EVALUATION OF THE RELATIONSHIP BETWEEN ULTRASONOGRAPHIC KIDNEY DIMENSIONS AND MODIFIED BODY MASS INDEX IN CLINICALLY HEALTHY NIGERIAN INDIGENOUS DOGS

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (MSc) DEGREE IN VETERINARY DIAGNOSTIC IMAGING

DEPARTMENT OF VETERINARY SURGERY AND RADIOLOGY

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ZARIA

OCTOBER, 2017

DECLARATION

I declare that the work in this dissertation entitled **"Evaluation of the Relationship between Ultrasonographic Kidney Dimensions and Body Mass Index in Clinically Healthy Nigerian Indigenous Dogs"** has been carried out by me in the Department of Veterinary Surgery and Radiology, Ahmadu Bello University, Zaria, Nigeria, under the supervision of Prof. C. A. Awasum and Dr. N. D. Chom. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

Ma'azu Nuhu BAPPAH

……..	…….	…….
Name of Student	Signature	Date

CERTIFICATION

This dissertations, entitled "EVALUATION OF THE RELATIONSHIP BETWEEN ULTRASONOGRAPHIC KIDNEY DIMENSIONS AND BODY MASS INDEX IN CLINICALLY HEALTHY NGERIAN INDIGENOUS DOGS" by Ma'azu Nuhu BAPPAH meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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Dean, School of Postgraduate studies A.B.U. Zaria	Signature	Date

DEDICATION

I dedicate the work to my Mother, for her care and prayers for me.

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ABSTRACTS

Ultrasonography was used to determine the correlation between the kidney dimensions in 115 clinically healthy Nigerian Indigenous Dogs (NID) with anthropometric indices such as Modified Body Mass Index (*m*BMI) and sex. In-vivo ultrasonographic kidney dimensions were obtained by measuring the kidneys' length, width and height to compute the kidney volume using prolate ellipsoid formula (L x W x H x 0.523) while anthropometric dimensions were measures of body weight and truncal length to obtained the modified body mass index (*m*BMI) for dogs (body weight/truncal length^2). The result showed that the right kidney length of clinically healthy NID was within the range of 3.86 - 7.40 cm with the mean of 5.54 ± 0.067, while the left kidney length was 4.12 – 7.57 cm with the mean of 5.81 ± 0.062. The right kidney width was within the range of 1.86 - 5.00 cm with the mean of 3.15 ± 0.056, while the range for left kidney width was 2.04 – 5.42 cm with the mean of 3.36 ± 0.049. The right kidney height was within the range of 1.77 - 4.40 cm with the mean of 2.79 ± 0.045, while the range for left kidney height was 1.84 – 4.64 cm with the mean of 3.10 ± 0.052. Correlation between modified body mass index and kidney dimensions revealed a significant but weak positive relationship in right and left kidney length (0.30 and 0.37), kidney height (0.22 and 0.18) respectively, and right kidney volume (0.21), while there were no significant correlation in right kidney width (0.083) and left kidney volume (0.18), but a negative correlation was revealed in left kidney width (-0.057). The values for the variations between males and females in right and left kidneys respectively included: kidney length (0.3001 and 0.4274), kidney width (0.5465 and 0.7045), kidney height (0.0294 and 0.6421) and kidney volume (0.0834 and 0.6727). The values for the differences between the right and left kidneys in males and females respectively included: kidney length (0.0008 and 0.0012), kidney width (0.0226 and 0.007), kidney height (0.0004

and 0.0001) and kidney volume (0.0004 and 0.0001). The right kidney volume of clinically healthy NID was within the range of 9.22 - 63.20 cm with the mean of 26.33 ± 0.94, while the left kidney volume was 13.66 – 70.21 cm with the mean of 32.36 ± 1.04. In conclusion, the mean values of the right and left kidney dimensions in NID are kidney length as 5.54 ± 0.067 cm and 5.81 ± 0.062 cm, kidney width as 3.15 ± 0.056 cm and 3.36 ± 0.049 cm and kidney height as 2.79 ± 0.045 cm and 3.10 ± 0.052 cm respectively; correlation between kidney dimensions and modified body mass index (*m*BMI) was a positive linear relationship except for the left kidney width that was a negative linear relationship; there were no statistically significant differences in kidney dimensions between male and female but left kidney appeared larger than the right kidney in both male and female; the mean values of right and left kidney volume were 26.33 ± 0.94 and 32.36 ± 1.04 respectively.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Ultrasonography is an excellent modality for examining abdominal structures including the location and dimensions of canine kidneys (Remichi *et al*., 2014). It involves a non-invasive procedure for examination of kidney diseases (Sampaio and Araujo, 2002) and offers advantages over radiography as there are no side effects of radiation and contrast agents (Nyland *et al*., 1995).

Canine kidneys are located in the retroperitoneal region of the abdomen around T_{12}-L_1 for right kidney and L_1-L_3 for left kidney (Burk and Feeney, 2003). The kidneys perform various important functions in the body such as excreting waste products, maintaining homeostasis, blood production and utilization of mineral such as calcium (Fitzgerald *et al*., 2011). The left kidney is situated caudal to the stomach, dorsal and medial to the spleen by the side of the left side of the abdomen, ultrasonographic visualization of the left kidney can be achieved at this point by gently dragging the transducer craniocaudal on longitudinal plane, if the left kidney is cited, kidney length can be obtained from the cranial and caudal poles of the image, then rotate the transducer at 90^0 anti-clockwise to transverse plane where the width of the left kidney can be measured along hilus positioned at the medial border to the lateral border of the kidney, then again the height of the left kidney can also be measured on the same transverse plane from the dorsal border down to the ventral border of the kidney. While right kidney is more cranially located than left kidney, having contact cranially with the caudate lobe of the liver, its ultrasonographical measurement can

be obtained just as described as that of the left kidney (Nyland and Matton, 2002). Researchers were able to use these kidney dimensions to determine the kidney volume which is a useful measurement in the diagnosis of kidney diseases (Barrera *et al*., 2009).

Many kidney disorders are associated with changes in kidney dimensions (Sohn *et al*., 2016) for instance chronic interstitial nephritis causes a decrease in kidney size while acute pyelonephritis, polycystic kidney disease and hydronephrosis results in renomegaly (Jeyaraja *et al*., 2015). Invariably, kidney length is the most important tool used in determining kidney size (Konde *et al*., 1984), so changes in kidney length, as well as other dimensions, indicate abnormal kidney function which is used in the diagnosis of kidney diseases (Sohn *et al*., 2016). Generally, a normal range for some canine kidney dimensions have been established (Ast, 2002), however, some researchers are of the opinion that normal range for canine kidney dimensions should be based on individual breed because of body size disparity among numerous breeds of dogs (Lobacz *et al*., 2012). Other important laboratory parameters used in the diagnosis of kidney diseases include total protein, calcium, sodium, phosphate, potassium, creatinine, blood urea nitrogen and albumin (Bush, 1993; Needham, 2005; Kovarikova, 2015; Arora and Batuman, 2016).

Body mass index is a diagnostic tool used in ascertaining the prevalence of obesity, overweight and thinness in a human population (Cole and Lobstein, 2012). It is a representative of body adiposity (Gallagher *et al*., 1996; Pasco *et al*., 2014). Body mass index is a commonly used diagnostic tool to analyse obesity and overweight based on weight and height (Murguia-Romero *et al*., 2012).

Body mass index measurement was introduced by Lambert Adolphe Jacques Quetelet (1842) to explain the connection between body weight and stature in humans, until recently, researchers were able to discover the usefulness of body mass index in estimating body fats (Deurenberg *et al*., 1991). WHO (2000) set cut-off points for body mass index for human as less than 18.5 kg/m^2 for underweight, greater than 18.5 kg/m^2 to less than 25 kg/m^2 for normal weight, greater than 25 kg/m^2 to less than 30 kg/m^2 for overweight and greater than 30 kg/m^2 for obesity. Body mass index has been considered as health indicator because overweight and obesity are implicated as consequence of metabolic syndrome (Murguia-Romero *et al*., 2012). There is a strong linkage between overweight and obesity with conditions such as osteoarthritis, gout, gallbladder disease (DerSarkissian, 2016) as well as cancer of various organs including kidney cancer in human (Bhaskaran *et al*., 2014). In Veterinary practice, a modified body mass index for dogs was been suggested due to the difference in body shapes between human and dogs (Thengchaisri *et al*., 2014).

NID are unclassified, they belong to the medium size breed of dogs with unique predominant features such as average body size and moderate hair coat with mesocephalic cranial index. The possible classification of dogs presently in Nigeria is indigenous and exotic breeds of dogs those imported into the country such as German shepherd, Rottweiler, Mastiff, Cocker spaniel, Chihuahua, Maltese, Lhasa Apso, Pitbull, Bull Dog and cross breeds of different degree between these breeds (Oluwatoyin and Fayemi, 2011).

1.2 Statement of Research Problem

NID are erroneously called "mongrels'' with little-classified information of the breed itself. There is a paucity of information on kidney dimensions of NID which their clinical importance cannot be over emphasized.

Several studies have shown that kidney dimensions vary among the breed of dogs (Lobacz *et al*., 2012). Therefore, there is a need to investigate the kidney dimensions in NID, as it is considered a useful tool in the accurate diagnosis of kidney diseases (Sohn *et al*., 2016).

Kidney dimensions in veterinary practice can be related to useful anthropometric indices such as modified body mass index (*m*BMI), age, breed, body weight and these relationships are known to be useful in diagnosis of nephropathy (Barr *et al*., 1990; Park *et al*., 2008; Huaijantug *et al*., 2016). Therefore, there is a need to investigate the relationship between the kidney dimensions and modified body mass index (*m*BMI) in NID.

1.3 Justifications of the Study

A better understanding of this breed necessitates establishing data such as kidney dimensions as well as the modified body mass index (*m*BMI) which both has clinical relevance. Kidney volume can also serve as a prognostic biomarker in monitoring progress in kidney diseases (Sharma *et al*., 2017).

Knowledge of the relationship between kidney dimensions and modified body mass index (*m*BMI) will assist clinicians in the accurate morphological diagnosis of kidney disorders in dogs, as inference on kidney function can be deduced from the evaluation of modified body mass index (*m*BMI) in NID. This relationship is also very useful in kidney transplantation,

as it gives the surgeon the best transplant match between the donor's kidney and recipient's metabolic demands (Oh *et al*., 2005).

1.4 Aim of the Study

The broad aim of the present study is to determine the kidney dimensions using ultrasonography and to correlate with anthropometric indices such as modified body mass index (*m*BMI) and sex in clinically healthy NID.

1.5 Objectives of the Study

The specific objectives of the study were to:

a) Determine the kidney dimensions such as length, width and height in the clinically healthy NID using ultrasonography.
b) Correlate the kidney dimensions at ultrasonography with the modified body mass index (*m*BMI) in clinically healthy NID.
c) Determine the sex differences in kidney dimensions and variation between right and left kidneys at ultrasonography, in clinically healthy NID.
d) Establish the kidney volume using the ellipsoidal method of clinically healthy NID.

1.6 Research Questions

a) What are the values of kidney dimensions in the clinically healthy NID?
b) What is the relationship between kidney dimensions and modified body mass index (*m*BMI) in clinically healthy NID?

c) Are there sex disparities in kidney dimensions between right and left kidneys at ultrasonography in clinically healthy NID?

d) What are the average kidney volume values in clinically healthy NID?

CHAPTER TWO

LITERATURE REVIEW

2.1 Canine Kidney

The kidney is an internal organ of the body which helps in maintaining homeostasis through regulating plasma concentration, osmotic pressure and eliminating waste and harmful products from the body (Laroute *et al*., 2005).

2.1.1 Anatomy of canine kidney

The location of kidneys in a dog is based on the animal's age, posture, and general body condition (Burk and Feeney, 2003), which are usually found in the retroperitoneal space of the abdomen (Jeong *et al*., 2016). Its appearance can be appreciated in this context, based on gross (Figure 2.1 and 2.2) and sonographic appearance.

2.1.1.1 Gross and histological appearance

Kidneys are usually a pair of brownish red bean-shaped organs situated on either side of the vertebral column. The kidney features from the utmost comprises of the convex lateral surface and concave medial surface, and the hilum that connect ureter, blood vessels, lymphatics, and nerves, then irrelative adrenal gland at the top, while the covering tissues are made up of three layers namely renal fascia, perirenal fat capsule and fibrous capsule (Wallace, 1998). Renal fascia is the outermost layer engross with dense fibrous connective tissue that secures the kidney and the adrenal gland in place and perirenal fat capsule is a fatty tissue that cushions the kidney against external forces and it very important as change in body adiposity greatly affects it, while fibrous capsule is a transparent capsule that

covered the kidney's surrounding including perirenal fat, which also obviates infections from spreading into surrounding regions of the kidney (DiBartola, 1995).

Internal features of a kidney from superficial lateral to medial are divided into the renal cortex, renal medulla, and renal pelvis respectively. Renal cortex is a light color in complexion with granular appearance, and renal medulla contains a cone-shaped tissue masses called renal pyramids, which the base of each pyramid faces toward the cortex, and its papillae, points internally and also contains renal columns that separate the pyramids, while renal pelvis is a funnel-shaped tube that connects with the ureter at the hilum (Figure 2.2), it is further divided into major calyces and minor calyces (Hill's Pet Nutrition, 2004).

Histologically, the renal cortex is represented by cortical labyrinth and medullary rays, while renal medulla contains stripe of tubules. The nephron is the functional unit that includes renal corpuscle, a convoluted capillary tuft which is surrounded by the glomerular capsule that contains podocytes and simple squamous epithelium as visceral and parietal layers respectively. Proximal and distal tubules are lined by simple cuboidal epithelium with well-defined microvilli at the border, while mesangial cells are located between afferent and efferent arterioles (Eurell, 2004).

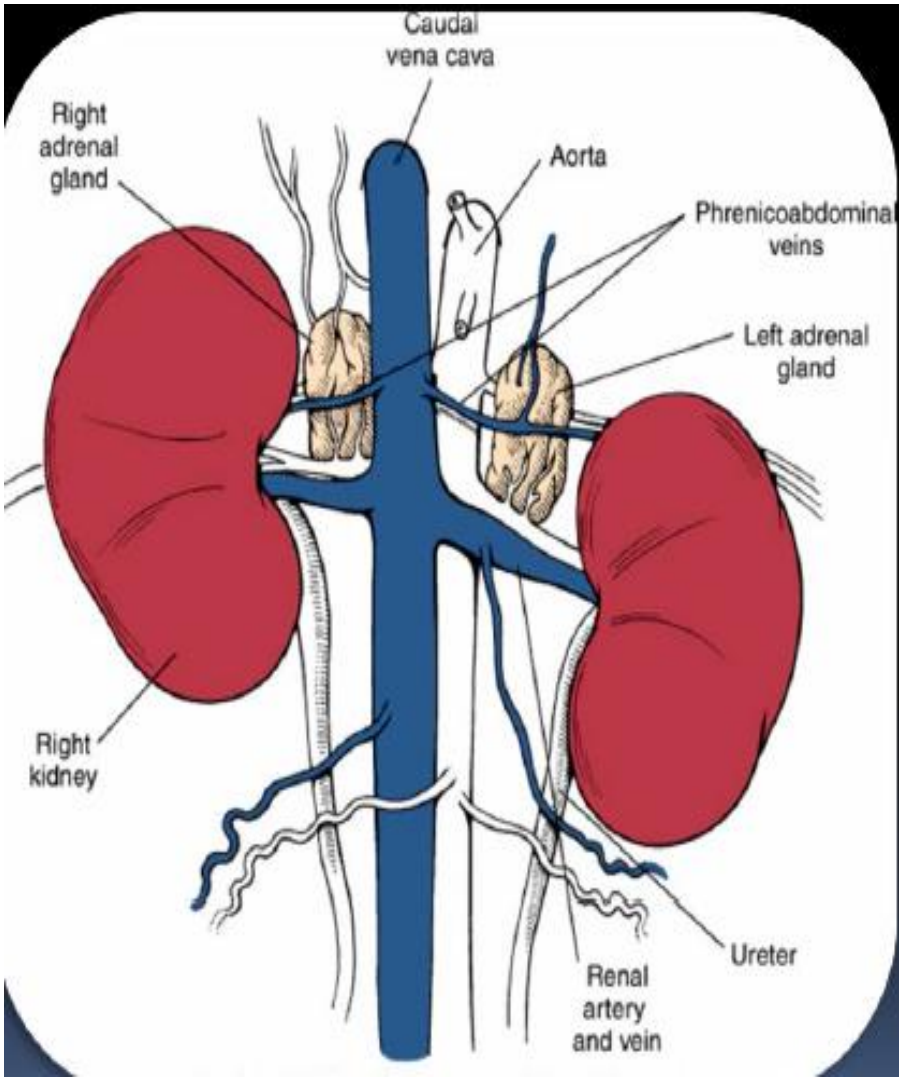


Figure 2.1: External features of a canine kidney. (Source: Anon, 2013)

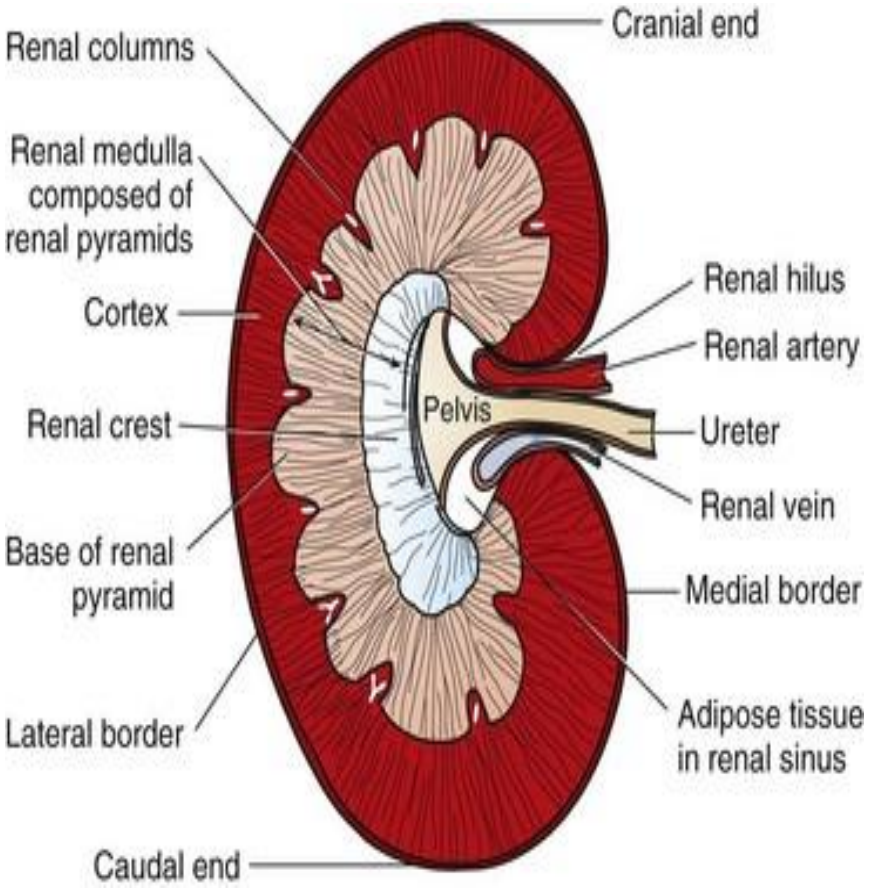


Figure 2.2: Gross appearance of the internal features of a canine kidney. (Source: Tillson and Tobias, 2016)

2.1.1.2 Blood supply and nerve innervations to the kidney

The blood supply to canine kidney is done by renal artery, that divide into a dorsal and ventral secondary branches, which further divide into tertiary branches known as interlobar arteries (tertiary branches) that supplied blood to the cortex of the cranial, mid-zone and caudal poles of the kidney through the renal columns, which are situated at the break of the renal pelvis (Marques-Sampaio *et al*., 2007).

Nerve innervations to the kidney and ureters are done by a network of autonomic nerve fibers and ganglia called renal plexus which originate from the celiac plexus, with additional contribution from intermesenteric plexus, greater splanchnic plexus, and superior hypogastric plexus (Ferguson *et al*., 1988).

2.1.1.3 Sonographic appearance

Kidney appearance in ultrasound revealed bean-shaped depression at the hilus medially (Nyland *et al*., 1995). Various regions of the kidney can be differentiated due to the differences in echogenicity, which can be recognized as the renal capsule, renal cortex, medullary pyramid and renal pelvis (Heuter, 2005). Renal capsule is represented by a hyperechoic thin line appearance separating the kidney and the perirenal fat, while renal cortex shows less echogenic (hypoechoic) with dotted echo-texture towards the outer region, and medullary pyramid reveals more hypoechoic or anechoic appearance in compares with renal cortex which surrounds the inner pelvis, and then renal pelvis manifest a hyperechoic appearance containing the calyces (Aref, 2013).

2.1.2 Modalities for kidney evaluation

Imaging modalities for canine renal examinations include Computed tomography scan (Vanbrugghe *et al*., 2011), Radiography (Lerman *et al*., 1999), Magnetic resonance imaging (Ritt *et al*., 2010), Scintigraphy (Vandermeulen *et al*., 2011) and Ultrasonography (Remichi *et al*., 2014). Ultrasonography is considered as the best modality of examining the location and dimensions of canine kidneys (Remichi *et al*., 2014). It involves a non-invasive procedure for examination of kidney diseases (Sampaio and Araujo, 2002) and offers advantages over radiography as there are no side effects of radiation and contrast agents (Nyland *et al*., 1995). Other modalities such as intravenous urography, computed tomography (CT) scan and magnetic resonance imaging (MRI) are beyond the scope of this research.

2.1.3 Ultrasonography

This is a diagnostic imaging modality that converts biological information into tomographic images through high frequency sound e.g. 2 Hz to 15 kHz (Kealy *et al*., 2000). Currently, ultrasound is gaining weight by becoming the most commonly used diagnostic imaging modality in veterinary medicine due to its ease of transporting, cheap and no radiation risk and also been utilized in some interventional procedures for visual guidance in real time (McConnell, 2008; Albury, 2015).

2.1.3.1 Principles of ultrasonography

There are three types of ultrasound display which are A-mode, B-mode, and T-M mode, where the A-mode is all about the amplitude of the reflected sound frequency as displayed

by the height of the vertical deflection on the oscilloscope, T-M mode displays the echo amplitude of motion objects (CIHR, 1999). But modern medical ultrasound B-mode display uses a pulse-echo approach (Brighter), which involves transmitting sound pulses from a transducer into the body that penetrates body tissues of various acoustic impedances along the direction of transmission, then the pulses are reflected back to the transducer in form of echo-signals which are processed to form a tomographic image on the monitor (Hangiandreou, 2003).

Ultrasound transducers (or probes) contain many piezoelectric crystals that have similar electrical properties and when an electric current pass through, it exert a vibration effect called the piezoelectric effect which forms the basis for compression and rarefaction of pulses through body tissues (Weyman, 1994; Otto, 2000). Pulses are usually identified in relation to their frequency (measured in cycles per second or hertz), wavelength (measured in millimeter), and amplitude (measured in decibel) (Chan and Perlans, 2011). The frequency is inversely proportional to the wavelength in ultrasound, where in its medical application utilizes pulses in the range of 1–20 MHz, so the selection of suitable transducer frequency is paramount in providing optimal image resolution in diagnostic and interventional procedures (Chan and Perlans, 2011). High-frequency (10-15 MHz) ultrasound pulses (short wavelength) gives images of high axial resolution but due to high degree of attenuation, they are only suitable for imaging superficial structures, while low-frequency (2-5 MHz) pulses (long wavelength) gives images of lower resolution but can penetrate in-depth structures due to a lower degree of attenuation (Lawrence, 2007).

Ultrasonography can be better explained based on the pulse-echo principle, when a high-frequency pulse is produced by the piezoelectric effects in the transducer and transmitted

into the body which travels along the direction of transmission until it reaches a reflecting organ, and then the pulse is being reflected into echo-signal which depends on the acoustic impedance of that tissue then back towards the same direction as the source of the pulse (Burk and Feeney, 2003). Transducer response as a two-way circuit between the pulses produce by the crystals and the echo received from the reflected surface then this sound energy is been transformed into electric energy in the ultrasound machine computer where image is formed by continually updating of the multiple echo-signal in a relatively short period which appears in form of tomographic display on the monitor in real time that can be frozen and stored, such that it can be manipulated or transferred for a second opinion (Chan and Perlans, 2011).

2.1.4 Determination of kidney dimensions

Assessment of kidney parameters in the diagnosis of renal diseases cannot be over emphasized, as a deviation from the normal range of the kidney dimensions are suggestive of a disorder (Forrest *et al*., 1998). Renal artery stenosis caused decreased kidney size, whereas hydronephrosis results to increased kidney size (Finco *et al*., 1971). Ultrasound have been employed in assessing canine renal dimensions such as kidney length, width, height, cortical thickness to compute for kidney size (Barella *et al*., 2012), renal volume (Felkai *et al*., 1992; Jeyaraja *et al*., 2015) and renal length (Konde *et al*., 1984).

2.1.4.1 Measurement of bipolar kidney length

Bipolar kidney lengths measurement is done by measuring the distances between the outermost points on the upper and lower kidney poles on the longitudinal plane of the image on the monitor, therefore, bipolar kidney length is defined as the maximum

longitudinal length of a kidney (Sampaio and Araujo, 2002). Kidney length is the most important tool used in determining kidney diseases (Konde *et al*., 1984). The canine kidney length for right and left kidneys are 5.87 cm and 5.79 cm (Barella *et al*., 2012), 5.99 cm and 5.97 cm (Mareschal *et al*., 2007), and 4.7 cm and 4.7 cm (Jeyaraja *et al*., 2015) respectively.

2.1.4.2 Measurement of kidney width

Kidney width is simply the measurement on a transverse plane along the hilus from side to side of a kidney on the monitor of an ultrasound machine, which is also measured the maximum distance between medial and lateral borders of a kidney (Nyland *et al*., 1989). The canine kidney width for right and left kidneys are 2.29 cm and 2.42 cm (Cunha *et al*., 2009), 3.44 cm and 3.39 cm (Sampaio and Araujo, 2002), and 2.5 cm and 2.5 cm (Jeyaraja *et al*., 2015) respectively.

2.1.4.3 Measurement of kidney height

Kidney height is the measurement on a transverse plane from dorsal to ventral of a kidney on the monitor of an ultrasound machine, which can also be measured as the maximum distance between proximal and distal borders of the kidney on a transverse plane (Barrera *et al*., 2009). The normal canine kidney height for right and left are 2.6 cm and 2.6 cm (Jeyaraja *et al*., 2015), 3.02 cm and 3.02 cm (Sampaio and Araujo, 2002), and 3.28 cm and 3.30 cm (Barella *et al*., 2012), 2.42 cm and 2.45 cm (Cunha *et al*., 2009) respectively.

2.14.4 Measurement of renal volume

Each kidney volumes can be measured using the ellipsoid formula which is volume = length × width × depth × π/6 (Nyland *et al*., 1989; Kim *et al*., 2008) or kidney volume = bipolar kidney length × width × height × 0.523, where the length and can be obtained at longitudinal plane while the hilar width and depth or height in transverse section. Kidney volume formula is considered due to its assumed shape that resembles ellipsoid (Bakker *et al*., 1999). This formula is modified by Dinkel *et al*, (1985) as 0.523 × *Length* × *Width* × $(D_1 + D_2)/2$ and it was further modified by Solvig *et al*, (1998) as 0.612 × Length × Width × $(D_1 + D_2)/2$, both formulas were derived using non-perfused kidneys and perfused kidneys respectively. From the kidney volume formulas mentioned above, none is superior to one another as either formula can be applicable (Sanusi *et al*., 2009). Kidney volume is a predictor of kidney health status (Jones *et al*., 1983). Kidney volume has been considered a reliable dimension for kidney diagnosis due to the fact that kidney length decreases with age while kidney volume remains relatively constant (Sanusi *et al*., 2009). Several studies reported established kidney volume as 13.69 cm^3 and 14.80 cm^3 in Dachshund Dogs (Cunha *et al*., 2009), and other undisclosed breed of dogs as 35.78 cm^3 and 35.29 cm^3 (Sampaio and Araujo, 2002), 57.34 cm^3 and 52.24 cm^3 (Mendonca *et al.*, 2012), 17.15 cm^3 and 17.04 cm^3 (Jeyaraja *et al.*, 2015) and 42.08 cm^3 and 54.60 cm^3 (Barrera *et al.*, 2009) for right and left kidneys respectively.

2.1.4.5 Measurement of cortical thickness of kidney

This is the perpendicular measurement of a distance from the base of the medullary pyramid to the renal capsule along a sagittal plane (Moghazi *et al*., 2005; Beland *et al*.,

2010). The normal canine cortical thickness was reported by researchers for right and left kidneys as 1.30 cm and 1.14 cm (Dinesh *et al*., 2017), 0.89 cm and 0.86 cm (Kolber and Borelli, 2005) respectively.

2.1.4.6 Measurement of kidney size

There are two methods for the estimation of this kidney dimension i.e. ultrasonographic measurement of kidney-to-aorta (Mareschal *et al*., 2007) and product of kidney length, kidney width and its cortical thickness (Buchholz *et al*., 2000; Raza *et al*., 2011). However, there is scarce information regarding kidney size in dogs using the latter method. Kidney size is an indicator for kidney functions (Guzman *et al*., 1994). This parameter is paramount for diagnosing counter-lateral kidney disease and offer limitation for diagnosis of upper and lower urinary tract infections (Dinkel *et al*., 1986). In human, the latter method is the most reliable estimation in respect to kidney function (Emamian *et al*., 1995; Cheong *et al*., 2007).

2.1.4.7 Measurement of medullary pyramid thickness

Medullary pyramid thickness is defined as the distance between the apex and the base of the medullary pyramid at the middle portion of the kidney (Kadioglu, 2010; Debruyn *et al*., 2013). The canine medullary thickness was reported for right and left kidneys as 1.50 cm and 1.50 cm respectively (Dinesh *et al*., 2017).

2.1.4.8 Measurement of parenchymal thickness

Parenchymal thickness is the distance between the cortex fat capsule and the renal sinus at the apex of the medullary pyramid from the middle portion of the kidney (Kadioglu, 2010). There is also scarce information regarding this dimension in the small animal.

2.1.5 Conditions that affect kidney dimensions

Abnormalities in kidney ultrasound are a direct reflection of many renal diseases, so, therefore, knowledge on ultrasonographical presentation of kidney diseases are relevance in research quest to obtain standard ultrasound measurement of kidneys, because any deviation from normal kidney dimensions may translate to kidney dysfunction (Sohn *et al*., 2016).

2.1.5.1 Acute kidney injury

Acute kidney failure is characterized by a decrease in kidney function which leads to accumulation of toxins, fluids and electrolytes imbalance (Cowgill and Francey, 2005) and also an indicator of functional nephron mass in Dogs (De Loor *et al*., 2013). This condition is also known as acute glomerulonephritis, interstitial nephritis, acute tubular necrosis or nephrosis (Debruyn *et al*., 2012).

Ultrasonographic features include enlarged and smooth outlined kidney with increased echogenicity of renal parenchyma, while renal medulla and cortex appear normal (Mantis, 2008).

2.1.5.2 Polycystic kidney disease

Polycystic kidney disease is the most common congenital disorder in small animals (Debruyn *et al*., 2012). It was first discovered in Persian cat (Appleman and Berent, 2006) and then Himalayans, exotics, Persian crosses, Ragdoll and domestic short hair cats (Paepe *et al*., 2012). Canine breeds that are predispose to this condition include bull terriers, Cairn terriers, and West Highland white terriers, where this condition demonstrate cysts in the renal cortex and medulla in one or both kidneys that occur as a result of defect in nephron structure and growth of this cyst leads to renomegaly and compression of the renal parenchyma, with subsequent decrease in kidney function (Appleman and Berent, 2006).

Ultrasonographic features are anechoic, irregular sized and thin-walled cysts with acoustic shadow are seen in the medulla, corticomedullary junction and/or cortex that deranged kidney tissues (Larson, 2009).

2.1.5.3 Renal neoplasia

Kidney neoplasm in dogs are lymphoma, nephroblastoma (Klein *et al*., 1987), cystadenocarcinoma (Lium and Moe, 1985), sarcoma (Lucke and Kelly, 1976), osteosarcoma (Munday *et al*., 2004), leiomyosarcoma (Sato *et al*., 2003), hemangioma (Mott *et al*., 1996), hemangiosarcoma (Ohler *et al*., 1994), giant cell tumor (Haziroglu *et al*., 2005), oncocytoma (Buergelt and Adjiri-Awere, 2000) and mixed mesenchymal tumor (Robison *et al*., 1997). But the primary renal tumor is uncommon in Dogs (Bryan *et al*., 2006).

Sonographic features of kidney neoplasm will reveal homogeneous or heterogeneous, and hypoechoic, isoechoic or hyperechoic, and also regular or irregular lesions with different

wall shape (D'Anjou, 2008). Hypoechoic leions are mostly lymphomatous (Debruyn *et al*., 2012) and hyperechoic regions are suggestive of carcinoma, haemangiosarcomas, haemangioma or metastatic thyroid carcinoma, chondrosarcoma (Mannion, 2006), but isoechoic masses are difficult to notice unless there is a change in echotexture (Nyland *et al*., 1995).

2.1.5.4 Hydronephrosis

Hydronephrosis describes abnormal dilation of the renal pelvis and calyces above 3 mm of one or both kidneys resulting in the formation of progressive atrophy and cystic enlargement of renal parenchyma (Jones *et al*., 1997). This condition mostly accompanied with dilation of the ureter (hydroureter) concurrently (Sahal *et al*., 2005). Hydronephrosis is caused by infection eg pyelonephritis, obstruction of the urinary tract and ectopic ureters (Dennis and McConnel, 2007).

Sonographic characteristics include anechoic renal pelvis due to the accumulation of fluid with acoustic shadowing (Sahal *et al*., 2005) and progress to cortical atrophy (Dennis *et al*., 2010).

2.1.5.5 Pyelonephritis

Pyelonephritis is inflammation of the renal pelvis and renal parenchyma caused by bacterial infection mostly from the bladder (Devictoria, 2013).

Ultrasonographically, it reveal a dilated pelvis and proximal ureter with anechoic or hyperechoic debris and blunted (Larson, 2009), the dilation may not be seen in acute pyelonephritis (Nyland *et al*., 1995) but hyperechogenicity will be noticed along the renal

cortex which can be seen in both acute and chronic pyelonephritis (Choi *et al*., 2010) and there will be lack of corticomedullary definition (Parry, 2005).

2.1.5.6 Multicystic kidney dysplasia

This is a congenital anomaly of the kidney affecting dogs with susceptibility in Shih Tzu (Ohara *et al*., 2001), border terrier (Clark and Panciera, 1992), golden retriever (Miyamoto *et al*., 1997), standard poodle (DiBartola, 1983), boxer, Finnish harrier (Hoppe and Karlstam, 2000), Rhodesian ridgeback (Lobetti *et al*., 1996), and Dutch kookier (Schulze *et al*., 1998) breeds. It is also known as renal dysgenesis (Thomsen *et al*., 1997). Clinical manifestations in dogs will be polyuria, polydipsia, lethargy, reduced appetite, weight loss, and vomiting, which may result in dehydration, anemia, oral ulcerations, and halitosis (Brum *et al*., 2008).

Ultrasonographic features include loss of normal kidney architecture, sometimes small cystic lesions may be seen (Sieler *et al*., 2010) due to acoustic shadowing caused by renal mineralization, but often, large anechoic cystic fluid with thin-walled, round boundaries of different sizes and strong distal acoustic shadowing (Kim *et al*., 2011).

2.1.5.7 Chronic kidney disease

Chronic kidney disease is the most common renal disorder of dogs and cats with common causes which include glomerulonephritis, polycystic kidney disease, autoimmune diseases, nephrotoxins, tubular diseases, pyelonephritis, interstitial nephritis and glomerular hypertension (Polzin, 2013).

This condition on ultrasound monitor will reveal small and irregularly margin, kidneys that reveal increased echogenicity of the cortex and medulla, reduced corticomedullary definition and blurred internal architecture (Mantis, 2008). As the disease progresses, small areas of mineralisation can be noticed as hyperechoic foci with or without distal acoustic shadowing (Dennis and McConnell, 2007).

2.2 Body Mass Index

Body mass index is a diagnostic tool used in ascertaining the prevalence of obesity, overweight and thinness in a population (Cole and Lobstein, 2012). It is also widely used as a predominant indicator for the amount of body fat (Pasco *et al*., 2014), which is supported by Gallagher *et al*., (1996) as a representative of body adiposity. Body mass index is a commonly used diagnostic tool to analyse obesity and overweight based on weight and height as anthropometric factors (Murguia-Romero *et al*., 2012).

2.2.1 Significances of body mass index

Body mass index is an accurate tool for diagnosing metabolic syndrome (Murguia-Romero *et al*., 2012). WHO (2000) set cut-off points for body mass index in human as less than 18.5 kg/m^2 for underweight, greater than 18.5 kg/m^2 to less than 25 kg/m^2 for normal weight, greater than 25 kg/m^2 to less than 30 kg/m^2 for overweight and greater than 30 kg/m^2 for obesity. Overweight and obesity in Dogs are connected to osteoarthritis, type II diabetes mellitus, lung problems, urinary and reproductive disorders (Yam *et al*., 2016) as well as cancer of various organs including kidney cancer (German, 2006).

2.2.2 Measurement of body mass indexes

The body mass index for the human is computed using the individual weight in kilogram against the square of height in meters (Florey, 1970).

$$\text{BMI (kg/m}^2\text{)} = \frac{\text{Weight of animal (kg)}}{\text{Height of animal (m}^2\text{)}}$$

However, the above formula cannot be used for BMI calculation for dogs. Modified body mass index for dogs was suggested, which is computed by the individual weight in kilogram against the square of the length of the trunk (truncal length) in meters because dogs are quadrupeds, therefore, length of the trunk should be used instead of the height in human (Thengchaisri *et al*., 2014).

$$m\text{BMI (kg/m}^2\text{)} = \frac{\text{Weight of animal (kg)}}{\text{Truncal length of animal (m}^2\text{)}}$$

Another proposed canine body mass index called Koury, by Alves *et. al.*(2009) as

$$\text{canine body mass index (Koury)} = \frac{\text{Weight of animal (kg)}}{\text{AA2} \times 1000}$$

Where AA stands for distance from the scapula to the ground, but this equation will not be considered in this research due to the fact that the authors reported it, as the most efficient formula for diagnosis of nutritional disorders in dogs.

2.3 Factors Influencing Relationship between Kidney and Anthropometric Dimensions

Different parameters of the kidneys such as length, width, and height can be measured from an ultrasound image (Atalabi *et al*., 2013). In dogs, a standard normal range for all dogs would be subjective due to differences in body size in various breeds (Lobacz *et al*., 2012), but in cats, due to their relative standard body size, the kidney length is reported to range from 3.8 to 4.4 cm (Nickel *et al*., 1979). However, these parameters have a positive

correlation with body weight in Dogs (Nyland *et al*., 1989; Barr, 1990; Felkai *et al*., 1992) and human (Raza *et al*., 2011; Okur *et al*., 2014; Karim *et al*., 2015).

2.3.1 Breed/Ethnic

Significant differences in measurement of kidney dimensions among the various breed of dogs are reported (Sohn *et al*., 2016). General standard values for normal kidney dimensions in dogs can not be accepted due to a wide disparity in body size among different breeds (Lobacz *et al*., 2012). Similarly, in human, kidney dimensions vary between ethnic groups (Okoye *et al*., 2005; Hammad, 2012; Muthusami *et al*., 2014).

2.3.2 Sex

2.3.2.1 Kidney dimensions

In small animal, there are differences in renal dimensions between sexes in normal adult kidney, such that it has been reported that males have larger kidney length than females (Kolber and Borelli, 2005), this was suggested to be influenced by the anabolic activity of androgens that causes hypertrophy of proximal tubule, so that the length differences are restricted in the renal cortex (Sabolic *et al*., 2007; Jackson *et al*., 2011). However, a research reported that females had larger kidneys (Stacco *et al*., 2016), while another, reported no differences between male and female kidney dimensions (Sampaio and Araujo, 2002). It is also important to note the differences between right and left kidneys, which it has been reported by Cunha *et al*, (2009) and Kolber and Borelli (2005), that left kidney is larger than right kidney, explanation for this was suggested by Karim *et al*, (2015) which could be because hepatic tissue may hinder longitudinal development of the right kidney

whereas left kidney has liberty for maximum growth without hindrance. Another possible suggestion could be that the left renal artery being shorter than the right, therefore allow increased blood flow that may cause a slight increase in left kidney volume (Okur *et al*., 2014). While some studies reported that right kidney is larger than the left kidney (Mareschal *et al*., 2007), and others reported no differences between right and left kidneys (Sampaio and Araujo, 2002; Barella *et al*., 2012; Jeyaraja *et al*., 2015).

Though, in human, Abdullah *et al*, (2014) reported larger kidney in males, while, Sampaio and Mandarin-de-Lacerda (1989) reported the same in females. It is also reported that left kidney appears larger than the right kidney (Hollinshead, 1971; Raza *et* al., 2011) and also reported that right kidney appears larger than the left kidney (Tisher and Madsen, 1996; Andersson *et al*., 2007).

2.3.2.2 Anthropometric dimensions

Males acquire greater anthropometric parameters than females due to sexual selection which is called sexual size dimorphism (Frynta *et al*., 2012).

In small animals, it is reported that body weight correlates positively with renal dimensions (Nyland *et al*., 1989; Barr, 1990; Felkai *et al*., 1992; Park *et al*., 2008), but there is scarce information in respect to correlation between kidney dimensions and modified body mass index in dogs.

In human, studies have reported that body weight has strong relationship with kidney dimensions (Ganesh *et al*., 2010; Harmse, 2011; Abdullah *et al*., 2014; Eze *et al*., 2014; Okur *et al*., 2014), whereas Muthusami *et al*, (2014) and Kim *et al*, (2013) demonstrate

moderate and weak relationship respectively. While El-Reshaid and Abdul-Fattah (2014), reported no relationship kidney dimensions with weight. Hekmatnia *et al*, (2004) also reported a strong correlation between kidney dimensions with its individual body height in adult human, which also supported by some studies (Arooj *et al*., 2011; Hermse, 2011; Abdullah *et al*., 2014), but some studies were able to report no relationship between kidney dimensions with body height (El-Reshaid and Abdul-Fattah, 2014; Muthusami *et al*., 2014; Abdoerlrahman *et al*., 2016). Kidney dimensions demonstrated a strong relationship with its individual body mass index (Buchholz *et al*., 2000; Elsayed, 2012; Abdullah *et al*., 2014). Many studies indicated a weak relationship between kidney dimensions with body mass index (Raza *et* al., 2011; El-Reshaid and Abdul-Fattah, 2014; Muthusami *et al*., 2014), while some reported that kidney dimensions did not have good correlation with body mass index (El-Reshaid and Abdul-Fattah, 2014).

CHAPTER THREE

MATERIALS AND METHOD

3.1 Materials

Materials that were used in this study are summarized in Table 3.1.

Table 3.1: Lists of Consumables, Ultrasound Scanning Materials and Other Items Used in the Study

Description of items	Quantity
Consumables	
500g Detergents powder	1
Chlorhexidine gluconate BP (0.3%w/v-Purit®)	1
Packet of disposable gloves (size 7.5, 100 pairs)	2
Packet of sterile deposable syringes (5ml, 100 pieces)	2
Big packet of cotton wool (500g)	1
Adhesives plaster 2 inches	1
Plain Test tubes	3
EDTA Test tubes	3
Ultrasonographic materials and equipment	
Sonostar C5® Laptop ultrasound scanner (Sonostar Technologies Co., Ltd)	
Generator	1
Aquostic gel	1
2 GB memory card/ USB	1
Tissue paper	10
Packet of razor blade	10
Measuring equipment	
Weighing scale balance	1
Measuring tape	2

3.2 Animal Subjects

One hundred and twenty-five (125) apparently healthy NID were selected from packs of dogs owned by local hunters and households residing in Zaria and its environs. The dogs' ages ranged from 1 to 4.5 years. The research was performed on dogs which were considered healthy on the basis of physical examination, body condition score of three (3) using a five (5) point scale (Baldwin *et al*., 2010), normal haemogram and serum biochemical profile, and these represented subjects in the inclusion category. While dogs with the history of renal disease, sonographic anomalies of kidneys, neutered and pregnant dogs were excluded from the research.

Of the total 125 Dogs, 7 Dogs with a known history of high serum creatinine values and 3 with pre-term pregnancies were excluded from the study. All experimental procedures and protocol were reviewed and approved by the Ethical Committee of the Ahmadu Bello University, Animal Care and Use Committee (ABUCAUC/2017/008), and informed consent was obtained from all the dog owners, prior to the commencement of the study. Features of NID used in this research that serves as the breed identification were average body size, moderate hair coat and mesocephalic cranial index as shown in Plates I and II below.

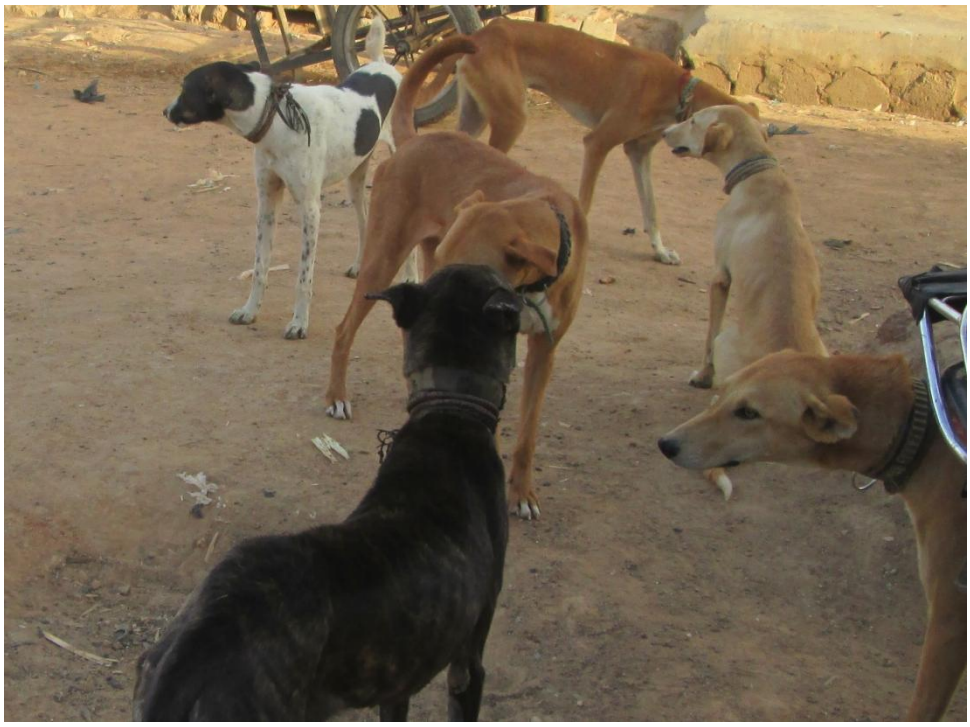


Plate I: A group of some NID obtained from local hunters in the Samaru neighborhood to be used for the study.

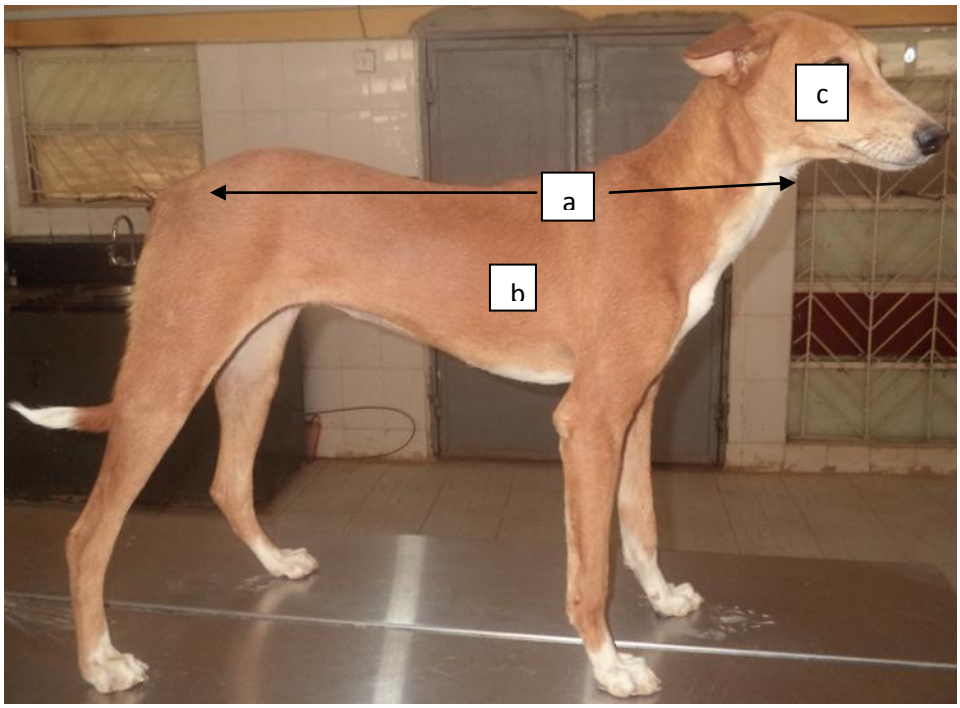


Plate II: A typical features of NID with (a) average body size, (b) moderate hair coat, and (c) mesocephalic cranial index.

3.3 Measurement of Modified Body Mass Index

The animals were restrained physically with aid of mouth guard by the owners to secure the mouth, on standing position. The body condition score (BCS) was recorded, subjectively, using five-point scale (1= very thin, 2= under weight, 3= ideal weight, 4= overweight, and 5= obese) as described by (Baldwin, *et al.*, 2010). Evaluation of the truncal length (length of the trunk) (TL) was performed by tape measurements in meters squared (m^2) (Plate III) was measured from the crest of humeral greater tubercle to the level of ischiatic tubercle at the hind limbs, while the body weights (BW) of the dogs were measured with the aid of a sensitive digital weighing scale (Kubei^{TM}) in kilogram (Kg). These indices were used to determine the modified body mass index (*m*BMI). In the present study, the *m*BMI rather than the body mass index (BMI), a measurement of human body shape based on mass and height (kg/m^2), was calculated. Hence, the truncal length rather than height was used for the *m*BMI calculation, due to Dog's pronograde posture, which has a great difference in body shapes, in contrast to that of humans (Kesavachandran *et al*., 2012). Therefore, the modified body mass index (*m*BMI) which measured the dog's body weight divided by the truncal length in meters squared BW (kg)/TL (m^2) according to the method of Thengchaisri *et al*., 2014, was used in this study.

$$m\text{BMI} = \frac{\text{BW (Kg)}}{\text{TL } (m^2)}$$



Plate III: Measuring the truncal length of the NID with the tape placed from humeral greater tubercle to the level of ischiatic tubercle

3.4 Ultrasonographic Examination of Kidney Dimensions

Restraint and site preparation

The dogs were restrained physically on dorsal recumbency then the ventral abdomen area was shaved using razor blade from the xiphoid process, lateral and caudal to the border of the last rib and extends posteriorly 20 cm to the umbilical scar to adequately provide scanning space. This was done to prevent air from being trapped in the hairs which can lead to displaying air pockets on monitor thereby altering the image displayed.

Ultrasonographic scanning procedure

After shaving the hairs at the ventrum on dorsal recumbency, aquostic gel (Erosonic^{TM}) was liberally applied to both the probe surface and skin of the cranial abdomen, caudal to the rib cage, to achieve transducer-skin contact. Scanning procedure was carried out using portable digital B-mode scan machine Sonostar^{TM} (Sonostar Technologies Co., Guangzhou, Guangdong, China) using a 5.0 MHz, curvilinear electronic transducer suitable for veterinary use (Plate IV). Longitudinal and transverse planes scan of right and left kidneys were carried out. The left kidney was located between L_1-L_3 with its cranial pole having contact with greater curvature of the stomach and the spleen on its dorsomedial aspect, while the caudal pole having contact with small intestines and the descending colon. The right kidney was deeper and cranially located in the para-costal region located between T_{12}-L_1 with its cranial pole having contact with caudate lobe of the liver and right pancreatic lobe ventromedially. To and fro movement of the transducer at these locations aided focusing of the ultrasound impulse on the kidneys along longitudinal plane (Plate V) in order to have visualization on B-mode. Once there was a clear image of the cranial and caudal poles of a kidney on the monitor, the freeze button on the keyboard of the ultrasound machine was pressed in order to freeze the image on the monitor and distance measurement

mode was activated. Kidney length was measured from the cranial to caudal poles of the kidney in centimeter (cm).

To obtain the width of the kidney, the transducer was rotated at 90^0 anti-clockwise from the longitudinal plane to be on a transverse plane, then freeze and distance measurement mode was activated, pointers were dragged from the medial limit to the lateral limit along the hilus of the kidneys. On transverse plane in a similar style, the height of the kidney was obtained by measuring the distance from the dorsal to the ventral limits of the kidneys.

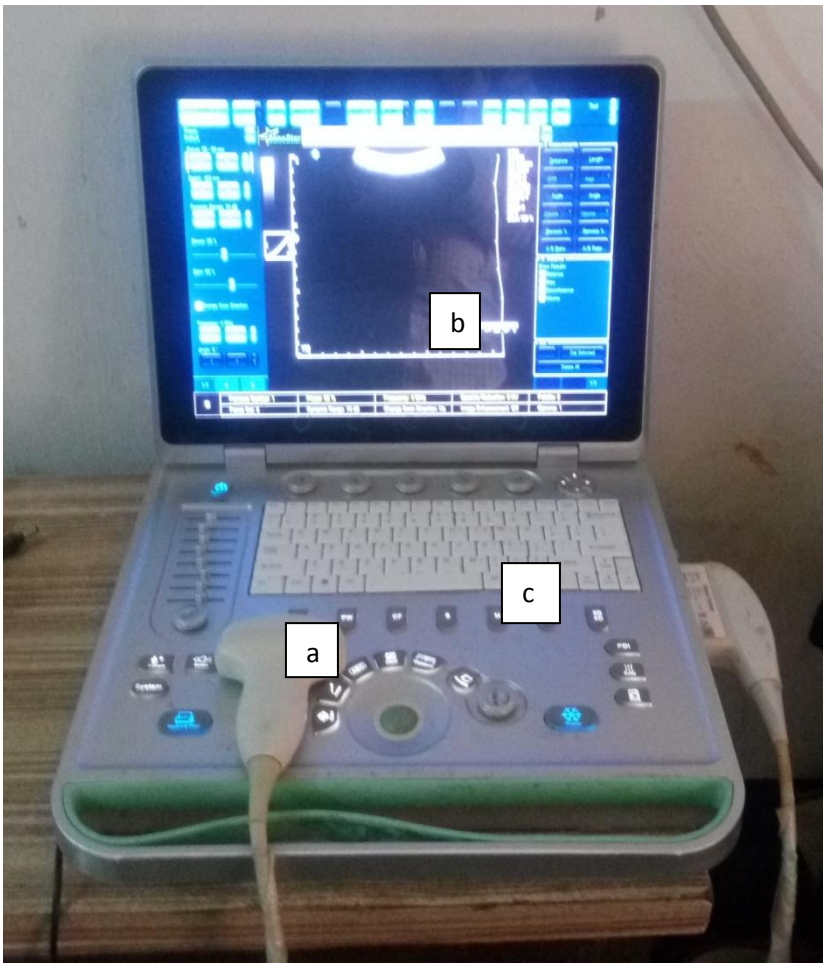


Plate IV: Features of Laptop B-mode Sonostar^{TM} C5 mounted on a table for use. It is equipped with its (a) curvilinear probe, (b) 15 inches HD LCD screen, and (c) control panel.



Plate V: Longitudinal plane scanning of the right kidney. The operator handled the curvilinear probe in a parallel manner on the long axis of the animal's body. The animal was restrained on dorsal recumbency with hindlimbs flexed.

In order to establish the renal volume (RV cm^3), the ellipsoidal method assumes the shape of the structure studied. Using the formula: Renal Volume (RV cm^3) = Kidney length (L cm) x kidney width (W cm) x kidney height (H cm) x 0.523 according to Barrera *et al*. (2009) as shown in Plates VI to VIII respectively.

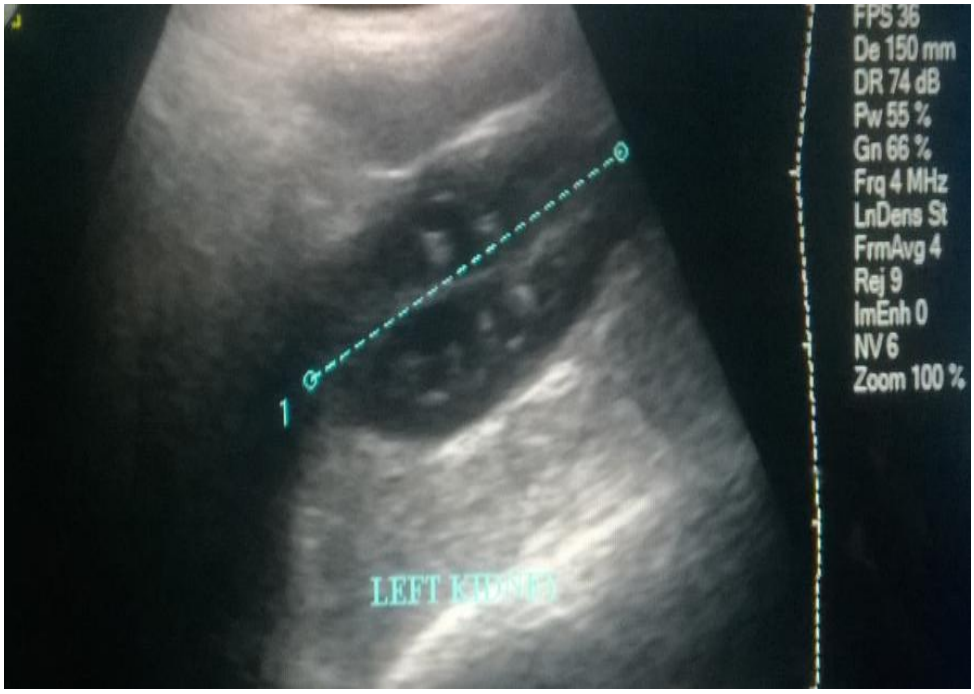


Plate VI: Sonographic measurement of kidney length. The diagonal broken lines indicate the oblique measurement to obtain the length of the kidney.

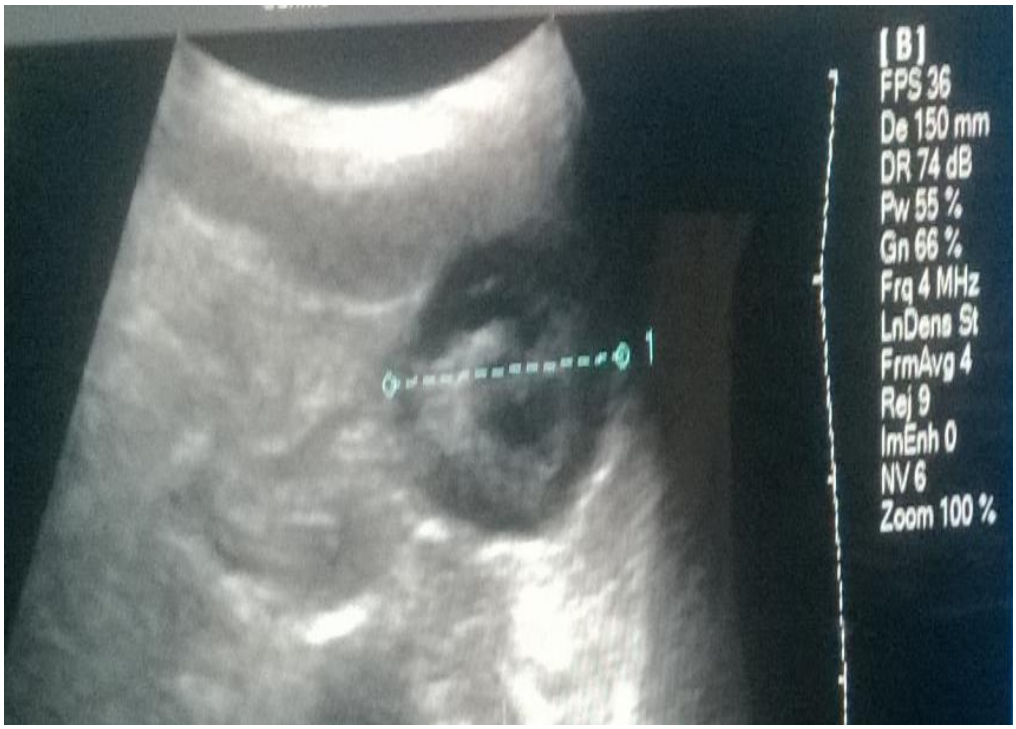


Plate VII: Sonographic measurement of kidney width. The horizontal broken lines indicate the oblique measurement to obtain the width of the kidney.

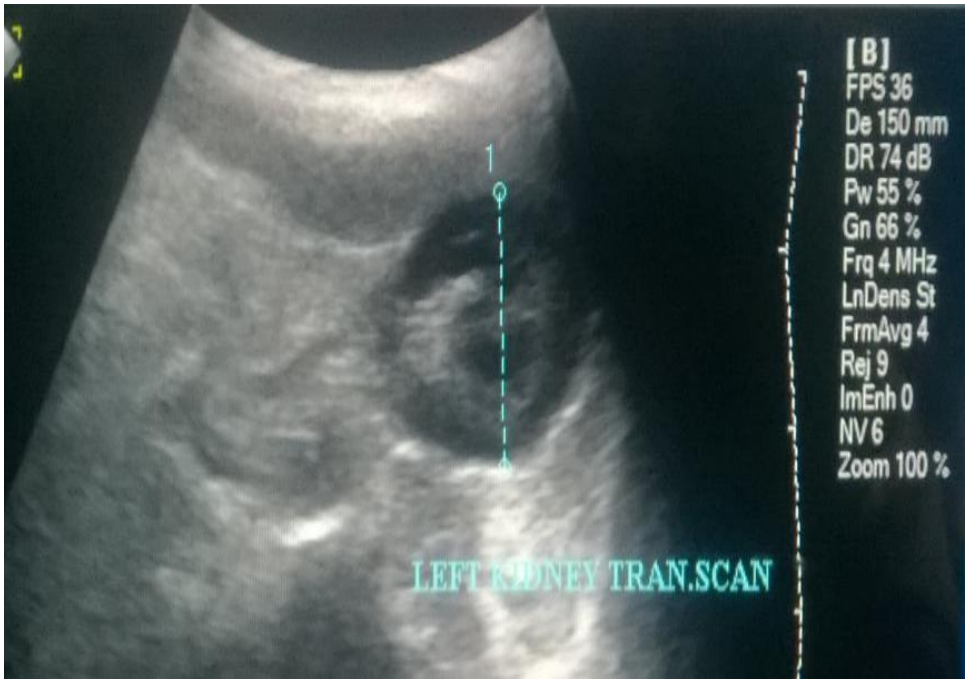


Plate VIII: Sonographic measurement of kidney height. The vertical broken lines indicate the oblique measurement to obtain the height of the kidney.

3.5 Data analysis

Data collected were subjected to statistical analysis using Graph Pad Prism® version 5.0 and mean ± SEM of the mean for each subject was calculated. Student's T-test was conducted on data obtained between paired kidneys and sexes. Correlation coefficient test was used to relate modified body mass index with kidney dimensions. The value of $P \leq 0.05$ was considered significant.

CHAPTER FOUR

RESULTS

This research was conducted on one hundred and fifteen (115) clinically healthy NID from which their ultrasonographic kidney and anthropometric dimensions were collected and computed for kidney volume and modified body mass index respectively. The age group distribution of males and females NID used in this research are presented in Table 4.1 and 4.2 respectively.

Table 4.1: Age Group Distributions of the Anthropometric and Kidney Dimensions of Male NID.

		Anthropometric dimensions			Kidney dimensions							
					Right kidney				Left kidney			
Age group (months)	**Count**	**Weight (Kg)**	**Length (m)**	**MBMI (Kg/m^2)**	**Length (cm)**	**Width (cm)**	**Height (cm)**	**Volume (cm^3)**	**Length (cm)**	**Width (cm)**	**Height (cm)**	**Volume (cm^3)**
12.00 - 23.00	9	12.00	0.49	50.88	5.47	3.06	2.43	22.05	5.61	3.40	2.78	28.80
24.00 - 35.00	13	14.69	0.52	55.29	5.38	3.07	2.54	22.77	5.51	3.25	2.99	28.29
36.00 - 47.00	9	16.33	0.54	55.15	5.31	3.11	2.76	23.98	5.95	3.44	3.32	36.16
48.00 - 54.00	7	16.86	0.55	55.86	5.68	3.21	3.00	28.94	6.07	3.54	3.24	36.17

Table 4.2: Age Group Distribution of the Anthropometric and Kidney Dimensions of Female NID

		Anthropometric dimensions			Kidney dimensions							
					Right kidney				Left kidney			
Age group (months)	**Sex count**	**Weight (Kg)**	**Length (m)**	**MBMI (Kg/m^2)**	**Length (cm)**	**Width (cm)**	**Height (cm)**	**Volume (cm^3)**	**Length (cm)**	**Width (cm)**	**Height (cm)**	**Volume (cm^3)**
12.00 – 23.00	15	12.60	0.50	51.13	5.41	3.31	2.61	25.76	5.49	3.16	2.77	25.28
24.00 - 35.00	13	15.69	0.55	50.65	5.19	3.11	2.85	26.15	5.60	3.39	3.31	33.54
36.00 - 47.00	11	17.45	0.55	57.07	5.42	3.02	2.94	25.56	5.67	3.10	3.08	28.51
48.00 - 54.00	38	20.42	0.57	62.82	5.85	3.19	2.94	29.16	6.13	3.47	3.20	36.49

4.1. Haematological Profile of 115 NID (NIDs) Studied at A.B.U. Zaria

Ranges and values of the measurement of the hematological profile and serum biochemistry in NID are shown in Table 4.3 and 4.4 respectively. The hematological profile are hemoglobin concentration, packed cell volume, erythrocytes, leucocytes, neutrophils, lymphocytes, eosinophils, monocytes and bands with mean ± SEM of 13 ± 0.33, 40 ± 0.98, 6.7 ± 0.16, 11 ± 0.37, 6.4 ± 0.31, 3.4 ± 0.17, 0.13 ± 0.03, 11 ± 0.02 and 0.14 ± 0.03 respectively, while the serum biochemistry are sodium, potassium, chloride, bicarbonate, urea, creatinine, albumin and total protein with mean ± SEM of 134.50 ± 1.39, 4.17 ± 0.10, 100.40 ± 1.77, 19.57 ± 0.44, 4.31 ± 0.11, 74.13 ± 2.27, 39.18 ± 0.77 and 67.06 ± 1.02 respectively.

Table 4.3: Mean Values of the Hematological Profile of 115 NID Studied at A.B.U. Zaria

Variables	Mean ± SEM	References values
Hemaglobin (g/dl)	13.00 ± 0.33	14.20 ± 1.60[a]
Leucocytes ($\times 10^9$/L)	11.00 ± 0.37	12.05 ± 4.59[a]
Neutrophil ($\times 10^9$/L)	6.40 ± 0.31	7.47 ± 1.34[a]
Lymphocytes($\times 10^9$/L)	3.40 ± 0.17	3.67 ± 1.40[a]
Eosinophils ($\times 10^9$/L)	0.10 ± 0.03	0.54 ± 0.42[a]
Monocytes ($\times 10^9$/L)	0.10 ± 0.02	0.33 ± 0.25[a]
Bands ($\times 10^9$/L)	0.10 ± 0.03	0.3 ± 0.16[a]
PCV (%)	40.00 ± 0.98	42.00 ± 4.59[b]
Erythrocytes ($\times 10^{12}$/L)	6.7 ± 0.16	5.50 ± 3.50[b]

References values: [a]Saror *et. al.*, 1979; [b]Esievo, 2017.

Table 4.4: Mean Values of Serum Biochemistry of 115 NID Studied at A.B.U. Zaria

Variables	Mean ± SEM	Reference values
Sodium (mmol/l)	134.50 ± 1.39	137.00 - 149.00
Potassium(mmol/l)	4.17 ± 0.10	3.70 - 5.60
Chloride (mmol/l)	100.40 ± 1.77	100.00 - 120.00
HCO_3 (mmol/l)	19.57 ± 0.44	17.00 - 24.00
Urea (mmol/l)	4.31 ± 0.11	2.50 - 7.00
Creatinine (umol/l)	74.13 ± 2.27	40.00 - 130.00
Albumin (g/l)	39.18 ± 0.77	25.00 - 40.00
Total protein (g/l)	67.06 ± 1.02	57.00 - 77.00

References values: Bush, 1993

4.2 Sonographic Dimensions of the Kidneys

4.2.1. Kidney length

The right kidney length of clinically healthy NID was within the range of 3.86 - 7.40 cm with the mean of 5.54 ± 0.07. The left kidney length was 4.12 – 7.57 cm with the mean of 5.81 ± 0.06 as shown in Table 4.5. In males, right kidney length has a range of 3.86 – 7.40 cm with the mean of 5.59 ± 0.08, while the left kidney length 4.40 – 7.57 cm with the mean of 5.85 ± 0.08 as presented in Table 4.6. Similarly, in females, right and left kidney length was within the range of 4.01 – 6.90 cm and 4.12 – 6.92 cm, their mean was 5.44 ± 0.11 and 5.74 ± 0.11 respectively as shown in Table 4.6.

4.2.2. Kidney width

The right kidney width of clinically healthy NID was within the range of 1.86 - 5.00 cm with the mean of 3.15 ± 0.06, while the range for left kidney width is 2.04 – 5.42 cm with the mean of 3.36 ± 0.05 as shown in Table 4.5. In males, right kidney width has a range of 2.09 – 5.00 cm with the mean of 3.18 ± 0.07, while the left kidney width 2.04 – 5.42 cm with the mean of 3.35 ± 0.06 as presented in Table 4.6. Similarly, in females, right and left kidney width was within the range of 1.86 – 4.50 cm and 2.40 – 4.59 cm, their mean were 3.11 ± 0.09 and 3.39 ± 0.08 respectively as shown in Table 4.6.

4.2.3. Kidney height

The right kidney height of clinically healthy NID was within the range of 1.77 - 4.40 cm with the mean of 2.79 ± 0.05, while the range for left kidney height is 1.84 – 4.64 cm with the mean of 3.10 ± 0.05 as shown in Table 4.5. In males, right kidney height has a range of

1.77 – 4.40 cm with the mean of 2.86 ± 0.06, while the left kidney height 1.84 – 4.64 cm with the mean of 3.12 ± 0.06 as presented in Table 4.6. Similarly, in females, right and left kidney height was within the range of 1.98 – 4.01 cm and 2.01 – 4.03 cm, their mean were 2.65 ± 0.07 and 3.06 ± 0.08 respectively as shown in Table 4.6.

Table 4.5: Mean Right and Left kidney Dimensions of Clinically Healthy NID.

Variables	Kidney dimensions n= 115			
	Right kidney		Left kidney	
	Range	**Mean ± SEM**	**Range**	**Mean ± SEM**
Kidney length (cm)	3.86 - 7.40	5.54 ± 0.067	4.12 - 7.57	5.81 ± 0.07
Kidney width (cm)	1.86 - 5.00	3.15 ± 0.06	2.04 - 5.42	3.36 ± 0.05
Kidney height (cm)	1.77 - 4.40	2.79 ± 0.05	1.84 - 4.64	3.10 ± 0.05
Kidney volume (cm^3)	9.22 - 63.20	26.33 ± 0.94	13.66 - 70.21	32.36 ± 1.04

Table 4.6: Mean Right and Left Kidney Dimensions of Clinically Healthy Male and Female NID.

Variables	Males n= 77				Females n= 38			
	Right Kidney		Left Kidney		Right Kidney		Left Kidney	
	Range	Mean ± SEM	Range	Mean ± SEM	Range	Mean ± SEM	Range	Mean ± SEM
Kidney length (cm)	3.86 - 7.40	5.59 ± 0.08	4.40 - 7.57	5.85 ± 0.08	4.01 - 6.90	5.44 ± 0.11	4.12 - 6.92	5.74 ± 0.11
Kidney width (cm)	2.09 - 5.00	3.18 ± 0.07	2.04 - 5.42	3.35 ± 0.06	1.86 - 4.50	3.11 ± 0.09	2.40 - 4.59	3.39 ± 0.08
Kidney height (cm)	1.77 - 4.40	2.86 ± 0.06	1.84 - 4.64	3.12 ± 0.06	1.98 - 4.01	2.65 ± 0.07	2.01 - 4.03	3.06 ± 0.08
Kidney volume(cm^3)	10.74-63.20	27.47 ± 1.22	13.66-70.21	32.67 ± 1.35	9.22-45.22	24.02 ± 1.35	15.56-51.80	31.73 ± 1.57

4.3. Correlation between Kidney Dimensions and Modified Body Mass Index

Ranges and mean values of the measurement of the kidney dimensions and modified body mass index for NID were presented in Table 4.6 and 4.7 respectively. Correlation between modified body mass index and kidney dimensions revealed a significant but weak positive relationship in right and left kidney length (0.30 and 0.37), kidney height (0.22 and 0.18) respectively, and right kidney volume (0.21) as shown in Table 4.8 and graphically represented in Figure 4.1, 4.2, 4.5, 4.6, and 4.7 respectively, while there were no significant correlation in right kidney width (0.083) and left kidney volume (0.18) as shown in Figure 4.3 and 4.8 respectively, but also negative correlation was revealed in left kidney width (-0.057) as represented in Figure 4.4.

Table 4.7: Mean Anthropometric Dimensions of Apparently Healthy NID

	Anthropometric dimensions (n= 115)	
Variables	**Range**	**Mean±SEM**
Age (months)		
Weight (Kg)	12.00 - 54.00	33.97 ± 1.32
Length (m)	8.00 - 30.00	16.74 ± 0.45
Modified body mass index	0.44 - 0.68	0.54 ± 0.01
(Kg/m^2)	36.00 - 98.00	57.00 ± 1.10

Table 4.8: Correlation of Kidney Dimensions with Modified Body Mass Index for Dogs

Parameters	**Right kidney**		**Left kidney**	
	Correlation	**Regression**	**Correlation**	**Regression**
Kidney length (cm)	0.30□ □	0.088□ □	0.37□ □ □	0.14□ □ □
Kidney width (cm)	0.083	0.0068	-0.057	0.0032
Kidney height (cm)	0.22□ □	0.046□	0.18□	0.034□
Kidney volume (cm^3)	0.21□	0.044□	0.18	0.033

* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$

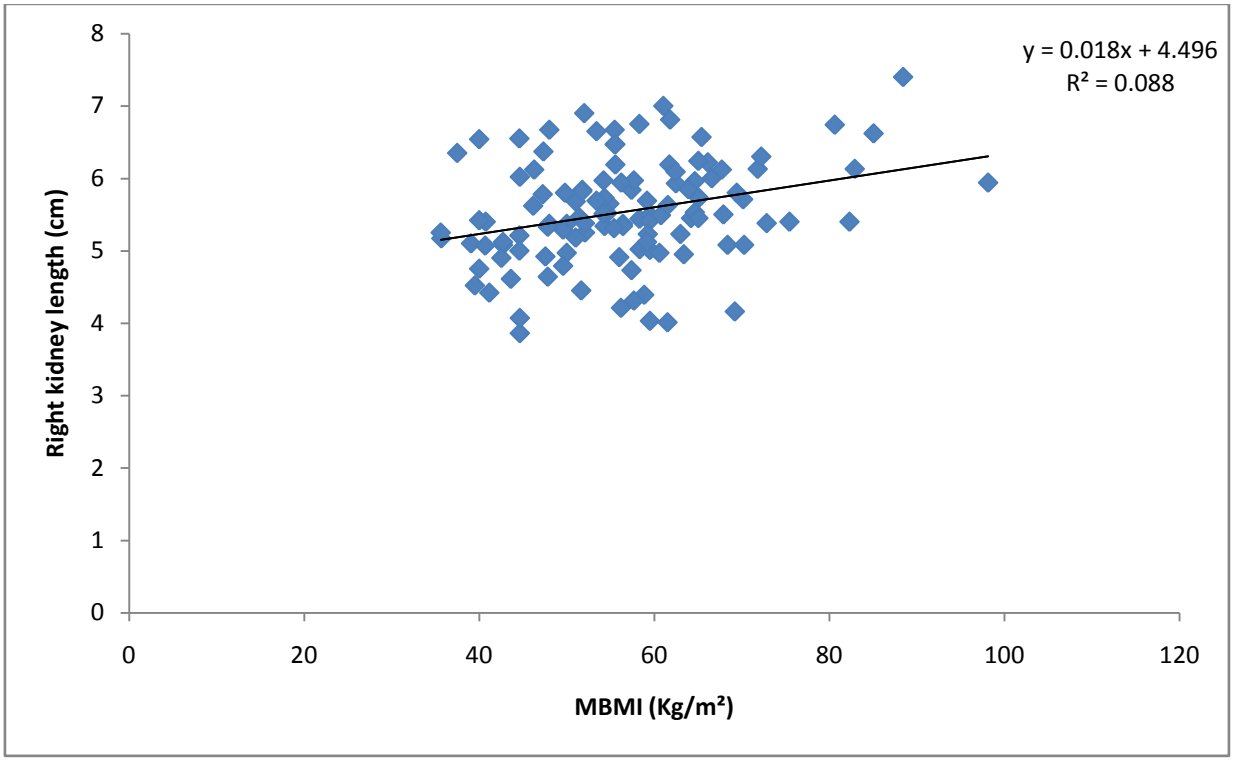


Figure 4.1: Positive linear relationship between of modified BMI with right kidney length. The relationship is weak as regression coefficient is 8.81%.

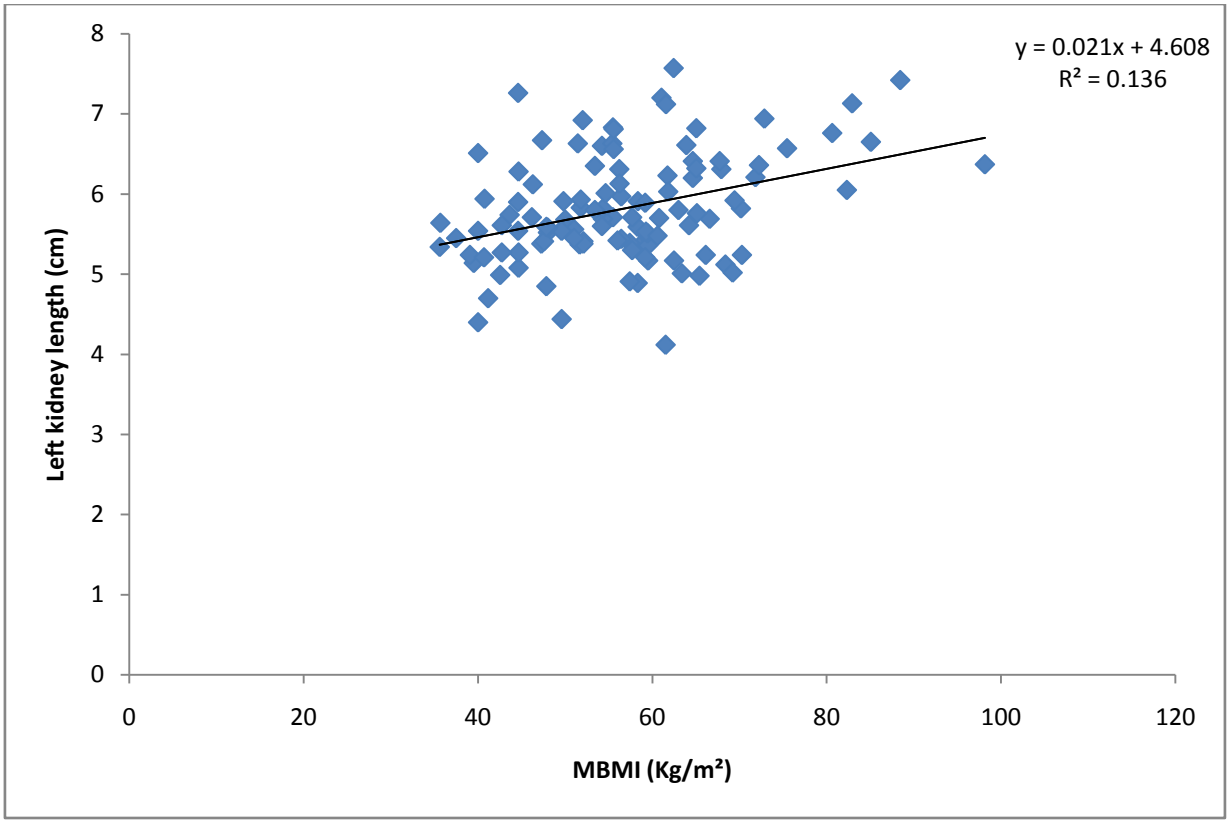


Figure 4.2: Positive linear relationship between modified BMI with left kidney length. The relationship is weak as regression coefficient is 13.6%.

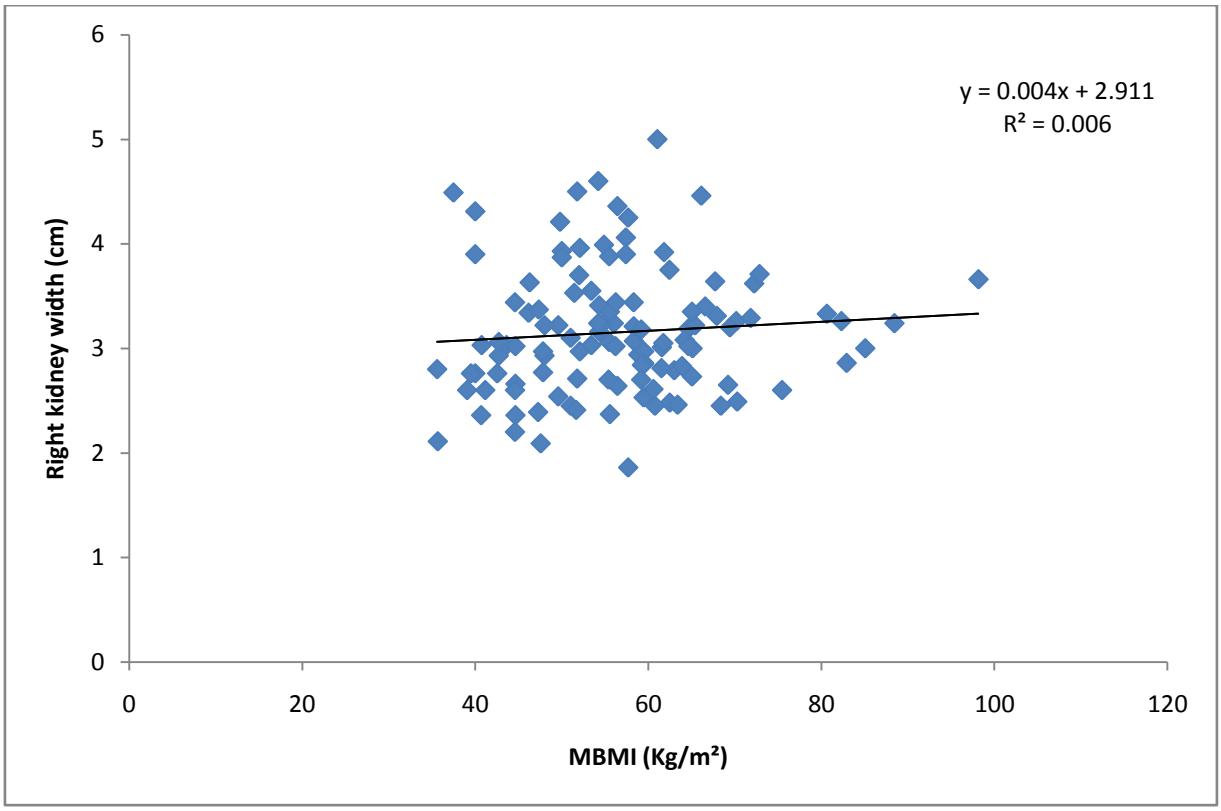


Figure 4.3: Positive linear relationship between modified BMI with right kidney width. The relationship is very weak as regression coefficient is 0.68%.

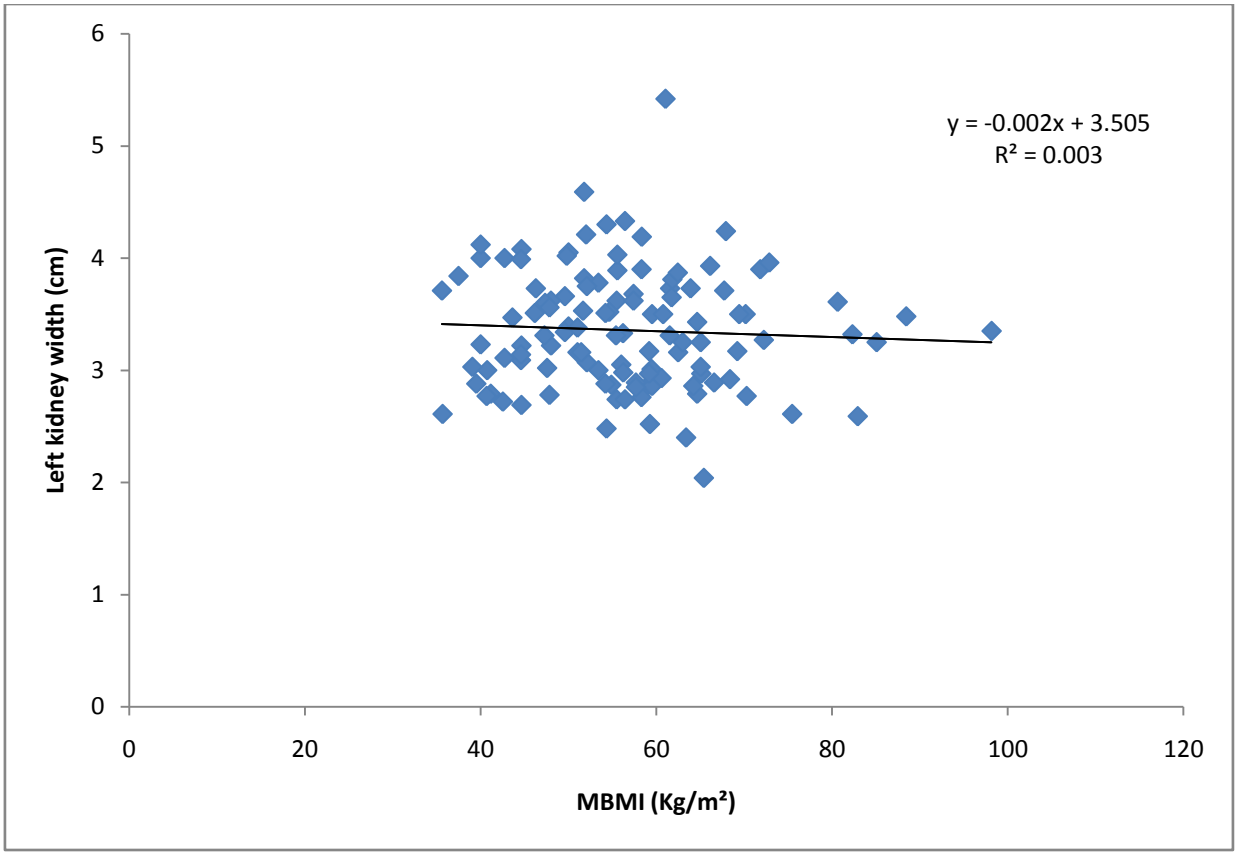


Figure 4.4: Negative linear relationship between modified BMI with left kidney width. The relationship is very weak as regression coefficient is 0.32%.

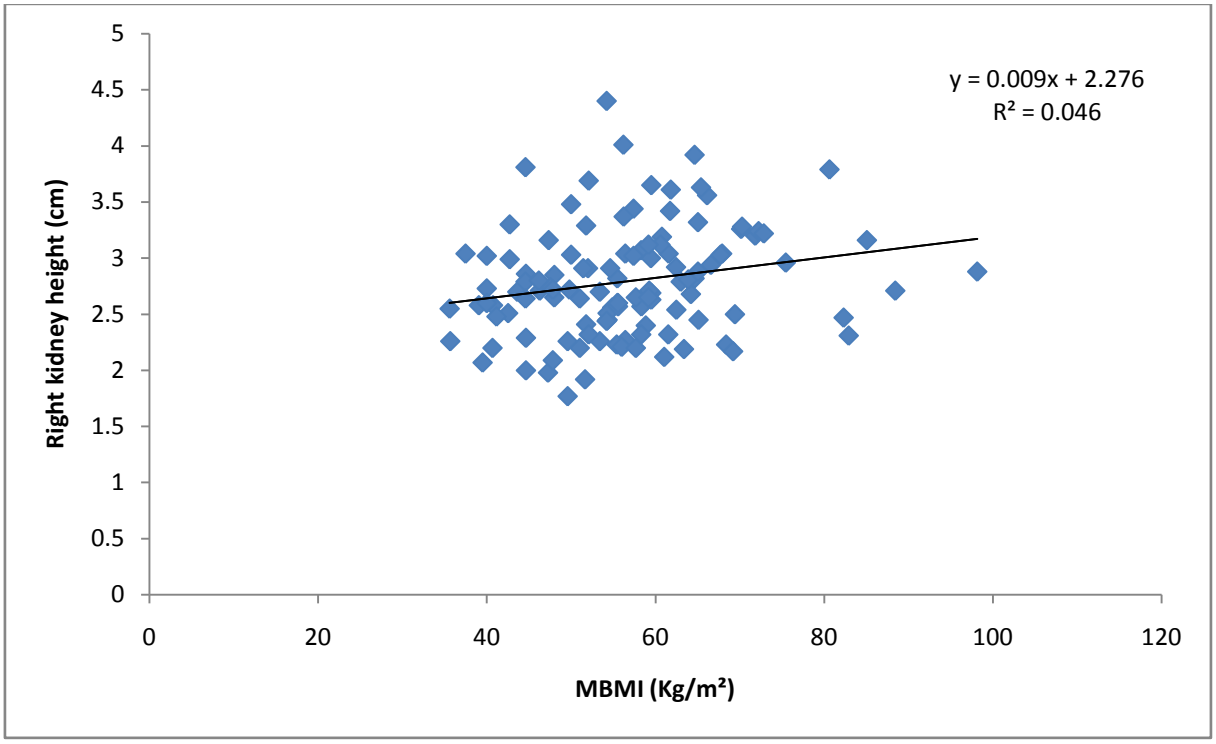


Figure 4.5: Positive linear relationship between modified BMI with right kidney height. The relationship is weak as regression coefficient is 4.63%.

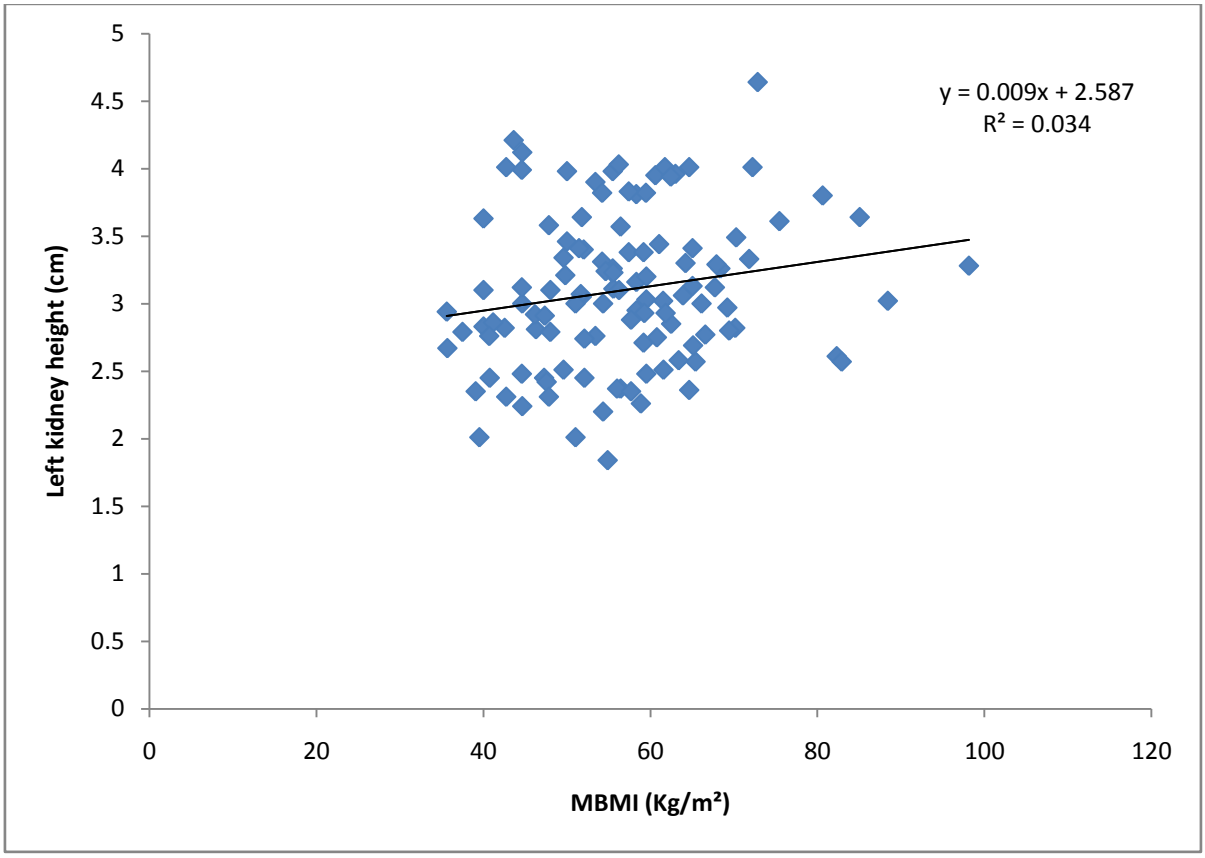


Figure 4.6: Positive linear relationship between modified BMI with left kidney height. The relationship is weak as regression coefficient is 3.41%.

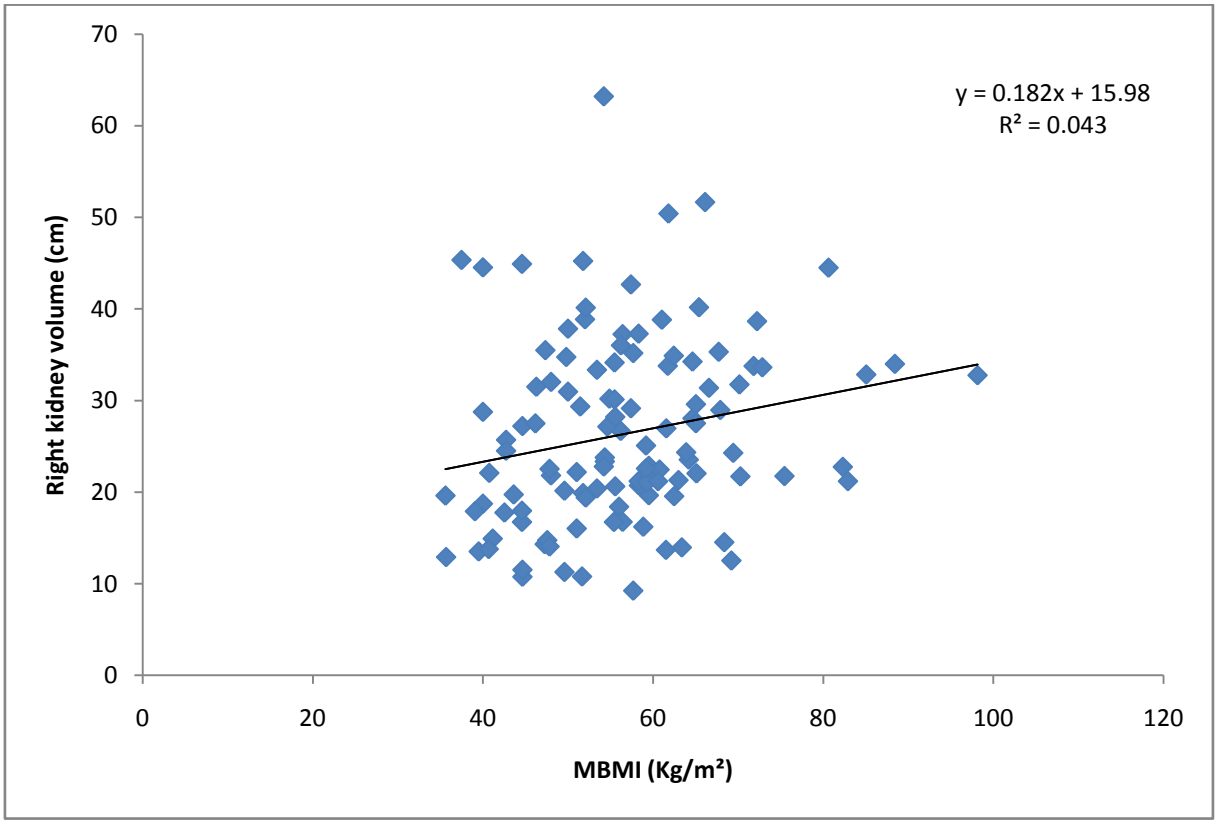


Figure 4.7: Positive linear relationship between modified BMI with right kidney volume. The relationship is weak as regression coefficient is 4.37%.

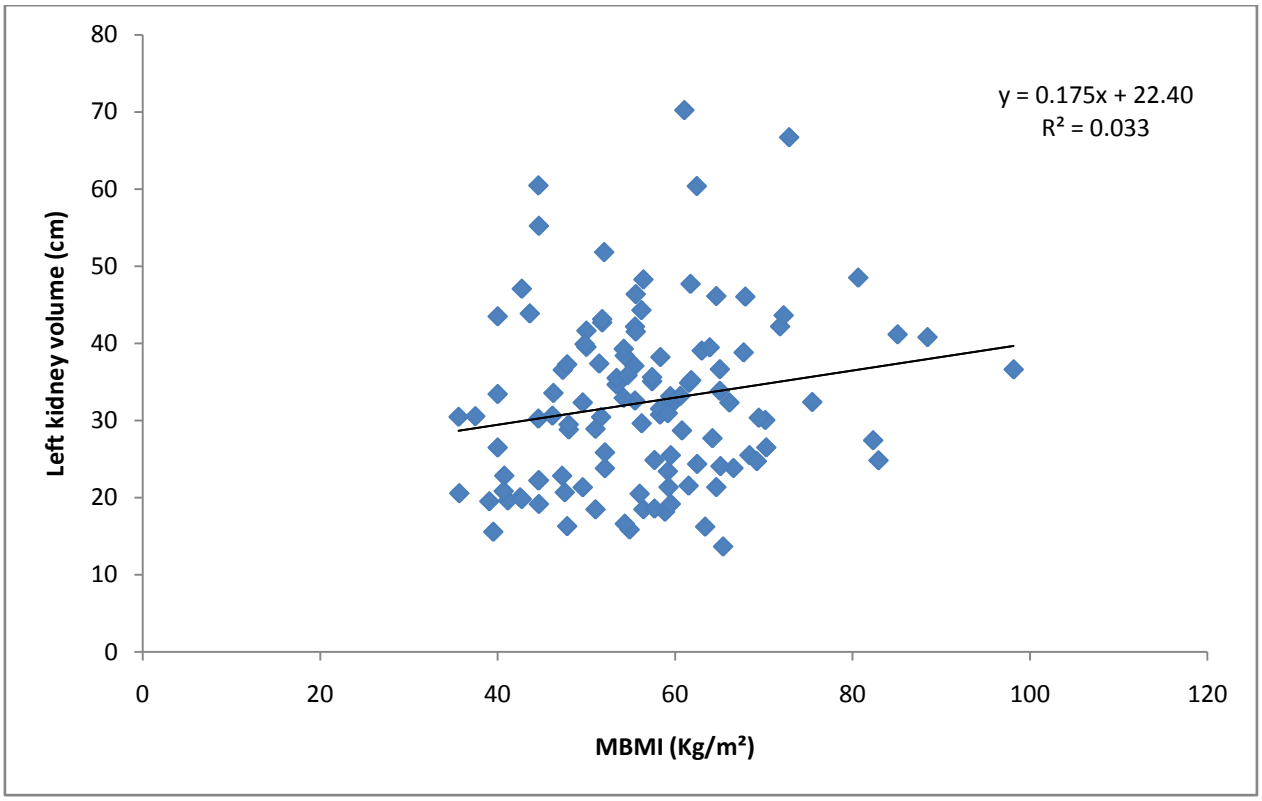


Figure 4.8: Positive linear relationship between modified BMI with left kidney volume. The relationship is weak as regression coefficient is 3.3%.

4.4. Sex and Paired Variation in Kidney Dimensions

4.4.1. Sex variations between kidneys

Range values and means of the measurement of the length, width, height, and volume of kidneys for both males and females are presented in Table 4.6. The values for the variations between males and females in right and left kidneys respectively are; kidney length (0.3001 and 0.4274), kidney width (0.5465 and 0.7045), kidney height (0.0294 and 0.6421) and kidney volume (0.0834 and 0.6727) as shown in Table 4.9.

4.4.2. Variations between paired kidneys

Ranges and mean values of the measurement of the length, width, height and volume of the right and left kidneys of both males and females are presented in Table 4.6. The values for the differences between the right and left kidneys in males and females respectively are; kidney length (0.0008 and 0.0012), kidney width (0.0226 and 0.007), kidney height (0.0004 and 0.0001) and kidney volume (0.0004 and 0.0001) as shown in Table 4.10.

Table 4.9: Comparism between Male and Female Kidney Dimensions.

	Right Kidney	Left kidney
Variables	**M Vs F**	**M Vs F**
Kidney length (cm)	0.3001	0.4274
Kidney width (cm)	0.5465	0.7045
Kidney height (cm)	0.0294□	0.6421
Kidney volume (cm³)	0.0834	0.6727

Table 4.10: Comparism between Right and Left kidney Dimensions in Male and Female.

	Males	Females
Variables	**RT Vs LT**	**RT Vs LT**
Kidney length (cm)	0.0008□ □ □	0.0012□ □
Kidney width (cm)	0.0226□	0.0007□ □ □
Kidney height (cm)	0.0004□ □ □	0.0001□ □ □
Kidney volume (cm³)	0.0004□ □ □	0.0001□ □ □

4.5. Kidney Volume in NIDs

The right kidney volume of clinically healthy NID was within the range of 9.22 - 63.20 cm with the mean of 26.33 ± 0.94, while the left kidney volume was 13.66 – 70.21 cm with the mean of 32.36 ± 1.04 as shown in Table 4.5. In males, right kidney volume had a range of 10.74 – 63.20 cm with the mean of 27.47 ± 1.22, while the left kidney volume 13.66 – 70.21 cm with the mean of 32.67 ± 1.35 as presented in Table 4.6. Similarly, in females, right and left kidney volume were within the range of 9.22 – 45.22 cm and 15.56 – 51.80 cm, their mean was 24.02 ± 1.35 and 31.73 ± 1.57 respectively as shown in Table 4.6.

CHAPTER FIVE

DISCUSSION

The kidney is an intra-abdominal organ usually located in the retroperitoneal space that takes the shape of bean grossly (Burk and Feeney, 2003) which its ultrasonographical image revealed renal cortex with mild echogenicity and finely granular particles, while renal medulla and pelvis with anechoic and irregular echogenicity appearance respectively; these findings agreed with the reports in other studies (Park *et al*., 2008; Barman and Gaikwad, 2014).

Hematological profile and plasma biochemistry analyses including biomarkers for kidney disorders such as creatinine and urea were within normal limits. This implied that dogs used were clinically healthy for the study of kidneys (Bush, 1993). It is appropriate to emphasize, that the creatinine and urea concentrations in the dogs under study were within normal range, in particular, since during physical examination of these dogs, only dogs with body condition score of three (ideal) from a five point scale were used, suggesting that the dogs were clinically healthy (Esievo, 2017). Therefore, the range limits obtained from in-vivo ultrasound measurement of the kidney dimensions in these subjects should be considered as normal for NID.

In small animals, kidney length, kidney width and kidney height (Konde *et al*., 1984; Felkai *et al*., 1992; Kolber and Borelli, 2005; Park *et al*., 2008; Cunha *et al*., 2009; Barella *et al*., 2012; Jeyaraja *et al*., 2015) can be measured from an ultrasound image of a kidney (Atalabi *et al*., 2013). Kidney length in NID was 5.54 ± 0.07 cm and 5.81 ± 0.06 cm for right and left kidneys respectively. Similar studies reported kidney length as 4.59 cm and 4.63 cm,

and 7.18 cm and 7.33 cm for right and left kidneys of Dachshund (Cunha *et al*., 2009) and German shepherd (Kolber and Borelli, 2005) dogs respectively. Several studies in undisclosed breed of dogs also reported kidney length as 5.87 cm and 5.79 cm (Barella *et al*., 2012), 5.99 cm and 5.97 cm (Mareschal *et al*., 2007), and 4.70 cm and 4.70 cm (Jeyaraja *et al*., 2015) for right and left kidneys respectively. Kidney width in NID was 3.15 ± 0.06 cm and 3.36 ± 0.05 cm for right and left kidneys respectively. Similarly, studies in Dachshund (Cunha *et al*., 2009) and German shepherd (Kolber and Borelli, 2005) dogs, reported kidney width as 2.29 cm and 2.42 cm, and 3.47 cm and 3.45 cm for right and left kidneys respectively. The kidney width in undisclosed breeds of dogs were reported as 3.44 cm and 3.39 cm (Sampaio and Araujo, 2002), and 2.50 cm and 2.50 cm (Jeyaraja *et al*., 2015) for right and left kidneys respectively. Kidney height in NID was 2.79 ± 0.05 cm and 3.10 ± 0.05 cm for right and left kidneys respectively. In Dachshund (Cunha *et al*., 2009) and German shepherd (Kolber and Borelli, 2005) dogs, the kidney height was reported as 2.42 cm and 2.45 cm, and 3.43 cm and 3.49 cm for right and left kidneys respectively. In the undisclosed breed of dogs, the kidney height were reported as 2.6 cm and 2.6 cm (Jeyaraja *et al*., 2015), 3.02 cm and 3.02 cm (Sampaio and Araujo, 2002), and 3.28 cm and 3.30 cm (Barella *et al*., 2012) for right and left kidneys respectively. Variations in kidney dimensions among the different breed of dogs was noticed. This was supported by Lobacz *et. al.* (2012) and Sohn *et. al.* (2016) which could be attributed to differences in body size the among various breed of dogs.

Modified body mass index for dogs was considered in this study because dogs are quadrupeds; it is preferred to used the truncal length (length of the trunk) of the animal instead of the height as in human, which leads to the establishment of an appropriate

anthropometric dimension for dogs known as modified body mass index for dogs, as the weight in kilograms per truncal length in meter square (Thengchaisri *et al*., 2014). Even though, some researchers have attempted using the human body mass index for dogs (Koc *et al*., 2009; Ajadi *et al*., 2016) but its value increases as the height decrease thereby becoming an inappropriate index for medium and smaller breed of dogs (Ajadi *et al*., 2016). There were positive correlations between kidney dimensions and modified body mass index except with left kidney width in NID. Unfortunately, the correlation between ultrasonographic kidney dimensions and modified body mass index have not yet been reported in the literature for healthy dogs, and the results obtained in this study will be the first to be reported in this species. But several studies in same species also reported a positive correlation between kidney dimensions and body weight (Nyland *et al*., 1989; Barr, 1990; Felkai *et al*., 1992; Sampaio and Araujo, 2002). However, in human, there were also studies that reported a positive correlation between kidney dimensions and body mass index (Safak *et al*., 2005; Shin *et al*., 2009), while, some studies opposed the findings (Emamian *et al*., 1993; Egberongbe *et al*., 2010). Correlation between the kidney and anthropometric dimensions have recently become accepted in the diagnosis of nephropathies (Sampaio and Araujo, 2002; Okur *et al*., 2014).

It was observed that there were no sex variations in kidney dimensions of NID. Similar findings were reported in a study by Sampaio and Araujo (2002), while a study in German shepherd by Kolber and Borelli (2005) reported that males had larger kidney dimension than females, and another study by Stocco *et al*, (2016) reported that females have larger kidney dimensions. In human, some studies reported no variation between males and females kidney dimensions (Hekmatnia and Yaraghi, 2004; Luyck and Brenner, 2010;

Muthusami *et al*., 2012; El-Reshaid and Abdul-Fattah, 2014). Other studies reported significant sex variations in kidney dimensions with male having greater values than female (Okoye *et al*., 2005; Kang *et al*., 2007). This finding was suggested to be influenced by the anabolic activity of androgens that causes hypertrophy of proximal tubule, so that the length differences were restricted in the renal cortex (Sabolic *et al*., 2007; Jackson *et al*., 2011). Another most likely explanation could be due to larger body size in male which reqiures a large quantity of nephron for its metabolic activities (Otiv *et al*., 2012).

There were significant findings that revealed that the left kidney was larger than the right kidney in NID. Some studies in Dachshund (Cunha *et al*., 2009) and German shepherd (Kolber and Borelli, 2005) dogs support this finding, while some studies reported that right kidney is larger than the left kidney (Mareschal *et al*., 2007), and others reported no differences between right and left kidneys (Sampaio and Araujo, 2002; Barella *et al*., 2012; Jeyaraja *et al*., 2015). In human, several studies reported the left kidney being larger than the right kidney (Hollinshead, 1971; Raza *et al*., 2011); explanation for this was suggested by Karim *et al*, (2015) which could be because hepatic tissue may hinder longitudinal development of the right kidney whereas left kidney has liberty for maximum growth without hindrance. Another possible suggestion could be that the left renal artery being shorter than the right, therefore allow increased blood flow that may cause a slight increase in left kidney volume (Okur *et al*., 2014).

The mean values of kidney volume of NID were 26.33 ± 0.94 cm^3 and 32.36 ± 1.04 cm^3 for right and left kidneys respectively. Several studies reported kidney volume as 13.69 cm^3 and 14.80 cm^3 in Dachshund dogs (Cunha *et al*., 2009), and other undisclosed breed of dogs as 35.78 cm^3 and 35.29 cm^3 (Sampaio and Araujo, 2002), 17.15 cm^3 and 17.04 cm^3

(Jeyaraja *et al.*, 2015) and 42.08 cm^3 and 54.60 cm^3 (Barrera *et al.*, 2009) for right and left kidneys respectively. Though, there is another method to determine volume of prolate ellipsoid using single plane area-length models (A^2 x 0.85/L) (Felkai *et al*., 1992; Barman and Gaikwad, 2014) which may produce slight different values as 47.39 ± 4.30 cm^3 and 44.53 ± 3.49 cm^3 for right and left kidneys respectively (Barman and Gaikwad, 2014). But the prolate ellipsoid using the biplane length-diameter models (L x W x H x 0.523) used in NID, stands to be the best method when considering prolate ellipsoid organs such as kidneys (Nyland *et al.*, 1989; Barrera *et al*., 2009). This method has also been advocated in the ultrasonographical determination of kidney volume in human by some scholars (Kim *et al*., 2013; Okur *et al*., 2014). Kidney volume has been considered as an accurate and reproducible kidney dimension that better explains the functionality of a kidney (Barr, 1990; Felkai *et al*., 1992; Barrera *et al*., 2009) in which its changes occur in presence of kidney disorders (Barman and Gaikwad, 2014; Jeyaraja *et al*., 2015) as well as early detection of nephropathies even before manifestation of clinical signs (Rossi *et al*., 2012).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The following findings were deduced from this study:

1. The mean values of the kidney dimensions in NID include: kidney length as 5.54 ± 0.067 cm and 5.81 ± 0.062 cm, kidney width as 3.15 ± 0.056 cm and 3.36 ± 0.049 cm and kidney height as 2.79 ± 0.045 cm and 3.10 ± 0.052 cm for right and left kidneys respectively.
2. Correlation between kidney dimensions and modified body mass index revealed positive linear relationships except in left kidney width that revealed a negative linear relationship in NID.
3. There were no differences in kidney dimensions between male and female but left kidney appeared larger than the right kidney in NID.
4. The mean values of right and left kidney volume in clinically healthy NID were 26.33 ± 0.94 cm^3 and 32.36 ± 1.04 cm^3 respectively.

6.2 Recommendation

Mean values of the kidney length, width, height and volume from this study should be considered as reference values in healthy NID. A source of central fund should be made available to pay rural dog owners as incentives to allow investigations on their dogs by veterinarians. Other ultrasonographic kidney estimations such as kidney size and parenchymal thickness were also reported to be useful in ascertaining kidney function in

human, so there is a need to compare them with the kidney volume to determine an estimate that is superior in ultrasonographic kidney diagnosis in NID.

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APPENDICES

Appendix 1a: Anthropometric and Kidney Dimensions of Apparently Healthy NID

SN	Sex	Age (months)	Weight (Kg)	Heigth (m)	Length (m)	BMI (Kg/m²)	MBMI (Kg/m²)	Right kidney (cm)			RK Volume	Left kidney (cm)			LK Volume
								L	W	H		L	W	H	
1	F	48	14	0.48	0.52	60.76	51.78	5.84	4.5	3.29	45.22	5.83	4.59	3.05	42.686
2	M	24	13	0.51	0.47	49.98	58.85	4.39	2.94	2.4	16.20	5.39	2.85	2.26	18.157
3	M	54	16	0.56	0.54	51.02	54.87	5.65	3.99	2.56	30.18	5.74	2.87	1.84	15.853
4	F	24	15	0.51	0.52	57.67	55.47	6.47	3.88	2.6	34.14	5.71	2.74	3.98	32.567
5	F	36	13	0.47	0.48	58.85	56.42	5.37	4.36	3.04	37.23	5.97	4.33	3.57	48.265
6	F	48	18	0.55	0.6	59.50	50.00	4.97	3.93	3.03	30.95	5.6	3.39	3.98	39.516
7	M	24	10	0.47	0.5	45.27	40.00	4.75	2.76	2.73	18.72	4.4	4	3.63	33.413
8	F	24	15	0.54	0.53	51.44	53.40	6.65	3.55	2.7	33.34	6.35	3.78	2.76	34.648
9	M	30	19	0.61	0.66	51.06	43.62	4.61	3.03	2.7	19.72	5.74	3.47	4.21	43.856
10	M	54	18	0.55	0.56	59.50	57.40	5.84	4.06	3.44	42.66	5.39	3.68	3.38	35.063
11	M	12	14	0.55	0.56	46.28	44.64	3.86	2.66	2	10.74	5.08	3.22	2.24	19.163
12	M	36	17	0.51	0.54	65.36	58.30	6.75	3.44	3.07	37.28	5.59	2.76	3.81	30.743
13	M	48	21	0.6	0.6	58.33	58.33	5.02	3.07	2.57	20.71	5.91	4.19	2.95	38.205
14	M	48	18	0.54	0.6	61.73	50.00	5.37	3.87	3.48	37.82	5.68	4.05	3.46	41.628
15	M	12	9	0.45	0.49	44.44	37.48	6.35	4.49	3.04	45.33	5.45	3.84	2.79	30.538
16	M	12	12	0.47	0.47	54.32	54.32	5.34	3.41	2.45	23.33	5.69	4.3	3	38.389
17	F	12	14	0.48	0.49	60.76	58.31	5.44	3.21	2.32	21.19	4.89	3.9	3.16	31.518
18	M	48	25	0.67	0.64	55.69	61.04	7	5	2.12	38.81	7.2	5.42	3.44	70.209
19	M	54	16	0.5	0.56	64.00	51.02	5.68	2.45	2.2	16.01	5.56	3.16	2.01	18.470
20	M	48	15	0.51	0.55	57.67	49.59	5.29	3.22	2.26	20.13	4.44	3.66	2.51	21.332
21	M	24	17	0.52	0.56	62.87	54.21	5.97	4.6	4.4	63.20	6.6	2.88	3.31	32.905
22	M	12	15	0.51	0.51	57.67	57.67	5.97	4.25	2.65	35.17	5.71	2.89	2.88	24.856
23	M	24	20	0.66	0.55	45.91	66.12	6.22	4.46	3.56	51.65	5.24	3.93	3	32.311
24	M	18	14	0.58	0.54	41.62	48.01	6.67	3.22	2.85	32.01	5.52	3.22	3.1	28.818

25	M	36	18	0.58	0.55	53.51	59.50	4.03	2.97	3.65	22.85	5.47	3.5	3.2	32.041
26	M	18	12	0.47	0.47	54.32	54.32	5.73	3.16	2.51	23.77	5.82	2.48	2.2	16.607
27	M	30	12	0.56	0.53	38.27	42.72	5.08	2.93	3.3	25.69	5.61	4	4.01	47.062
28	M	42	18	0.53	0.52	64.08	66.57	6	3.4	2.94	31.37	5.69	2.89	2.77	23.823
28	F	42	9	0.44	0.46	46.49	42.53	4.9	2.76	2.51	17.75	4.99	2.72	2.82	20.018
30	F	54	15	0.44	0.52	77.48	55.47	6.67	3.06	2.82	30.10	6.83	3.62	3.26	42.155
31	M	12	10	0.5	0.5	40.00	40.00	6.54	4.31	3.02	44.52	5.54	3.23	2.83	26.485
32	F	12	8	0.44	0.45	41.32	39.51	4.52	2.76	2.07	13.51	5.14	2.88	2.01	15.562
33	M	54	24	0.53	0.54	85.44	82.30	5.4	3.26	2.47	22.74	6.05	3.32	2.61	27.418
34	M	36	21	0.58	0.57	62.43	64.64	5.96	3.19	2.82	28.04	6.2	2.79	2.36	21.351
35	F	18	10	0.48	0.46	43.40	47.26	5.78	2.39	1.98	14.31	5.38	3.31	2.45	22.818
36	M	48	22	0.57	0.58	67.71	65.40	6.57	3.22	3.63	40.16	4.98	2.04	2.57	13.655
37	M	48	18	0.56	0.55	57.40	59.50	5.49	2.86	2.69	22.09	5.17	2.86	2.48	19.178
38	M	48	15	0.53	0.49	53.40	62.47	5.93	2.48	2.54	19.54	5.17	3.16	2.85	24.351
39	M	12	9	0.48	0.47	39.06	40.74	5.4	3.03	2.58	22.08	5.94	3	2.45	22.834
40	M	12	15	0.47	0.48	67.90	65.10	5.73	3	2.45	22.03	5.76	2.97	2.69	24.068
41	M	18	10	0.5	0.44	40.00	51.65	4.45	2.41	1.92	10.77	5.37	3.53	3.07	30.436
42	F	24	9	0.46	0.48	42.53	39.06	5.1	2.6	2.58	17.89	5.24	3.03	2.35	19.514
43	M	30	14	0.55	0.56	46.28	44.64	6.02	3.02	2.86	27.19	6.28	4.08	4.12	55.210
44	F	36	17	0.53	0.55	60.52	56.20	4.21	3.02	4.01	26.66	6.31	3.33	4.03	44.287
45	F	12	13	0.49	0.5	54.14	52.00	6.9	3.7	2.91	38.85	6.92	4.21	3.4	51.805
46	F	24	13	0.47	0.53	58.85	46.28	6.12	3.63	2.71	31.49	6.12	3.73	2.81	33.548
47	M	48	22	0.51	0.56	84.58	70.15	5.71	3.26	3.26	31.74	5.82	3.5	2.82	30.043
48	M	12	18	0.54	0.55	61.73	59.50	5.01	2.85	2.63	19.64	5.36	3	3.03	25.482
49	M	24	25	0.61	0.63	67.19	62.99	5.23	2.79	2.79	21.29	5.8	3.25	3.96	39.040
50	M	36	12	0.51	0.58	46.14	35.67	5.17	2.11	2.26	12.89	5.64	2.61	2.67	20.556
51	F	36	23	0.57	0.58	70.79	68.37	5.08	2.45	2.23	14.52	5.12	2.92	3.26	25.490
52	M	48	20	0.53	0.58	71.20	59.45	5.41	2.53	3	21.48	5.51	3.01	3.82	33.135
53	F	42	21	0.59	0.55	60.33	69.42	5.8	3.2	2.5	24.27	5.92	3.5	2.8	30.342
54	M	24	14	0.45	0.56	69.14	44.64	4.07	2.36	2.29	11.50	5.27	2.69	3	22.243
55	M	24	15	0.48	0.55	65.10	49.59	4.79	2.54	1.77	11.26	5.54	3.34	3.34	32.322

56	M	12	12	0.51	0.54	46.14	41.15	4.42	2.6	2.48	14.91	4.7	2.79	2.86	19.614
57	F	48	14	0.47	0.48	63.38	60.76	5.49	2.45	3.19	22.44	5.7	3.5	2.75	28.693
58	M	36	15	0.54	0.47	51.44	67.90	5.5	3.31	3.04	28.94	6.31	4.24	3.29	46.035
59	M	36	15	0.56	0.58	47.83	44.59	5.21	2.2	2.79	16.73	5.54	3.09	2.48	22.204
60	M	48	16	0.56	0.58	51.02	47.56	4.92	2.09	2.74	14.74	5.41	3.02	2.42	20.679
61	M	36	13	0.45	0.48	64.20	56.42	5.34	2.64	2.27	16.74	5.44	2.74	2.37	18.476
62	F	24	15	0.47	0.53	67.90	53.40	5.69	3.03	2.26	20.38	5.8	3	3.9	35.491
63	F	36	15	0.57	0.58	46.17	44.59	5	2.6	2.64	17.95	5.9	3.14	3.12	30.230
64	M	48	25	0.63	0.59	62.99	71.82	6.13	3.29	3.2	33.75	6.21	3.9	3.33	42.180
65	M	48	20	0.65	0.57	47.34	61.56	5.63	3.01	3.04	26.94	7.12	3.73	2.51	34.863
66	F	12	12	0.47	0.45	54.32	59.26	5.23	2.84	2.71	21.05	5.53	2.52	2.93	21.355
67	M	24	22	0.52	0.57	81.36	67.71	6.12	3.64	3.03	35.30	6.41	3.71	3.12	38.805
68	F	18	15	0.56	0.57	47.83	46.17	5.62	3.34	2.8	27.49	5.71	3.51	2.92	30.607
69	F	48	18	0.57	0.57	55.40	55.40	5.31	2.7	2.23	16.72	6.63	3.31	3.23	37.072
70	F	36	14	0.51	0.52	53.83	51.78	5.82	2.71	2.41	19.88	5.93	3.82	3.64	43.124
71	F	24	16	0.47	0.51	72.43	61.51	4.01	2.81	2.32	13.67	4.12	3.31	3.02	21.539
72	M	48	26	0.65	0.6	61.54	72.22	6.3	3.62	3.24	38.65	6.36	3.27	4.01	43.617
73	M	12	13	0.41	0.45	77.33	64.20	5.45	3.08	2.68	23.53	5.61	2.86	3.3	27.691
74	M	48	22	0.61	0.54	59.12	75.45	5.4	2.6	2.96	21.74	6.57	2.61	3.61	32.375
75	M	36	19	0.54	0.56	65.16	60.59	4.97	2.61	3.12	21.17	5.48	2.93	3.95	33.170
76	F	24	15	0.55	0.56	49.59	47.83	4.64	2.77	2.09	14.05	4.85	2.78	2.31	16.289
77	M	48	30	0.6	0.61	83.33	80.62	6.74	3.33	3.79	44.49	6.76	3.61	3.8	48.500
78	F	12	14	0.45	0.47	69.14	63.38	4.95	2.46	2.19	13.95	5.01	2.4	2.58	16.224
79	M	54	18	0.5	0.54	72.00	61.73	6.19	3.05	3.42	33.77	6.23	3.65	4.01	47.690
80	M	48	18	0.45	0.51	88.89	69.20	4.16	2.65	2.17	12.51	5.02	3.17	2.97	24.718
81	M	48	23	0.57	0.51	70.79	88.43	7.4	3.24	2.71	33.98	7.42	3.48	3.02	40.784
82	M	48	23	0.57	0.52	70.79	85.06	6.62	3	3.16	32.82	6.65	3.25	3.64	41.144
83	M	48	26	0.58	0.56	77.29	82.91	6.13	2.86	2.31	21.18	7.13	2.59	2.57	24.821
84	F	24	12	0.48	0.5	52.08	48.00	5.37	2.93	2.65	21.81	5.58	3.62	2.79	29.475
85	M	24	12	0.55	0.53	39.67	42.72	5.12	3.06	2.99	24.50	5.27	3.11	2.31	19.801
86	M	12	12	0.48	0.48	52.08	52.08	5.25	3.96	3.69	40.12	5.41	3.07	2.74	23.801

87	M	48	11	0.42	0.47	62.36	49.80	5.8	4.21	2.72	34.74	5.91	4.02	3.21	39.886
88	F	24	16	0.53	0.52	56.96	59.17	5.12	3.18	2.65	22.57	5.21	3.17	2.71	23.408
89	F	48	19	0.52	0.52	70.27	70.27	5.08	2.49	3.28	21.70	5.24	2.77	3.49	26.493
90	M	48	20	0.57	0.6	61.56	55.56	6.47	2.37	2.57	20.61	6.56	3.89	3.11	41.506
91	M	12	14	0.54	0.5	48.01	56.00	4.91	3.24	2.21	18.39	5.42	3.05	2.37	20.490
92	M	48	10	0.57	0.53	30.78	35.60	5.25	2.8	2.55	19.60	5.34	3.71	2.94	30.462
93	M	48	23	0.63	0.6	57.95	63.89	5.85	2.83	2.81	24.33	6.61	3.73	3.06	39.458
94	M	48	21	0.55	0.57	69.42	64.64	5.53	3.02	3.92	34.24	6.41	3.43	4.01	46.110
95	M	48	25	0.68	0.62	54.07	65.04	6.24	2.73	3.32	29.58	6.82	3.03	3.13	33.828
96	M	48	21	0.59	0.62	60.33	54.63	5.52	3.23	2.91	27.14	6.01	3.52	3.24	35.848
97	M	48	23	0.65	0.61	54.44	61.81	6.81	3.92	3.61	50.40	6.03	3.81	2.93	35.206
98	M	48	17	0.56	0.56	54.21	54.21	5.51	3.24	2.44	22.78	5.6	3.51	3.82	39.270
99	M	36	18	0.58	0.56	53.51	57.40	4.73	3.9	3.02	29.14	4.91	3.62	3.83	35.603
100	F	24	15	0.51	0.51	57.67	57.67	4.31	1.86	2.2	9.22	5.3	2.85	2.35	18.565
101	F	36	15	0.55	0.54	49.59	51.44	5.46	3.53	2.91	29.33	6.63	3.16	3.41	37.364
102	M	24	11	0.54	0.52	37.72	40.68	5.07	2.36	2.2	13.77	5.21	2.77	2.76	20.832
103	F	12	12	0.48	0.48	52.08	52.08	5.38	2.97	2.32	19.39	5.38	3.75	2.45	25.851
104	F	48	20	0.66	0.65	45.91	47.34	6.37	3.37	3.16	35.48	6.67	3.6	2.91	36.545
105	M	48	15	0.6	0.58	41.67	44.59	6.55	3.44	3.81	44.90	7.26	3.99	3.99	60.448
106	F	36	20	0.58	0.6	59.45	55.56	6.19	3.35	2.6	28.20	6.81	4.03	3.23	46.361
107	M	42	26	0.75	0.68	46.22	56.23	5.94	3.44	3.37	36.01	6.13	2.98	3.1	29.617
108	F	24	19	0.52	0.44	70.27	98.14	5.94	3.66	2.88	32.75	6.37	3.35	3.28	36.607
109	M	48	25	0.68	0.62	54.07	65.04	5.45	3.35	2.88	27.50	6.32	3.25	3.41	36.632
110	F	18	10	0.5	0.5	40.00	40.00	5.42	3.9	2.6	28.74	6.51	4.12	3.1	43.485
111	F	24	15	0.52	0.56	55.47	47.83	5.33	2.97	2.72	22.52	5.59	3.56	3.58	37.260
112	M	48	28	0.66	0.62	64.28	72.84	5.38	3.71	3.22	33.61	6.94	3.96	4.64	66.692
113	M	48	16	0.57	0.52	49.25	59.17	5.69	2.7	3.12	25.07	5.89	2.97	3.38	30.924
114	M	48	24	0.66	0.62	55.10	62.43	6.09	3.75	2.92	34.88	7.57	3.87	3.94	60.368
115	F	24	16	0.57	0.56	49.25	51.02	5.18	3.1	2.64	22.17	5.45	3.38	3	28.903

Appendix 1b: Anthropometric and Kidney Dimensions of Apparently Healthy Male NID

SN	Age (months)	Weight (Kg)	Heigth (m)	Length (m)	BMI (Kg/m²)	MBMI (Kg/m²)	Right kidney (cm)			RK Volume	Left kidney (cm)			LK Volume
							L	W	H		L	W	H	
1	24	13	0.51	0.47	49.98	58.85	4.39	2.94	2.4	16.20	5.39	2.85	2.26	18.16
2	54	16	0.56	0.54	51.02	54.87	5.65	3.99	2.56	30.18	5.74	2.87	1.84	15.85
3	24	10	0.47	0.5	45.27	40.00	4.75	2.76	2.73	18.72	4.4	4	3.63	33.41
4	30	19	0.61	0.66	51.06	43.62	4.61	3.03	2.7	19.72	5.74	3.47	4.21	43.86
5	54	18	0.55	0.56	59.50	57.40	5.84	4.06	3.44	42.66	5.39	3.68	3.38	35.06
6	12	14	0.55	0.56	46.28	44.64	3.86	2.66	2	10.74	5.08	3.22	2.24	19.16
7	36	17	0.51	0.54	65.36	58.30	6.75	3.44	3.07	37.28	5.59	2.76	3.81	30.74
8	48	21	0.6	0.6	58.33	58.33	5.02	3.07	2.57	20.71	5.91	4.19	2.95	38.21
9	48	18	0.54	0.6	61.73	50.00	5.37	3.87	3.48	37.82	5.68	4.05	3.46	41.63
10	12	9	0.45	0.49	44.44	37.48	6.35	4.49	3.04	45.33	5.45	3.84	2.79	30.54
11	12	12	0.47	0.47	54.32	54.32	5.34	3.41	2.45	23.33	5.69	4.3	3	38.39
12	48	25	0.67	0.64	55.69	61.04	7	5	2.12	38.81	7.2	5.42	3.44	70.21
13	54	16	0.5	0.56	64.00	51.02	5.68	2.45	2.2	16.01	5.56	3.16	2.01	18.47
14	48	15	0.51	0.55	57.67	49.59	5.29	3.22	2.26	20.13	4.44	3.66	2.51	21.33
15	24	17	0.52	0.56	62.87	54.21	5.97	4.6	4.4	63.20	6.6	2.88	3.31	32.91
16	12	15	0.51	0.51	57.67	57.67	5.97	4.25	2.65	35.17	5.71	2.89	2.88	24.86
17	24	20	0.66	0.55	45.91	66.12	6.22	4.46	3.56	51.65	5.24	3.93	3	32.31
18	18	14	0.58	0.54	41.62	48.01	6.67	3.22	2.85	32.01	5.52	3.22	3.1	28.82
19	36	18	0.58	0.55	53.51	59.50	4.03	2.97	3.65	22.85	5.47	3.5	3.2	32.04
20	18	12	0.47	0.47	54.32	54.32	5.73	3.16	2.51	23.77	5.82	2.48	2.2	16.61
21	30	12	0.56	0.53	38.27	42.72	5.08	2.93	3.3	25.69	5.61	4	4.01	47.06
22	42	18	0.53	0.52	64.08	66.57	6	3.4	2.94	31.37	5.69	2.89	2.77	23.82
23	12	10	0.5	0.5	40.00	40.00	6.54	4.31	3.02	44.52	5.54	3.23	2.83	26.49
24	54	24	0.53	0.54	85.44	82.30	5.4	3.26	2.47	22.74	6.05	3.32	2.61	27.42

25	36	21	0.58	0.57	62.43	64.64	5.96	3.19	2.82	28.04	6.2	2.79	2.36	21.35
26	48	22	0.57	0.58	67.71	65.40	6.57	3.22	3.63	40.16	4.98	2.04	2.57	13.66
27	48	18	0.56	0.55	57.40	59.50	5.49	2.86	2.69	22.09	5.17	2.86	2.48	19.18
28	48	15	0.53	0.49	53.40	62.47	5.93	2.48	2.54	19.54	5.17	3.16	2.85	24.35
29	12	9	0.48	0.47	39.06	40.74	5.4	3.03	2.58	22.08	5.94	3	2.45	22.83
30	12	15	0.47	0.48	67.90	65.10	5.73	3	2.45	22.03	5.76	2.97	2.69	24.07
31	18	10	0.5	0.44	40.00	51.65	4.45	2.41	1.92	10.77	5.37	3.53	3.07	30.44
32	30	14	0.55	0.56	46.28	44.64	6.02	3.02	2.86	27.19	6.28	4.08	4.12	55.21
33	48	22	0.51	0.56	84.58	70.15	5.71	3.26	3.26	31.74	5.82	3.5	2.82	30.04
34	12	18	0.54	0.55	61.73	59.50	5.01	2.85	2.63	19.64	5.36	3	3.03	25.48
35	24	25	0.61	0.63	67.19	62.99	5.23	2.79	2.79	21.29	5.8	3.25	3.96	39.04
36	36	12	0.51	0.58	46.14	35.67	5.17	2.11	2.26	12.89	5.64	2.61	2.67	20.56
37	48	20	0.53	0.58	71.20	59.45	5.41	2.53	3	21.48	5.51	3.01	3.82	33.13
38	24	14	0.45	0.56	69.14	44.64	4.07	2.36	2.29	11.50	5.27	2.69	3	22.24
39	24	15	0.48	0.55	65.10	49.59	4.79	2.54	1.77	11.26	5.54	3.34	3.34	32.32
40	12	12	0.51	0.54	46.14	41.15	4.42	2.6	2.48	14.91	4.7	2.79	2.86	19.61
41	36	15	0.54	0.47	51.44	67.90	5.5	3.31	3.04	28.94	6.31	4.24	3.29	46.04
42	36	15	0.56	0.58	47.83	44.59	5.21	2.2	2.79	16.73	5.54	3.09	2.48	22.20
43	48	16	0.56	0.58	51.02	47.56	4.92	2.09	2.74	14.74	5.41	3.02	2.42	20.68
44	36	13	0.45	0.48	64.20	56.42	5.34	2.64	2.27	16.74	5.44	2.74	2.37	18.48
45	48	25	0.63	0.59	62.99	71.82	6.13	3.29	3.2	33.75	6.21	3.9	3.33	42.18
46	48	20	0.65	0.57	47.34	61.56	5.63	3.01	3.04	26.94	7.12	3.73	2.51	34.86
47	24	22	0.52	0.57	81.36	67.71	6.12	3.64	3.03	35.30	6.41	3.71	3.12	38.81
48	48	26	0.65	0.6	61.54	72.22	6.3	3.62	3.24	38.65	6.36	3.27	4.01	43.62
49	12	13	0.41	0.45	77.33	64.20	5.45	3.08	2.68	23.53	5.61	2.86	3.3	27.69
50	48	22	0.61	0.54	59.12	75.45	5.4	2.6	2.96	21.74	6.57	2.61	3.61	32.38
51	36	19	0.54	0.56	65.16	60.59	4.97	2.61	3.12	21.17	5.48	2.93	3.95	33.17
52	48	30	0.6	0.61	83.33	80.62	6.74	3.33	3.79	44.49	6.76	3.61	3.8	48.50
53	54	18	0.5	0.54	72.00	61.73	6.19	3.05	3.42	33.77	6.23	3.65	4.01	47.69
54	48	18	0.45	0.51	88.89	69.20	4.16	2.65	2.17	12.51	5.02	3.17	2.97	24.72
55	48	23	0.57	0.51	70.79	88.43	7.4	3.24	2.71	33.98	7.42	3.48	3.02	40.78

56	48	23	0.57	0.52	70.79	85.06	6.62	3	3.16	32.82	6.65	3.25	3.64	41.14
57	48	26	0.58	0.56	77.29	82.91	6.13	2.86	2.31	21.18	7.13	2.59	2.57	24.82
58	24	12	0.55	0.53	39.67	42.72	5.12	3.06	2.99	24.50	5.27	3.11	2.31	19.80
59	12	12	0.48	0.48	52.08	52.08	5.25	3.96	3.69	40.12	5.41	3.07	2.74	23.80
60	48	11	0.42	0.47	62.36	49.80	5.8	4.21	2.72	34.74	5.91	4.02	3.21	39.89
61	48	20	0.57	0.6	61.56	55.56	6.47	2.37	2.57	20.61	6.56	3.89	3.11	41.51
62	12	14	0.54	0.5	48.01	56.00	4.91	3.24	2.21	18.39	5.42	3.05	2.37	20.49
63	48	10	0.57	0.53	30.78	35.60	5.25	2.8	2.55	19.60	5.34	3.71	2.94	30.46
64	48	23	0.63	0.6	57.95	63.89	5.85	2.83	2.81	24.33	6.61	3.73	3.06	39.46
65	48	21	0.55	0.57	69.42	64.64	5.53	3.02	3.92	34.24	6.41	3.43	4.01	46.11
66	48	25	0.68	0.62	54.07	65.04	6.24	2.73	3.32	29.58	6.82	3.03	3.13	33.83
67	48	21	0.59	0.62	60.33	54.63	5.52	3.23	2.91	27.14	6.01	3.52	3.24	35.85
68	48	23	0.65	0.61	54.44	61.81	6.81	3.92	3.61	50.40	6.03	3.81	2.93	35.21
69	48	17	0.56	0.56	54.21	54.21	5.51	3.24	2.44	22.78	5.6	3.51	3.82	39.27
70	36	18	0.58	0.56	53.51	57.40	4.73	3.9	3.02	29.14	4.91	3.62	3.83	35.60
71	24	11	0.54	0.52	37.72	40.68	5.07	2.36	2.2	13.77	5.21	2.77	2.76	20.83
72	48	15	0.6	0.58	41.67	44.59	6.55	3.44	3.81	44.90	7.26	3.99	3.99	60.45
73	42	26	0.75	0.68	46.22	56.23	5.94	3.44	3.37	36.01	6.13	2.98	3.1	29.62
74	48	25	0.68	0.62	54.07	65.04	5.45	3.35	2.88	27.50	6.32	3.25	3.41	36.63
75	48	28	0.66	0.62	64.28	72.84	5.38	3.71	3.22	33.61	6.94	3.96	4.64	66.69
76	48	16	0.57	0.52	49.25	59.17	5.69	2.7	3.12	25.07	5.89	2.97	3.38	30.92
77	48	24	0.66	0.62	55.10	62.43	6.09	3.75	2.92	34.88	7.57	3.87	3.94	60.37

Appendix 1c: Anthropometric and Kidney Dimensions of Apparently Healthy Female NID

SN	Age (months)	Weight (Kg)	Heigth (m)	Length (m)	Right kidney (cm)			RK Volume	Left kidney (cm)			LK Volume
					L	W	H		L	W	H	
1	48	14	0.48	0.52	5.84	4.5	3.29	45.22	5.83	4.59	3.05	42.69
2	24	15	0.51	0.52	6.47	3.88	2.6	34.14	5.71	2.74	3.98	32.57
3	36	13	0.47	0.48	5.37	4.36	3.04	37.23	5.97	4.33	3.57	48.26
4	48	18	0.55	0.6	4.97	3.93	3.03	30.95	5.6	3.39	3.98	39.52
5	24	15	0.54	0.53	6.65	3.55	2.7	33.34	6.35	3.78	2.76	34.65
6	12	14	0.48	0.49	5.44	3.21	2.32	21.19	4.89	3.9	3.16	31.52
7	42	9	0.44	0.46	4.9	2.76	2.51	17.75	4.99	2.72	2.82	20.02
8	54	15	0.44	0.52	6.67	3.06	2.82	30.10	6.83	3.62	3.26	42.15
9	12	8	0.44	0.45	4.52	2.76	2.07	13.51	5.14	2.88	2.01	15.56
10	18	10	0.48	0.46	5.78	2.39	1.98	14.31	5.38	3.31	2.45	22.82
11	24	9	0.46	0.48	5.1	2.6	2.58	17.89	5.24	3.03	2.35	19.51
12	36	17	0.53	0.55	4.21	3.02	4.01	26.66	6.31	3.33	4.03	44.29
13	12	13	0.49	0.5	6.9	3.7	2.91	38.85	6.92	4.21	3.4	51.80
14	24	13	0.47	0.53	6.12	3.63	2.71	31.49	6.12	3.73	2.81	33.55
15	36	23	0.57	0.58	5.08	2.45	2.23	14.52	5.12	2.92	3.26	25.49
16	42	21	0.59	0.55	5.8	3.2	2.5	24.27	5.92	3.5	2.8	30.34
17	48	14	0.47	0.48	5.49	2.45	3.19	22.44	5.7	3.5	2.75	28.69
18	24	15	0.47	0.53	5.69	3.03	2.26	20.38	5.8	3	3.9	35.49
19	36	15	0.57	0.58	5	2.6	2.64	17.95	5.9	3.14	3.12	30.23
20	12	12	0.47	0.45	5.23	2.84	2.71	21.05	5.53	2.52	2.93	21.35
21	18	15	0.56	0.57	5.62	3.34	2.8	27.49	5.71	3.51	2.92	30.61
22	48	18	0.57	0.57	5.31	2.7	2.23	16.72	6.63	3.31	3.23	37.07
23	36	14	0.51	0.52	5.82	2.71	2.41	19.88	5.93	3.82	3.64	43.12
24	24	16	0.47	0.51	4.01	2.81	2.32	13.67	4.12	3.31	3.02	21.54

25	24	15	0.55	0.56	4.64	2.77	2.09	14.05	4.85	2.78	2.31	16.29
26	12	14	0.45	0.47	4.95	2.46	2.19	13.95	5.01	2.4	2.58	16.22
27	24	12	0.48	0.5	5.37	2.93	2.65	21.81	5.58	3.62	2.79	29.47
28	24	16	0.53	0.52	5.12	3.18	2.65	22.57	5.21	3.17	2.71	23.41
29	48	19	0.52	0.52	5.08	2.49	3.28	21.70	5.24	2.77	3.49	26.49
30	24	15	0.51	0.51	4.31	1.86	2.2	9.22	5.3	2.85	2.35	18.56
31	36	15	0.55	0.54	5.46	3.53	2.91	29.33	6.63	3.16	3.41	37.36
32	12	12	0.48	0.48	5.38	2.97	2.32	19.39	5.38	3.75	2.45	25.85
33	48	20	0.66	0.65	6.37	3.37	3.16	35.48	6.67	3.6	2.91	36.54
34	36	20	0.58	0.6	6.19	3.35	2.6	28.20	6.81	4.03	3.23	46.36
35	24	19	0.52	0.44	5.94	3.66	2.88	32.75	6.37	3.35	3.28	36.61
36	18	10	0.5	0.5	5.42	3.9	2.6	28.74	6.51	4.12	3.1	43.49
37	24	15	0.52	0.56	5.33	2.97	2.72	22.52	5.59	3.56	3.58	37.26
38	24	16	0.57	0.56	5.18	3.1	2.64	22.17	5.45	3.38	3	28.90

Appendix 2a: Haemogram of 115 Apparently Healthy NID

PCV (%)	HGB (g/dl)	TP (g/dl)	TWBC ($\times 10^9$/l)	TRBC ($\times 10^{12}$/l)	Neutrophil	Lymphocytes	Monocytes	Eosinophil	Basophil	Band
47	15.6	8	8.6	8.2	4.128	4.3	0.172	0	0	0
44	14.6	7.6	10	7	6.6	3	0	0.4	0	0
48	16	9	4.8	8	2.784	2.016	0	0	0	0
40	13.6	8	6	6.6	4.08	1.8	0	0	0	0.12
34	11.3	7	18	6	13.32	4.68	0	0	0	0
40	13.3	7	8	6.6	3.52	4.24	0	0	0	0.24
50	16.6	7.4	8.1	8.1	4.86	2.916	0.324	0	0	0
18	6	7.4	14	3.4	11.48	2.24	0.28	0	0	0
49	16.3	8	13.1	8.2	7.86	4.716	0.131	0	0	0.524
57	19.6	8	6.6	10	4.62	1.386	0	0.594	0	0
37	12.3	7	12	6.4	6.84	4.8	0.36	0	0	0
45	15	7.6	10	8	3.6	7	0.1	0	0	0.3
56	18.6	8	6.8	9.1	3.4	3.128	0.068	0	0	0.204
50	16.6	9.4	7.1	8.4	4.331	2.556	0.071	0	0	0.142
57	19	8	8.4	9.8	5.88	2.352	0.168	0	0	0
46	15.3	64	16.8	7.8	10.08	6.72	0	0	0	0
40	13.3	7	10.3	6.6	6.798	3.09	0.412	0	0	0
51	17	7	11	8.4	6.38	3.3	0	0	0	1.32
38	12.6	7	5.8	6.3	3.828	1.972	0	0	0	0
24	8	7.2	17	3.4	11.9	4.42	0.68	0	0	0
35	11.6	8	6	6	4.08	1.08	0	0.84	0	0
41	13.6	9	7.4	6.8	5.476	1.924	0	0	0	0
40	13.3	6.6	4.5	6.9	2.43	2.07	0	0	0	0
34	11.3	6.4	8	5.8	4.72	3.2	0.08	0	0	0
38	12.3	8	6.6	6.1	4.224	1.98	0.396	0	0	0
49	16.3	7.4	8	8.1	5.52	2.24	0.16	0	0	0.08
43	14.3	6.8	9.1	7.2	2.548	6.37	0.182	0	0	0

25	8.3	7.4	14.8	4.8	8.88	5.032	0.296	0	0	0.592
40	13.3	9	8	6.8	5.28	2.72	0	0	0	0
42	14	10	6.1	7	4.392	1.525	0.183	0	0	0
38	12.3	6	12.2	6	8.174	2.806	0.61	0	0	0.61
42	14	6.4	11.2	7	6.944	3.36	0.448	0.448	0	0
55	18.3	6.4	16.1	8.9	12.88	3.22	0	0	0	0
60	20	7	10	10	6.4	1.6	0.9	0.4	0	0.4
25	8.3	9.8	22.1	4.1	17.459	3.978	0	0.884	0	1.547
52	17.3	8	11	8.6	5.06	5.94	0	0	0	0
36	12	7	6	6	3.66	2.16	0	0.18	0	0
51	17	8	8.1	8.6	5.67	2.106	0.243	0	0	0.081
44	14.6	6	18.1	7.3	10.86	7.24	0	0	0	0
26	8.6	8.4	9	6.6	5.58	3.42	0	0	0	0
30	10	5.8	4.4	5	2.376	1.452	0.132	0	0	0
51	17	9.6	18	9	12.42	4.68	0.18	0.72	0	0
31	10.3	9.8	10	5.3	7.1	2.9	0	0	0	0
54	18	11	6	9	3.9	2.1	0	0	0	0
48	16	10	9	8	4.95	3.6	0	0	0	0.45
54	18	9.4	16.1	8.8	10.465	4.025	0	1.61	0	0
38	12.6	11	9	6.3	7.29	1.71	0	0	0	0
43	14.3	9	10.9	7.1	7.194	3.706	0	0	0	0
55	18.3	12	11.8	9.1	5.9	5.9	0	0	0	0
43	14.3	8.6	10.4	7	4.992	5.096	0.104	0	0	0
32	10.6	8.8	16.8	5.4	14.784	2.016	0	0	0	0
40	13.3	12	12.4	6.8	9.424	2.852	0.124	0	0	0
35	11.6	8	10.6	6	5.83	4.77	0	0	0	0
37	12.3	8	11.8	6.8	6.844	3.54	0.59	0.708	0	0.118
40	13.3	7	10	6.6	6	4	0	0	0	0
10	3.3	9.2	19.1	2	13.752	4.775	0	0	0	0.573
20	6.6	7	14	3.6	7.84	3.92	0.84	0.84	0	0.56
43	14.3	7	10.1	7.2	5.05	4.444	0.404	0	0	0

39	13	7.4	13.1	7	8.384	4.716	0	0	0	0
19	6.3	6.8	14.1	3.8	9.024	4.23	0	0.846	0	0
36	12	8	10.1	6.4	6.666	3.434	0	0	0	0
20	6.6	10	8.6	3.8	6.106	2.494	0	0	0	0
36	12	8.2	13	6	8.58	3.9	0.13	0	0	0.39
36	12	8	10.9	5.8	5.886	5.014	0	0	0	0
34	11.3	6	8.1	5.8	4.86	2.916	0.081	0	0	0.243
38	12.6	8.2	6	6.1	3.84	1.8	0.06	0	0	0.3
50	16.6	7	7.8	8.2	5.928	1.872	0	0	0	0
45	15	7	8	8	4.8	3.12	0.08	0	0	0
45	15	9.4	9	7.6	5.85	3.06	0	0	0	0.09
39	13	8.8	6	6.6	4.08	1.32	0.36	0	0	0.24
38	12.6	8.2	15.1	6.3	4.832	10.268	0	0	0	0
41	13.3	7.6	11.1	6.8	6.105	4.884	0.111	0	0	0
47	15.6	9	5.4	8	2.754	2.646	0	0	0	0
33	11	8.4	6	6	3.3	2.4	0.18	0	0	0.12
25	8.3	7	4	4.1	2.64	1.24	0	0	0	0.12
52	17.3	5.8	9	8.6	5.22	2.79	0.18	0	0	0.81
47	15.6	7	8.1	8	4.131	3.888	0.081	0	0	0
36	12	9.6	11.8	6.4	7.198	4.012	0	0	0	0.59
50	16.6	8	10	8.4	5.8	3	0.2	1	0	0
32	10.6	6	14.5	5.4	6.525	7.685	0	0	0	0.29
16	5.3	9	18.1	3.1	14.661	3.439	0	0	0	0
28	9.3	6	10.2	4.8	2.55	7.14	0	0.51	0	0
37	12.3	8	5.6	6.1	3.696	1.904	0	0	0	0
44	14.6	9	13	7.3	8.19	2.6	0.13	0.91	0	1.17
40	13.3	5.6	9	6.6	6.66	2.34	0	0	0	0
25	8.3	6	11.2	4.1	7.616	2.8	0.224	0.112	0	0.448
30	10	6.4	8	5	4.8	2.88	0.08	0	0	0.24
45	15	8.2	8.4	8	4.62	3.78	0	0	0	0
51	17	8	16.6	9	10.956	4.98	0.166	0	0	0.498

46	15.3	9	10.2	7.7	7.548	1.632	0.306	0	0	0.714
28	9.3	8	8	4.8	6.4	1.6	0	0	0	0
40	13.3	6.4	16	6.6	7.2	8.64	0.16	0	0	0
48	16	8	9.8	8	6.37	2.94	0	0	0	0.49
17	5.6	6.6	12.8	2.8	7.68	4.864	0.256	0	0	0
28	9.3	7.4	10	4.6	7.4	2.6	0	0	0	0
30	10	6.8	18	5.1	15.48	1.8	0	0.72	0	0
46	15.3	6	16	7.6	4	11.2	0.16	0.64	0	0
44	14.6	8.2	10	7	6	4	0	0	0	0
54	18	6	8.1	10	4.05	4.05	0	0	0	0
20	6.6	5.6	17.6	3.4	12.672	2.464	0	2.112	0	0.352
42	14	9	12	7.1	9.96	2.04	0	0	0	0
44	14.6	6.6	9.4	7.4	6.204	2.82	0.188	0	0	0.188
21	7	8	8.1	3.6	5.67	2.268	0.162	0	0	0
29	9.6	7	13.1	4.8	7.86	4.716	0.524	0	0	0
44	14.6	7	16	7.2	9.92	4.64	0.16	1.28	0	0
48	16	7.4	8.1	8.2	5.67	2.43	0	0	0	0
46	15.3	5.8	4.5	7.6	2.7	1.62	0	0	0	0.18
36	12	6	10	6	7	3	0	0	0	0
48	16	6.2	8.4	8.1	5.712	2.688	0	0	0	0

Appendix 2b: Serum Biochemistry of 115 Apparently Healthy NID

Sodium mmol/L	Potassium mmol/L	Chloride mmol/L	Bicarbonate mmol/L	Urea mmol/L	Creatinine umol/L	Albumin g/L	Total protein g/L
126	4.2	110	22	3.2	82	32	60
140	5.6	94	30	2.8	101	40	72
138	8.1	115	18	2	68	38	62
130	4	84	15	5.2	122	30	60
160	2.4	100	10	3	94	28	64
140	2	89	24	5.4	80	34	80
146	3	80	20	4.4	61	29	90
150	3.2	101	24	4.6	58	38	73
130	1.4	201	23	3	60	42	55
128	4	101	18	3.2	73	28	48
100	4.2	88	14	1.8	65	20	66
120	5.4	60	10	2.2	66	40	70
168	6	74	18	4.6	79	36	80
120	7	100	20	3.8	86	42	71
100	3	102	25	4	67	41	75
151	3.1	100	17	5	50	18	80
151	2.2	120	29	4.8	116	33	45
116	4.1	154	30	3.6	114	24	90
106	4.4	118	19	3.6	49	36	40
140	6	58	15	6	70	40	60
152	5.2	104	15	4	52	46	90
101	4.8	115	14	5.1	49	52	54
96	5	64	20	4	86	50	52
160	6	101	16	6	52	60	60
121	3	122	12	5.4	66	42	72
86	3.6	109	15	6	80	46	88
148	4	100	24	8.1	80	28	68
120	3.8	86	20	5	62	25	70

136	4	94	24	6.2	45	35	71
100	2.4	104	19	4.4	104	30	60
145	4.2	118	21	6	259	30	64
150	6	101	28	3.4	72	40	72
100	4	140	12	4.8	64	44	64
108	4	106	14	5	81	50	60
130	3.9	91	17	6	55	30	65
136	5.4	145	22	7.2	47	32	45
141	6.2	100	22	4.2	108	44	54
202	4.2	86	18	3	100	38	50
140	5	70	24	4.4	72	30	60
138	3.8	104	21	4.7	82	30	63
136	6	101	30	2.6	68	40	70
139	4.6	107	20	6.3	82	30	69
144	4.1	104	22	5	66	29	70
145	2.8	108	20	3	47	35	80
138	3.8	100	25	6	71	31	73
122	3.6	101	20	5	59	30	63
140	3.8	108	23	3.5	47	44	82
120	4	64	14	3	74	46	62
134	3.3	80	21	4	84	37	60
135	3.8	104	21	3	59	43	68
140	4.9	101	23	5	47	49	80
140	3.7	97	21	5	74	40	79
133	3.3	96	21	6.5	106	34	66
135	4	97	21	2.5	79	33	75
143	5.3	110	20	5.2	59	34	68
146	5.3	105	20	5	71	39	73
122	2.9	95	22	3.5	82	44	84
147	2.5	102	17	3	71	43	70
135	4	97	21	5	42	29	73

130	3.7	97	24	3.5	94	39	68
134	3.3	100	22	4	71	43	66
142	3.7	105	22	2.5	47	24	70
146	5.3	110	20	4.5	82	35	72
139	3.4	102	21	2.5	71	42	76
143	5.3	103	20	5	71	42	78
127	3.7	94	20	5.5	59	43	66
143	4.7	106	21	3.5	59	42	79
138	4.6	108	21	6.5	72	39	70
140	4.5	140	25	6	82	46	83
139	6.3	114	15	3.5	118	35	68
131	3.9	94	20	3.5	47	42	72
136	2.8	99	25	6	71	41	83
136	5.8	103	20	3.5	47	41	81
137	4.4	109	21	3	71	38	73
133	3.8	104	21	3	42	33	69
148	3.7	121	17	5	82	33	72
136	3.9	104	20	4	71	30	65
140	4.2	104	16	5.4	42	40	60
151	3.7	116	22	4	49	36	60
130	3	80	24	2.6	59	51	70
132	2.1	84	10	4	72	42	81
145	3.4	68	14	3.6	80	48	60
144	3	72	24	3.6	100	52	64
129	3.4	60	20	4	74	54	67
130	4.2	82	16	4.4	70	50	81
133	4.8	80	12	2.4	67	42	50
140	4.4	90	14	3	80	48	52
136	3.6	60	18	4.9	66	50	56
130	4	74	12	6	59	34	61
141	4.2	84	21	4.8	64	45	80

136	4.8	104	21	4	63	36	66
140	6.2	106	20	4	73	30	70
132	5	94	16	4.5	40	29	80
140	2.8	108	14	3.6	65	54	90
133	4.4	81	18	6.2	70	39	48
148	4	79	20	7	74	42	55
106	4.2	102	16	4	70	50	74
120	5	142	11	2.9	80	54	60
124	4.4	111	23	4	68	60	67
146	5	90	20	4.5	82	50	70
120	4.6	84	10	6	101	34	54
141	5	102	17	3.3	69	40	60
115	5.4	92	15	4	75	30	64
122	4.8	80	19	4	60	43	71
128	6.3	112	14	5	80	30	68
136	4.4	105	21	4	112	36	70
130	3	124	17	3.6	108	42	80
139	3.8	100	24	6	45	50	60
142	4.4	99	20	4	96	44	64
140	2.4	106	31	2.4	107	38	64
131	3.3	101	24	4.4	79	40	70
160	2.6	102	20	3.8	80	38	80
134	3.4	112	21	3.5	84	33	30
138	4.9	114	15	4	54	44	60
138	3.4	101	26	3	60	50	70