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Investigating Renal Volume Changes in Type 2 Diabetes Mellitus Using Sonography

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Abstract: Diabetic nephropathy (DN) is the leading cause of end-stage renal disease (ESRD) worldwide, and it is estimated that more than 20% of type 2 diabetic patients may develop ESRD during their lifetime. The study is a prospective ultrasonography evaluation of kidney volumes in 228 adults with type 2 diabetes and 228 normal non-diabetic adult controls carried out at Aminu Kano Teaching Hospital, Nigeria, from June 2015 to May 2016. The data were analyzed using computer-based SPSS version 23 software for Windows.

The 228 patients with type 2 diabetes included 120 (53%) females and 108 (47%) males with a mean age of 47.7 years (range 29–67 years). The 228 normal control participants included 108 (47%) females and 120 (53%) males with a mean age of 46.9 years (range 28–69 years). The age difference between the study and control groups was not statistically significant (p=0.43). The mean renal volumes were significantly higher in the study group (114.10 ± 3.97 ml) compared to the control group (95.34 ± 2.59 ml); this difference was statistically significant (p=0.001). The mean renal volumes were higher in males compared to females in both the study group and the control group (p=0.001). The left mean renal volumes were higher than those of the right in both the study and the control groups (p=0.001). However, there was no significant correlation between renal volume and BMI (p=0.086).

The mean renal volume is significantly higher among diabetics compared to normal controls. Patients with type 2 diabetes mellitus have no significant correlation between renal volume and BMI.

Keywords: Type 2 diabetes mellitus, BMI, renal volume.

Introduction

Type 2 diabetes mellitus (T2DM) is a metabolic disorder characterized by chronic hyperglycemia (elevated blood glucose levels) primarily due to insulin resistance and a relative deficiency in insulin production. This contrasts with type 1 diabetes, which results from an absolute insulin deficiency due to autoimmune destruction of pancreatic islet cells. Classic symptoms of T2DM include excessive thirst (polydipsia), frequent urination (polyuria), and persistent hunger (polyphagia).

T2DM accounts for approximately 90% of all diabetes cases, with the remaining 10% largely due to type 1 diabetes and gestational diabetes. The condition is strongly linked to both genetic predisposition and lifestyle factors. Key contributors include obesity (body mass index > 30 kg/m^2), physical inactivity, sedentary behavior, psychological stress, and urbanization. Obesity alone is responsible for a substantial proportion of cases across populations—30% in Chinese and Japanese individuals, 60–80% in people of European and African descent, and nearly 100% in Pima Indians and Pacific Islanders.

Dietary habits also play a significant role in the development of T2DM. High intake of sugar-sweetened beverages increases the risk, whereas consumption of polyunsaturated and monounsaturated fats is protective, in contrast to harmful trans fats and certain dairy fats. A sedentary lifestyle contributes to approximately 7% of T2DM cases.

Diagnosis of diabetes mellitus involves persistent or recurrent hyperglycemia and can be confirmed by any of the following criteria:

- ✓ Fasting plasma glucose ≥ 7.0 mmol/L (126 mg/dL)
- ✓ Plasma glucose ≥ 11.1 mmol/L (200 mg/dL) two hours after a 75g oral glucose tolerance test
- ✓ Random plasma glucose ≥ 11.1 mmol/L (200 mg/dL) with hyperglycemic symptoms
- ✓ Glycated hemoglobin (HbA1C) ≥ 6.5%

In sub-Saharan Africa, the prevalence and burden of T2DM are rapidly increasing, posing a significant public health and socioeconomic challenge, especially in the context of limited healthcare resources. A high proportion of undiagnosed cases further exacerbates the risk of long-term complications. Among these, **diabetic nephropathy (DN)** has emerged as a major complication, becoming a leading cause of end-stage renal disease (ESRD). In elderly populations, DN accounts for at least 46% of chronic kidney disease cases.

DN is a clinical syndrome defined by persistent albuminuria, progressive decline in glomerular filtration rate (GFR), elevated blood pressure, and increased cardiovascular risk. The pathophysiology begins with glomerular hyperfiltration, progressing to thickening of the glomerular basement membrane—the earliest detectable change—followed by mesangial expansion and nodular sclerosis. As the condition advances, the kidneys may excrete abnormal amounts of albumin in the urine (albuminuria), detectable through routine urinalysis.

Although hyperfiltration is a key early marker, it is not practical for routine clinical use due to measurement difficulties. Renal volume assessment, however, may serve as a useful alternative for early detection of DN. Various imaging modalities have been used for renal volume estimation, each with inherent prediction errors. Currently, **ultrasound** is the preferred imaging technique due to its simplicity, non-invasiveness, affordability, wide availability, and lack of ionizing radiation or contrast agents. Despite its limitations—such as underestimating renal volume compared to CT and MRI—ultrasound remains the most commonly employed method, especially where repeated assessments are necessary.

Ultrasonography plays a crucial role in evaluating diabetic patients, not only in assessing the severity of nephropathy but also in excluding other renal conditions like chronic glomerulonephritis and ischemic nephropathy. Type 2 diabetes is the leading global cause of ESRD, particularly in patients with long-standing disease.

Method Study Design

This is a prospective hospital-based cross-sectional study that determines the renal volume in 228 patients with type 2 diabetes (study group) as well as 228 normal non-diabetic adults (control group) aged between 18 to 69 years at Aminu Kano Teaching Hospital between June 2015 and May 2016.

Study population

Subjects recruited in this study included adults aged between 18 and 69 years of both sexes seen at the diabetic clinic of Aminu Kano Teaching Hospital (AKTH), with the diagnosis of type 2 diabetes without any known background renal parenchymal pathology. The control group constituted matched healthy non-diabetic individuals referred to the radiology department of AKTH for investigations of non-renal conditions.[14]

Inclusion criteria for the study group

1. Adults with laboratory-confirmed type 2 diabetes
2. Adults with type 2 diabetes aged 18 to 69 years (The upper limit of 69 years was set to limit bias that may arise from the normal ageing process)
3. Those who willingly consented to participate in the study

Exclusion criteria for the study group

1. Individuals less than 18 years and individuals who are 70 years and above
2. Patients with type 2 diabetes who do not give informed consent for the study
3. Individuals with established congenital disease of the renal system such as

a. renal ectopia

b. multi-cystic dysplastic kidneys

c. polycystic kidney diseases etc

4. Individuals with any of the following known causes of kidney disease or established kidney disease unrelated to diabetes

i. Hypertension

ii. iii. Glomerulonephritis Pyelonephritis

iv. Obstructive renal diseases such as pelvic ureteric junction obstruction, obstructive ureteric calculus, obstruction, etc.

5. Patient with bladder intra-abdominal outlet masses or malignancies with obstructive renal effects Inclusion criteria for the control group Healthy adults aged 18 years to 69 years of age and gender-matched visiting the radiology department for other investigations.

Exclusion criteria for the control group

1. Individuals with confirmed diabetes mellitus (DM)
2. Others as for the study group.

These conditions were excluded by obtaining a thorough history from the participants, and a review of the clinical records of the diabetic patients. Blood pressure was also taken to exclude hypertension.

Congenital or acquired renal pathologies like hydronephrosis, hydroureteronephrosis, polycystic kidney, ectopic kidney, and pyelonephritis were excluded in the course of data collection by use of ultrasonography[15].

Ultrasound technique

All participants who voluntarily provided informed consent and agreed to be enrolled in the study had their demographic and anthropometric data collected, including age, sex, weight, and height, from which body mass index (BMI) was subsequently calculated. Participant ages were obtained through history-taking and verified against patient case files or request cards [16]. Height measurements were conducted using a vertical stadiometer calibrated in centimeters, while weight was measured using a digital scale. BMI was computed using the standard formula: weight (kg) divided by the square of height (m^2).

The control group primarily consisted of individuals referred to the radiology department for unrelated investigations, as well as healthy volunteers. To ensure adherence to the study's inclusion and exclusion criteria, a brief clinical history (e.g., presence of hypertension or end-stage renal disease) and a physical examination (e.g., blood pressure measurement) were performed [17].

For diabetic participants, hospital case files were reviewed—following approval from the medical records department—to confirm renal biochemical status. All subjects received thorough psychological reassurance, and the procedures were explained in detail prior to scanning.

Ultrasound examinations were conducted using a real-time greyscale Mindray D-6 (Shenzhen, China) ultrasound system equipped with a 3.5–5 MHz curvilinear transducer and electronic calipers [18].

calculated using the ellipsoid formula:

Volume = Length × Width × Thickness × π/6,

where π/6 is approximated as 0.523 [23].

Laboratory Methods

- All laboratory information was obtained from the patient's case files. The latest fasting plasma glucose level of all subjects was recorded to ascertain their level of glycaemic control. [20]

WHO definition of diabetes mellitus as demonstrating a fasting plasma glucose level of ≥7.0mmol/l (126mg/dl) was used to diagnose patients as diabetics. • The albuminuria status of each subject was recorded following urinalysis. This was defined according to the standards of medical care of the American Diabetes Association as: Normal (<30mg/mg) Micro albuminuria (30-299mg/mg) Macro albuminuria (≥300mg/mg)

Ethical Consideration

Clearance from the Ethical Committee of Aminu Kano Teaching Hospital Kano was obtained before the commencement of the study with registration number NHREC/21/08/2008/AKTH/EC/1450.

Results

A total of 456 subjects comprising 228 Type 2 diabetic subjects as well as 228 age and sex-matched controls were studied. There was a slightly higher number of female subjects in the study group who constituted 53% (120 out of 228) while the males constituted 47% (108 out of 113) Borno Medical Journal as shown in Fig 2. This difference however was not statistically significant (p=0.43). The distribution of individuals sampled as the control group for the study was also nearly even between the sexes. Although males were slightly higher constituting 53% of all individuals sampled (i.e. 120 of 228 individuals) while females made up 47% (i.e. 108 of 228 individuals) (Fig. 2). This difference was also not statistically significant (p=0.43). The ages of male patients in the study group ranged from 29-67 years with a mean of 47.7±10.7 years while those of the female patients ranged from 28- 69 years with a mean of 46.9±10.9 years (Table 1). There was no significant statistical difference between the mean age of male and female patients in the study group (P=0.49). The ages of male subjects in the control group ranged from 31-69 years with a mean of 47.1±10.4 years while the age of the female subjects in the control group ranged from 28-69 years with a mean of 47.8±10.3 years. (Table 1) There was no significant statistical difference between the mean ages of male and female subjects in the control group (P=0.43). The mean age of the study group was 47.70 +10.84 years while that of the control group was 46.86 + 10.33 years. There was no significant difference between the mean ages of the subjects and the control groups (p=0.46). The age distribution of the study and control groups is depicted in Fig 3. The BMI of male patients in the study group ranged from17.1- 31.6kg/m2 with a mean of 24.2 ±4.5 kg/m2, while the BMI of female patients in the study group ranged from 16.6-40.2kg/m2with a mean of 27.7±5.0kg/m2. The BMI of the male subjects in the control group ranged from 16.9-33.3kg/m2 with a mean of 23.6±5.3 kg/while the BMI of female subjects in the control group ranged from 15.0- 36.6-kg/m2 with a mean of 23.6 ± 5.3kg/m2. (Table 2). The mean BMI of the study group was 25.96 + 4.76 kg/m2 while that of the control group was 23.61 + 5.30 kg/m2. This difference was not statistically significant

(p=0.43). Renal volume related significantly with the sex of individuals sampled ($p < 0.001$) with diabetic males having higher mean renal volume as compared to diabetic females. ($p < 0.001$) (Fig. 3). However, there was no statistically significant relationship between renal volume with age ($p = 0.875$) and BMI ($p = 0.877$) of individuals in the study population.

Generally, in both males and females combined, there was a significant difference between right renal volume (Rvol) and left renal volume (Lvol) in diabetic patients ($p < 0.001$) with left renal volume being larger than right. (Table 3) The left renal volume in diabetic males also were significantly larger than the right renal volume ($p < 0.001$). Similarly, in diabetic females left renal volume was larger than the right renal volume ($p < 0.001$). For the control subjects, renal volume in males was also significantly higher than that of females ($p = 0.001$), with the left renal volume being larger than the right in both sexes (Table 4). There was no statistically significant relationship between BMI and right renal volume in diabetic males ($p = 0.086$). Similarly, BMI did not correlate significantly with right renal volume among diabetic females ($p = 0.604$). Also, in the control group, BMI did not have a significant correlation with right renal volume among male subjects. ($p = 0.913$). However, BMI related significantly to right renal volume among female subjects of the control group ($p < 0.001$) Fig. 4 and 5).

Table 1: Tabular Age distribution of the Study and Control Groups

Group	Sex	Lowest age	Highest age	Mean ± SD
Study Group	Male	32	67	48.29± 10.70
	Female	29	67	47.10 ± 10.98
Control Group	Male	31	69	46.62± 10.35
	Female	28	69	47.10± 10.30

Table 2: Tabular presentation of BMI range and mean for Study and Control Groups

Group	Sex	Lowest BMI	Highest BMI	Mean ± SD
Study Group	Male	17.10	31.55	24.22 ± 4.48
	Female	16.61	40.15	27.69± 5.04
Control Group	Male	16.85	33.27	23.59± 5.34
	Female	15.03	36.63	23.63± 5.26

Table 3: Comparison of Lvol and Rvol in both sexes of diabetic individuals

Sex	Mean Lvol± S.D.	Mean Rvol± S.D.	P
Males	155.41 ± 7.18	128.54 ± 5.23	< 0.001*
Females	115.78 ± 6.10	101.35 ± 5.40	< 0.001*

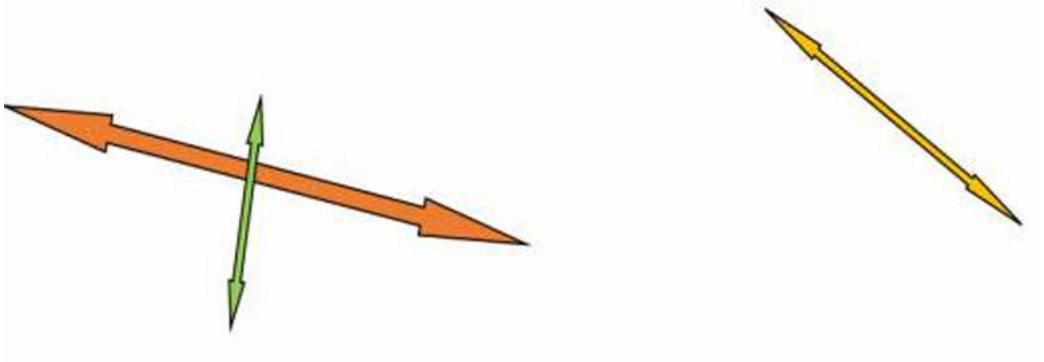
Average	134.37 ± 5.01	114.10 ± 3.97	< 0.001*

* = significant at 0.05 level

Table 4: Comparison of Lvol with Rvol in sexes of the Control group (Paired Samples test)

Sex	Mean Lvol± S.D.	Mean Rvol± S.D.	P
Male	120.59 ± 3.32	103.55 ± 3.78	< 0.001*
Female	139.53 ± 26.06 ±3.09	86.78	0.041*
Average	129.56 ± 12.52 ±2.58	95.61	0.006*

*=significant at 0.05 level (Paired Samples test)



A (Longitudinal Scan) B (Transverse Scan) Fig 1: Sonograms obtained with the patient in a prone position showing measurements of renal dimensions (in cm). Longitudinal scan showing Renal length (L); Red arrow, and renal thickness (T); Green arrow. B-Transverse scan showing renal width (W); Yellow arrow[22]

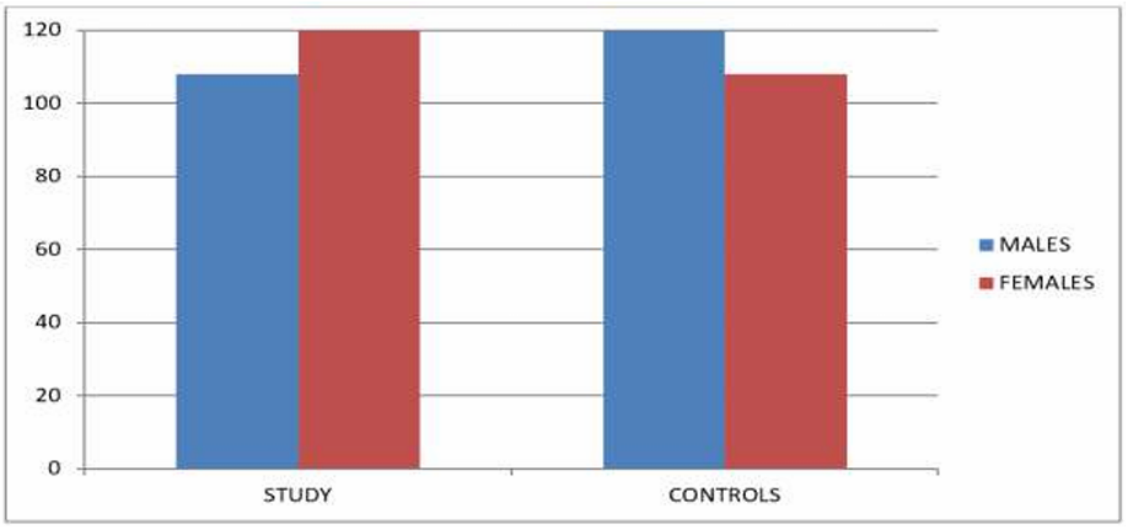


Fig. 2: Bar charts showing the sex distribution of study and control groups

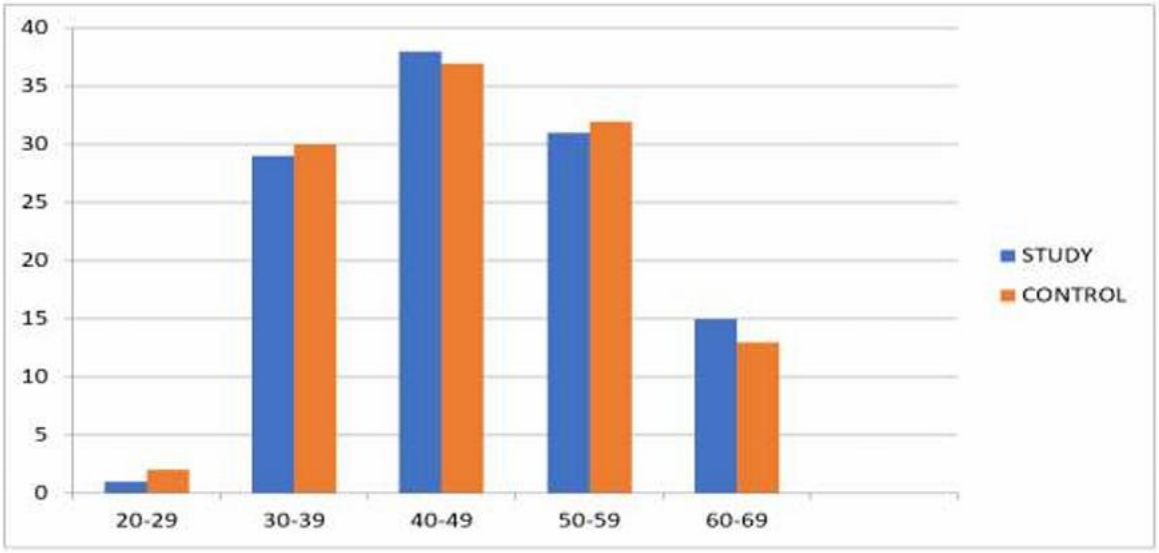


Fig. 3: Bar Chart Showing Age distribution of both study and control groups

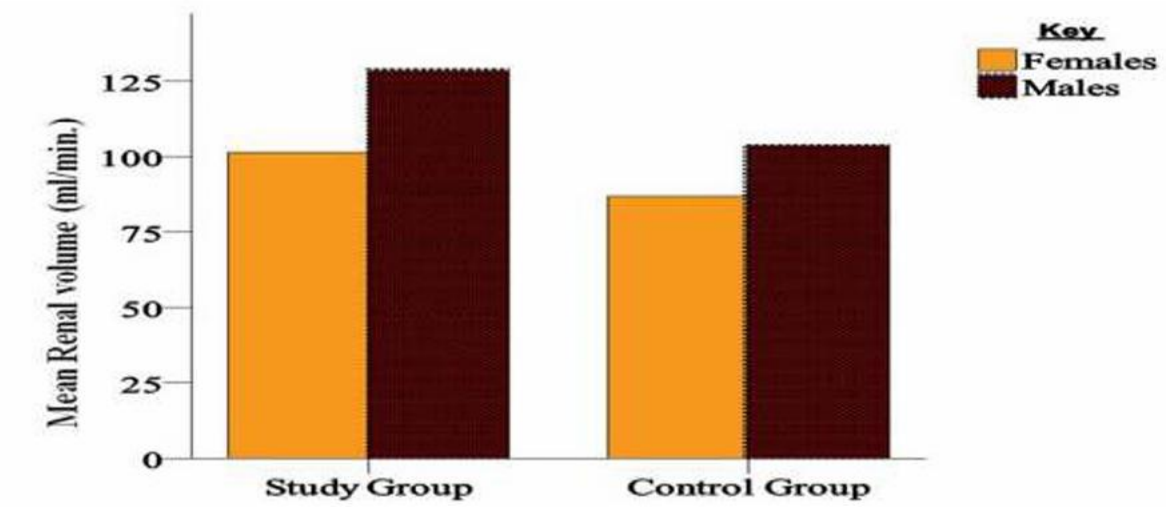


Fig. 4: Bar chart presentation of renal volume between study and control groups

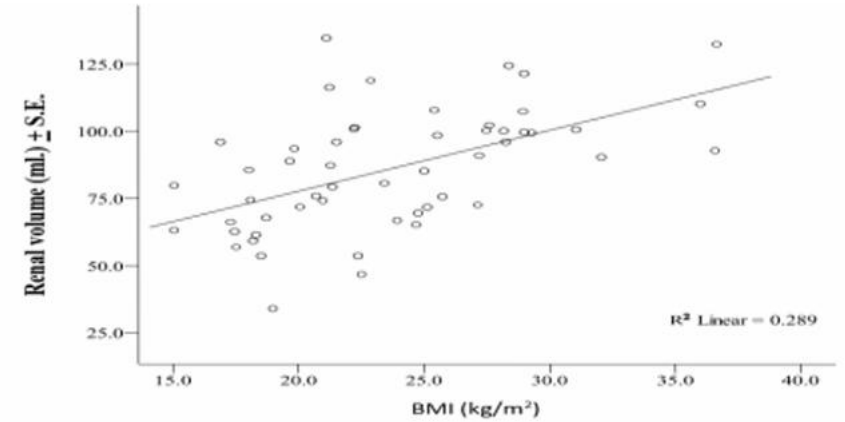


Fig. 5: Scattergram Showing Relationship between Rvol and BMI in control group females

Discussion

There were more females found with diabetes mellitus (53%) compared with males (47%) in this study. This is concordant with the findings of Chukwu (24) in Enugu, Chinenye (25)in Kano, and Zafar [22] in Pakistan who found more females affected with diabetes than males. There was

no significant statistical difference between the number of male and female diabetics. (p=0.43). Similarly, Chineye (25) also did not find a significant statistical difference between the number of female and male diabetics. The peak age group of the subjects with diabetes mellitus in this study was within the range of 40 – 49 years. This was found to be higher than the 34 – 36 year range in the study by Mumtaz [23] in Pakistan. This difference may be a result of the disparity in diet and lifestyle of Nigerians and Pakistanis. The mean age of the study group was 47.7±10.9 years[24]. This was similar to the report by Nyenwe et al.28 in Port Harcourt who found a mean age of 49.5 years. This is slightly lower than the findings of Chinenye et al25 who found a mean age of 57.1±12.3 years. This slight difference could be accounted for by the difference in the sample sizes of both studies[25]. The sample size in this study was significantly lower than that of Chinenye et al.25 Among the study group, the mean age for males and females is 48.3±10.7 years and 47.1±10.9 years respectively. This is similar to the findings of Nyenwe et al.28 in Port Harcourt who found the mean age of male diabetics to be 50.3 years and 47.6 years for females. The higher mean renal volume in the study group (101.4±5.4ml) compared to that of the control group (128.5±5.2ml) in this study is similar to the findings of Zerbini et al.29 in Milan Italy, Ruggenenti [26] in Bergamo, Italy and Vincent et al31 in de Bordeaux, France. Similarly, the statistically significant difference noted between the mean renal volume Borno Medical Journal amongst the female diabetics compared to the female controls (p=0.015) and amongst the male diabetics compared to the male control group ($p \leq 0.001$) is similar to the findings of Zerbini et al.29 Ruggenenti et al.30 and Vincent et al. respectively31. The mean renal volume for the control group in this study on the left and right sides (129.6±12.5ml and 95.6±2.6 ml respectively) is similar to the findings of Ma'aji et al.32 in Sokoto, who found mean renal volumes of 119.7±32.8 ml and 109.6±29.3 ml, with the left kidney larger than the right. The findings are also comparable to the report by Justo et al.33 in Mexico, who also found that the left kidney is larger in the normal healthy adult population[27].

Conclusion

This study established values of renal volume in patients with type 2 diabetes. The mean renal volume for male diabetics was higher than in females. The renal volume for normal individuals was also found to be higher in males than in females. The mean renal volume is shown to be significantly higher among diabetics compared with normal controls. Renal volume was generally found to be larger on the left than on the right side. Renal volume showed no significant positive correlation with age and BMI. Renal volume was significantly higher amongst subjects with type 2 diabetes compared to their controls. Therefore, routine requests for renal scans which are relatively cheap and readily available for diabetic patients would help to mitigate the death toll from end-stage renal diseases caused by type 2 diabetes mellitus.

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