SONOGRAPHIC MEASUREMENT OF SPLEEN DIMENSIONS IN HEALTHY ADULTS IN KANO, NORTH WESTERN NIGERIA.

BY

Dr. Mansur Adamu YAHUZA MB,BS(BUK,2002).

Department of Radiology,
Aminu Kano Teaching Hospital,
Kano.

A Dissertation submitted in Partial Fulfillment for the Award of the Fellowship of the National Postgraduate Medical College of Nigeria in the Faculty of Radiology.

November,2011.
ATTESTATION

This is to certify that the dissertation titled ‘Sonographic Measurement of Spleen Dimensions in Healthy Adults in Kano, Northwestern Nigeria’, submitted to the National Postgraduate Medical College of Nigeria was supervised and reviewed by us.

Supervisor I  

Supervisor II  

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Signature and Date  Signature and Date  

Dr A.M Tabari FMCR(2002)  

Dr K. Isyaku FMCR(2002)  

Department of Radiology, Aminu Kano Teaching Hospital, Kano, Nigeria.

Head of Department  

Name:..........................................................  

Year of Fellowship...........................................  

Signature and Date.........................................
DECLARATION

I declare that the dissertation titled ‘Sonographic Measurement of Spleen Dimension in Healthy Adults in Kano, Northwestern Nigeria’, submitted to the National Postgraduate Medical College of Nigeria was carried out by me. No part of this work is under consideration for publication or award of any other qualification.

Dated this……………………Day of……………………………………20

……………………………………

Signature of candidate
DEDICATION

This work is dedicated to GOD Almighty for everything, my parents, my wife and daughter and my teachers for all the support and encouragement given to me.
ACKNOWLEDGEMENT

I am grateful to my supervisors Dr A.M Tabari and Dr K Isyaku for their effort and guidance throughout the research period and the residency period. The personal efforts, encouragement and guidance of Drs S K Idris, M A Suwaid and M K Saleh in my training and in the course of this work is highly appreciated.

To all my colleagues fellow residents in the department, I thank you for standing solidly with me throughout this period. Members of department of radiology, Aminu Kano Teaching Hospital, Kano your support is highly appreciated.
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SUMMARY

INTRODUCTION: In the last two decades sonography has become the most important imaging modality for the study of the spleen. Different studies were conducted in different parts of the world so as to determine the normal reference values of splenic dimension using ultrasound scan in healthy adults and the values obtained are diverse, thus prompting more work that tends to establish normal values for different regions based on geographic and racial differences.

MATERIALS AND METHOD: A prospective study of normal spleen dimensions using ultrasound in 400 Nigerian adults at Aminu Kano Teaching Hospital was conducted. Sonographic measurement of splenic dimensions was done with the patient in supine and right lateral decubitus position. Height and weight were measured using standard anthropometric technique. The data was analysed using computer based SPSS 11.0 software for windows.

RESULTS: There were 212 males and 188 females, their age ranged between 20 and 70 years. The mean age of the subjects was 33.0 years (±12.0), mean height was 1.64m (±0.1) and mean weight was 61.4kg (±11.0). The mean splenic length width and depth for the subjects studied were 101.6mm (±13.7), 46.8mm (±8.2), and 86.8mm (±12.7) respectively.

CONCLUSION: The mean spleen dimensions obtained in this study were similar to those obtained in other regions of Nigeria but slightly lower than those reported from studies among Caucasians confirming the need for normal values for each region. There was no statistically
significant correlation of the splenic dimensions with age in either sex. There was positive correlation between subjects height and weight with splenic length (P<0.001 and P<0.001), depth (P<0.01 and P<0.001) and width (P<0.01 and P<0.001).

INTRODUCTION

The spleen is an intraabdominal organ and the largest in the reticuloendothelial system. It has been the standard practice for many years to use splenic size as an indicator of disease activity in a variety of disorders of the reticuloendothelial system\textsuperscript{1}. Determination of spleen size is important in diagnosing small or infarcted, normal, and enlarged spleens. Splenomegaly is an important clinical sign for diagnosis and serial follow up of a variety of diseases, including portal hypertension, glycogen storage disease, leukaemia, lymphoma, melanoma, celiac disease, schistosomiasis and other hematologic diseases. Evaluation of splenic size by palpation can produce extremely inaccurate results\textsuperscript{3}.

Nigeria is situated in the malaria endemic geographical region of the world, where its large population suffers from malaria and also ranks second in the world in incidence of the sickle cell trait\textsuperscript{3}. Previous studies of ultrasound measurement of the spleen have reported good correlation of in vivo measurements with the weight of the resected spleen and with the volume of the resected spleen as measured by water displacement\textsuperscript{1}. There also appears to be a good correlation between linear ultrasound measurements of cadaveric spleens in situ and ultrasound measurement of the volume of the excised spleen\textsuperscript{1}.
As a result of the recent advances in ultrasonography, assessment of splenic size (either palpable or unpalpable) became feasible and both reliable and accurate. Ultrasonography is a simple, safe and accurate method of assessing splenic size and patients with persistent splenomegaly should be followed closely for development of complications which may necessitate splenectomy. Ultrasound scanning, apart from being non-ionising, is painless, non-invasive, widely available, easy to use and less expensive than most other imaging methods. However, its main limitation is being operator dependence.

Imaging splenic disorders is achievable in the great majority of cases using ultrasonography, computed tomography (CT) or magnetic resonance imaging (MRI). Scintigraphic examination of the spleen at present is helpful in localizing ectopic splenic tissue.

It has been suggested there may be racial differences in splenic size. Such differences would make it difficult to standardize expected splenic length and to determine non-palpable splenic enlargement.

The endemicity of malaria, high incidence of sickle cell disease and the prevalence of other haematological and lymphomatous diseases including portal hypertension amongst adults in northern Nigeria with consequent splenomegaly make the need to establish a baseline sonographic normogram with which reference can be made. This is the rationale of this study.
AIMS AND OBJECTIVES

The aims and objectives of this study are:

General:

To determine the dimensions of the spleen in healthy adults aged twenty (20) and above in Kano, Nigeria.

Specific:

To determine the relationship between splenic dimensions (length, width, and thickness) and

1) The age and sex of this group of individuals.

2) The height and weight of this group of individuals.
JUSTIFICATION

The limitations of abdominal palpation for the diagnosis of splenomegaly are certainly due to the fact that many factors other than splenic size are important to determine if splenic border could be palpated. These factors probably include the thickness of abdominal wall, the position of the spleen, its shape, mobility and co-operation of the patient during physical examination and position of left hemidiphragm. It is possible that such variables, that have never been adequately analyzed, have acted as complicating factors in previous works on diseases causing splenomegaly.

While many imaging techniques can be used to determine spleen size, ultrasonography is particularly useful because of its ease of use and lack of radiation exposure. Diagnostic imaging to assess spleen size is routinely accomplished by ultrasound measurement along its long axis. However, there is variation among radiological literature in defining the upper limits of normal.

There is paucity of work describing splenic dimension in healthy adult Nigerians, Okoye et al.\(^3\) established population specific ultrasonic splenic sizes that can be more reliably used as standards to evaluate splenic disorders, though a regional bias was not confirmed by the study. Thus, a need for a study in Kano (Northern Nigeria) to establish a normogram of splenic dimensions in adults using ultrasound with which comparison could be made in the determination of splenomegaly.
LITERATURE REVIEW

The spleen is found in the left upper quadrant of the abdomen. It arises from a mass of mesenchymal cells located between the layers of the dorsal mesentery, between the aorta and the stomach. Its long axis is in the line of the tenth rib and its lower pole does not usually extend beyond the midaxillary line\(^9\).

The spleen has a smooth diaphragmatic surface related through the diaphragm to the costodiaphragmatic recess of the pleura and the ninth, tenth and eleventh ribs. The visceral surface of the spleen faces anteroinferiorly to the right. Its contours correspond to its relationship to the stomach anteriorly, the splenic flexure of the colon inferiorly and the left kidney posteriorly\(^9\).

At ultrasound, the spleen has a homogenous echo texture and differentiation between white and red pulp is not possible. The presence of focal heterogeneity in echo texture should raise suspicion of a pathologic condition\(^10\). The spleen is of similar echogenicity to the liver or even higher, although the liver may appear more echogenic because of the reflectivity of its many vessels. The enlarged spleen is seen anterior to the colon and becomes easier to see on ultrasound\(^9\).
The blood supply to the spleen is from the splenic artery which arises from the celiac trunk. The splenic vein receives the inferior mesenteric vein and joins with the superior mesenteric vein to form the portal vein\(^9\).

The spleen traps blood, and rhythmic contractions of its capsule pumps plasma into the lymphatics. The spleen therefore contains a reservoir of blood rich in cells. Noradrenergic nerve discharge and epinephrine make the spleen contract strongly, discharging the blood into the circulation\(^{11}\).

A number of studies have evaluated sonographic measurement of the spleen dimensions. Okoye et al\(^3\), Mustapha et al\(^{12}\) and Ehimwenma and Tagbo\(^{13}\) determined normal sonographic dimensions in healthy adult population. Prassopoulos and Cavouras\(^{14}\) correlated CT measurements of the spleen with age and vertebral body size in a paediatric population. Loftus et al\(^{15}\), Downey\(^{16}\), and Rodrigues et al\(^{17}\) evaluated sonographic assessment of the size of the spleen using several methods in cadaveric spleens.

Enlargement of the spleen is an important criterion in diagnosing primary myeloproliferative diseases. Because splenomegaly may occur in patients in whom the spleen is not palpable, the most sensitive imaging procedure for measuring splenic size has been sought\(^{18}\). The spleen is an irregularly shaped organ that may enlarge at different rates in its various dimensions, physical examination and imaging using one-dimensional measurements may underestimate the true organ size, thus suggesting an erroneously low incidence of splenomegaly\(^{18}\).
Splenomegaly is an important clinical finding and can be present in a variety of diseases, including malaria, sickle cell disease, schistosomiasis, liver disease, portal hypertension, splenic vein thrombosis, lymphoma and other primary and metastatic neoplastic processes, and hematologic entities. Assessment of splenic size by physical examination is subjective and known to be inaccurate\textsuperscript{13,17,19} therefore, evaluation with radiologic imaging is common. Sonography is a quick, simple, portable and relatively inexpensive modality that carries no risk of ionizing radiation.

In Nigeria alone, about 150 000 children are born annually with sickle-cell anaemia\textsuperscript{20}. While in Kano the prevalence rate of sickle cell is as high as 12.5\% between the ages of 16-45 years, though this value is not as high as those reported from other parts of Africa\textsuperscript{21}.

The sickle-cell gene has become common in Africa because the sickle-cell trait confers some resistance to falciparum malaria during a critical period of early childhood, favouring survival of the host and subsequent transmission of the abnormal haemoglobin gene. Although a single abnormal gene may protect against malaria, inheritance of two abnormal genes leads to sickle-cell anaemia and confers no such protection, and malaria is a major cause of ill-health and death in children particularly and adults in general with sickle-cell anaemia. There is increasing evidence that malaria not only influences outcome but also changes the manifestations of sickle-cell anaemia in Africa\textsuperscript{20}.

One of the main organs to be affected in sickle cell disease (SCD) is the spleen. The spleen commonly enlarges during the first decade of life but then undergoes progressive atrophy due to repeated attacks of vaso-occlusion and infarction leading to autosplenectomy, however,
sometimes splenomegaly persists beyond the first decade of life, and in some cases even into adult life.

The reason for the failure of these individuals to undergo autosplenectomy is unknown. Though it has been suggested that HbF exhibits favourable influence through inhibition of HbS polymerization and thus survival of HbF containing cells and less sickling in patients who had persistent marked splenomegaly.

The occurrence of enlarged spleens and its age distribution has long been used as a crude measure to estimate malaria endemicity in cross-sectional surveys. Spleen size, however, is influenced by several variables that should be considered if they are observed in a population under study. Spleen indices are dependent on distinct red blood cell polymorphisms. Accordingly, it is expected that a lower prevalence of splenomegaly would be recorded among patients with the sickle-cell trait (HbAS) than in patients without red cell disorders, possibly due to the lower incidence of malaria attacks in these individuals.

Adults and children in tropical areas do present with massive splenomegaly. After excluding known causes of splenomegaly, Tropical splenomegaly syndrome (TSS) was defined as a separate entity and was later defined as hyperactive malarial syndrome (HMS) using clear diagnostic criteria. HMS is prevalent in residents of regions where malaria is endemic and has high levels of antibody P.Falciparum, P.Vivax and P.Ovale.

Transient splenomegaly is a feature of acute attacks of malaria in non-immune or partially immune patients, while progressive splenomegaly is seen in children resident in malaria endemic areas during the process of acquiring immunity to the infection. HMS is thought to
result from an aberrant immunological response to repeated infection by one of the species of malaria parasite\textsuperscript{24}.

Physical diagnostic techniques for the detection of splenomegaly are relatively insensitive with high interobserver variability which did not appear to be associated to the level of experience\textsuperscript{25}. The optimal clinical assessment of splenic enlargement using specific bedside manoeuvres including Traube's space percussion, the splenic percussion sign, Middleton's manoeuvre, supine palpation, and right lateral decubitus palpation recorded low sensitivity and specificity. Also, palpation was significantly more accurate when performed on lean patients versus obese patients\textsuperscript{26}. Splenic palpation is a poor method for the diagnosis of splenomegaly\textsuperscript{7}.

Some investigators have sought to establish an internal reference standard against which spleen size can be calibrated. The most common such strategy is to compare the length of the spleen to the length of the left kidney. A spleen-kidney ratio of 1.25 was proposed as measured on sonography, as the upper limit of normal in a paediatric population\textsuperscript{27}. However subsequent studies showed spleen length was correlated with kidney length in women but not in men\textsuperscript{28}. Spielman et al\textsuperscript{28} reported spleen length greater than 120mm in 31.7% of men (mean spleen length of 114±17mm) and in 12.8% of women (103±13mm).

Ultrasound scan, scintigraphy, computed tomography (CT), and magnetic resonance imaging (MRI), are the imaging methods that can be used to evaluate the spleen. All these modalities give structural information about the spleen, can localize and show the size of lesions\textsuperscript{10,29}.

Several prior studies have sought to develop standards for spleen size, using a variety of imaging techniques, such as CT, scintigraphy, MRI and sonography. One study used four
measurements from two imaging planes in the volume formula for an ellipsoid to estimate splenic volume. The spleen however, has a variable 3D configuration, and its shape does not easily conform to the simple geometry of an ellipsoid. Therefore, volumetric measurement is obtained most accurately on CT or MRI. Nevertheless, routine CT for the diagnosis and serial follow up of patients for suspected splenic enlargement is difficult to justify in view of the radiation exposure (especially in a paediatric or young adult population) and the expense. As an alternative, MRI is hampered by expense and limited availability in many areas of the world.

While many imaging techniques can be used to determine spleen size, conventional ultrasonography is a well established and particularly useful because of ease of use and lack of radiation exposure. A study by Rosenberg et al found that a simple measurement of splenic length was accurate as a guide to spleen size. However, there is variation among radiological texts in defining the upper limits of normal. Hosey et al reported mean splenic length of 106.5mm (±15.5) and width of 51.6mm (±12.1). Also that men have larger spleens than women (P<0.001) and white subjects had larger spleen sizes than Afro-American subjects (P<0.001).

The morphology of visceral organs varies from person to person. During the maturation process from infancy through adolescence, growth of visceral organs, including the spleen, shows a high correlation with gains in height, weight, and body surface area. Splenic length measured by ultrasonography provides an objective and reliable way to assess spleen size.

Rosenberg found that there was an approximately linear increase in spleen size, as measured on sonography, in the course of development in the paediatric population and that spleen size correlated best with the body height.
Frank et al\textsuperscript{30} used conventional sonography to evaluate 793 healthy patients (17–82 years) and found that 95% of patients had a splenic length that did correlate with height. They reported spleen length of less than 120mm and width below 50mm and depth of less than 70mm. Ehimwenma and Tagbo\textsuperscript{13} reported men splenic length, width and depth of 111mm, 44mm and 78mm respectively. They also showed statistically significant correlation between subject height and splenic length ($r=0.723$, $P<0.001$), depth ($r=0.607$, $P<0.001$) and width ($r=0.595$, $P<0.001$).

Niederau et al\textsuperscript{32} studied 915 healthy adult subjects using sonography and found that spleen size did correlate weakly with height in the general population. Also correlation of spleen length and width with subjects height and weight was poor ($r=0.03$). They also found that spleen size decreased with increasing age.

Mustapha et al\textsuperscript{12} found that spleen length has a high correlation with spleen volume and can be used in daily clinical practice to determine splenomegaly. Spleen volume correlated significantly with spleen width ($r=0.85$), thickness ($r=0.83$) and length ($r=0.80$). They also reported maximal splenic length of 127mm. Though very tall individuals can have a spleen length greater than the accepted criteria\textsuperscript{8}.

Sonographic measurements of splenic length have also been correlated with actual spleen dimensions at autopsy. A study by Loftus et al\textsuperscript{15} on 30 cadavers found a clear linear relationship between sonographic measurement of splenic length and the actual length ($r=0.33$) and weight ($r=0.42$) as measured at autopsy. The preponderance of evidence indicates that a simple measurement of spleen length is a practical and reasonably accurate estimate of spleen size\textsuperscript{32}.

Downey et al\textsuperscript{16} in a retrospective study of 81 patients who had undergone a total of 101 abdominal ultrasound examinations within 4 months prior to death and whose spleen were
weighed during autopsy showed significant correlation of splenic weight in grams ($r=0.43, P<0.001$) and splenic length in centimetres ($r=0.78, P<0.001$).

Okoye et al$^3$ also showed that the splenic length and width of both sexes increase linearly with age until the middle age and thereafter undergoes gradual diminution. A poor correlation was shown to exist between splenic dimensions and age but splenic weight increased with body height ($r=0.75$). They reported normal splenic length, width and depth ranging from 99-115mm, 60-75mm and 40-45mm respectively.

Progressive increase in splenic length with age and corresponding increase in the 90th percentile, up to the age of 15 years was recorded and above 15 years, no increase in splenic length or the 90th percentile was noted$^3$. The spleen size and renal length correlations were stronger in women than in men$^{32}$.

Spielmann et al$^{28}$ reported that in men, height correlated with spleen length ($r=0.4, P<0.0003$), width ($r=0.5, P<0.0001$) and less with depth ($r=0.5, P<0.01$). Whereas in women height correlated with spleen length ($r=0.3, P<0.005$) and width ($r=0.4, P<0.001$) but not thickness ($r=0.08, P<0.6$). Splenic measurements did not correlate with subject weight.

Positive correlations between height and weight with splenic length were observed$^{13}$. These are far less than those seen in paediatric and adolescent populations$^{31}$. This observation probably results from the cessation of rapid body growth that occurs with attainment of mature body morphology. Thus it is difficult to predict spleen size reliably on the basis of these variables alone$^8$.

Hosey et al$^8$ reported that sex and race differences in normal splenic length and width were found to be significant. As there were moderate correlations between spleen size and both
height and weight, we would expect a larger average spleen size in men on the basis of their larger body size. The fact that these significant differences persisted when controlling for height and weight independently may suggest that spleen size varies more as a product of these two variables, or that there are additional factors involved. As a group, African Americans had smaller spleens despite being taller and heavier than the Caucasians in the study.

Okoye et al\(^3\) showed that splenic sizes were similar to those of Caucasian population compared with (P>0.05). Maximal splenic weight occurred in the 4\(^{th}\) decade in Nigerians and in the 2\(^{nd}\) decade in Caucasians. Ehimwenma and Tagbo\(^{13}\) also showed no significant racial bias of spleen size compared with Caucasians.

Markisz et al\(^{34}\), in their sulphur colloid scintigraphy study carried out to measure splenic volume, found the linear correlation with age and weight to be poor. Rosenberg et al\(^{31}\), in their sonographic study of 230 cases in the first and second decades of life, evaluated only one dimension of the spleen and found a rough logarithmic correlation between spleen size and age. Again, it was stated that there is a correlation between the size of the spleen with height and weight. They reported that the difference between the two sexes emerges after 15 years and that the difference is related to the differences in body measurements. Kaya et al\(^{35}\) reported no significant relation between body measurements and age group and the size of the spleen.
MATERIALS AND METHODS

Study design:

This is a prospective study involving healthy adults conducted at the ultrasound clinic of Aminu Kano Teaching Hospital, Nigeria within a period of six months (April 2010 to September 2010). Informed consent was obtained from all the subjects.

Study population:

The subjects studied are adults aged 20 years and above attending AKTH that serves the population of over 20 million people mainly from the states of Kano, Jigawa and Katsina states all in the North-Western region of Nigeria.

Inclusion criteria:

All adults above the age of 20 years referred to the ultrasound clinic at the Department of Radiology, Aminu Kano Teaching hospital on account of routine medical check up who consented to being recruited into this study.

Exclusion criteria: Include

1) Age younger than 20 years

2) Splenic resection
3) History of prolonged febrile illness

4) Recurrent/chronic illness or haematological disorder that may compromise the splenic size such as sickle cell disease, chronic renal disease, chronic liver disease or any known malignancy.

5) Pregnant women

**Sample size:** Sample size was determined using Fisher’s statistical formula;

\[ n = \frac{Z^2pq}{d^2} \]

for population greater than 10,000.

Where \( n \) = Desired sample size

\( Z = \) standard deviation, using set at 1.96, which corresponds to 95% confidence level.

\( P = \) proportion in target population estimated to have a particular characteristic. If no reasonable estimate, 50% (0.5) was used.

\( Q = 1.0-p \)

\( D = \) degree of accuracy desired, usually set at 0.5

Therefore \( n = 1.96^2 \times 0.5 \times (1.0-0.5)/0.5^2 \)

\[ = 386.16 \text{ thus 400 was the sample size.} \]

**Methodology:** The procedure was explained to the subjects. To ensure adequate compliance with inclusion and exclusion criteria, brief clinical history and physical examination of the patient was undertaken.
The height and weight of the patient were measured using standard anthropometric technique\textsuperscript{36}. Height was recorded in metres, and weight was recorded in kilogram.

Patients were scanned using Mindray Digiprince DP8800 plus (Shenton, China) coupled with 3.5MHz transducer. Subject lies down supine on the examining couch. Scanning was done after the application of adequate amount of coupling gel with subsequent placement of the transducer in the left upper quadrant. The spleen with its homogenous echo texture was located and the general architecture of the gland noted.

Measurement of the spleen dimensions was acquired with the patient in the supine position and was then repeated with the patient in the right lateral decubitus position on deep inspiration. Occasionally, when the lung base obscured the spleen on deep inspiration, scans were obtained on shallow inspiration or at rest. The oblique intercostals approach was adopted for all patients as this view allows the optimal window for spleen imaging in the majority of patients.

All measurements were taken on sections through the splenic hilum in order to create a constant reference point for repeating measurements. Splenic length, defined as the maximum distance between the dome of the spleen and the spleen tip, was measured on a longitudinal section (fig 1). Splenic width, defined as the maximum distance between the medial and lateral borders of the spleen, was measured in a plane perpendicular to the length (fig 2). Splenic depth, defined as the maximum anteroposterior dimension, was measured on a transverse section (fig 2). Each measurement was recorded to the nearest millimetre. An average reading was taken after three different measurements to avoid intraobserver error. Images were printed using Sony UP895ND videographic printer.
Figure 1: Longitudinal sonogram showing the measurement technique of splenic length (+-)
Figure 2: Transverse sonogram showing measurement technique of depth (X-X) and width (+-) of spleen.
LIMITATIONS OF THE STUDY

1. Ultrasonography is operator dependent and a single investigator performed the sonographic measurement of the spleen, hence the potential for minor optimal reproducibility.

2. Overlying bowel gas shadows obscured the spleen from view in some cases.
DATA MANAGEMENT

Data was transferred from the data sheet into the computer and was analysed using SPSS 11.0 statistical software for windows. The mean dimension of the spleen for patient of the same age was calculated and tabulated generating the desired normogram for the study. The dimensions were correlated to sex determining possible variation and establishing sex related normogram. The relationship with age, weight, height and the different splenic dimensions in males and females was examined using the regression and correlation coefficients. The analysis of variance was performed to test the significance of regression coefficients.
ETHICAL CONSIDERATION

Permission was sought and granted from the ethical and research committee of Aminu Kano Teaching Hospital (AKTH), Kano before the commencement of the study. Subjects used for the study gave their informed consent prior to recruitment for the study. Participation was voluntary and subjects were free to withdraw at any stage of the study. Refusal to participate in the study did not in anyway affect the quality of care provided to the subjects. Sonography is safe, not painful and free of ionizing radiation. Confidentiality was ensured. Subjects were also told that it will take about 30 minutes to complete the data sheet and to carry out the examination.
RESULTS:
A total of 400 consecutive adults comprising of 212 (52.9%) males and 188 (47.1%) females were recruited in this study (Fig 3). The age range of the subjects in this study was between 20 and 70 years. The mean age for the subjects was 33 years (±12.0) Table 1. The mean age for the males was 36.8 (±13.5) and that for the females was 28.3 (±8.3). Age group 20-29 (Fig 4) had the highest number of subjects.

Table 1 shows the mean height and weight of the subjects studied to be 1.64m (±0.1) and 61.4kg (±11.0) respectively.

The maximal splenic dimensions were attained at age group 40-49 (Table 2) whereas Table 3 shows maximal splenic dimensions were attained at age range 40-49 and 30-39 for females and males respectively. It was also observed from Table 3 that no difference in spleen dimensions between males and females.

For the overall subjects studied, the mean splenic length, width and depth were 101.6mm (±13.7), 46.8mm (±8.2), and 86.8mm (±12.7) respectively (Table 4). The maximum measurement obtained for the spleen length, width and depth were 137mm, 70.2mm, and 124mm respectively (Table 4).

The mean length of spleen for females was 97.8mm (±15.8) and that of males was 103.9mm (±13.5) indicating that the mean splenic length for females is lower than that for males. The mean splenic width and depth for females were 45.5mm (±7.7) and 84.0mm (±14.8) respectively while that for males were 48.0mm (±8.4) and 88.4mm (±12.5) respectively.
Figure 5 depicts a scatter diagram of the age against splenic length of the subjects and showed that most points tended to cluster in the 20-30 year age group.

The relationship of splenic length, width and depth with age was determined using regression analysis. It shows poor correlation with values of \( r=0.011, P<0.071 \), \( r=0.085, P<0.010 \) and \( r=0.041, P<0.065 \) respectively. (Table 5)

There was positive correlation between subjects height with splenic length \( r=0.990, P<0.001 \), depth \( r=0.320, P<0.01 \) and width \( r=0.189, P<0.01 \). The strongest correlation was with splenic length followed by depth and width. (Table 5)

There was positive correlation between subjects weight with splenic length \( r=0.283, P<0.001 \), width \( r=0.181, P<0.01 \) and then with depth \( r=0.345, P<0.02 \). (Table 5)
FIGURE 3: A pie chart showing subjects distribution according to sex.
FIGURE 4: A bar chart showing age distribution of the subjects.
TABLE 1: The mean, range and standard deviation of the age, height and weight of the subjects.

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<td></td>
<td>Length (mm)</td>
<td>Width (mm)</td>
</tr>
<tr>
<td>1</td>
<td>20-29</td>
<td>197</td>
<td>101.1</td>
<td>47.2</td>
</tr>
<tr>
<td>2</td>
<td>30-39</td>
<td>82</td>
<td>100.4</td>
<td>45.2</td>
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<tr>
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<td>40-49</td>
<td>77</td>
<td>104.5</td>
<td>49.4</td>
</tr>
<tr>
<td>4</td>
<td>50-59</td>
<td>26</td>
<td>95.32</td>
<td>43.5</td>
</tr>
<tr>
<td>5</td>
<td>&gt;60</td>
<td>17</td>
<td>96.45</td>
<td>42.9</td>
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</table>

TABLE 2: Mean splenic length, width and depth for the age groups.
<table>
<thead>
<tr>
<th>S/N</th>
<th>Age (Years)</th>
<th>Freq.</th>
<th>Males</th>
<th>Freq.</th>
<th>Females</th>
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</thead>
<tbody>
<tr>
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<td></td>
<td>Length (mm)</td>
<td>Width (mm)</td>
<td>Depth (mm)</td>
</tr>
<tr>
<td>1</td>
<td>20-29</td>
<td>83</td>
<td>107.0</td>
<td>49.2</td>
<td>90.6</td>
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<tr>
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<td>30-39</td>
<td>37</td>
<td>108.9</td>
<td>48.0</td>
<td>93.2</td>
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<tr>
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<td>52</td>
<td>102.7</td>
<td>50.8</td>
<td>88.2</td>
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<tr>
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<td>50-59</td>
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<td>97.4</td>
<td>41.1</td>
<td>83.9</td>
</tr>
<tr>
<td>5</td>
<td>&gt;60</td>
<td>17</td>
<td>96.5</td>
<td>42.9</td>
<td>78.9</td>
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</table>

TABLE 3: Mean splenic length width and thickness for both sexes.
FIGURE 5: A scatter diagram showing relationship between age of subjects and splenic length
<table>
<thead>
<tr>
<th>Spleen</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>Length (mm)</td>
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<td>74.3</td>
<td>137</td>
<td>13.7</td>
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<tr>
<td>Width(mm)</td>
<td>46.8</td>
<td>29.4</td>
<td>70.2</td>
<td>8.2</td>
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<tr>
<td>Depth(mm)</td>
<td>86.8</td>
<td>58.8</td>
<td>124.0</td>
<td>12.7</td>
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</tbody>
</table>

TABLE 4: The mean, range and standard deviation of the splenic dimensions of the subjects studied.
Correlation is significant at the 0.01 level

TABLE 5: Pearson’s correlation(r) of spleen dimension with anthropometric measurements
DISCUSSION

The morphology of visceral organs varies from person to person. Splenic length measured by ultrasonography provides an objective and reliable way to assess spleen size. A total of 400 subjects were studied comprising of 211 (52.9%) males and 189 (47.1%) females with a mean age of 33 years (±12.0) and range of 20-70 years. While Okoye et al. studied 250 subjects consisting of 86 (34.4%) males and 164 (65.6%) females and a modal age of 30-80 years. Hosey et al. in their study of 631 adults consisting of 341 (54%) males and 290 (46%) females reported a mean age of 24 years (±9.5). The range of subjects studied by Okoye et al. is similar to the index study while the mean age of Hosey et al. is lower than that of the current study.

The mean height and weight of subjects studied were 1.64 m (±0.77) and 61.40 kg (±10.97) respectively. Okoye at al. reported a mean height of 1.65 m (±1.4) and weight of 69 kg (±5.4) while Ehimwenma et al. reported a mean height and weight of 1.67 m (±6.5) and 68.3 kg (±9.0) respectively. Mean height and weight of 1.72 m (±0.58) and 76.3 kg (±8.7) respectively were reported by Spielman et al. in their study of tall healthy adults. The mean height and weight of the subjects in the index study are similar to those of Okoye et al. and Ehimwenma et al. but lower to that of Spielman et al.

The range of splenic length, width and depth were 74.3 mm - 137 mm, 29.4 mm - 70.2 mm and 58.8 mm - 124 mm respectively for the index study. These values are similar though with a wider range to those obtained in the studies by Okoye et al. in Nigeria’s south east (99 mm - 115 mm, 40 mm - 45 mm, and 60 mm - 75 mm). The mean splenic length, width and depth from this study were 102 mm (±13.7), 47 mm (±8.2), and 87 mm (±12.7) respectively. These values are similar to those obtained by Hosey et al. for Caucasian population 106.5 mm (±15.5), 51.6 mm (±12.1) and
89.2mm (±13.8). This finding is surprising and important as larger splenic size is expected to occur in falciparum malaria and sickle cell endemic areas like Nigeria.

Smaller spleen size in African-American collegiate athletes compared to their white American colleagues was reported in a previous study (P<0.001)\(^8\). Although subjects in this study were from a region endemic with malaria, and sickle cell anaemia and trait, the questionnaire was used to exclude selection of study subjects with these and other conditions associated with splenomegaly.

In agreement with previous reports this study found no correlation between spleen dimensions with subject’s age\(^3,6,8,13,17,24\). Some authors showed a decrease in spleen diameter with increasing age\(^32,42\), but others showed no correlation\(^43\). A steady decrease in the mean splenic length with increase in age is noted. The mean splenic length at 30-39 age range is seen to be higher than that at 50-59 years age range. Similar changes are noted in the mean width and depth of the spleen with age.

This study documents that the maximum spleen length occurred at the 30-39 years age range for males and 50-59 years range for females, in consonance with the findings of Okoye et al\(^3\). Also the splenic length of males increase with age until the middle age and thereafter undergoes gradual diminution.

This study found no significant difference between the spleen dimensions of males and females. This corroborates the findings of earlier studies\(^13,39,42\), but some other studies have found significant difference in spleen dimension between the genders\(^8,24,28,40\).
The normal splenic length for adults in this study ranged from 76mm to 131mm and has a strong positive correlation with subject height (r=0.990, P<0.001) and also correlates with weight (r=0.283 P<0.001). These agrees with the findings of Ehimwenma\textsuperscript{13} in Benin, south-south of Nigeria that for all splenic measurements, there was a stronger correlation with subject height than with their weight.

This study showed a positive correlation between spleen length and width with subject’s height (P<0.001 and P<0.01). However the study by Mustapha et al in north eastern Nigeria showed a negative correlation between spleen length and subject height (r = -0.22). Also the other spleen dimension namely depth showed negative correlation with subject’s height (r = -0.06).

Some authors showed that subject’s weight has no correlation with splenic dimensions\textsuperscript{28,42,43}. However in this study strong positive correlation exists between the subject’s weight with the measured spleen length and width and weak positive correlation with depth. Hosey et al\textsuperscript{8} showed a positive correlation between respondents weight and spleen length. These are far less than those seen in paediatric and adolescent populations. This observation probably results from the cessation of rapid body growth that occurs with attainment of mature body morphology. Thus it is difficult to predict spleen size reliably on the basis of these variables alone.

Spleen length has been shown in several studies to have a high correlation with spleen volume, and can be used in daily clinical practice to determine splenomegaly\textsuperscript{1,37}. Mustapha et al\textsuperscript{12} also reported statistically significant correlation between spleen volume and length (r=0.8, P<0.001).

There is variable data for the upper limits of normal spleen dimensions in adults. A maximum spleen length of between 10 and 12cm has been suggested in the literature as being normal, and widely accepted in clinical practice\textsuperscript{27,38}. Prassopoulos P et al\textsuperscript{38} showed a maximum spleen length
of 125mm in one study of 140 subjects, and another study of 207 subjects though from CT assessment showed maximum spleen length of 128mm and 122mm in men and women, respectively\textsuperscript{40}.

In another study using 2D and 3D ultrasound, a maximum spleen length of 134 and 128mm, respectively, was found\textsuperscript{41}. The largest spleen from the index study was 137mm, which is slightly larger than that from other studies but a mean spleen length of 102mm similar to the accepted criteria. In one study, the mean spleen length measurements were shown to have a higher reproducibility than maximal spleen length measurements\textsuperscript{39}. Some investigators found that very tall healthy individuals can have spleen sizes larger than currently accepted\textsuperscript{28}. One study of healthy collegiate athletes showed 7% of their participants had spleen length greater than 130mm\textsuperscript{8}.

Another study suggested that the maximum spleen length for individuals taller than 1.8m (6 feet) is greater than 130mm\textsuperscript{28}.

In conclusion this study showed no significant difference in the mean spleen dimensions of males and females in Kano, Nigeria and there was steady increase in spleen dimension with increase in age up to the 4\textsuperscript{th} decade where a gradual decline sets in. The spleen length, width and depth showed poor correlation with age. Subjects height shows strong positive correlations with spleen length and then with depth and width, indicating that height could be predictive of spleen length in Kano. Mean splenic length in Kano, Nigeria where sickle cell anaemia and trait and malaria are endemic is virtually same as that reported in other parts of Nigeria and slightly lower than that seen in Caucasians thus emphasizing the fact that normograms should be established for each region.
REFERENCES


