functional biometry in healthy individuals with those suffering from chronic kidney disease (CKD) as well as those looking at creatinine clearance among CKD patients have advocated the use of renal volume as the most sensitive marker to assess decline in renal function.^{3,8} However, importantly authors have suggested that in those with normal renal function, renal length supersedes all renal measurements, showing a positive correlation with renal function; consistent with the findings of our study.²⁶

Though MRI-determined kidney length and volume are superior to sonographically determined kidney length but the associated high cost restricts its use in a resource limited country like ours.⁷ Hence, knowing ultrasonic findings of normal renal parameters for respective population would help in evaluation and follow up of patients with chronic kidney disease.

Seven percent of the respondents in our initial study sample, with no history of kidney disease, were found to have moderate renal impairment with $GFR < 60\text{ml}/\text{min}/1.73\text{m}^2$ which corresponds to CKD stage 3. This finding in itself is very surprising and highlights possible underestimation of the incidence and prevalence of CKD among adults in our part of the world.

Limitations

Though we tried to target the more frequented areas of the city, since we recruited people from among those who were visiting the market places where our study centers were set up, this may have lead to inevitable exclusion of the less mobile and house-bound citizens. Our applied method of convenience sampling may also reduce the generalize-ability of results since the difference between demographics and co-morbidity status of responders and non responders is not known. We were able to exclude all those with renal impairment when analyzing for normal renal biometry; however, a significant proportion of our sample had diabetes and/or hypertension which could be potentially affecting our results which aimed to establish renal dimensions in healthy adults. Other markers for kidney damage such as microalbuminuria could also have been obtained to make sure none of the diabetics/hypertensives had any other evidence of underlying kidney injury. Lastly, increasing sample size with inclusion of more pockets of population including rural population would help in generalize ability.

Conclusion

We established the normal values of renal dimensions in our adult population. Important influencing factors were side, gender, age, height, weight and body area; left kidney, male gender, a larger body habitus and age <70 years being strong positive predictors of renal size. Positive correlation existed between renal length and creatinine clearance, predictive of renal functional status. Our study signifies the potential of ultrasound as a useful tool for diagnostic and follow-up purposes of kidney diseases. By extending this research and including data from other parts of the country; we can formulate a gender and age specific nomogram for kidney dimensions for adequate comparison in evaluation of kidney diseases.

Disclosure

Dr. Syed Hussain received an independent educational grant from by Glaxo Smith Kline® co.ltd which only covered the laboratory, logistics and equipment costs incurred. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript and the authors declare no conflict of interest.

Acknowledgement

We want to thank Ms. Safia Awan for helping us with the statistical analysis, Ms. Zunera Tariq and Ms.Salima Kherani for volunteering the data collection.

References

1. Wong IY, Copp HL, Clark CJ, Wu HY, Shortliffe LD. Quantitative ultrasound renal parenchymal area correlates with renal volume and identifies reflux nephropathy. *J Urol.* 2009; 182: 1683-7.
2. Troell S, Berg U, Johansson B, Wikstad I. Ultrasonographic renal parenchymal volume related to kidney function and renal parenchymal area in children with recurrent urinary tract infections and asymptomatic bacteriuria. *Acta Radiol Diagn (Stockh).* 1984; 25: 411-6.
3. Buturovic-Ponikvar J, Visnar-Perovic A. Ultrasonography in chronic renal failure. *Eur J Radiol.* 2003; 46: 115-22.
4. Gheissari A. The place of ultrasound in renal medicine. *Saudi J Kidney Dis Transpl.* 2006; 17: 540-8.

5. Ninan VT, Koshi KT, Niyamthullah MM, Jacob CK, Gopalakrishnan G, Pandey AP, *et al.* A comparative study of methods of estimating renal size in normal adults. *Nephrol Dial Transplant.* 1990; 5: 851-4.
6. Emamian SA, Nielsen MB, Pedersen JF. Intraobserver and interobserver variations in sonographic measurements of kidney size in adult volunteers. A comparison of linear measurements and volumetric estimates. *Acta Radiol.* 1995; 36: 399-401.
7. Cheong B, Muthupillai R, Rubin MF, Flamm SD. Normal values for renal length and volume as measured by magnetic resonance imaging. *Clin J Am Soc Nephrol.* 2007; 2: 38-45.
8. Sanusi AA, Arogundade FA, Famurewa OC, Akintomide AO, Soyinka FO, Ojo OE, *et al.* Relationship of ultrasonographically determined kidney volume with measured GFR, calculated creatinine clearance and other parameters in chronic kidney disease (CKD). *Nephrology Dialysis Transplantation.* 2009; 24: 1690-94.
9. Webb JA. Ultrasonography in the diagnosis of renal obstruction. *BMJ.* 1990; 301: 944-6.
10. Brandt TD, Neiman HL, Dragowski MJ, Bulawa W, Claykamp G. Ultrasound assessment of normal renal dimensions. *J Ultrasound Med.* 1982; 1: 49-52.
11. Okoye IJ, Agwu KK, Idigo FU. Normal sonographic renal length in adult southeast Nigerians. *Afr J Med Med Sci.* 2005; 34: 129-31.
12. Oyuela-Carrasco J, Rodriguez-Castellanos F, Kimura E, Delgado-Hernandez R, Herrera-Felix JP. [Renal length measured by ultrasound in adult mexican population]. *Nefrologia.* 2009; 29: 30-4.
13. Ali Jaffar Naqvi S. Nephrology services in Pakistan. *Nephrology Dialysis Transplantation.* 2000; 15: 769-71.
14. Dubois D DE. A formula to estimate the approximate surface area if height and weight be known. *Arch Intern Med* 1916; 17: 863-71.
15. Dinkel E, Ertel M, Dittrich M, Peters H, Berres M, Schulte-Wissermann H. Kidney size in childhood. Sonographical growth charts for kidney length and volume. *Pediatr Radiol.* 1985; 15: 38-43.
16. 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: 12-6.
17. Sahni D, Jit I, Sodhi L. Weight and measurements of kidneys in northwest Indian adults. *Am J Hum Biol.* 2001; 13: 726-32.

18. Emamian SA, Nielsen MB, Pedersen JF, Ytte L. Kidney dimensions at sonography: correlation with age, sex, and habitus in 665 adult volunteers. *Am J Roentgenol.* 1993; 160: 83-86.
19. Wang F, Cheok SP, Kuan BB. Renal size in healthy Malaysian adults by ultrasonography. *Med J Malaysia.* 1989; 44: 45-51.
20. Melk A, Halloran PF. Cell senescence and its implications for nephrology. *J Am Soc Nephrol.* 2001; 12: 385-93.
21. Wald H. The weight of normal adult human kidneys and its variability. *Arch Pathol Lab Med.* 1937; 23: 493-500.
22. Fliser D, Ritz E. Renal haemodynamics in the elderly. *Nephrol Dial Transplant.* 1996; 11 Suppl 9: 2-8.
23. Anderson S, Brenner BM. Effects of aging on the renal glomerulus. *Am J Med.* 1986; 80: 435-42.
24. Egberongbe AA, Adetiloye VA, Adeyinka AO, Afolabi OT, Akintomide AO, Ayoola OO. Evaluation of renal volume by ultrasonography in patients with essential hypertension in Ile-Ife, south western Nigeria. *Libyan J Med.* 5.
25. Paivansalo MJ, Merikanto J, Savolainen MJ, Lilja M, Rantala AO, Kauma H, *et al.* Effect of hypertension, diabetes and other cardiovascular risk factors on kidney size in middle-aged adults. *Clin Nephrol.* 1998; 50: 161-8.
26. 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: 206-9.

Table 1: Demographic data and Clinical Features of the Study Population

	N = 225
Sex - Males, % (n)	65.3 (147)
Females, % (n)	34.7 (78)
Age (yrs) - mean, range	47, (30-80)
Education – Illiterate	14.7 (33)
Primary (less than grade 10)	12.9 (29)
Undergraduates	37.8 (85)
Graduates and above	34.4 (78)
Income (Pakistani Rupee) mean, range	31,867(1000-700000)
Height (m), mean, range	1.70 (1.50-1.90)
Weight (kg), mean, range	76.31 (40-118)
BMI (kg/m²), mean, range	26.41 (14.7-46.8)
Co-morbidities: -- Diabetes Mellitus, % (n)	13.3 (30)
- Hypertension % (n)	24.0 (54)
- Hepatitis B/C, % (n)	2.2 (5)

Table 2: Renal measurements in 225 volunteers with normal eGFR. Mean (with 95% confidence intervals)

Measurements	Age (yrs)					Sex		All
	30-39	40-49	50-59	60-69	70 & above	Males	Females	
Subjects- males		38	40	11	12	147	0	147
females	45	21	22	15	3	0	78	78
	17							
Right Length (cm)	9.94 (9.7-10.1)	9.83 (9.66-10.0)	9.92 (9.71-10.1)	9.82 (9.55-10.1)	9.22 (8.81-9.64)	9.82 (9.69-9.96)	9.88 (9.72-10.0)	9.85 (9.74-9.95)
Left Length (cm)	10.0 (9.81-10.3)	10.3 (10.0-10.5)	9.99 (9.78-10.2)	9.85 (9.50-10.2)	9.13 (8.69-9.57)	10.1 (9.90-10.2)	9.92 (9.74-10.1)	10.0 (9.85-10.1)
Right Width (cm)	4.42 (4.24-4.61)	4.46 (4.28-4.64)	4.37 (4.21-4.53)	4.37 (4.07-4.67)	4.03 (3.69-4.38)	4.52 (4.41-4.63)	4.13 (3.98-4.29)	4.39 (4.30- 4.48)
Left Width (cm)	4.96 (4.80-5.11)	4.89 (4.71-5.07)	4.75 (4.59-4.91)	4.74 (4.48-5.01)	4.35 (4.06-4.64)	5.03 (4.93-5.13)	4.42 (4.29-4.56)	4.82 (4.73- 4.90)
Right renal volume (cm ³)	33.4 (31.1-35.8)	32.1 (29.5-34.7)	33.3 (30.6-36.0)	32.2 (28.3-36.1)	26.1 (22.6-29.7)	33.6 (31.9-35.2)	30.2 (28.1-32.3)	32.4 (31.1-33.7)
Left renal volume (cm ³)	41.4 (38.4-44.2)	39.9 (36.9-42.9)	39.0 (35.9-42.0)	36.5 (31.5-41.5)	29.7 (24.6-34.8)	41.8 (39.8-43.8)	33.6 (31.5-35.6)	39.0 (37.4-40.5)

Table 3: Multivariate regression showing predictors of average renal length

	B	SE (β)	Odds ratio	P-value
(Constant)	5.653	1.381		0.000*
Sex (male)	0.475	0.144	1.60	0.001*
Age	-0.110	0.004	0.89	0.011*
Weight	0.022	0.004	1.02	0.000*
Height	2.047	0.768	7.77	0.008*
Hypertension	0.017	0.119	1.18	0.889
Diabetes	0.311	0.126	1.36	0.07

* Indicates statistically significant value

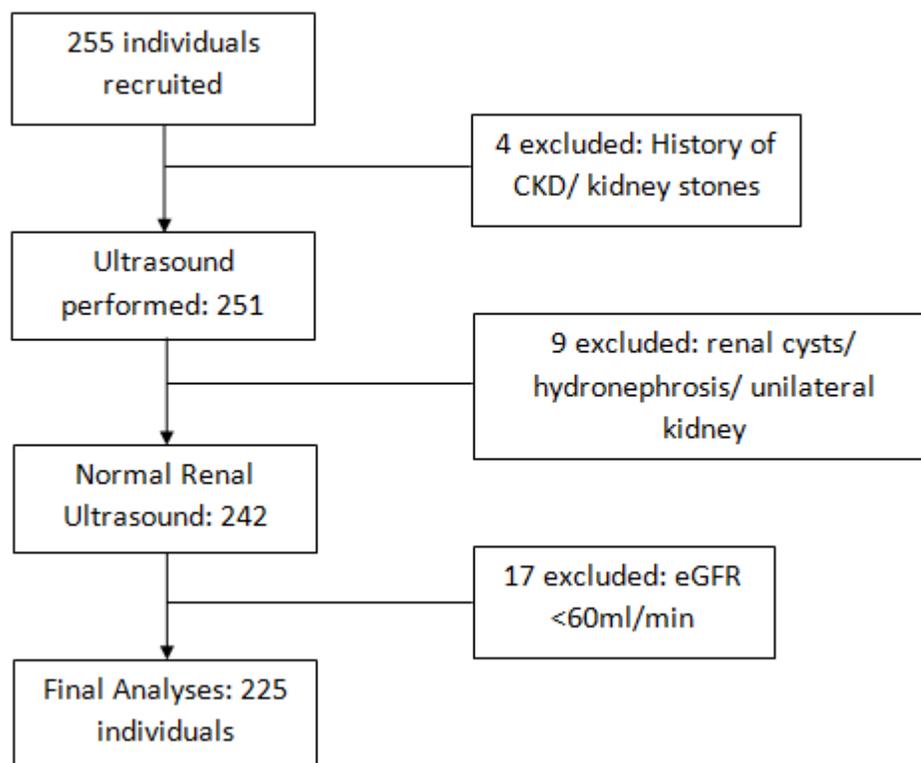


Diagram Flow Sheet: Flow sheet to demonstrate selection methods of study sample

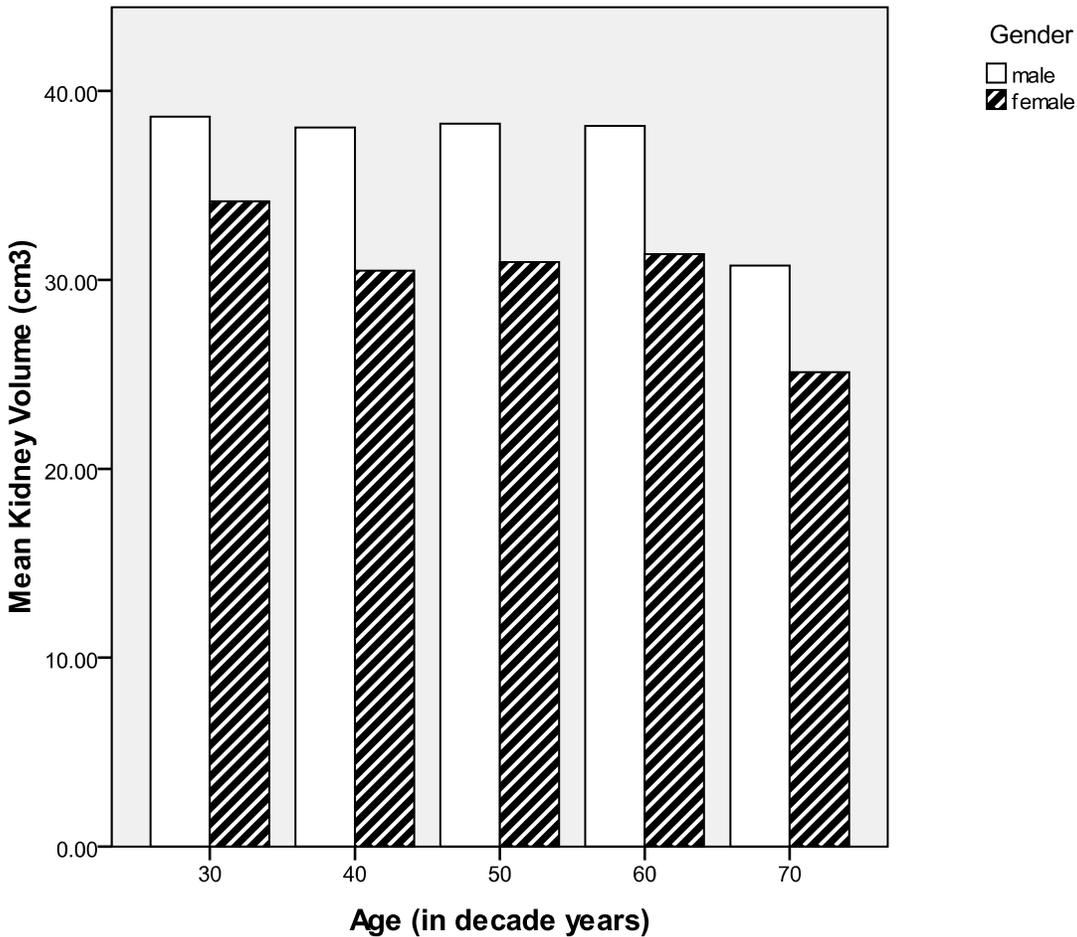


Figure 1: Change in Average Kidney Volume in Both Sexes with Age

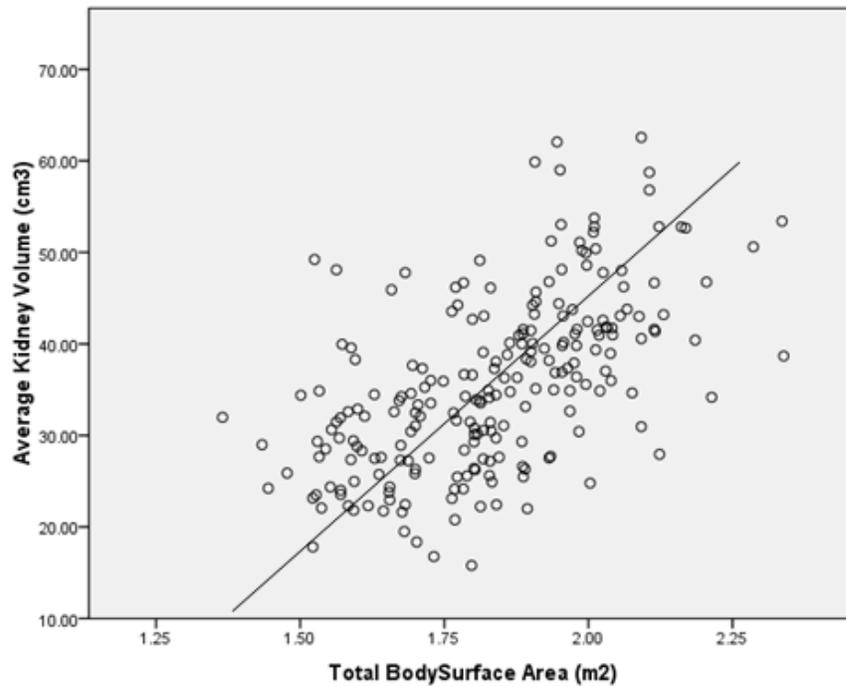


Figure 2: Scatter- Dot Graph showing correlation between renal volume (cm³) and total body area (m²)

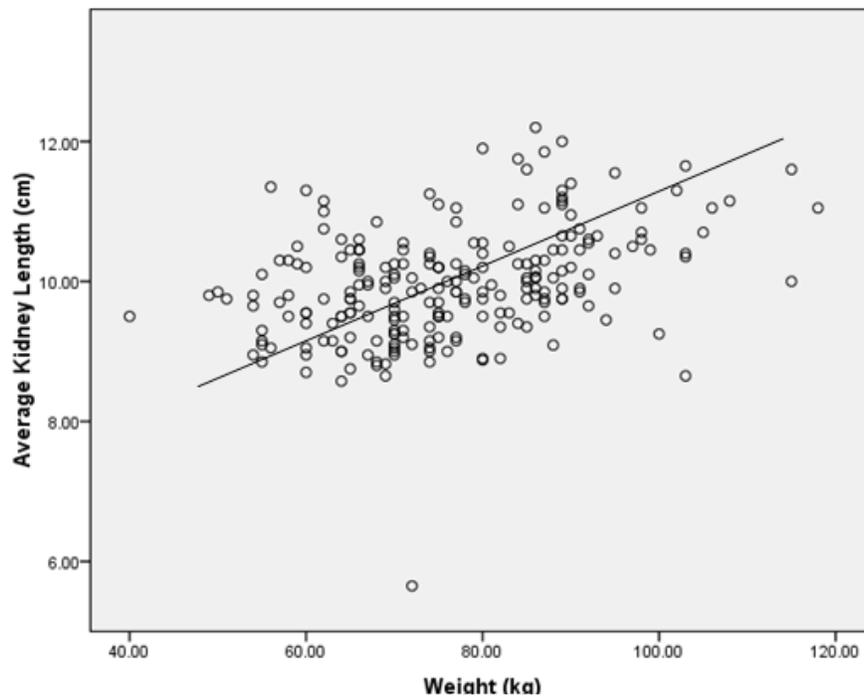


Figure 3: Scatter- Dot Graph showing correlation between Average Renal Length (cm) and Body weight (kg)

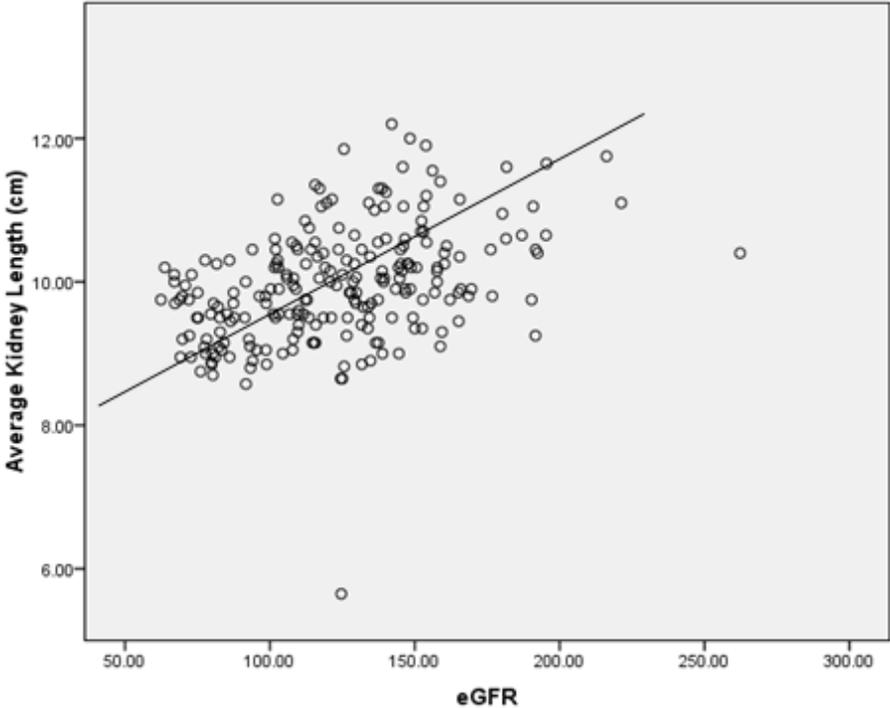


Figure 4: Scatter- Dot Graph showing correlation between Average Renal Length (cm) and eGFR