SEX DETERMINATION FROM NORMAL POSTERO – ANTERIOR CHEST RADIOGRAPHS OF ADULTS IN GOMBE STATE, NIGERIA

BY

Zubairu Saidu RAYYANU
M.Sc/MED/4765/2009-2010

DECEMBER, 2014

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DECEMBER, 2014

DECLARATION

I, Zubairu Saidu RAYYANU, declare that the work in the thesis entitled **“Sex Determination from Normal Postero – Anterior Chest Radiographs of Adults in Gombe State, Nigeria”** has been performed by me in the department of Human Anatomy, Faculty of Medicine, Ahmadu Bello University, Zaria, Nigeria, under the supervision of Dr. A. U. Hamidu, and Dr. B. Danborno. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any University.

ZUBAIRU SAIDU RAYYANU

Name of student	Signature	Date

CERTIFICATION

This thesis entitled **"Sex Determination from Normal Postero – Anterior Chest Radiographs of Adults in Gombe State, Nigeria"** by Saidu Rayyanu Zubairu meets the regulation governing the award of the Master of Science of Ahmadu Bello University for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This Thesis is dedicated

To

My parents Alh. Saidu Rayyanu and Hajiya Sa'adatu Saidu, my wife Zainab Sani Hamza, for their prayers, and my children Muhammad Badamasi (Ameer), Maryam (Ihsan) and Ibrahim (Khalil) who really missed my paternal support when they needed it most, and to those who lose their live in fatal accident, genocide and insurgency.

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ABSTRACT

This study was set to radiologically evaluate the normal posterior- Anterior chest radiographs of Gombe adults, which was undertaken using 500 chest radiographs that were reported normal by radiologist, males (n = 250 and mean age 43.38 ± 16.55) and females (n = 250 and mean age 39.28 ± 14.68). In males the mean length of left clavicles was 163.70 ± 10.52 mm and the right was 157.65 ± 10.06 mm, while in females the mean length of the left clavicles was 150.47 ± 8.58 mm and the right clavicle was found to be 144.72 ± 8.36 mm, also the males mean mid – thickness of the left clavicles was 13.38 ± 1.42 mm and right clavicle was 14.06 ± 1.38 mm, while in females the mean mid-thickness of the left clavicle was 11.19 ± 1.09 mm and the right clavicle was 11.81 ± 0.89 mm, in which the sex difference in the mean length and mid- thickness of the clavicles on both left and right sides was found to be highly significance ($P<0.001$) with the males having longer and thicker clavicles than females, the clavicles in both males and females show side difference with the right clavicles being significantly the shorter and thicker than left clavicles. In males mean height of left scapular 166.99 ± 14.40 was found to be significantly different from right 161.07 ± 15.27 with ($P<0.001$), likewise the females mean height of the left scapular was significantly different from right ($P<0.001$). The males mean width of the left scapular was 84.89 ± 8.90 mm and right scapular was found to be 83.32 ± 9.46 mm, the females mean width of the left scapular was 77.57 ± 7.96 mm and the width of right scapular was 74.44±10.63 mm, which indicates that the scapula in the both side were significantly greater in males than in females with $P<0.001$.

The thoracic dimension were also found to be greater in males than in females, in which the males thoracic diameter at T3 was 213.16 ± 17.36 mm, T5 was 256.81 ± 15.76 mm, T7

was 276.93 ± 16.64 mm and T9 was 288.94 ± 19.50 mm, while the thoracic diameter in females at T3 was 200.90 ± 15.76 mm, T5 was 238.88 ± 14.36 mm, T7 was 257.06 ± 15.28 mm and T9 was 268.65 ± 18.96 mm, where the differences were highly significant with $P < 0.001$, the height of left and right hemidiaphragm dome shows significance difference between males and females, with the height of left and right hemidiaphragm dome in males as 241.23 ± 20.04 mm and 222.34 ± 20.57 mm and in females as 224.14 ± 12.78 mm respectively. The left and right hemidiaphragm dome shows side difference in males and females ($p<0.001$). The long and short axis of cardiac ellipsoid were measured in males as 145.61 ± 7.19 mm and 116.84 ± 8.76 mm, while in females as 138.44 ± 8.31 mm and 111.02 ± 6.73 mm respectively, this indicated that the long and short axis of cardiac ellipsoid are significantly greater in males than in females ($p<0.001$).

The shape of C7/T1 and T1/T2 intervertebral discs also show greater sex difference ($P<0.001$) in which the males intervertebral disc were mostly curved (inverted V) at both levels, whereas the females intervertebral disc is parallel in shaped at both levels.

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LIST OF ABBREVIATION

AP	Anteroposterior
C	Curved
CT:	Computed tomography
D-T3	Thoracic diameter at level of third thoracic vertebra
D-T5	Thoracic diameter at the level of fifth thoracic vertebra
D-T7	Thoracic diameter at the level of seventh thoracic vertebra
D-T9	Thoracic diameter at the level of ninth thoracic vertebra
HLHD	Height of left hemidiaphragm dome
HRHD	Height of right hemidaiphragm dome
HLS	Height of the left scapula
HRS	Height of the right scapula
LAO	Left anterior oblique
LCA	Long axis of cardiac ellipsoid
LHEC	Local health ethical committee
LLC	Length of the left clavicle
LRC	Length of right clavicle
P	Parallel
PA	Posteroanterior
RAO	Right anterior oblique
S- C7/T1	Shape of seventh cervical first thoracic intervertebral disc
S- T1/T2	Shape of first thoracic second thoracic intervertebral disc
SCA	Short axis of cardiac ellipsoid

TLC	Mid- thickness of the left clavicle
TRC	Mid- thickness of the right clavicle
WLS	Width of the left scapula
WRS	Width of the right scapula

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Identification of the sex of skeletonized or dismembered human bodies is the first step in bio-archaeological and forensic anthropological investigations (Derya *et al*., 2010).

Positive identification of the deceased is necessary for an accurate death certificate to be filed, a Will to be executed, benefits to be distributed, and most importantly for families to find closure. Decedent identification is also necessary for the conclusive investigation of homicide (Brogdon, 1998). Methods of identification include fingerprints, dental radiograph comparison, axial and appendicular radiograph comparison, and in selected cases, DNA analysis. Visual identification alone is often unreliable due to thermal damage, immersion, mutilation, disarticulation or decomposition of the remains (Fierro, 1993).

The human thoracic region is relatively important in biological and forensic anthropological studies as it is active between adolescent growth and adult maturational and degenerative periods (Carla *et al*., 2005). As such, it presents an opportunity to obtain information with respect to personal identification during much of an individual's life span and may be especially important when dealing with only partial remains, where sex determination and age estimation may become more difficult (Carla *et al*., 2005). Most anthropological methods for dealing with situations of questionable identity have been developed for use on dry bone and, at the very least, require a partially or totally defleshed body. While all individuals requiring a forensic examination are in some stage of decomposition, in the majority of situations these bodies are relatively intact. In such instances it may be a straightforward procedure to initiate identification processes using fingerprints, visual confirmation, unique physical characteristics, dental records, or past medical procedures as corroborating evidence. However, on occasion, an individual may be too decomposed to successfully use these methods or ante-mortem medical and/or dental records may be inadequate, unavailable, or difficult to locate. Thus any technique that is able to facilitate a rapid, simple, and inexpensive determination of sex is extremely important. Of particular relevance to this study, is the determination of sex in forensic contexts from radiographs of the chest (McComick *et al.*, 1985).

The key to the successful determination of sex is the use of measurements that have shown consistently high replicability and accuracy in allocating both male and female sex. One of the first metric methods, Hyrtl's Law (Hyrtl, 1893), has been using sternal size for over 170 years as an estimator of sex. According to Hyrtl, in females the manubrium generally exceeds half the length of the sternal body whereas in males the body of the sternum is usually twice as long as the manubrium. Numerous other investigators have used sternal or thoracic area measurements as useful predictors of sex (Dwight, 1881 and 1890; Paterson, 1904; Pons, 1956; Ashley, 1956; Stewart, 1983; Jit, 1985; Iscan, 1985). Stewart and McCormick (1983) examined 64 radiographs to determine if there was a relationship between sternal length and pattern of costal cartilage mineralization. They observed that mean manubrio-mesosternal length in male is >158 mm, while in female is <142 mm, which correctly predicted sex in 40 of the 42 (95.2 %) applicable cases with mineralization patterns accurately predicting sex in 38 of the 41 (92.7 %) applicable cases. Using both methods, they achieved an accuracy rate of 96.4 % on 87.5 %, or on 56 of the 64 cases examined.

In 1985, McCormick *et al*. examined sex differences in chest radiographs of 698 males and 435 females over the age of 20 years. Which was made directly from high-resolution chest radiographs, thus eliminating the need to de-flesh the individual (McCormick *et al*., 1985).

Francois *et al*. (2003) and Bellemare *et al*. (2001) examined and measured the thoracic dimensions of the chest radiographs of 40 normal subjects (21 males and 19 females) at the level of third, fifth, seventh and ninth vertebrae and ribs, the Height of each hemidiaphragm dome below the first thoracic vertebra on the posterioanterior (PA) films and averaged and the inclination of rib was as acute angle formed by the lower border of the sixth rib and the vertical the lateral films, and found the thoracic dimension of males is greater than females.

1.1.1 Brief History of Gombe State

Gombe State was created out of former Bauchi State in 1st October 1996 by Late General Sani Abacha administration, it occupies a total land area of about 20, 265 sq. km. The topography of the state is mountainously undulating and hilly to the south and flatly open-plain to the north (Ibrahim, 2004; Harper, 2009).

The Gongola river traverses the state, watering most of the north and north-eastern parts of it before emptying into river Benue at Numan. Numerous streams that are mostly seasonal also serve as tributaries to the Gongola river (Ibrahim 2004; Harper, 2009).

The vegetation of the state is generally guinea savannah grassland with concentration of woodlands in the south-east and south-west. Gombe State is generally warm with average maximum temperature during the hot season not exceeding 30^0 centigrade. There are two distinct seasons: the dry season (November to March) and wet season(April to October).

Average annual rainfall is 850 mm. The State is endowed with rich agricultural land and about 80% of the people are mainly peasant farmers involved in farming food and cashcrops such as millet, sorghum, maize, vegetable, cotton and groundnut, though rain-fed as well as irrigation agriculture. Some of the people are also engaged in livestock farming, fishingand craft works (Ibrahim, 2004; Harper, 2009).

Gombe State has large deposits of solid mineralssuch as limestone, gypsum, kaolin, silica, talc, uranium and dolomite (Ibrahim, 2004; Harper, 2009).

1.1.1.1 Demography and People of Gombe State

The 1998 census returned a population of 1,895,597 people for Gombe state. By 2004 and 2006, it was projected to 2,174,118 and 2,353,000 people, respectively. There are slightly more males than females in the State. The sex ratio being 100 males to 98.9 females. That is, the gender composition of the population is almost equally distributed (Ibrahim, 2004; Census, 2006).

Gombe state has a multi-ethnic composition mainly of Fulani, Tangale, Waja, Bolawa, Tera, Jukun, Pero, Gera, Tula, Chamawa, Lunguda, Dadiya, Kanuri, Hausa, Kamo, Jaraamong others. In addition, there is quite an appreciable population of Yoruba and Igbo in the State (Ibrahim, 2004; Census, 2006).

Gombe State has a rich cultural heritage. Crafts, such as leather works, cloth weaving and calabash decoration abound in the state. There are also notable musical forms and dances performed by different groups. e.g Ngorda in Yamaltu-Deba, Bid-bid dance group in Billiri (Ibrahim, 2004; Census, 2006).

The state is also multi-religious, with Muslims and Christians being the most predominant groups. Traditional religion also exists to a lesser degree, e.g eku among the Tangale communities and nabakwa among the Tula (Ibrahim, 2004; Census, 2006).

1.2 STATEMENT OF THE RESEARCH PROBLEM

In conditions of natural or man made mass disasters, genocides or aircraft accidents where direct or positive identification of victims is difficult, there is need for an accurate, timely, simple and inexpensive method of sex determination. For the purpose of identifying victims, one of such method that has proved reliable is the use of high resolution chest radiographs (McCormick *et al.*, 1985).

Because there are no reference values for sex determination using normal chest radiographs for the people of Gombe State, Nigeria, there is a need to carry out a study in order to fill this gap.

1.3 AIM AND OBJECTIVES OF THE STUDY

1.3.1 Aim of the study

The aim of the present study is to radiologically evaluate the anatomy of normal postero-anterior chest radiographs of adults in Gombe.

1.3.2 Objectives of the study

The objectives of this study are to:

i. Evaluate the radiological anatomy of adult in Gombe using normal posteroanterior chest radiographs.
ii. Establish reference values for determination of sex from the dimensions of structures in the normal chest radiographs.
iii. Investigate the radiological anatomy of adults in Gombe according to sex and age using normal posteroanterior chest radiographs .
iv. Investigate the relationship between the scapula, clavicle, heart, and chest dimensions in sex determination using normal chest radiographs.
v. Investigate gender difference in the intervetebral disc shape in chest radiographs of normal Gombe adults.

1.4 Significance of the study

This study will provide rapid, simple, and inexpensive method of sex determination from human chest radiographs when other conventional methods typically used for such are not available.

1.5 Justification

The chest radiograph is the most commonly requested radiograph and the radiation dose to the patient is very minimal (Carrie *et al.,* 2002). Therefore the need to use chest radiographs to determine sex is highly desirable in order to establish reference value for sex determination for the people of Gombe.

1.6 Hypotheses of the study

i. There will be difference between the dimensions of male and female normal chest radiographs.

ii. There will be differential relationship between scapula, clavicle, heart and overall chest diameters in male and female.

iii. There will be difference in the intervertebral disc shape between males and females.

1.7 The Scope of the Study

This study was limited to evaluation of posteroanterior (PA) chest radiographs in determination of sex for normal Gombe individuals.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Chest Radiograph

The application of radiographs as a useful tool in sex assessment had earlier been reported by Adebisi and Singh, (2003).

The frontal chest radiograph (CR) is the most commonly requested plain film. The image is taken either as a "PA" (posteroanterior) or as an "AP" (anteroposterior), depending on the direction of the X-ray beam. The projection is usually marked on the film (Felson, 1973; Chan *et al.*, 2000; Abiru *et al*., 2005; Naveed and Orlando, 2008).

A PA projection is the better quality film and allows the size and shape of the heart and mediastinum to be assessed accurately. This, of course, requires the patient to be reasonably mobile (Felson, 1973; Chan *et al.*, 2000; Abiru *et al*., 2005; Naveed and Orlando, 2008). Since it is taken in an erect position.

However, in some patients, who are unable to be positioned for the PA view, the antero-posterior projection will sufficient. Occasionally, when the anatomical localization of lung abnormalities is difficult to discern, a lateral view of the chest will be requested (Felson, 1973; Chan *et al.*, 2000; Abiru *et al*., 2005; Naveed and Orlando, 2008).

2.1.1 Views for chest radiographs

Chest x-ray views are divided into two (2)

a. Basic views:-

i. Posteroanterior (PA) view.

ii. Lateral view,

b. Supplementary view:-

i. Lateral decubitus view,

ii. Oblique view,

iii. Anteroposterior (AP) view

iv. Others like Apical or Lordotic views

2.1.1.1 Basic views

2.1.1.1.1 Posteroanterior (PA) view

For posteroanterior (PA) projections, the patient to sit or stand upright. Patients are positioned to face the film-screen cassette in order to minimize magnification of the anteriorly positioned heart and consequent obscuration of the lungs. The patient should stand straight and the weight of his body should be equally distributed on both feet (Felson, 1973; Chan *et al.,* 2000; Abiru *et al*., 2005; Naveed and Orlando, 2008).

2.1.1.1.2 Lateral view

A lateral chest projection is part of standard x-ray examination of the chest. Although the PA view is the mainstay of diagnosis, it provides a clear view of about 80 % of the lungs; the retrosternal and retrocardiac spaces as well as the posterior sulci are obscured by overlying anatomical strache. The lateral view clearly displays these areas and is especially useful in detecting lower-lobe lung disease, pleural effusions, and anterior mediastinal masses (Felson, 1973; Chan *et al.,* 2000; Abiru *et al*., 2005; Naveed and Orlando, 2008).

2.1.1.2 Supplementary views

2.1.1.2.1 Lateral decubitus view

Decubitus means lying down; thus, this projection is made with the patient lying on their side and the x-ray beam horizontal (parallel) to the floor. The primary goal of performing the lateral decubitus projection is to demonstrate fluid in the pleural cavity (a pleural effusion), which is otherwise not clearly visible on a supine or upright chest radiograph (Felson, 1973; Chan *et al.,* 2000; Abiru *et al*., 2005; Naveed and Orlando, 2008).

Lateral decubitus films are helpful for determining if effusion is free flowing, and are also used to determine whether there is enough fluid to sample by thoracocentesis. A lateral decubitus projection can also be helpful in showing small amounts of air in the pleural cavity (a pneumothorax) as well as air fluid levels in other cases (Felson, 1973; Chan *et al.*, 2000; Abiru *et al*., 2005; Naveed and Orlando, 2008).

2.1.1.2.2 Oblique view

Oblique projections are not ordered as frequently as a few years ago, because CT is more commonly employed whenever pathology is not clearly visualized on a standard chest x-ray(Felson, 1973; Chan *et al.,* 2000; Abiru *et al*., 2005; Naveed and Orlando, 2008).

However, oblique-view chest x-rays may be helpful and are requested in the following reasons:

i. For separating a pulmonary or mediastinal mass or opacity from structures that overlie it on the PA and lateral views.
ii. For studying lesions that are visible in the PA view but not in the lateral view.
iii. For determining the site of origin of an intrathoracic lesion.

iv. Right anterior oblique (RAO) and left anterior oblique (LAO) positions are routinely used to study the esophagus in barium examinations.

v. As an aid for the differential diagnosis of cardiac and great vessel enlargement (Felson, 1973; Chan *et al.,* 2000; Abiru *et al*., 2005; Naveed and Orlando, 2008).

2.1.1.2.3 Anteroposterior (AP) View

Anteroposterior (AP) chest radiographs can be made in the intensive care unit, the operating suite, or the patient's room using mobile equipment. They are often known as a portable film when performed with a mobile unit. They are generally of lesser quality than a posteroanterior (PA) radiograph or recumbent films made in the radiology department. Hence, it is preferable to obtain a film in the radiology department unless the patient cannot be moved without hazard (Felson, 1973; Chan *et al.,* 2000; Abiru *et al*., 2005; Naveed and Orlando, 2008).

2.2 ANATOMY OF THE THORAX

2.2.1 Anatomy of the Rib cage

The skeleton of the **thorax** or **chest** is an osseo-cartilaginous cage, containing and protecting the principal organs of respiration and circulation. It is conical in shape, being narrow above and broad below, flattened from before backward, and longer behind than in front. It is somewhat reniform on transverse section on account of the projection of the vertebral bodies into the cavity (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

2.2.1.1 Boundaries

The **posterior surface** is formed by the twelve thoracic vertebræ and the posterior parts of the ribs. It is convex from above downward, and presents on either side of the middle line a deep groove, in consequence of the lateral and backward direction which the ribs take from their vertebral extremities to their angles (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

The **anterior surface,** formed by the sternum and costal cartilages, is flattened or slightly convex, and inclined from above downward and forward (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

The **lateral surfaces** are convex; they are formed by the ribs, separated from each other by the intercostal spaces, they are eleven in number and are occupied by the Intercostal muscles and membranes (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

2.2.1.2 Opening of rib cage

The **upper opening** of the thorax is reniform in shape, being broader from side to side than from before backward. It is formed by the first thoracic vertebra behind, the upper margin of the sternum in front, and the first rib on either side. It slopes downward and forward, so that the anterior part of the opening is on a lower level than the posterior. Its antero-posterior diameter is about 5 cm, and its transverse diameter about 10 cm (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

The **lower opening** is formed by the twelfth thoracic vertebra behind, by the eleventh and twelfth ribs at the sides, and in front by the cartilages of the tenth, ninth, eighth, and seventh ribs, which ascend on either side and form an angle, the **subcostal angle,** into the apex of which the xiphoid process projects. The lower opening is wider transversely than from before backward, and slopes obliquely downward and backward, it is closed by the diaphragm which forms the floor of the thorax (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

2.2.1.3 Applied Anatomy of the thorax

The thorax of the female differs from that of the male as follows: 1. Its capacity is less. 2. The sternum is shorter. 3. The upper margin of the sternum is on a level with the lower part of the body of the third thoracic vertebra, whereas in the male it is on a level with the lower part of the body of the second. 4. The upper ribs are more movable, and so allow a greater enlargement of the upper part of the thorax (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

2.2.2 Clavicle

The clavicle lies almost horizontally between the sternoclavicular and the acromioclavicular joints. It is also attached to the first costal cartilage by the costoclavicular ligament, which arises from the rhomboid fossa on its inferomedial surface. It is connected to the coracoid process by the coracoclavicular ligament at the conoid tubercle and the trapezoid line on its inferolateral surface. The subclavian vessels and the trunks of the brachial plexus pass behind its medial third (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

2.2.2.1 Radiological feature of clavicle

The clavicle overlies the apices of the lungs in chest radiographs. Apical or lordotic views are used to project the clavicles above the lungs to evaluate this area further. In portable

AP chest radiography, if the patient is inclined backwards from a true vertical position the horizontal beam projects the clavicles above the lungs. On a chest radiograph, the distance between the medial end of the clavicle and the spine of the vertebrae is equal on both sides unless the patient is rotated. The rhomboid fossa is seen in 0.6 % of normal chest X-rays and 33 % are bilateral (David *et al*., 2002; Ryan *et al.*, 2007; Paul *et al.*, 2007).

2.2.3 Scapula

This flat triangular bone has three processes:

i. The glenoid process, which is separated from the remainder by the neck of the scapula. The glenoid cavity forms part of the shoulder joint;
ii. The spine, which arises from the posterior surface of the scapula and separates the supraspinous and infraspinous fossae extends laterally over the shoulder joint as the acromial process.
iii. The coracoid process, which projects anteriorly from the upper border of the neck of the scapula (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

2.2.3.1 Radiological features of scapula

The inferior angle of the scapula lies over the seventh rib or interspace - this is a useful guideline in identifying ribs or thoracic vertebral levels (David *et al*., 2002; Ryan *et al.*, 2007; Paul *et al.*, 2007).

The scapula lies over the ribs and obscures some of the lung fields in PA chest radiographs unless the shoulders are rotated forwards. In AP views it is not usually possible to rotate the scapulae off the lung fields. Similarly, in AP views of the scapula the beam is centred over the head of the humerus to project the thoracic cage away from the scapula. In lateral chest radiographs, the lateral border of the scapula may be confused with an oblique fissure. The inferior angle of the scapula may be slightly bulbous and simulate a mass on this view (David *et al*., 2002; Ryan *et al.*, 2007; Paul *et al.*, 2007).

2.2.4 Heart

The heart is pyramidal in shape and lies obliquely in the chest. Its square-shaped base points posteriorly and the elongated apex to the left and inferiorly.

The left atrium forms the base or posterior part, with the superior and inferior pulmonary veins draining into its four corners. The right atrium forms the right border, with superior and inferior venae cavae draining into its upper and lower parts. The apex and left border are formed by the left ventricle. The right ventricle forms the anterior part. The inferior (diaphragmatic) part of the heart is formed by both ventricles anteriorly and a small part of right atrium posteriorly where the IVC enters this chamber (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

2.2.4.1 Radiological features of the heart

The cardiac contour is seen on the frontal and lateral chest film. Posteroanterior films are preferred to anteroposterior ones as the heart, being anterior, is closer to the film and is not magnified to the same extent as with anteroposterior films. The cardiothoracic ratio, usually less than $\leq$ 50 %, may be up to 55 % in Asian and Afro-Caribbean subjects and up 55 to 60 % in infants. (For a description of the cardiac contour, see the section on the mediastinal contour (David *et al*., 2002; Ryan *et al.*, 2007; Paul *et al.*, 2007).

2.2.5 Vertebral column

The vertebral column is situated in the median line, as the posterior part of the trunk; its average length in the male is about 71 cm. Of this length the cervical part measures 12.5 cm, the thoracic about 28 cm, the lumbar 18 cm, and the sacrum and coccyx 12.5 cm. The female column is about 61 cm. in length (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

2.2.5.1 Curves of vertebral column

Viewed laterally the vertebral column presents several curves, which correspond to the different regions of the column, and are called cervical, thoracic, lumbar, and pelvic (David *et al*., 2002; Ryan *et al*., 2007; Standring *et al.*, 2009).

i. **The cervical curve**, convex forward, begins at the apex of the odontoid process, and ends at the middle of the second thoracic vertebra; it is the least marked of all the curves (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

ii. **The thoracic curve**, concave forward, begins at the middle of the second and ends at the middle of the twelfth thoracic vertebra. Its most prominent point behind corresponds to the spinous process of the seventh thoracic vertebra (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

iii. **The lumbar curve** is more marked in the female than in the male; it begins at the middle of the last thoracic vertebra, and ends at the sacrovertebral angle. It is convex anteriorly, the convexity of the lower three vertebræ being much greater than that of the upper two (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

iv. **The pelvic curve** begins at the sacrovertebral articulation, and ends at the point of the coccyx; its concavity is directed downward and forward.

The thoracic and pelvic curves are termed primary curves, because they alone are present during fetal life (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

The cervical and lumbar curves are compensatory or secondary, and are developed after birth, the former when the child is able to hold up its head (at three or four months), and to sit upright (at nine months), the latter at twelve or eighteen months, when the child begins to walk.The vertebral column has also a slight **lateral** curvature, the convexity of which is directed toward the right side (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009).

2.3 Posteroanterior (PA) Erect View or Frontal View

The patient is placed facing the cassette with the chin extended and centered to the middle of the top of the cassette. The feet are placed slightly apart so that the patient achieves a stable stance. The median sagittal plane is adjusted at a right angle to the middle of the cassette. The dorsal side of both hands is positioned below and behind the hips with the elbows brought forward. Alternatively, the arms encircle the cassette to allow the shoulders to rotate forward and downward and come in contact with the cassette (Swallow *et al.*,1986; Richard *et al.*, 2010; Delrue *et al.*, 2011). This position avoids a superimposition of the scapulae over the lung fields. The breasts should be compressed against the screen to prevent them from obscuring the lung bases and diaphragm (Swallow *et al.*,1986; Richard*et al.*, 2010; Delrue *et al.*, 2011).

The horizontal central x-ray is directed first at right angles to the cassette at the level of the fourth thoracic vertebra, and then angled 5°caudally to make the central ray coincide with the middle of the cassette. This results in a confining of the radiation field to the film/ detector without unnecessary exposure to head and eyes (Swallow *et al.,*1986; Richard*et al.,* 2010; Delrue *et al.,* 2011). Inappropriately centered x-rays may lead to hyperlucency simulating pulmonary emphysema, massive vascular embolism, or an anomaly of the soft tissues. Improper positioning (rotation) of the patient can obscure certain regions of the lung such as the hila and mediastinal lines, and borders cannot be seen anymore. It can also produce a distorted position of the trachea, which can be misinterpreted as a paratracheal mass (Swallow *et al.,*1986; Richard*et al.,* 2010; Delrue *et al.,* 2011).

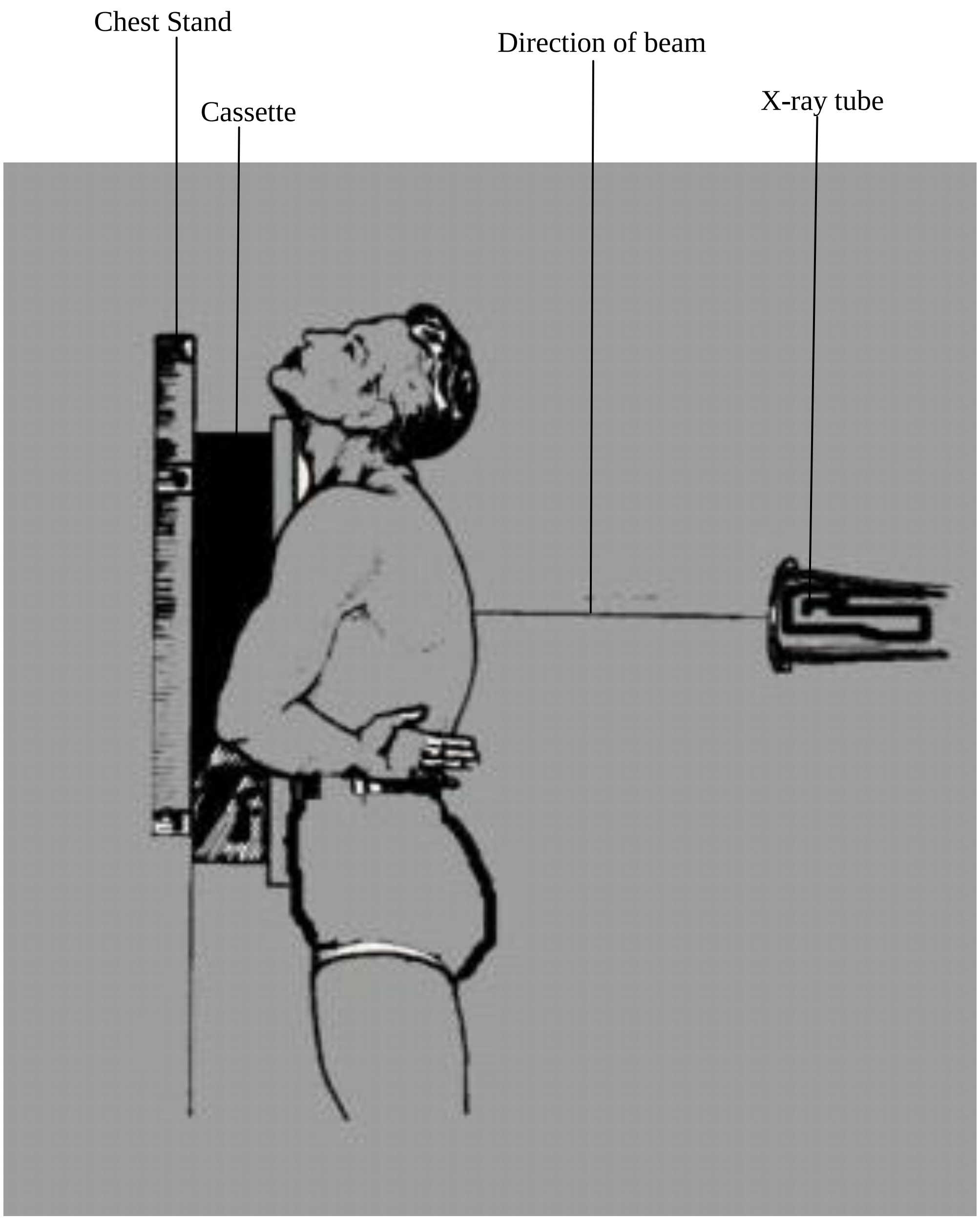


Fig. 2.1 Posteroanterior **(**PA**)** chestprojectionposition **(**NaveedandOrlando**,** 2008**)**

2.3.1 Appearance of structures in normal chest radiograph

X-rays are high-energy ionizing photons that penetrate matter to an extent that depends generally on the density of the substance. Gases are least dense (Chan *et al.,* 2000; Louke *et al.,* 2011). Soft tissues including all solid organs are of intermediate density, while bones and other calcium-containing structures are the most dense. Plain X-ray films are produced by passing X-rays through the body and onto a film. There is an intervening cassette which converts the X-ray energy into light; the light so produced creates an image on the film. Intervening matter attenuates the X-rays to a variable extent, with the result that areas of the film underlying dense structures are exposed to a lesser degree than areas of the film underlying less dense structures. On the developed film, there are four basic densitiesrecognized (Chan *et al.,* 2000; Louke *et al.,* 2011):

i. Gas appears black.
ii. Fat appears dark grey.
iii. Water appears light grey.
iv. Bone appears white.

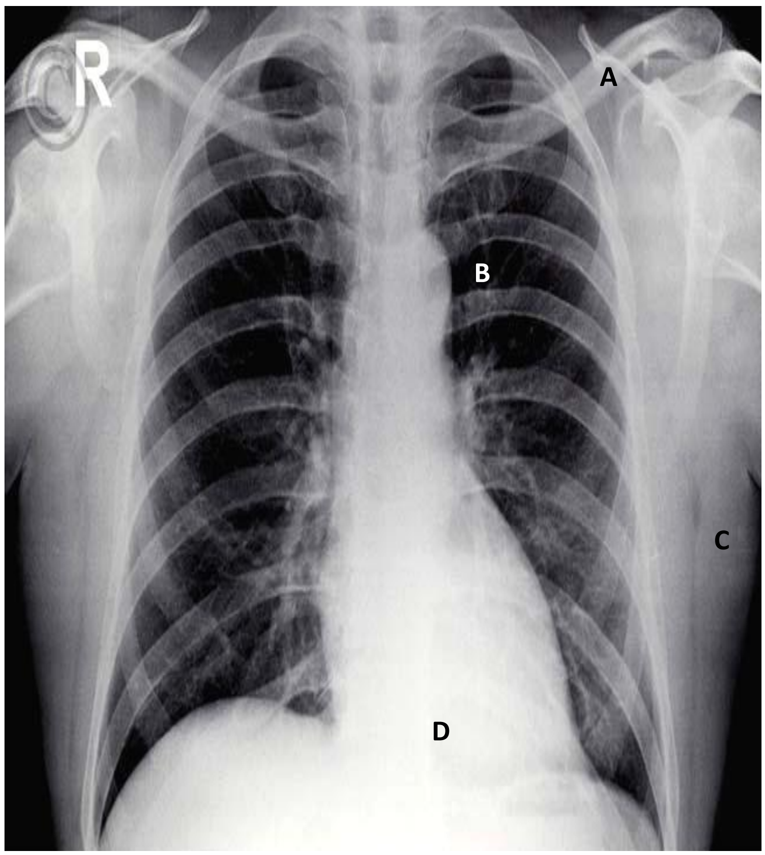


Plate 2.1: Appearance of structures in normal plain chest PA radiographs (Chan, *et al.*, 2000).

Key:

A= White

B= Black

C= Dark Grey

D= Light Grey

2.3.2 Good exposure of posteroanterior chest radiograph

Exposure is made in full arrested inspiration for optimal visualization of the lung bases (the diaphragm must descend to the level of the tenth or eleventh ribs posteriorly, or to the level of the sixth ribs anteriorly) (Chan *et al.,* 2000; Louke *et al.,* 2011). Poor inspiration may lead to under-expansion of the thoracic cage with crowding of basal vessels simulating congestion or fibrosis. Moreover, small pleural effusions will be masked (Chan *et al.,* 2000; Louke *et al.,* 2011).

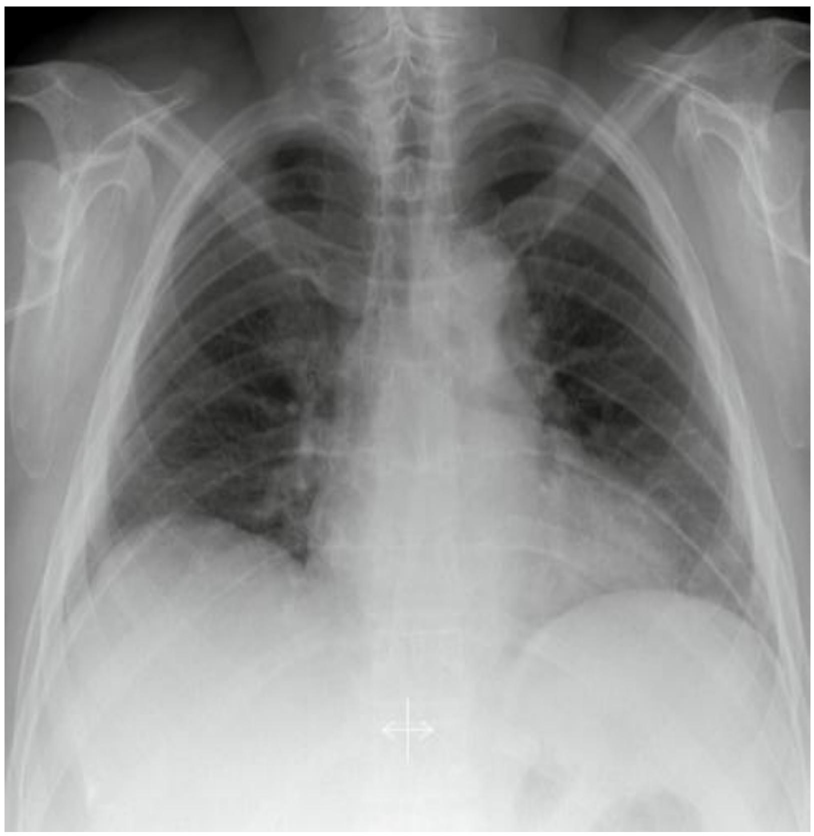


Plate 2.2: A plain posteroanterior chest radiograph indicating poor inspiration (Louke *et al.*, 2011).

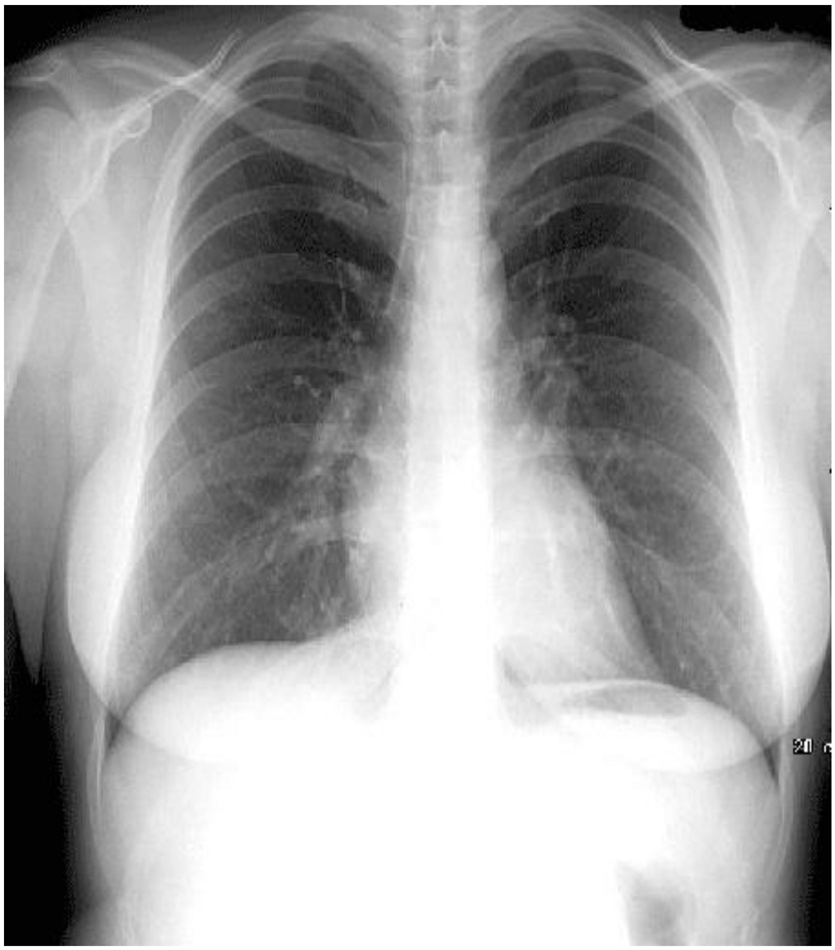


Plate 2.3: A plain posteroanterior chest radiograph indicating full inspiration.(Louke *et al.*, 2011).

2.3.3 Determination of Good quality posteroanterior (PA) chest radiographs

In approaching a chest x-ray, the first piece of information to note is the "L or R" (left or right) markers that signifies the patient's left or right side to ensure the correct view of the film. The most apparent feature that may suggest a reversed film is the cardiac configuration. An inappropriate cardiac configuration may indicate dextrocardia; however, it is more commonly due to human error (Chan *et al.,* 2000; Louke *et al.,* 2011). The patient's name is an obvious detail that should be verified before proceeding with the interpretation of the film. The ethnic background of the patient may be deduced from the name, which may hint at a disease process that is more prevalent within that ethnic group. Other written data that may be useful include patient's age or date of birth and possibly the hospital ward or department that ordered the film (Chan *et al.,* 2000; Louke *et al.,* 2011)..

A number of technical factors should be considered before attempting to interpret any chest radiograph, and they include exposure, inspiration, position, and miscellaneous factors. These features constitute the quality of the film, which is a crucial component in chest radiology (Chan *et al.,* 2000; Louke *et al.,* 2011)..

2.3.3.1 Exposure of Chest Radiograph

In a correctly exposed film, the degree of penetration should be such that the lower thoracic disc spaces can be barely seen through the cardiac silhouette. In an underpenetrated film, the intervertebral spaces are not visible through the heart shadow. On the other hand, an overexposed film will be too dark to discern lung vessels (Chan *et al.,* 2000; Louke *et al.,* 2011).

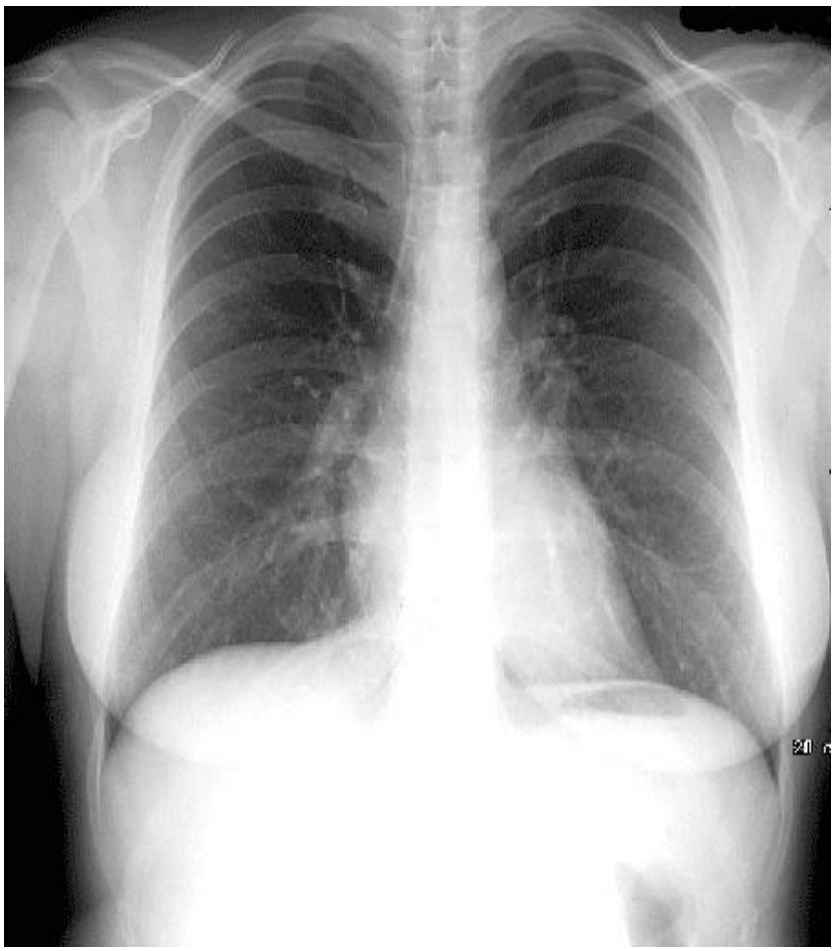
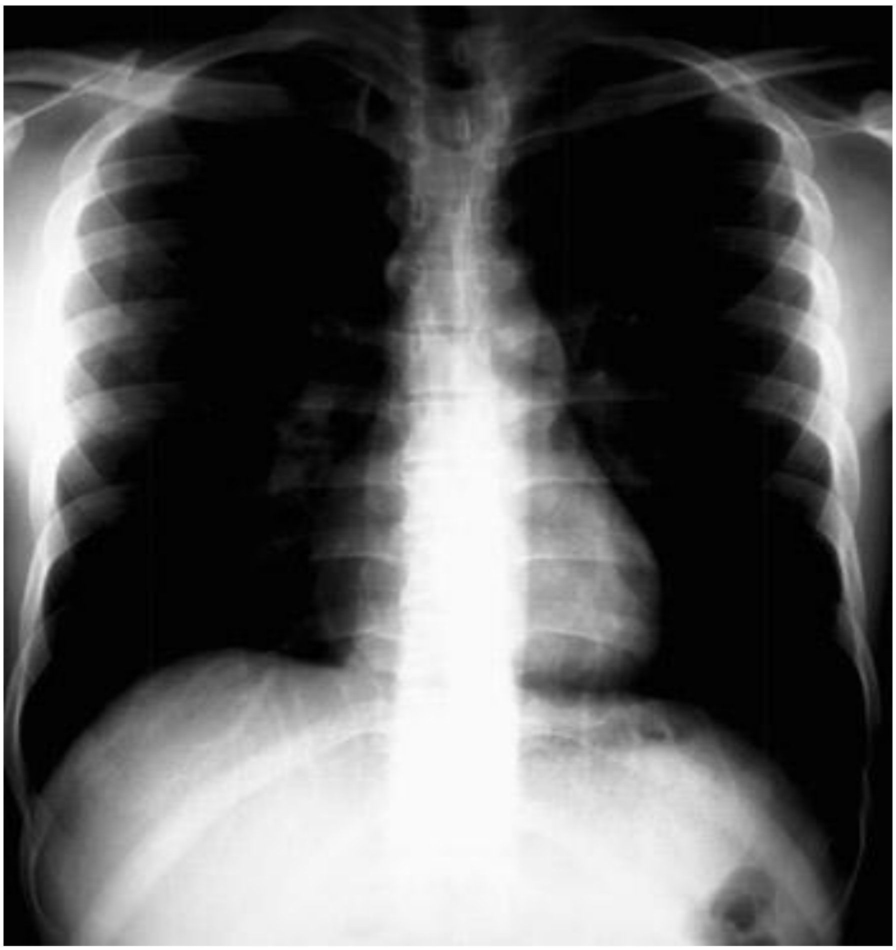


Plate 2.4:A plain posteroanterior chest radiograph indicating normal penetration (Chan *et al.*, 2000).

Plate 2.5: A plain posteroanterior chest radiograph indicating under penetration (Chan *et al.*, 2000).



1.3.3.2 *Inspiration*

Routine chest films are taken while the patient is holding the breath on full inspiration. The dome of the right hemidiaphragm should project over a level between the anterior fifth rib and seventh inter-costal space (Chan *et al.,* 2000; Louke *et al.,* 2011)..

1.3.3.3 *Position*

The patient should be positioned such that the coronal plane of the thorax is parallel to the film and at right angles to the X-ray beam. In this position, the spinous processes should project midway between the medial heads of the clavicles (Chan *et al.,* 2000; Louke *et al.,* 2011).. The bony thorax should be the focus when looking for rotation since other midline structures such as the trachea can be shifted in disease (Chan *et al.,* 2000; Louke *et al.,* 2011). Even slight rotation is undesirable in a chest film because the cardiac and mediastinal shadows will appear distorted (Chan *et al.,* 2000; Louke *et al.,* 2011).

The lordotic position is employed to look at the apices of the lungs (Chan *et al.,* 2000; Louke *et al.,* 2011). The patient leans back such that the medial end of the first rib anteriorly projects above the lung apex as opposed to the standard radiographic position in which it projects over the medial end of the fourth or fifth rib posteriorly (Chan *et al.,* 2000; Louke *et al.,* 2011).

1.3.3.4 *Miscellaneous factors*

Other possible objects that may be obscuring intrathoracic structures include necklaces, hair braids, and, on lateral view, the patient's arms (Chan *et al.,* 2000; Louke *et al.,* 2011).The importance of assessing technical factors before interpreting chest radiographs is that if there is no full inspiration the chest x- ray will show the demonstration of pulmonary edema, but chest x- ray in full inspiration, will not demonstrate the "edema" (Chan *et al.,* 2000; Louke *et al.,* 2011).

2.4 Examination of Anatomy of the Chest Radiograph

The radiological assessment of the thoracic cage and its associated soft tissues is an integral part of chest radiology (Chan *et al.,* 2000; Louke *et al.,* 2011). Radiological changes in the chest wall may be due to a pulmonary disease process (Chan *et al.,* 2000; Louke *et al.,* 2011). However, they may also represent primary lesions of the bones or soft tissues that may be missed if not looked for specifically (Chan *et al.,* 2000; Louke *et al.,* 2011).

2.4.1 The Thoracic Cage

2.4.1.1 Ribs, Sternum and Vertebrae

The thorax is roughly cylindrical in shape and shielded by the ribs, thoracic vertebrae, and the sternum. All 12 pairs of ribs are attached posteriorly to their respective vertebral bodies (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.,* 2009).. In addition, the upper seven pairs attach anteriorly to the sternum via individual costal cartilages. The eighth, ninth and tenth ribs effectively are attached to each other and also to the seventh rib by means of a "common" costal cartilage (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.,* 2009). With age, the costal cartilages may calcify and are then readily visible on a frontal radiograph. The two lowermost ribs (the 11th and 12th) are described as "floating" since they have no anterior attachment (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.,* 2009). An interesting variation to the normal arrangement (occurring in around 6 % of the population) is the so-called “cervical” rib, which articulates with a cervical, instead of a thoracic vertebral body (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009). Cervical ribs may be uni- or bilateral. Occasionally, there will simply be a fibrous band but, when calcified, the appearance of a “true rib” will be seen (David *et al*., 2002; Ryan *et al.*, 2007; Standring *et al.*, 2009). Some cervical ribs are symptomatic because of the potential for compression of the subclavian artery and first thoracic nerve root (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

The sternum can be considered to comprise three components: the manubrium sterni, the body of the sternum, and the xiphoid process (or xiphisternum) (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The manubrium is the uppermost and widest portion, which articulates laterally with the clavicles and also the first and upper part of the second costal cartilages; inferiorly, the manubrium articulates with the body of the sternum (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). On a conventional frontal chest radiograph, the bulk of the manubrium is generally not visible (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

However, the articulation of the manubrium with the clavicles (the manubrio-clavicular joint) can be seen (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). By contrast, on a lateral radiograph the manubrium can be clearly identified (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The body of the sternum is a roughly rectangular structure which has a notched lateral margin, where it articulates with the costal cartilages of the third to seventh ribs (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007;

Standring *et al.*, 2009). The xiphoid is the most inferior portion of the sternum and prinicipally consists of hyaline cartilage that may become ossified in later life (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

The thoracic vertebrae provide structural support to the thorax in both the axial (vertical) and, through the attachment with ribs and muscles, the coronal and sagittal plane(David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). Whilst individual vertebrae are rigid, their articulations mean there is considerable potential mobility in terms of flexion, extension, and rotational movements over the length of the twelve vertebrae (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

There is a progressive increase in the height of thoracic vertebrae bodies from T1 to T12 and these vertebrae can be distinguished by the presence of lateral facets, which articulate with the heads of the ribs (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). Facet joints for articulation with the tubercles of the ribs are also present on the transverse processes of T1 to T10 (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

Furthermore, when viewed in the sagittal plane, each vertebrae can be seen to possess a long spinous process; with the exception of T1 (whose spinous process is almost horizontal), the spinous processes all point downward (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). Initial analysis of the thoracic vertebrae is still best done with a suitably penetrated plane film. However, in the presence of complex trauma or where the contents of the spinal canal need to be visualized, CT and MRI are being employed increasingly (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

2.4.1.2 Muscles of the chest wall

There is a complex arrangement of muscles around the chest which, in addition to the vital act of breating, help to maintain stability (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). Outermost and anteriorly are the pectoralis (major and minor) muscles; serratus anterior is situated laterally, and posterolaterally are the muscles of the shoulder girdle (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). Posteriorly and adjacent to the vertebrae are erector spinae and trapezius(David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009). These muscle groups are readily depicted on axial (CT and MRI) images (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

The deeper muscles of the chest include the intercostal muscles (external, internal, and innermost), which are situated between the ribs. Elsewhere, the subcostal muscles span several ribs and further muscles attach the ribs to the sternum and vertebrae(David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009). All these muscles may be visualized accurately with MR (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

Each intercostal space is supplied by a single large posterior intercostals artery and paired anterior intercostal arteries. Incidentally, each posterior intercostal artery also gives off a spinal branch, which supplies the vertebrae and spinal cord(David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009). The venous drainage is via the posterior intercostal veins running backward to drain into the azygos (or hemi-azygos) and the anterior intercostal veins into the internal thoracic and musculophrenic veins (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

2.4.1.3 Nerve supply to the chest wall

The innervation of the chest wall is via 12 paired thoracic nerves(David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The 11 pairs of intercostal nerves run between the ribs while the twelfth pair (the subcostal nerves) runs below the twelfth rib in the anterior abdominal wall (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The intercostal nerves are the anterior rami of the first 11 thoracic spinal nerves, which enter the intercostals space between the parietal pleura and posterior intercostals membrane to run in the subcostal groove of the corresponding ribs and below the intercostal artery and vein (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). It is for this reason that, whenever possible, needle aspiration or pleural drainage should be performed by entering the pleural space immediately above (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

In addition to the peripheral nervous system, the sympathetic chain is also found within the thorax. There are either 11 or 12 sympathetic ganglia within the thorax(David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The first ganglion is frequently fused with the inferior cervical ganglia to form the cervicothoracic or “stellate” ganglia (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The remaining ganglia are simply numbered so that they correspond to the adjacent segmental structures(David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007;

Standring *et al.,* 2009). A number of plexi are formed through the fusion of different ganglia, for example, the cardiac plexus and aortic plexus (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009).

2.4.2 Clavicles and proximal humeri

Due to their unique curved shape, the shadows of the two clavicles will appear symmetrical on the radiographs only if there is no rotation of the chest (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). Irregular erosion can sometimes be seen on the inferior aspect of the medial end of the clavicle. This is a normal anatomical appearance called the rhomboid fossa (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009). Abnormalities of the proximal humerus may also be evident on a chest film (Chan, *et al.,* 2000; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

2.4.3 Scapular

The medial edges of each scapulae will be observed to see if they are retracted laterally with only a small portion projected over each lung. The lungs are therefore more easily seen (Chan, *et al.*, 2000;David*et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

2.4.4 The lungs and airways

Each lung occupies, and almost completely fills, its respective hemithorax. On the right, there are three lobes (the upper, middle, and lower) and on the left, two (the upper and lower); incidentally, the lingula generally is considered a part of the left upper lobe (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009). The upper and lower lobes, on each side, are separated from each other by the oblique fissure. On the

right, the middle lobe is divided from the upper by the horizontal fissure (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). By contrast, it should be noted that, on the left, there is no fissural division between the left upper lobe and lingula. On a PA chest radiograph, the oblique fissure is generally not visible (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). Futhermore, because the upper lobe lies anteriorly, most of the lung that is seen on the frontal view will be the upper lobe (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).
The horizontal fissure is seen readily on a standard PA radiograph as a thin line crossing from the lateral edge of the hemithorax to the hilum (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). On a lateral view of the chest, both the oblique fissures may be visualized, running obliquely in a cranio-caudal distribution; the horizontal fissure can also be seen running forward from the oblique fissure Occasionally, accessory fissures will be seen on a chest radiograph (Jonathan and Sujal, 2007).

The lungs are lined by two layers of pleura, which are continuous at the hila. The parietal pleura cover the inner surface of the chest wall whereas the visceral layer is closely applied to the lung surface (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). A small volume of “normal” pleural fluid is generally present within the pleural cavity to facilitate the smooth movement of one layer over the other during breathing (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). In the absence of disease, the pleural layers will not be seen on chest radiograph. However, because of the superior contrast resolution, the normal pleura may be visualized on CT images (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

The trachea is a vertically orientated tube (measuring approximately 13 cm in length), which commences below the cricoid cartilage and extends to the approximate level of the sternal angle where is bifurcates (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). In cross-section the outline of the trachea may vary from being oval to a D-shape, depending on the phase of breathing cycle. Anteriorly and laterally, the trachea is bounded by hoops of hyaline cartilage but posteriorly there is a relatively pliable membrane (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

On a chest radiograph, the trachea is seen as a tubular region of lucency in the midline, as it passes through the thoracic inlet (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). At the level of the aortic arch, there may be slight (but entirely normal) deviation of the trachea to the right. At the level of the carina, the trachea divides into right and left main bronchi; the former is shorter, wider and more vertically oriented than its counterpart on the left (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

Each main bronchus gives rise to lobar bronchi, which divide to supply the bronchopulmonary segments in each lobe (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). Individual bronchopulmonary segments are not readily identified (on chest radiography or CT) but it is worth revising the anatomy because segmental airways and arteries can be seen particularly well on CT images and such information is important to clinicians (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). On the right, there are ten segments (three in the upper lobe, two in the middle and five in the lower lobe), whereas on the left there are nine (three in upper lobe, two in the lingula and four in the lower lobe (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

2.4.5 The mediastinum

For descriptive purposes, the mediastinum has always been thought of in terms of its arbitrary compartments (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). Thus, the superior mediastinum is considered to lie above a horizontal line drawn from the lower border of the manubrium, the sternal angle or angle of Louis, to the lower border of T4 and below the thoracic inlet (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The inferior compartment, lying below this imaginary line (and above the hemidiaphragm) is further subdivided into the anterior mediastinum which lies in front of the pericardium and root of the aorta (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

The middle medistinum comprises the heart and pericardium together with hilar structures and the posterior mediastinum lies between the posterior aspect of the pericardium and the spine (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). Whilst the above division is entirely arbitrary, the validity of remembering such a scheme is that the differential diagnosis of mediastinal masses is defined by considering the localization of a mass in a particular mediastinal compartment (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

2.4.6 The esophagus

The esophagus extends from the pharynx (opposite the C6 vertebral body) through the diaphragm (at the level of T10) to the gastroesophageal junction and measures approximately 25 cm in length (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). In its intrathoracic course the esophagus is a predominantly a left sided structure, a feature which is readily appreciated on CT images (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). By contrast, the esophagus is normally not visible on a standard PA radiograph, and radiographic examination requires the patient to drink a radioopaque contrast media e.g. barium suspension (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

2.4.7 The thymus

The thymus is a bilobed structure, which is positioned in the space between the great vessels (arising from the aorta) and the anterior chest wall (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The volume of the thymus normally changes with age: in the newborn, for example, the thymus may occupy the entire volume of the mediastinum anterior to the great vessels (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). With age, the thymus initially hypertrophies, but after puberty there is progressive atrophy, such that in normal adults, the normal thymus is barely discernible (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

2.4.8 The hilum of the lungs

The hilum can be considered to be the region at which pulmonary vessels and airways enter or exit the lungs (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The main components of each hilum are the pulmonary artery, bronchus, veins, and lymph nodes (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). On a frontal radiograph, the right hilum may be identified as a broad V-shaped structure; the left hilum is often more difficult to identify confidently (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). A useful landmark for the radiologist, on the PA radiograph, is the so-called “hilar point” which, whilst not being a true anatomical structure, is the apparent region where the upper lobe pulmonary veins meet the lower pulmonary artery (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). In normal subjects, the hilar point is sited roughly between the apex and the base of the hemithorax: in some patients, significant elevation or depression of the hilar point will be the only clue to the presence of volume loss in the lungs (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

2.4.9 The heart

In the embryo, the heart is one of the earliest organs to develop, following fusion of two parallel tubular structures known as the primitive aorta; with subsequent septation and coiling, the characteristic asymmetric configuration of the adult heart is attained (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The pericardium, which like the pleura is a two-layered membrane which encases the heart; the inner (or visceral) pericardium is applied directly to the myocardium except for a region that reflects around the pulmonary veins (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The outer (parietal) pericardium is continuous with the adventitial fibrous covering of the great vessels (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). Inferiorly, the parietal pericardium blends with the central tendon of the diaphragm. As with the pleura, the potential space between the visceral and parietal pericardium (the pericardial sac) is not normally visible on plain radiographs (Corne *et al*., 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). Again, because of the superior contrast resolution of CT, the normal pericardial lining may be identified on axial images (Corne *et al.*, 2001; David *et al.*, 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

In normal subjects there are four cardiac chambers (the paired atria and ventricles). Deoxygenated blood is normally delivered to the right atrium via the superior vena cava (from the upper limbs, thorax, via the azygos sytem, and the head and neck), the inferior vena cava (from the lower limbs and abdomen), and the coronary sinus (from the myocardium) (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The right atrium is separated from its counterpart on the left by the inter-atrial septum which, with the changes in pressure that occur at or soon after birth, normally seals; a depression in the interatrial septum marks the site of the foramen ovale in the fetal heart (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The right atrium is a "border-forming" structure on a PA chest radiograph that is immediately adjacent to the medial segment of the right middle lobe, a feature that is readily appreciated on CT images (Corne *et al.*, 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). The right ventricle communicates with the atrium via the tricuspid valve (Jonathan and Sujal, 2007).

Deoxygenated blood leaves the right ventricle through the pulmonary valve and enters the pulmonary arterial tree. Because the right ventricle is an anterior chamber, it does not form a border on the standard PA radiograph but the outline of the chamber is visible on a lateral radiograph (Corne *et al.*, 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). The left atrium is a smooth-walled chamber and is posteriorly positioned (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). Oxygenated blood enters the atrium from the paired pulmonary veins on each side and exits via the mitral valve to the left ventricle from where blood is delivered into the systemic circulation (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). As on the right, there is a left atrial appendage (sometimes referred to as the auricular appendage), which may be the only part of the normal atrium that is seen on the frontal radiograph; conversely, the wall of the left atrium is easily identified on a lateral radiograph (Corne *et al.*, 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

The left ventricle is the most muscular cardiac chamber and is a roughly cone-shaped structure whose axis is oriented along the left anterior oblique plane (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). On a frontal chest radiograph, the left ventricle accounts for most of the left heart border (Corne *et al.*, 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). It is worth mentioning at this point that the widest transverse diameter of the heart (extending from the right (formed by the right atrium) to the left margin) is an important measurement on the frontal radiograph: as a general rule, the transverse diameter should be less than half the maximal diameter of the chest (this measurement is called the cardiothoracic ratio) (Corne *et al*., 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

Oxygenated blood normally enters the ventricle from the left atrium via the mitral valve and is pumped into the systemic circulation through the aortic valve. Just above the aortic valve there are three focal dilatations, called the sinuses of Valsalva (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The right coronary artery originates from the anterior sinus, whilst the left posterior sinus gives rise to the left coronary artery; the coronary circulation is described as either right (the most common arrangement) or left dominant depending on which vessel supplies the posterior diaphragmatic region of the interventricular septum and diaphragmatic surface of the left ventricle (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

The right coronary artery usually runs forward between the pulmonary trunk and right auricle, as it descends in the atrioventricular groove, branches arise to supply the right atrium and ventricle (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). At the inferior border of the heart, it continues and ultimately unites with the left coronary artery (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

The larger left coronary artery descends between the pulmonary trunk and left auricle, and runs in the left atrioventricular groove for about 1 cm before dividing into the left anterior descending (interventricular) artery and the circumflex arteries (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). In around one-third of normal subjects, the left coronary artery will trifurcate and in such cases there is a "ramus medianus" or "intermediate" artery between the left anterior descending and circumflex arteries supplying the anterior left ventricular wall (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

The venous drainage of the heart is via the coronary sinus (which enters the right atrium) and receives four main tributaries (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The great cardiac vein, middle cardiac vein, small cardiac vein, and left posterior ventricular vein. A smaller proportion of the venous drainage is directly into the right atrium via the anterior cardiac veins that enter the anterior surface of the right atrium (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

As might be imagined, the normal cardiac circulation is not seen on standard radiographic examinations. However, the injection of intravenous contrast via a coronary artery catheter (inserted retrogradely via the femoral artery) will render the vessels visible (Corne *et al.*, 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). An alternative approach (which has only become possible since the advent of "fast" CT scanning machines) is for the cardiac circulation to be imaged following a peripheral injection of contrast. More recently, there has been considerable interest in the imaging of the heart and its circulation using magnetic resonance imaging (Corne *et al*., 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

2.4.10 The aorta

The intrathoracic aorta can conveniently be considered in four parts: the root, the ascending aorta, the arch, and the descending aorta (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The root comprising the initial few centimeters is invested by pericardium and includes three focal dilatations, the sinuses of Valsalva (described above) above the aortic valve leaflets (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The ascending aorta continues upward and to the right for approximately 5 cm to the level of the sternal angle (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The arch lies inferior to the manubrium sterni and is directed upward, inferiorly, and to the left. The arch initially lies anterior to the trachea and esophagus, but then extends to the bifurcation of the pulmonary trunk (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009). The three important branches of the aortic arch are the brachiocephalic artery, the left common carotid artery, and the left subclavian artery, all of which are readily visible on angiographic studies (Corne *et al.*, 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). Variations to this normal pattern of branching occur in approximately one-third of subjects; the most common variant is that in which the left common carotid arises from the brachiocephalic artery (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

By convention, the descending aorta begins at the point of attachment of the ligamentum arteriosum to the left pulmonary artery (roughly at the level of T4). The descending aorta passes downward in the posterior mediastinum on the left to the level of T12, where it passes through the diaphragm and into the abdomen (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009). Within the thorax, the descending aorta gives rise to the intercostal, subcostal arteries, bronchial, esophageal, spinal, and superior phrenic arteries (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

2.4.11 Pulmonary arteries

At its origin from the right ventricle, the pulmonary conus or trunk is invested by a pericardial reflection . The main divisions of trunk are the left and right pulmonary arteries (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). The right pulmonary artery passes in front of the right main bronchus and behind the ascending aorta anteriorly, the right superior pulmonary vein crosses the right main artery at the hilum, the artery divides into the upper and lower divisions, from which the lobar and segmental branches orginate; It is important to remember that arterial branching (unlike the pulmonary veins) closely follows the branching of the airways (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

The left main pulmonary artery passes posteriorly from the pulmonary trunk and then arches over the left main bronchus (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). As with the coronary arteries, the pulmonary circulation is visualized optimally after the injection of intravenous contrast, as in conventional pulmonary angiography (a technique seldom performed in modern radiology departments) or on CT images (Corne *et al.*, 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). The venous drainage of the lungs is via the left and right pulmonary veins, two on each side, which enter the left atrium beneath the level of the pulmonary arteries. Occasionally, the veins can be seen to unite prior to their entry into the left atrium (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

It should be remembered that, in addition to the main pulmonary arterial supply, there is a bronchial circulation originating from the systemic circulation. The most common arrangement is of a single right bronchial artery (usually arising from the third posterior intercostal) and two left bronchial arteries (originating from the descending thoracic aorta) (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). However, there is considerable normal variation. There are two groups of bronchial veins: the deep veins taking blood from the lung parenchyma and draining into the pulmonary veins. The superficial bronchial veins receive blood from the extrapulmonary bronchi, visceral pleura, and hilar lymph nodes, both draining into the pulmonary veins (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009). The bronchial vessels, although small, are of great clinical importance. They maintain perfusion of the lung after a pulmonary embolism so that, if the patient recovers, the affected lung returns to normal (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009).

2.4.12 The thoracic duct

The thoracic duct is the main channel by which lymph is returned to the circulation (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009). The thoracic duct begins within the abdomen as a dilated sac known as the cisterna chyla and ascends through the diaphragm on the right of the aorta at the level of the sixth thoracic vertebral body, the thoracic duct crosses to the left of the spine and passes upwards to arch over the subclavian artery (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009). The duct drains lymph into a large central vein, which is close to the union of the left internal jugular and subclavian veins. The diameter of the thoracic duct may vary between 2 and 8 mm and, although usually single, multiple channels may exist (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009). In normal subjects, the thoracic duct is collapsed and, as such, cannot be visualized on imaging studies (Corne *et al.,* 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007). A variation on the normal is for a right-sided lymphatic duct, which drains lymph from the right side of the thorax, the right upper limb, and right head and neck into the right brachiocephalic vein (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009).

2.4.13 The diaphragm

The diaphragm is the domed structure, which serves to separate the contents of the thorax from those of the abdomen and plays a vital role in breathing; the components of the diaphragm are a peripheral muscular portion and a central tendon (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.,* 2009). The diaphragm is fixed to the chest wall at three main points: the vertebral attachment (via the crura which extend down to the level of the lumbar vertebrae), the costal component (comprising slips of muscle attached to the deep part of the six lowermost ribs), and finally the sternal component (consisting of slips of muscle arising from the posterior aspect of the xiphoid process). At three points, roughly in the midline, the central tendon transmits (and is pierced) by the esophagus, descending aorta, and inferior vena cava (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

The normal diapragm is easily visualized on both frontal and lateral radiographs as a smooth but curved structure. Laterally, on the frontal radiograph, the diaphragm appears to make contact with the chest wall. At the apparent point of contact (called the costophrenic recess) the angle subtended to the chest wall is acute and well defined. This is of practical value since even small collections of fluid (pleural effusions) will lead to a blunting of the costophrenic recess (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009).

In PA chest radiographs, the highest point of the right dome is at the sixth intercostals space anteriorly (ranging from the fifth to seventh ribs); it is more accurate to count anterior rather than posterior ribs, as the diaphragmatic dome is nearer to the anterior ribs and the film, and is therefore less subject to distortion by slight angulation of the patient or the beam. The right dome is higher than the left by 2 cm but the left may be higher than the right in the normal subject, especially with swallowed gas in the colon(Corne *et al.*, 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

The range of movement of the diaphragm with respiration is as follows:

i. Quiet respiration: 1 cm; and
ii. Deep inspiration /expiration: 4 cm (wide range of normal). In each case the left hemidiaphragm moves more than the right.

The variation of the diaphragm with posture is as follows:

i. Supine: higher; and
ii. Lateral decubitus: dome on the dependent side is higher.

In dextrocardia, even if the liver is on the right side the left dome of the diaphragm tends to be higher. Partial reduplication of the diaphragm - known as accessory hemidiaphragm - may occur. This is much commoner on the right side (Corne *et al*., 2001; David *et al*., 2002; Ryan *et al*., 2007; Jonathan and Sujal, 2007).

In lateral chest radiograph the following anatomical details help identify the domes of the diaphragm:

i. The heart shadow obliterates part of the left dome. The inferior vena cava may be seen piercing the right dome.
ii. Air within the gastric fundus lies under the left dome. There is apparent thickness of the diaphragm on radiographs:
iii. With the pleura and peritoneum when there is air in the peritoneum: 2-3 mm thick; and

iv. With the pleura and fundal wall of stomach: 5-8 mm thick.

The perpendicular height of the dome of the diaphragmfrom a line between costophrenic and cardiophrenic anglesis 1. 5 cm (Corne *et al.*, 2001; David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007).

2.4.14 Breast

The presence or absence of breasts should be noted. The shadows cast by female breasts are variable in size and shape(Chan *et al.*, 2000; Corne *et al.*, 2001; Louke *et al.*, 2011). They may be asymmetrical. Nipples may cast rounded shadows that may mimic a pulmonary nodule. Mastectomy usually produces characteristic radiological changes that are often missed (Chan *et al.*, 2000; Corne *et al.*, 2001; Louke *et al.*, 2011).

2.4.15 The Pleura

The pleura are thin layers of tissue that envelop each of the pulmonary lobes, forming the fissures where two lobes lie adjacent to one another and line the inner surface of the thoracic cage (David *et al*., 2002; Ryan *et al.*, 2007; Jonathan and Sujal, 2007; Standring *et al.*, 2009). Under normal circumstances, aside from the fissures, the pleura is too thin to be seen radiographically; however, it may be visible when it is thickened by disease processes such as inflammation. The pleural space normally contains a small amount of fluid that is not visible radiographically. However, gas and abnormal amounts of fluid in the pleural space can be visualized (Chan *et al.*, 2000; Corne *et al.*, 2001; Louke *et al.,* 2011).

2.5 SEX DETERMINATION

2.5.1 Historical background of sex determination from human skeletal remains

Almost all bones of the human skeleton have been used to estimate the sex of an individual. The reason is that within a forensic and archaeological context the degradation of bone could sometimes render some skeletal elements unusable. There are two methods used to estimate sex, metric and morphological analyses. These types of methodologies need to be tested and retested for accuracy and reliability, especially those methods that are deemed population specific. Only methods with the highest level of accuracy should be used within a medico-legal context to ensure admissibility of evidence within a court of law.

2.5.1.1 Sex determination from pelvis

In 1969, T.W. Phenice developed a method for sex determination from the morphological characteristics of the pelvis. This research stemmed from previous studies on the sexual dimorphic traits of the pelvis by Washburn (1948).

The Phenice Method involves visually comparing three aspects of the pelvis: the ventral arc, the subpubic concavity, and the medial aspect of the ischio-pubic ramus. The benefits of this method were to allow researchers to accurately and reliably determine the sex of the individual using the os coxae. Two hundred and seventy-five individuals were tested with this method and an accuracy rate of 95 % was obtained. It has been shown that some limitations of the results could be from the age of the individual and the biological affinity of the individual (Phenice 1969).

Lovell (1989) tested the Phenice Method on a modern population of 50 individuals. Twelve participants were used to score each of the 50 pubic bones. All of the pubic bones tested were from individuals of White European descent between 52 and 92 years of age. The results of the test showed an accuracy rate of 83 % compared to the 95 % previously recorded by Phenice. The reliability of the method, i.e. the consistency of accurate classification, was high. However, one of the errors discovered in this research was that as the individual`s age increases the accuracy of the Phenice Method decreases (Lovell 1989).

In 2002, Bruzek developed a method for determining the sex of an individual from different morphological characteristics of the pelvis. This research stemmed from previous studies on sexual dimorphism of the pelvis by Ferembach and colleagues (1980), Işcan and Derrick (1984), and Phenice (1969). The five characteristics that were visually assessed were the: preauricular surface, greater sciatic notch, form of the composite arch (the anterior arm of the auricular surface), morphology of the inferior pelvis (ischiopubic ramus), and ischiopubic proportions (proportion of the length of the ishium and pubis). Each of these characteristics is significantly sexually dimorphic and the researcher designates male, female, or indeterminate for each characteristic. This method produced an accuracy rate of 98 % when evaluating the os coxae (Bruzek 2002).

Population specific traits of the pelvis have also been investigated. In 2003, Patriquin *et al*., observed sexually dimorphic characteristics between South African Whites and Blacks. They examined five visual characteristics of the pelvis: the shape of the greater sciatic notch, subpubic concavity, ischiopubic ramus roughness, orientation of the ischial tuberosity, and the pubic bone shape. Each characteristic was classified as male, female, or intermediate. The researchers found significant sexually dimorphic differences in the pelvis. When comparing their results to other studies they noticed significant sexually dimorphic differences between African American and South African Black populations (Patriquin et al. 2003).

In 1941, Letterman conducted a study on the morphology of the greater sciatic notch and its relationship to both sex and ancestry. Letterman (1941) measured the width and height of the greater sciatic notch of individuals from White European and Black African populations. This research showed that this area of the pelvis was sexually dimorphic when subjected to metric analyses. Also, the research found that there were sexually dimorphic differences of the width and height of the greater sciatic notch between White European and Black African ancestral groups. Another study on population diversity was conducted by Walker in 2005. This was a test of estimating sex from the greater sciatic notch, which was developed by Buikstra and Ubelaker (1994). The method was tested on skeletal remains of White European and Black African descent. Walker (2005) reported that the accuracy of the procedure did not decrease between and within population groups. However, Walker (2005) suggested that the age at death of the individual could affect the accuracy of this methodology as younger individuals tended to have more feminine appearing sciatic notches.

Flander (1978) studied the sacrum to develop a method for sex determination of an individual. Five measurements of the sacrum were taken and subjected to univariate statistical analyses. Those measurements were the mid-ventral line, anterior breadth, maximum articular surface, mid-ventral curve length, and transverse diameters of the S1 body. A discriminate function formula was created from the measurements. The accuracy rate of this method for identifying the sex of an unknown individual ranged from 80 % to 94 %.

Arsuaga and Carretero (1994) and Gonzalez *et al*., (2009) used multivariate statistical analyses of the pelvis to investigate sexual dimorphism. Both of these studies utilized the skeletal collections at the Museu Antropologico de Coimbra in Portugal. Arsuaga and Carretero (1994) discovered that female pelvic bones were relatively larger with respect to the pelvic inlet. Also, females exhibited a broader sciatic notch. Gonzalez and colleagues (2009) used geometric and morphometric techniques, along with discriminate function analyses, to develop a method for estimating the sex of an individual. This method involved two sexually dimorphic characteristics: the greater sciatic notch and the ischiopubic complex. These two areas were evaluated using targeted landmarks from two-dimensional photographs. The research found that there were marked differences between the sexes with regard to both the shape and size of the sciatic notch and ischiopubic complex. The researchers used this information to formulate a methodology to determine sex of an individual using multivariate analysis. When tested against a sample set of individuals from their original skeletal population, the accuracy rate of this method ranged between 90.1 % and 93.4 %.

Murphy (2000) and Benazzi *et al*., (2008) used metric analyses of the acetabulum to determine sex of unknown human remains. Murphy (2000) used skeletal remains from a prehistoric New Zealand population and Benazzi *et al*., (2008) used Italian remains from the University of Bologna. Murphy (2000) measured the maximum diameter of the acetabulum while Benazzi *et al*., (2008) measured the perimeter and total area of the acetabulum using digital photographs. In both studies, the measurements were subjected to discriminate function analyses and formulae were derived for determining sex of an unknown individual. The accuracy rate for Murphy‘s (2000) research was 86.2 %. The accuracy rate for Benazzi *et al*. (2008) ranged from 85.2 % to 86.2 %. Both of these studies showed sex determination to be population specific and that the discriminate function analyses should be recalculated for that specific population to obtain higher levels of accuracy

2.5.1.2 Sex determination from skull

Many of the methodologies for sex determination from the skull have originated from early investigations of skeletal analyses by Giles and Elliot (1963), Krogman and Işcan (1986) and Stewart (1979). Buikstra and Ubelaker (1994) and France (1998) developed methodologies for sex determination based on visible changes in the skull‘s features. Those features included the mastoid process shape, nuchal crest size, browridge shape, frontal bone angle, supraorbital margin shape, supraorbital ridge shape, and chin size. Each of these characteristics was shown to be sexually dimorphic and a method for scoring their physical changes was developed. This allowed the investigator to visually determine the sex of an individual based on the skull.

In 1998, Konigsberg and Hens used visual characteristics of the skull and used multivariate cumulative probit models to help determine the sex of an individual. The sexually dimorphic features evaluated were the superciliary arch form, chin form, mastoid process size, supraorbital margin shape, and nuchal cresting. From these characteristics, logistic regression analyses were used to create single indicator and multivariate indictor models to determine the sex of an unknown individual. The overall accuracy rate of this method was

81 %. However, the overall rate of accurately determining males was considerable higher than that of females.

Noren *et al*., (2005) and Lynnerup and colleagues (2005) used the petrous part of the temporal bone to determine the sex of an individual. Noren *et al*., (2005) examined the angle between the lateral part of the internal auditory canal and the medial surface of petrous part of the temporal bone. They tested this method against 113 petrous bones with known sex. The researchers found a significant correlation between sex and the angle of this bone. The accuracy rate of this method is 83.2 %.

Lynerup *et al*., (2005) studied the diameter of the internal opening of the acoustic canal in the petrous bone. They measured the diameter of 113 left petrous bones. The results suggested a small measurement difference between males and females. Unfortunately, when the predictive value of this method was tested with inter- and intra- observer error, there is an accuracy rate of 70.0 %.

In 1996, Loth and Henneberg developed methods from the mandible to determine sex. The researchers discovered that males have a distinct angulation of the posterior border of the mandibular ramus, which may be related to development because it only manifests consistently after adolescence. However, in many of the females, the posterior ramus kept the same shape as seen in the juvenile population. When this morphological characteristic was tested in a blind study, the accuracy rate was as high as 99.0 % in predicting the sex of an unknown mandible.

Byers (2008) promotes the idea that the skull is the second best indicator for determining the sex of an individual next to the human pelvis. However, Spradely and Jantz (2010) conducted a study to test the accuracy rates and reliability of sex determination methodologies from the skull and postcranial elements and found Byers statement to be incorrect. The researchers studied 11 postcranial bone methodologies for determining the sex of an unknown individual; the bones included the clavicle, scapula, humerus, radius, ulna, sacrum, os coxae, femur, tibia, and fibula. Postcranial bone measurements were then tested against a metric analysis of the skull to determine which measurements were more sexually dimorphic. The researchers discovered that the humerus and radius were the best indictors of sex with an accuracy rate between 93.8 % and 94.3 %, respectively. The cranium had an accuracy level of 90.0 %. All other postcranial elements had an accuracy level between 92.0 % and 94.0 %. Spradely and Jantz (2010) showed that the postcranial bones provided a better determination of sex than when only using the skull by multivariate metric analyses

2.5.1.3 Sex determination from long bones

Black (1978), MacLaughlin and Bruce (1985), and Safont *et al*., (2000) used bone circumference of the femur to determine sex from human remains. Safont *et al*., (2000) also included the radius, ulna, and humerus within their analyses. The data from each study were subjected to discriminate function analyses. Black (1978) found that the length of the femur was a more accurate indicator of sex than the circumference of the femoral head. MacLaughlin and Bruce (1985) discovered that the maximum anteroposterior diameter of the femoral shaft was more sexually dimorphic than the midshaft circumference. Safont *et al*., (2000) observed that the circumference of the radius, ulna, and humerus could more accurately determine the sex of an individual than the femur. They concluded that there was more mechanical stress on the radii, ulnae, and humeri, created distinct sexually dimorphic differences between males and females in the Mediterranean population they examined (Safont et al. 2000).

Charisi *et al*., (2011) examined sexually dimorphic traits present in the radii, ulnae, and humeri using metric analyses from a modern Greek skeletal population. The maximum length and epiphyseal widths were measured and then subjected to discriminate function analyses. The results of the study showed sexual dimorphism between the three long bones. The right humerus had the highest accuracy rate (95.7 %) and left ulna had the lowest accuracy rate (90.3 %). However, the results were shown to be population specific and the authors suggested that the method should only be used to estimate sex from a modern Greek population.

In 1999, Rogers used four visual characteristics of the posterior distal humerus to create a methodology for estimating the sex of an unknown individual. Those four characteristics were the trochlear constriction, trochlear symmetry, olecranon fossa shape and depth and angle of the medial epicondyle. This method was developed on the Grant Skeletal Collection at the University of Toronto, which consists mainly of White European males. When the author tested this method on skeletal collections in New Mexico and Tennessee the combined accuracy rates were 92 % for correctly identifying males and females. Falys and colleagues (2005) conducted a blind study of the Rogers‘ method on a skeletal collection in Great Britain and found that when all traits were combined to determine sex an overall accuracy rate of 79.1 % was achieved.

Işcan and Shihai (1995), Işcan *et al*., (1998) and King *et al*., (1998) examined sexual dimorphism of the arm and leg bones in different Asian population groups. Işcan and

Shihai (1995) and King *et al*., (1998) conducted a study on femora from Thai and Chinese populations. Işcan *et al*., (1998) examined the right humerus in three Asian populations: Chinese, Japanese, and Thai. In each study, the bones were measured from each population group and subjected to both stepwise and discriminate function analyses. Işcan *et al*., (1998) showed that the humerus is sexually dimorphic in all three populations; the Chinese group showed the least sexual dimorphism and the Japanese and Thai groups showed the most sexual dimorphism. In order to create a standard for determining sex based on the humerus, a discriminate function formula was created for each population group, i.e. the formulae were population specific.

Srivastava *et al.,* (2012) conducted a study on determining sex using femora from a contemporary North Indian population group. Eight parameters were measured and analyzed by discriminant function analyses. The accuracy rate of sex prediction ranged from 70.5 % to 83.6 %. Also, Milner and Boldsen (2012) examined sexual dimorphism of humeral and femoral head diameters in a contemporary White European population. However, this study did not use discriminate function or logistic regression analyses to develop a methodology to determine sex. Rather, they used probability ratios to help determine whether a group of skeletal remains deviated from fixed measurements of humeral and femoral head diameters. If the unknown individual‘s humeral or femoral head diameters were in a range above or below those fixed measurements then the individual was classified as either male or female. Their results are used in disaster related fatalities in which there could be an overrepresentation of one sex.

2.5.1.4 Sex determination from metacarpals, carpals, metatarsals and tarsals

Studies on estimation of sex based on metacarpal measurements have been developed by several researchers (Falsetti, 1995; Scheuer and Elkington, 1993; Smith, 1996; Stojanowski, 1999). All authors used metric measurements from metacarpals one to five to derive equations for the determination of sex of an unknown individual. However, Smith (1996) also used hand phalanges to create an equation to determine sex for left and right hands as well as between two population groups: Black African and White European. The accuracy rates for Scheuer and Elkington (1993), whose sample came from contemporary White European cadaver specimens, ranged from 74.0 % to 94.0 %. The accuracy rates for assigning both ancestry and sex for the Smith (1996) study ranged from 72.0 % to 89.0 %. Falsetti (1995) and Stojanowski (1999) both used contemporary White European and Black African skeletal collections and had accuracy rates from 79.0 % to 92.0 %.

Case and Ross (2007), Lazenby (1994) and Zanella and Brown (2003) validated the research by Falsetti (1995), Scheuer and Elkington (1993) and Stojanowski (1999). The overall results of each study suggested that the accuracy rates that were reported by the original researcher varied considerably when tested on a different population sample. Zanella and Brown (2003) used a contemporary White European cadaveric sample and showed that the methodologies created by Falsetti (1995) and Scheuer and Elkington (1993) had accuracy rates lower than those originally reported. Lazenby (1994) used a 19th century White European population and found that Scheuer and Elkington‘s (1993) methodology more correctly classified males than females.

Barrio *et al*., (2006), Khanpetan *et al.*, (2012) and Manolis *et al.*, (2009) created population specific metacarpal sex determination methodologies. Each study used similar methodologies by Falsetti (1995), Scheuer and Elkington (1993) and Stojanowski (1999), however, Barrio *et al*. (2006) used a contemporary Spanish population, Khanpetan *et al*. (2012) used a contemporary Thai population and Manolis *et al*. (2009) used a contemporary Greek population. The accuracy rates for each methodology were: 81 % to 91 % for the Barrio *et al*. (2006), 83.2 % to 89.8 % for the Khanpetan *et al*. (2012) and 83.7 % to 89.7 % for the Manolis *et al*. (2009).

A preliminary study on the metric methodology for determining sex from the carpal bones was conducted by Sulzmann *et al.*, (2008). who used a White European historic 18th and 19th century cemetery population. Each carpal bone was assigned four to nine measurements based on its size and shape and from those measurements discriminate function equations were created to determine the sex of the individual. The accuracy rates for these equations ranged between 64.6 % and 88.6 %.

Mastrangelo *et al.*, (2011a) and Mastrangelo *et al.*, (2011b) conducted studies on population specific methodologies for determining sex from the carpal bones. Mastrangelo *et al.*, (2011a) used a 20th century Spanish population and Mastrangelo *et al.*, (2011b) used a contemporary Mexican population. Following the methodologies outlined by Sulzmann *et al.*, (2008), both studies created discriminate function models for the targeted population group within their study. The accuracy rates for Mastrangelo *et al.*, (2011a) and Mastrangelo *et al.*, (2011b) ranged between 88.2 % to 98.1 % and 81.3 % to 92.3 %, respectively.

Robling and Ubelaker (1997) and Smith (1997) used metric analyses of the metatarsals to develop sex determination methodologies for unknown individuals. Robling and Ubelaker

(1997) used contemporary White European and Black African individuals. They developed discriminate function models from individual carpal bones and by combining measurements from all five of the carpal bones. The accuracy rates for the Robling and Ubelaker (1997) study ranged between 83.0 % and 100.0 %. Smith (1997) also used foot phalanges to create an equation to determine sex for left and right feet as well as between two population groups: Black African and White European. The accuracy rates for assigning both ancestry and sex for the Smith (1997) study ranged from 70.0 % to 84.0 %. Mountrakis *et al.,* (2010) developed a population specific discriminate function model for the metatarsals. They used a contemporary Greek population group. The results suggested that the metatarsal bones for this population group were highly sexually dimorphic with an accuracy rate from 80.7 % to 90.1 %.

Steele (1976), Introna *et al.,* (1997), and Gualdi-Russo (2007) used metric analyses of the tarsals to develop sex determination methodologies for unknown individuals. Steele (1976) used Black African and White European individuals and measured the talus and calcaneus to develop his discriminate function models. The accuracy rates for Steele (1976) ranged from 79.0 % to 89.0 %. Gualdi-Russo (2007) and Introna and colleagues (1997) used a contemporary Italian sample to develop their methodologies using multivariate discriminate function analyses. However, Introna *et al.,* (1997) used only measurements of the calcaneus and Gualdi-Russo (2007) measured the talus and calcaneus. The accuracy rates for assigning the correct sex for Introna *et al.,* (1997) was 85.0 %. The accuracy rates for the Gualdi-Russo (2007) study ranged from 87.9 % to 95.7 %.

Bidmos and Asala (2003), Bidmos and Asala (2004) and Bidmos and Dayal (2004) examined sexual dimorphism of the tarsal bones in South African populations. Bidmos and

Asala (2003) measured the calcaneus of South African White individuals and Bidmos and Asala (2004) measured the calcaneus of South African Black individuals. They developed ancestry specific discriminate function models from nine parameters of the calcaneus. The average accuracy rate for the Bidmos and Asala (2003) study ranged from 73.0 % to 86.0 % and the Bidmos and Asala (2004) study ranged from 79.0 % to 86.0 %. Bidmos and Dayal (2004) measured nine parameters of the talus in South African Black individuals to validate previous discriminate functions equations for determining sex and developed their own methodology for determining sex from the talus. The average accuracy rate for the Bidmos and Dayal (2004) study ranged from 80.0 % to 89.0 %.

Harris and Case (2012) conducted a study to determine which of the seven tarsals would demonstrate the greatest sexual dimorphism and which could be used for accurate sex determination. Eighteen measurements were obtained from the tarsals of contemporary White European males and females. Logistic regression analyses were performed to create equations for sex discrimination. The average accuracy rate for the Harris and Case (2012) study ranged from 88.0 % to 92.0 %.

2.5.1.5 Sex determination from posteroanterior chest radiographs

The determination of sex in forensic contexts from chest radiographs is a technique that will be able to facilitate a rapid, simple, and inexpensive method in a situation where an individual is too decomposed to successfully use methods like fingerprints, visual confirmation, unique physical characteristics, or ante-mortem medical and/or dental records (McComick *et al*. 1985).

Francois *et al.,* 2003, examined and measured the thoracic dimensions using chest radiographs of 40 normal subjects (21 males and 19 females) at the level of third, fifth, seventh and ninth vertebrae and ribs and the Height of each hemidiaphragm dome below the first thoracic vertebra on the anterior- posterior plain films and the inclination of rib as acute angle formed by the lower border of the sixth rib and the vertical the lateral films (, and found the thoracic dimension of males is greater than females. (Işcan 1985,Cologlu*et al*., 1998, Wiredu *et al*., 1999 and Ramadan *et al*., 2010) used the sternal ribs ends and found their accuracy rate to be 74.0 % to 90.0 %. (Sharp *et al*., 1986, Marino 1995, Wescott 2000 and Marlow and Pastor 2011) used the vertebral column and found its accuracy rate to be 75.0 % to 85.0 %.

Also in the year 2000 Goh, *et al.,* studied the morphometric analysis and examined disc degeneration of thoracic spine of 169 people in which 88 were females and 81 were males, the association between vertebral shape and disc degeneration was analyzed and found that they are statistically significant in allocating sexes.

In 1998 Heminway *et al*., used postero anterior and lateral chest radiograph to calculate the volume of the heart, they measured long axis and short axis on posteroanterior chest radiographs and horizontal antero- posterior axis on lateral chest radiographs and found that they are statistically significant in sex determination.

2.5.1.6 Sex determination from clavicle

Doengen (1963) studied the shoulder girdles of Australian aborigines, and found that the clavicles length and mid- shaft thickness are highly significant in differentiating sex using discriminant functional analysis, and concluded that the length and mid- shaft thickness were better criteria for sexing females clavicles.

Terry (1932) and Singh *et al*., (1972) observed the difference in different parameters of clavicle between Whites and Negros, Singh and Gangrade (1968b) show that even within India, parameters of the clavicles of Amritsar zone differ from those of the clavicles of Varanasi zone. Same was observed by Jit and Sahani (1983) in Chandigarh zone.

Padeyappanavir (2009) studied clavicles of the adult of known and unknown sex, and found that the length of the male right clavicle ranges from 120.0 mm to 167 mm (141.9 mm ± 9.732) whereas that of the female right clavicle ranges from 100 to 145 mm (125.4 mm ± 8.86). The length of male left clavicles ranges from 121 to 170 mm (143.5 mm ± 10.35) Whereas that of female left clavicles ranges from 105 to 145 mm (129.7 mm ± 9.55).

2.5.1.7 Sex determination from the scapula

One of the first metric studies conducted on the variation of the human scapula was published in 1887 by a medical professor named Thomas Dwight. Dwight collected statistics on scapular indices for people of different ancestries, Native American, White European, and Black African. The two scapular indices were defined as the breadth of the scapula and the infra-spinous index. Dwight used scapular remains from the skeletal collection at the Harvard Medical School, the Boston Society of Natural History, and the Peabody Museum of Archaeology. Assumptions were made regarding the biological affinities of some of the individuals within the study. For example, human remains from

Kentucky and California were presumed to be Native American in origin and were labeled ―Mound Builders‖ because they were part of museum collections (Dwight 1887: 629). Dwight compared the two scapular indices of the ―Mound Builder‖ population to 113 White European scapulae. He concluded that both indices were much smaller in the ―Mound Builder‖ group than in the White European group which he attributed to the individuals‘ occupation and health (Dwight 1887). Although determining sex was not specifically addressed in this study, his research revealed that variation in the scapula could be related to differences in biological sex.

In 1956, Bainbridge and Genovese-Tarazaga examined human scapulae for differences related to sexual dimorphism. They employed morphological and metric analyses of the scapula. The morphological characteristics assessed in this study were the costal facets, shape of the glenoid cavity, angle of the axillary border, form of the supraspinous fossa and suprascapular notch. The results were inconclusive for the determination of sex based on morphological assessment of the scapula. However, the metric analyses proved to be significant for the determination of sex from the scapula. The metric measurements included the maximum length of the scapula, breadth of the scapula, maximum length of the spine, length of the axillary border, maximum width of the process of teres major, maximum length of the coracoid, length of the glenoid cavity, breadth of the glenoid cavity, maximum and minimum length of the crest of the spine and width of the axillary border. The results showed that the breadth of the glenoid fossa, the maximum breadth of the scapula, and the maximum length of the scapula are sexual dimorphic.

Bainbridge and Genovese-Tarazaga (1956) also used the sexually dimorphic characteristics of the scapula to create a method for determining sex. This method examined the deviation of an established mean of six different measurements of the scapula. The measurements include: breadth of the glenoid fossa, maximum breadth of the scapula, maximum length of the scapula, width of the axillary border, maximum length of the spine and length of the axillary border. The measurement obtained from each area of the scapula has an upper and lower limit from the standard deviation of the mean. If the measurement reaches or exceeds the upper limit then it is classified as male, if the measurement reaches or falls below the lower limit then it is classified to be female, and if the measurement was between the male and female limit it would be considered as ―indeterminate‖ .

In 1979, Stewart re-examined Dwight‘s (1887) original method for determining sex from the human scapula. Stewart (1979) measured the maximum length of the scapula and the maximum length of the glenoid cavity. Stewart‘s results are similar to Dwight‘s findings in that the maximum lengths of female scapulae rarely surpass 14 cm and that the maximum length of male scapulae rarely falls below 17 cm. However, Stewart‘s (1979) study had limitations in that those individuals who fell between 14 cm and 17 cm were classified as indeterminate. Stewart (1979) also re-examined the length of the glenoid cavity and its relationship to determining sex. He measured the glenoid cavity of males and females and discovered that no glenoid cavity that had a total length of 3.6 cm or greater was female and that no glenoid cavity measuring less than 3.6 cm was male.

Murphy (2002) and Ozer *et al*., (2006) used scapular measurements and statistical analyses to develop determination of sex methodologies for unknown individuals. Murphy (2002) used a prehistoric New Zealand population and Ozer *et al.,* (2006) used a medieval bone collection from East Anatolia. All studies employed the length and breadth of the glenoid cavity but Ozer and colleagues (2006) also used the maximum length and breadth of the scapula. These measurements were then subjected to discriminate function analyses to illustrate which characteristics were more sexually dimorphic. The measurements were also subjected to logistic regression analyses, which were then used to formulate an equation to determine the sex of an individual for that specific population. Once a logistic regression equation was formulated for each population, the accuracy rates increased for determining the sex of individuals within the specific population. The research concluded that high accuracy rates for determining sex were population specific.

Frutos (2002) and Papaioannou *et al.,* (2012) used scapular measurements and clavicle measurements to develop sex determination methodologies for unknown individuals. Frutos (2002) used a contemporary Guatemalan population and Papaioannou and colleagues (2012) used a contemporary Cretan population. All studies employed the length and breadth of the glenoid cavity but Papaioannou *et al.,* (2012) also used the maximum length of the scapular spine. These measurements were then subjected to discriminate function analyses to illustrate which characteristics were more sexually dimorphic. The measurements were also subjected to logistic regression analyses, which were then used to formulate an equation to determine the sex of an individual for that specific population. Once a logistic regression equation was formulated for each population, the accuracy rates increased for determining the sex of individuals.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 MATERIALS

The materials used are:

i. Viewing box, Model 2960 Richard Wolf Co., Ltd, WA United State of America.
ii. 500 normal chest radiographs form Federal Medical center Gombe.
iii. Meter rule, Model E09- series-1, Fiber- Glass Co. Ltd, Shaghai,China.
iv. Vanier caliper, Model number K131- 1115, Manufactured by Youfound Precistion Co., Ltd, Zhejiang, China.
v. Compass, Model number AH1205, Hangzhou Aihua stationary Co. Ltd., Shanghai China.

3.2 METHODS

3.2.1 Study location

Gombe State, Jewel in the Savannah, was created out of the former Bauchi State on 1st October 1996 by the Late General Sani Abacha administration (Ibrahim, 2004).

The State has eleven Local Government Areas (LGA_S) namely Akko, Balanga, Billiri, Dukku, Funakaye, Gombe, Kaltungo, Kwami, Nafada, Shongom and Yamaltu-Deba (Ibrahim, 2004).

It is Located between latitudes 9.30^0 and 12.30^0 North and Longitudes 8.45^0 and 11.45^0 East, Gombe State lies in the centre of the North-East geopolitical zone of Nigeria. It shares a common boundary with all the other states in the zone, namely, Adamawa, Bauchi, Borno, Taraba, and Yobe.

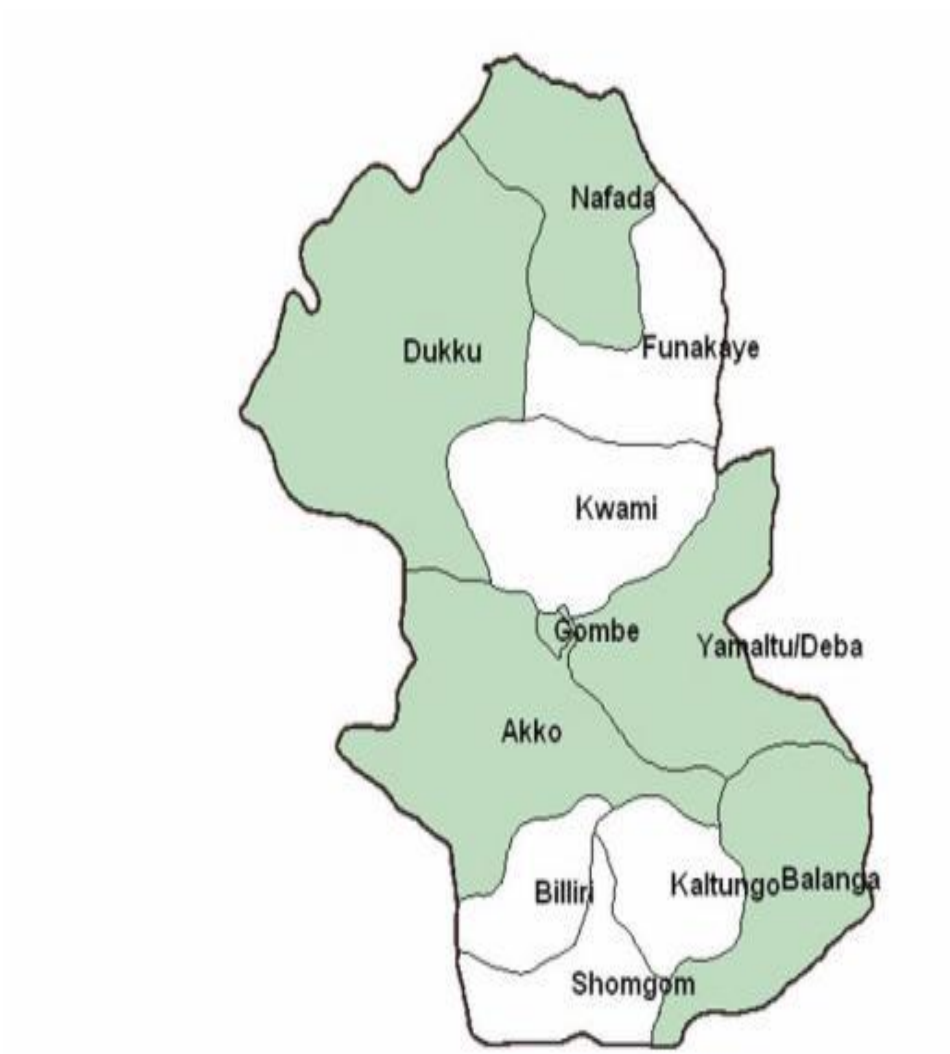


Fig 3.1 Map of Gombe showing its Local Government (Harper, 2009)

3.2.2 Sample Size

A total number of 500 posteroanterior chest radiographs of Gombe adults that were reported normal by consultant radiologist in the Department of Radiology Federal Medical Center (Federal Teaching Hospital) Gombe, Gombe state.

3.2.3 Sample Size Determination

The sample size was calculated using formula; $N = \frac{z^2pq}{\mathrm{d}^2}$ (Naing, *et al.*, 2006)

Where N= desired sample size

Z= standard normal deviation 1.96 at 95% confidence level

P= proportion = 0.03 (3%)

Q= 1-p = 1- 0.03= 0.97

D= degree of precision = 0.015

$N = \frac{(1.96)^2(0.03)(0.97)}{0.015^2}$ = 497

3.2.4 Sampling Technique

This is a retrospective study in which the posteroanterior chest radiographs of 18 – 85 years old people that were reported normal were randomly selected from Radiology Department of Federal Medical center Gombe.

3.3 INCLUSION AND EXCLUSION CRITERIA

3.3.1 Inclusion Criteria

i. Normal postero-anterior chest X-ray of both adult sexes was considered for the measurements.

ii. Normal postero-anterior chests X-ray without any deformity, cardiovascular disease or degeneration were considered for the measurements.

3.3.2 Exclusion Criteria

i. Plain chest postero-anterior radiograph of subject under 18 years of age with incomplete in ossification.

ii. Abnormal chest X-ray with thoracic cage, lungs or pleural disease.

3.4 MEASUREMENTS OF CHEST X-RAY

3.4.1 Thoracic cage Dimensions

Diameters of the rib cage were measured from right outer border to left outer border at the levels of:-

i. Third thoracic vertebra and ribs (T3).

ii. Fifth thoracic vertebra and ribs(T5).

iii. Seventh thoracic vertebra and ribs (T7).

iv. Ninth thoracic vertebra and ribs (T9).

v. The height of each (right and left) hemidiaphragm dome below the first thoracic vertebra at inferior end plate were also measured in millimeter (mm) (see plate 3.2) as described by Francios *et al.* (2003).

3.4.2 Clavicular Dimensions

3.4.2.1 Length of Clavicle

The maximum length of each clavicle was measured in millimeters (mm) from sternal end to acromial end by ignoring the curves of the bone (see plate 3.3) using vernier caliper and ruler.

3.4.2.2 Mid- shaft Thickness of Clavicle

By bisecting the entire length of the clavicles using compass and measure the thickness (superior to inferior border) of the clavicle at that level in millimeter (mm) (see plate 3.3) using ruler, as described by Shobha *et al*. (2011) with modification.

3.4.3 Scapular dimensions

3.4.3.1 Maximum Scapular Height

Maximum distance between the highest point of the superior angle (Medial angle) and the lowest point of the inferior angle was measured in millimeter (mm) (see plate 3.3) using ruler, as described by Ozer*et al*. (2006).

3.4.3.2 Maximum Scapular Width

The maximum distance between the longitudinal axis of the glenoid cavity and the medial border of the scapular was measured (see plate 3.3) using ruler in millimeter (mm), as described by Ozer et al. (2006).

3.4.4 Measurement of Heart Dimensions

3.4.4.1 The Long Axisof the Cardiac Ellipsoid

Which is a distance between the left cardiophrenic junction and the junction of the right heart border with great vessel shadow (superior vena cava) was measured (see plate 3.3) in millimeter (mm) using ruler, as described by Hemingway *et al.*(1998).

3.4.4.2 The Short Axisof the Cardiac Ellipsoid

Which is a distance between the junction formed by the pulmonary trunk and left heart border with the right cardiophrenic junction was measured (see plate 3.3) in millimeter (mm) using ruler, as described by Hemingway *et al.* (1998).

3.4.5 Observation of Intervertabral disc shape.

The shape of two upper thoracic intervertabral disc (C7/T1 and T1/T2 IVD) were observed to see if they were inverted (□**)** or parallel (=) (see plate 3.3).

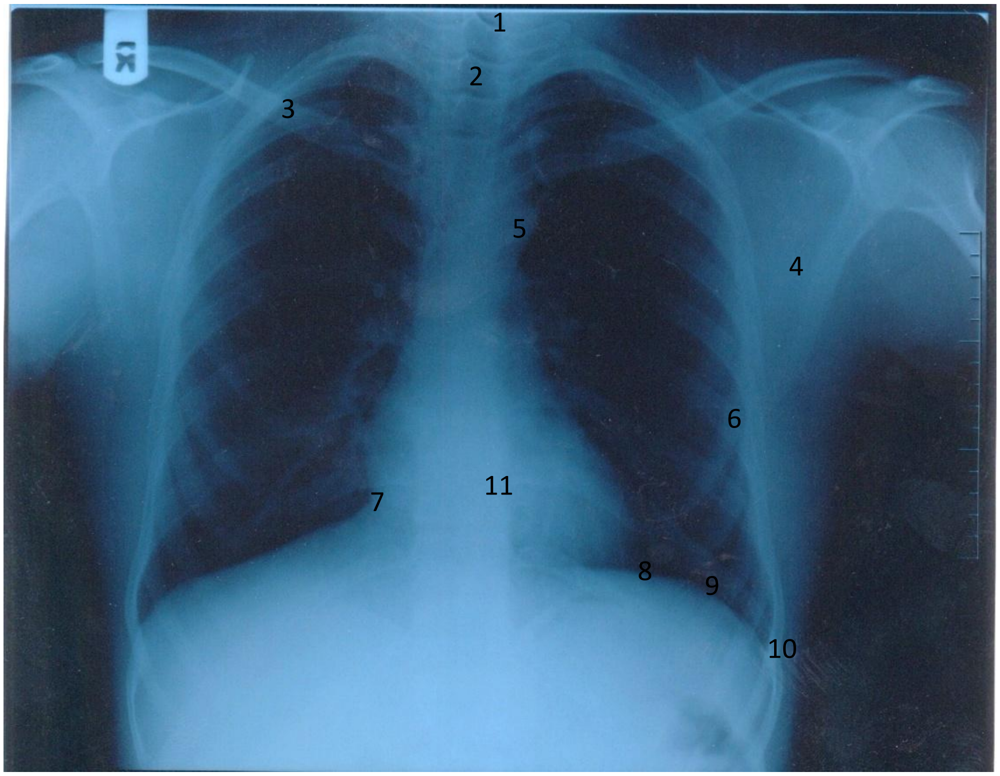


Plate 3.1; Illustration of some structures on normal posteroanterior chest radiograph.

KEY :-

1. Intervertebral disc.
2. 2nd Thoracic vertebra.
3. Clavicle.
4. Scapular.
5. Aortic knucle.
6. 7th Rib.
7. Right Cardiophrenic junction.
8. Left Cardiophrenic junction.
9. Hemidiaphragm.
10. Costophrenic Angle.
11. Heart.

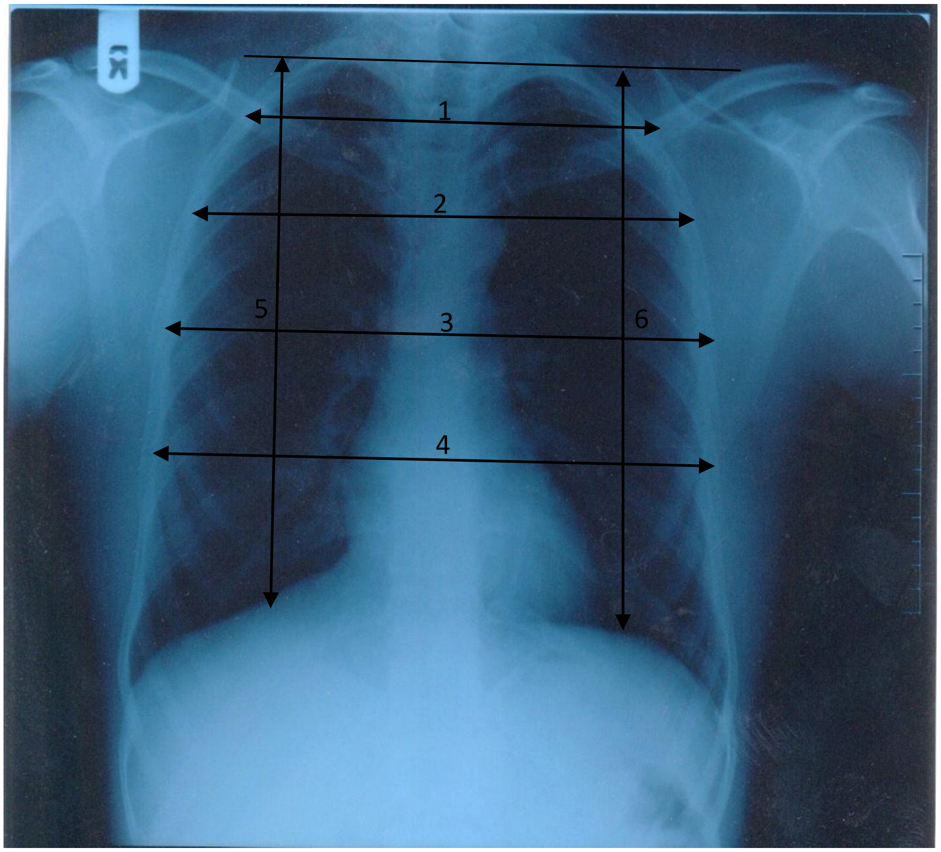


Plate 3.2; Chest radiograph illustrating thoracic cage measurements.

KEY :-

1. Measurement of chest diameter at the level of third thoracic vertebra (D- T3).
2. Measurement of chest diameter at the level of fifth thoracic vertebra (D- T5).
3. Measurement of chest diameter at the level of seventh thoracic vertebra (D- T7).
4. Measurement of chest diameter at the level of ninth thoracic vertebra (D- T9).
5. Measurement of right hemidiaphragm dome.
6. Measurement of left hemidiaphragm dome.

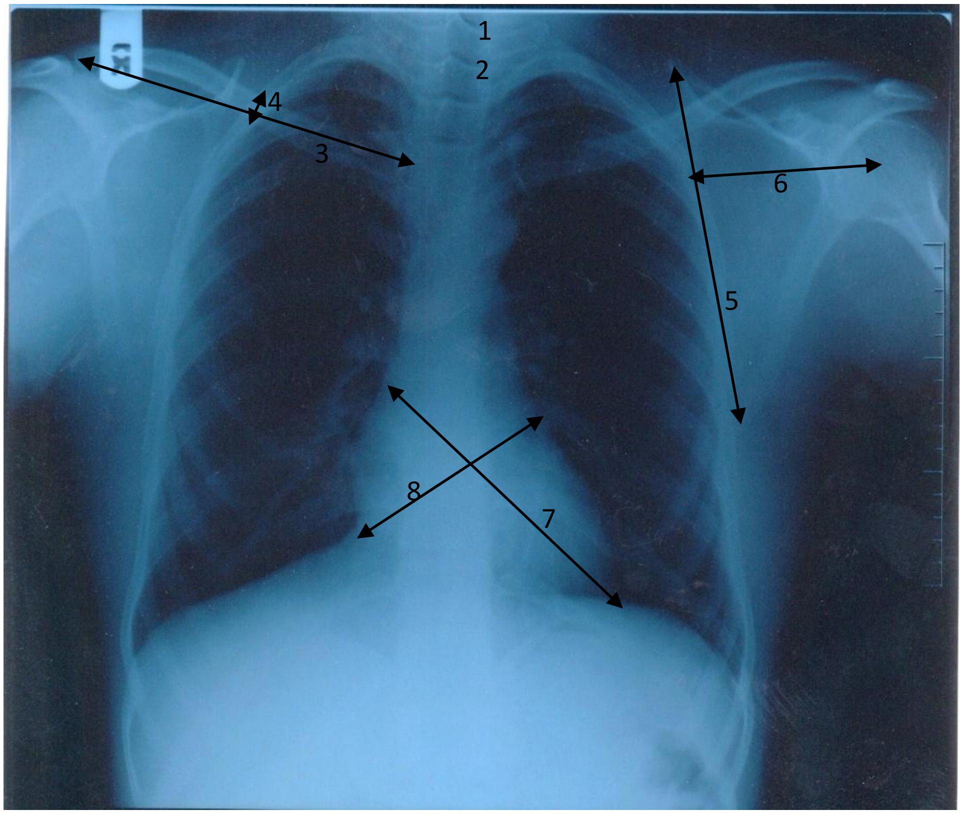


Plate 3.3; Chest Radiograph Illustrating Measurement of Clavicle, Scapula, Heart and Intervertebral disc shape.

Key :-

1. Shape of C7/T1 Intervertebral disc (IVD).
2. Shape of T1/T2 Intervertebral disc (IVD).
3. Measurement of the length of clavicle.
4. Measurement of mid- shaft thickness of clavicle.
5. Measurement of scapula height.
6. Measurement of width of scapula.
7. Measurement of long axis of cardiac ellipsoid.
8. Measurement of short axis of cardiac ellipsoid.

3.6 ETHICAL APPROVAL

Ethical approval was obtained from the Local Health Ethical Committee (LHEC) of the Federal Medical Center, Gombe, Gombe state before commencing the data collection.

3.7 DATA ANALYSIS

The data were expressed as mean ± standard deviation. All the variables measured in males and females were tested for significant differences using independent Student t- test and paired t- test. Pearson's correlation was used to investigate the relationship between scapula, heart, clavicle and chest parameters. Data analysis was carried out using SPSS version 18.0 software (IBM Corporation, Armonk New York, USA). P-value less than 0.05 ($p < 0.05$) was considered significant.

CHAPTER FOUR

4.0 RESULTS

4.1 Sexual Dimorphism Studies

Five hundred (500) chest radiographs of both males and females adults aged 18 to 85 years that were reported normal in the department of radiology Federal medical center Gombe were considered for this study.

These were composed of two hundred and fifty (250) males with a mean age of 43.38 ± 16.55 years and two hundred and fifty (250) females with a mean age of 39.28 ± 14.68 years.

Table 4.1 shows the number of subjects, means and standard deviation of all the parameters of the overall samples for males (n = 250) and females (n = 250). While table 4.2 shows the number of subjects the ranges of all the variable measured in males differently and for females differently.

Table 4.1: Descriptive statistics all the parameters in male and female chest radiographs of Gombe state adults

Variables	Male +Female Mean ±SD (n=500)	Max	Min	Range
AGE	41.33±15.76	85.00	18.00	67.00
LRC	151.19±11.19	189.00	120.00	69.00
TRC	12.94±1.62	19.50	9.00	10.50
LLC	157.09±11.65	193.00	126.00	67.00
TLC	12.28±1.68	20.00	8.50	11.50
HRS	151.99±16.41	193.00	99.00	94.00
WRS	78.88±10.99	174.00	52.00	122.00
HLS	157.81±16.38	204.00	115.00	89.00
WLS	81.23±9.19	120.00	46.00	74.00
D-T3	207.03±17.66	262.00	158.00	104.00
D-T5	247.85±17.53	305.00	201.00	104.00
D-T7	267.00±18.08	325.00	181.00	144.00
D-T9	278.80±21.73	398.00	219.00	179.00
HRHD	211.71±21.94	281.00	153.00	128.00
HLHD	232.69±86.90	291.00	169.00	194.00
LCA	142.02±8.55	185.00	109.00	76.00
SCA	113.93±8.33	134.00	102.00	122.00

Key:-

LRC=Length of right clavicle; TRC= Thickness of the right clavicles LLC=length of left clavicle; TLC= Thickness of left clavicle; HRS= Height of right scapula; WRS= width of right scapula; HLS= Height of left scapula; WLS= Width of left scapula; D-T3= Thoracic diameter at level third thoracic vertebra; D- T5= Thoracic diameter at level fifth thoracic vertebra; D- T7= Thoracic diameter at level of seventh thoracic vertebra; D- T9= Thoracic diameter at level of ninth thoracic vertebra; HRHD= Height of the right hemidiaphragm

Table 4. 2: Comparison of all the parameters between males and females radiographs of Gombe adults.

	Males(n=250) (mm)				Females(n=250) (mm)			
Variables	Mean±SD	Max	Min	Range	Mean±SD	Max	Min	Range
AGE	43.38±16.55	80.00	18.00	62.00	39.28±14.68	85.00	18.00	67.00
LRC	157.65±10.06	189.00	130.00	59.00	144.72±8.36	168.00	120.00	48.00
TRC	14.06±1.38	19.50	10.05	9.00	11.81±0.89	15.00	9.00	6.00
LLC	163.70±10.52	193.00	126.00	67.00	150.47±8.58	170.00	130.00	40.00
TLC	13.38±1.42	19.00	10.00	9.00	11.19±1.09	20.00	8.50	11.50
HRS	161.07±15.27	193.00	116.00	77.00	142.92±11.89	173.00	99.00	74.00
WRS	83.32±9.46	114.00	62.00	52.00	74.44±10.63	174.00	52.00	122.00
HLS	166.99±14.40	204.00	120.00	84.00	148.62±12.70	182.00	115.00	67.00
WLS	84.89±8.90	120.00	65.00	55.00	77.57±7.96	107.00	46.00	61.00
D-T3	213.16±17.36	262.00	167.00	95.00	200.90±15.76	241.00	158.00	83.00
D-T5	256.81±15.76	305.00	214.00	91.00	238.88±14.36	272.00	201.00	71.00
D-T7	276.93±16.64	325.00	181.00	144.00	257.06±15.28	294.00	215.00	79.00
D-T9	288.94±19.50	398.00	231.00	167.00	268.65±18.96	361.00	219.00	142.00
HRHD	222.34±20.57	274.00	153.00	121.00	201.07±17.73	281.00	154.00	127.00
HLHD	241.23±20.04	305.00	184.00	121.00	224.14±12.78	209.00	169.00	94.00
LCA	145.61±7.19	169.00	118.00	51.00	138.44±8.31	185.00	109.00	76.00
SCA	116.84±8.76	134.00	120.00	122.00	111.02±6.73	127.00	94.00	33.00

KEY

LRC= Length of right clavicle; TRC= Thickness of the right clavicles LLC=length of left clavicle; TLC= Thickness of left clavicle; HRS= Height of right scapula; WRS= width of right scapula; HLS= Height of left scapula; WLS= Width of left scapula; D-T3= Thoracic diameter at level third thoracic vertebra; D- T5= Thoracic diameter at level fifth thoracic vertebra; D- T7= Thoracic diameter at level of seventh thoracic vertebra; D- T9= Thoracic diameter at level of ninth thoracic vertebra; HRHD= Height of the right hemidiaphragm dome; HLHD= Height of left hemidiaphragm dome; LCA= long cardiac axis; SCA= short cardiac axis.

4.2 Sex Difference between Males and Females Parameters.

Figures 4.1 and 4.2 are graphical presentations of two samples t-test of the length and mid shaft thickness of the right clavicle (LRC and TRS) which show high level of significant with $P<0.001$, likewise Figures 4.3 and 4.4 show the graphical presentation of the length and mid shaft thickness of left clavicle (LLC and TLC) which also show high level of significance with $p<0.001$.

The two sample t-test of the height and width of the right scapula (HRS and WRS) are highly significant and are graphically represented in Figures 4.5 and 4.6, likewise that of left scapula (HLS and WLS) are highly significant and are represanted in Figures 4.7 and 4.8 all there with P values <0.001.

The two sample t-test that compared the thoracic diameters at the levels of 3^{rd}, 5^{th}, 7^{th} and 9^{th} thoracic vertebrae between male and female are all highly significant with P value < 0.001 and are represented in Figures 4.9, 4.10,4.11and 4.12 respectively, also the height of right hemidiaphragm dome (HRHD) is greater in male than in female with P value <0.001, which is highly significant and is represented in Figure 4.13 while the two sample t-test for left hemidiaphragm dome between male and female is significant with the P value <0.05 figure 4.14.

The two sample t-test of long and short axis of cardiac ellipsoid (LCA and SCA) between male and female shows that they are significantly greater in male than in female with P value < 0.001 are represented in the Figures 4.15 and 4.16.

Table 4.3 - 4.18 show the comparison of all the parameters measured between male and female based on age grouping from < 20 year to ≥ 70, which also indicated that the parameters in males are significantly greater than those in females.

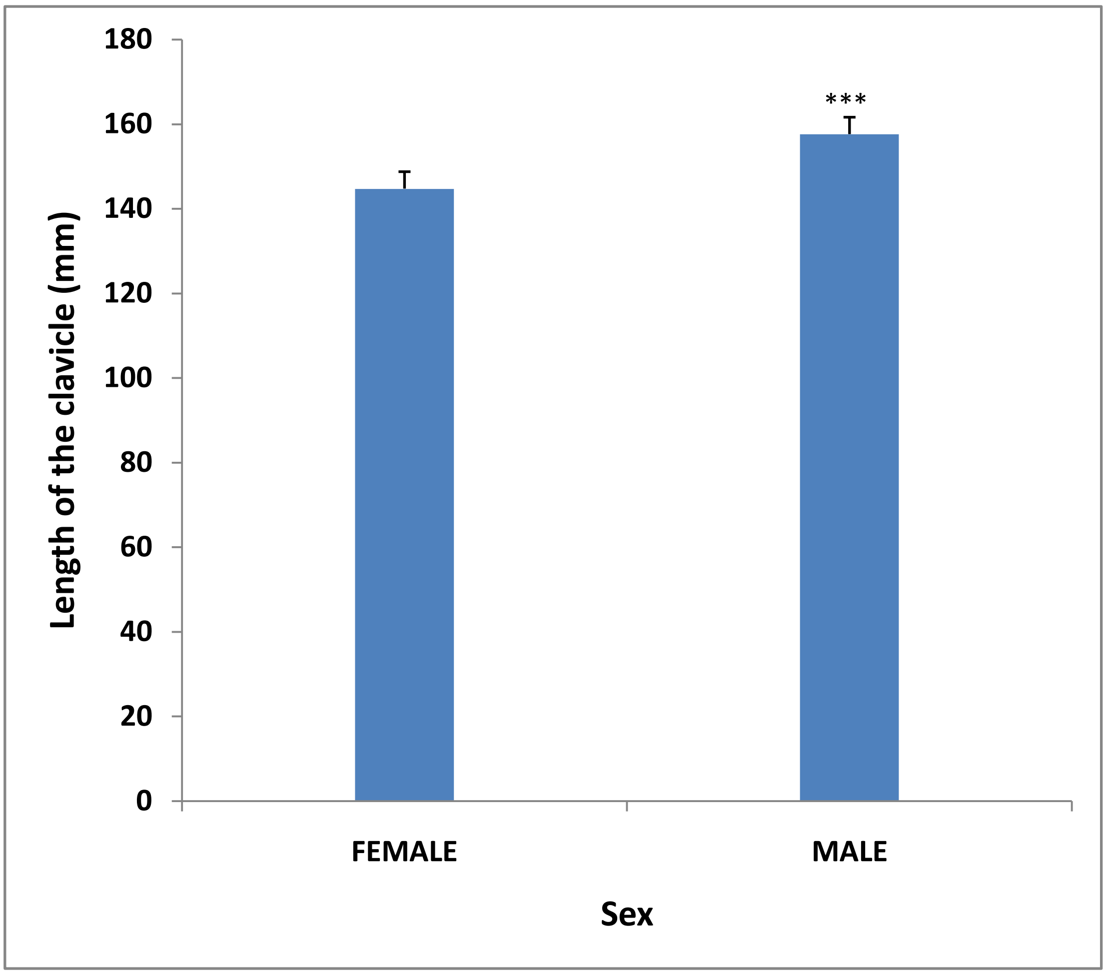


Fig. 4.1: Comparison of the length of the right clavicle between males and females. Significant difference was observed between males and females (t = 157.65 mm – 144.72 mm, ***$P < 0.001$)

Table 4.3: Comparison of the length of right clavicle (LRC) between males and females based on age groups.

AGE GROUPS	MALES (MEAN±SD) (mm)	FEMALES (MEAN±SD) (mm)	t -value	p- Value
< 20	140.40 ± 9.02 (n=9)	145.50 ± 9.55 (n= 9)	-1.162	0.262
20 - 29	158.11 ± 11.49 (n= 54)	144.06 ± 8.00 (n= 70)	8.023	<0.001
30 - 39	157.19 ± 7.67 (n= 47)	145.25 ± 8.08 (n= 57)	7.676	<0.001
40 - 49	160.17 ± 10.35 (n= 47)	144.30 ± 8.97 (n= 44)	7.793	<0.001
50 - 59	158.14 ± 8.30 (n= 43)	146.05 ± 9.40 (n = 38)	6.148	<0.001
60 -69	156.62 ± 9.76 (n= 26)	146.39 ± 6.71 (n = 23)	4.217	<0.001
≥ 70	156.63 ± 12.22 (n = 24)	145.67 ± 7.57 (n = 9)	2.502	<0.05

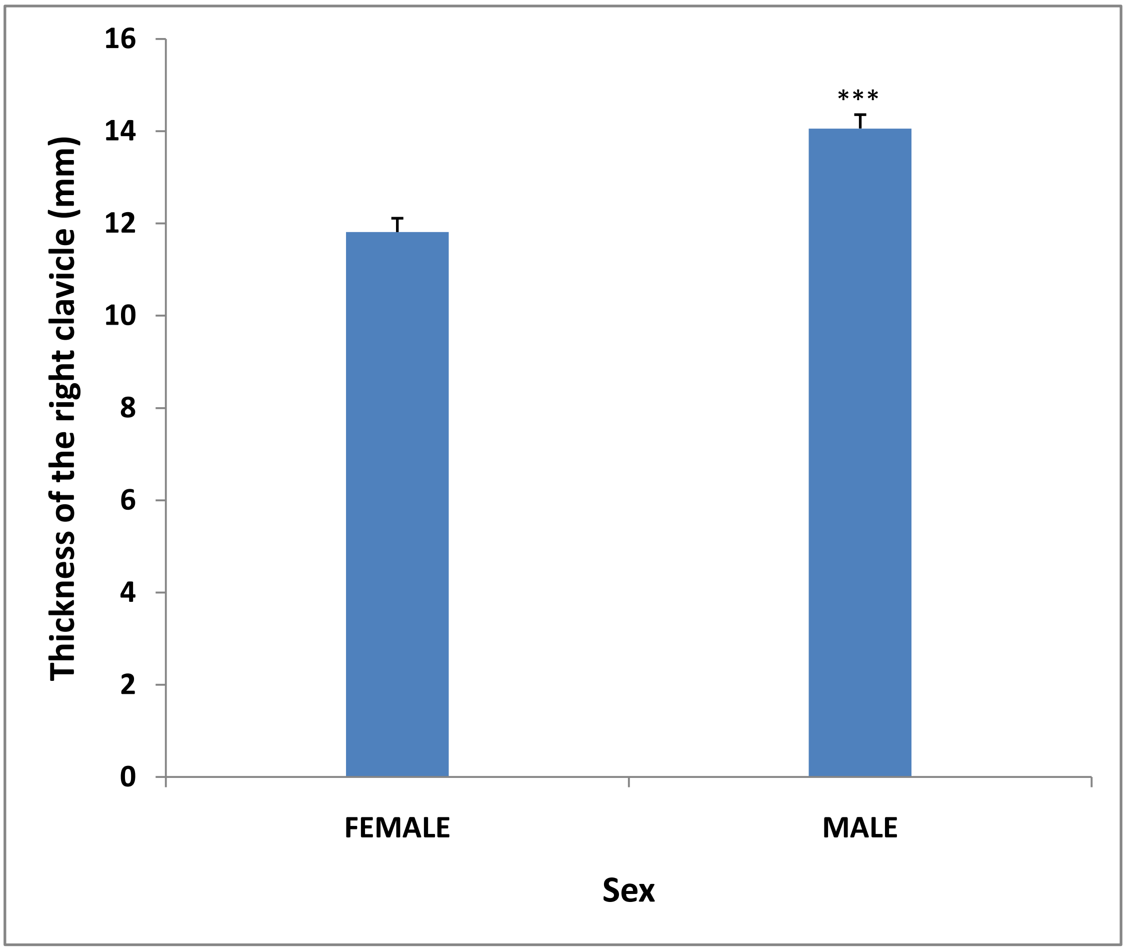


Fig. 4.2: Comparison of the mid shaft - thickness of the right clavicle, significant difference was observed between males and females (t = 14.06 mm – 11.81 mm, ***P< 0.001).

Table 4.4: Comparison of the mid shaft - thickness of right clavicle (TRC) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	13.28 ± 1.03 (n = 9)	11.28 ± 0.76 (n = 9)	4.687	<0.001
20 - 29	14.03 ± 1.49 (n = 54)	11.71 ± 0.94 (n = 70)	10.545	<0.001
30 - 39	13.78 ± 1.62 (n = 47)	11.85 ± 0.82 (n = 57)	7.831	<0.001
40 - 49	14.04 ± 0.88 (n = 47)	11.91 ± 0.92 (n = 44)	11.304	<0.001
50 - 59	14.33 ± 1.56 (n = 43)	11.86 ± 0.83 (n = 38)	8.737	<0.001
60 -69	14.48 ± 1.51 (n = 26)	11.85 ± 0.99 (n= 23)	7.119	<0.001
≥ 70	14.60 ± 0.83 (n = 24)	12.11 ± 0.74 (n = 9)	6.209	<0.001

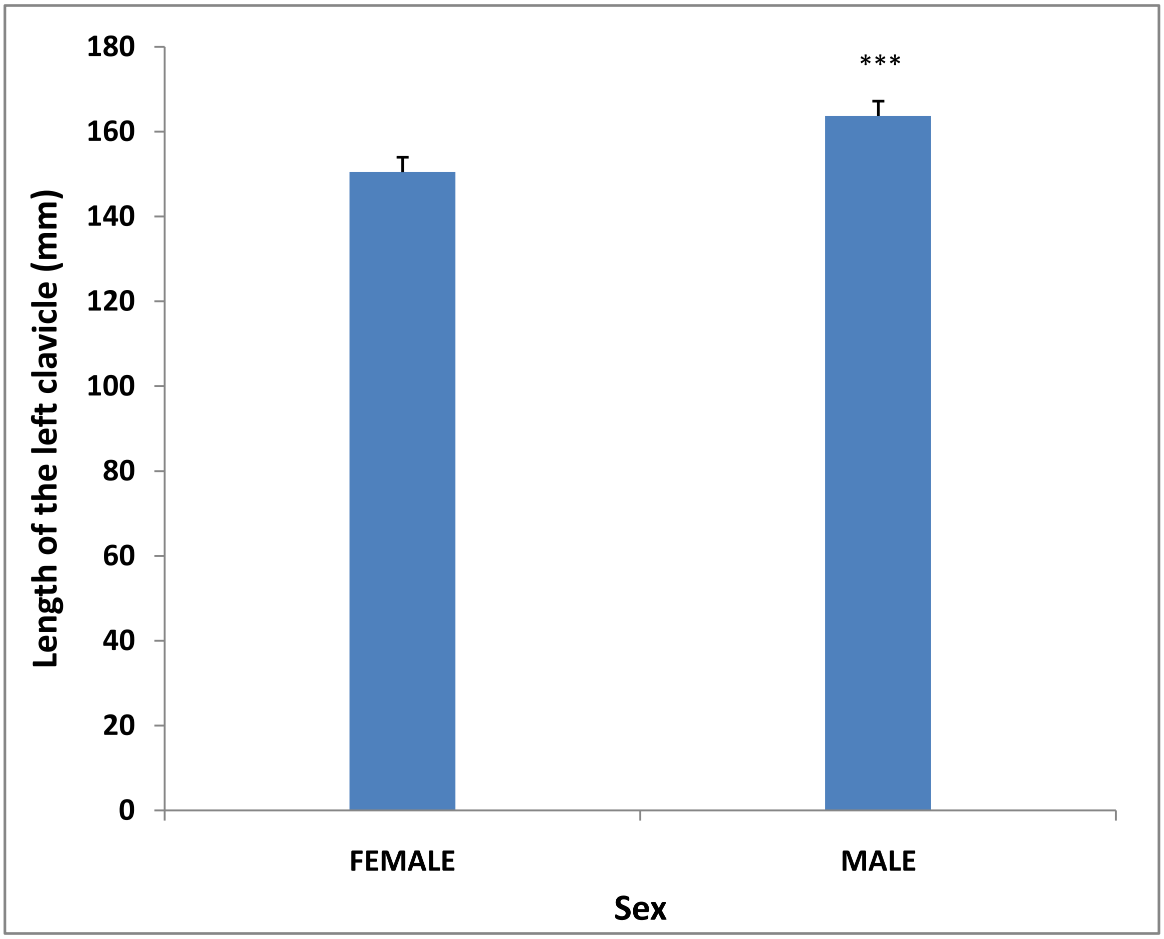


Fig. 4.3: Comparison of length of the left clavicle, the significant difference was observed between males and females (t = 163.70mm – 150.47 mm, ***P<0.001).

Table 4.5: Comparison of the length of left clavicle (LLC) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	155.56 ± 13.44 (n = 9)	145.67 ± 7.62 (n = 9)	1.921	0.073
20 - 29	164.22 ± 10.55 (n = 54)	149.77 ± 8.94 (n= 70)	8.250	<0.001
30 - 39	164.26 ± 8.60 (n = 47)	151.04 ± 8.16 (n = 57)	8.027	<0.001
40 - 49	166.15 ± 11.35 (n = 47)	150.46 ± 7.96 (n = 44)	7.592	<0.001
50 - 59	163.16 ± 10.09 (n = 43)	150.47 ± 9.48 (n = 38)	5.809	<0.001
60 -69	162.62 ± 10.02 (n = 26)	152.57 ± 8.26 (n = 23)	3.799	<0.001
≥ 70	161.88 ± 11.59 (n = 24)	151.89 ± 9.29 (n = 9)	2.313	<0.05

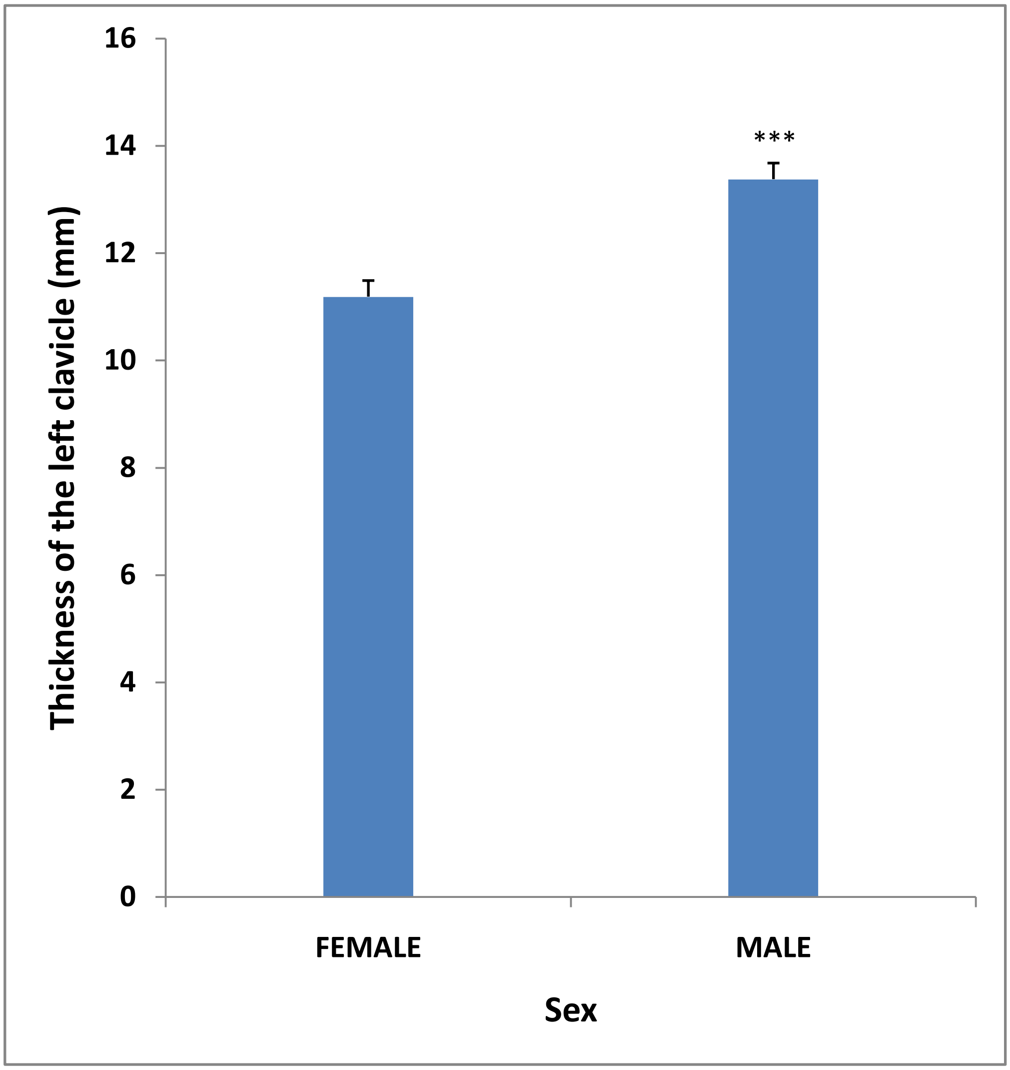


Fig. 4.4: Comparison of mid shaft - thickness of left clavicle, the significant difference was observed between males and females (t = 13.38 mm – 11.19 mm, ***P<0.001).

Table 4.6: Comparison of the mid shaft - thickness of left clavicle (TLC) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	12.67 ± 0.83 (n = 9)	10.50 ± 0.55 (n = 9)	6.500	<0.001
20 - 29	14. 03 ± 1.49 (n = 54)	11.71 ± 0.94 (n = 70)	10.545	<0.001
30 - 39	13.77 ± 1.62 (n = 47)	11.85 ± 0.82 (n = 57)	7.831	<0.001
40 - 49	13.31 ± 0.81 (n = 47)	11.19 ± 0.90 (n = 44)	11.765	<0.001
50 - 59	13.72 ± 1.63 (n = 43)	11.16 ± 0.88 (n = 38)	8.641	<0.001
60 -69	13. 79 ± 1.49 (n = 26)	11.17 ± 0.95 (n = 23)	7.212	<0.001
≥ 70	13.48 ± 0.88 (n = 24)	11.39 ± 0.82 (n = 9)	6.191	<0.001

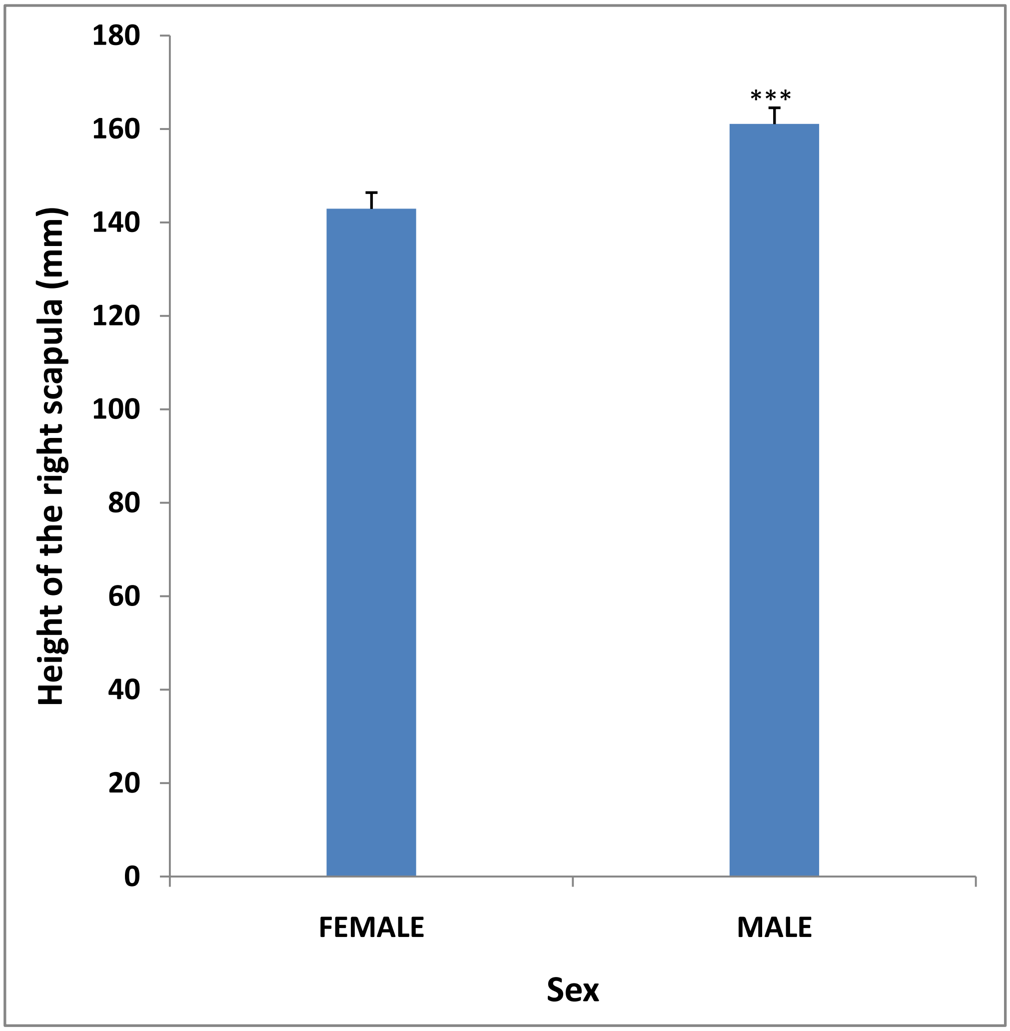


Fig. 4.5: Comparison of height of the right scapula, the significant difference was observed between males and females (t = 161.07 mm – 142.92 mm, ***P<0.001).

Table 4.7: Comparison of the height of right scapula (HRS) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	152.00 ± 21.07 (n = 9)	139.67 ± 8.16 (n = 9)	1.638	0.121
20 - 29	158.30 ± 14.11 (n = 54)	142.16 ± 12.18 (n = 70)	6.827	<0.001
30 - 39	161.13 ± 17.57 (n = 47)	142.88 ± 12.54 (n = 57)	6.168	<0.001
40 - 49	162.79 ± 13.43 (n = 47)	143.14 ± 10.24 (n = 44)	7.809	<0.001
50 - 59	163.79 ± 13.30 (n = 43)	142.00 ± 10.74 (n = 38)	8.042	<0.001
60 -69	164.92 ± 14.78 (n = 26)	146.13 ± 15.88 (n = 23)	4.290	<0.001
≥ 70	158.17 ± 16.59 (n = 24)	147.00 ± 9.60 (n = 9)	1.890	0.068

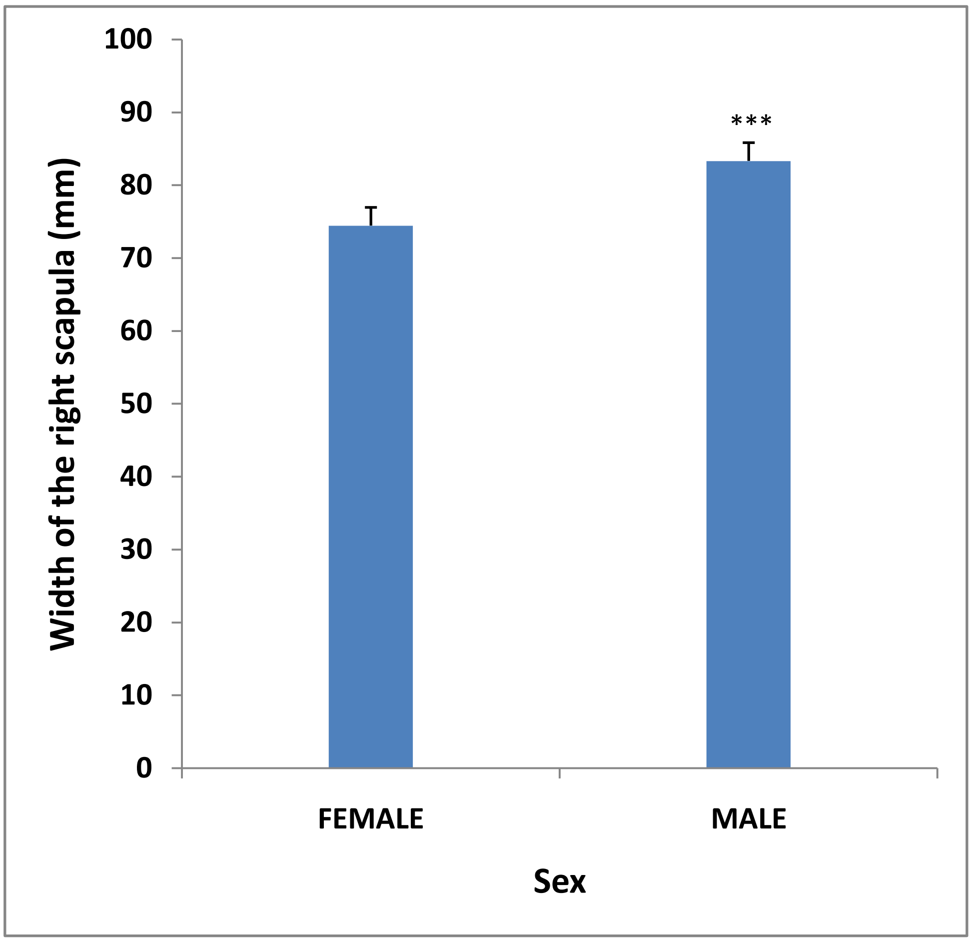


Fig 4.6: Comparison of width of the right scapula, the significant difference was observed between males and females (t = 83.32 mm – 74.44 mm, ***P<0.001).

Table 4.8: Comparison of the width of right scapula (WRS) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	P – Value
< 20	81.22 ± 9.59 (n = 9)	72.44 ± 6.93 (n = 9)	2.226	<0.05
20 - 29	81.56 ± 10.24 (n = 54)	75.00 ± 14.90 (n = 70)	2.767	<0.05
30 - 39	83.28 ± 8.49 (n = 47)	74.72 ± 7.81 (n = 57)	5.346	<0.001
40 - 49	84.49 ± 9.76 (n = 47)	73.84 ± 8.15 (n = 44)	5.628	<0.001
50 - 59	84.54 ± 9.62 (n = 43)	73.03 ± 8.33 (n = 38)	5.720	<0.001
60 -69	83.12 ± 10.49 (n = 26)	75.61 ± 9.16 (n = 23)	2.652	<0.05
≥ 70	83.96 ± 7.54 (n = 24)	76.33 ± 13.69 (n = 9)	2.050	<0.05

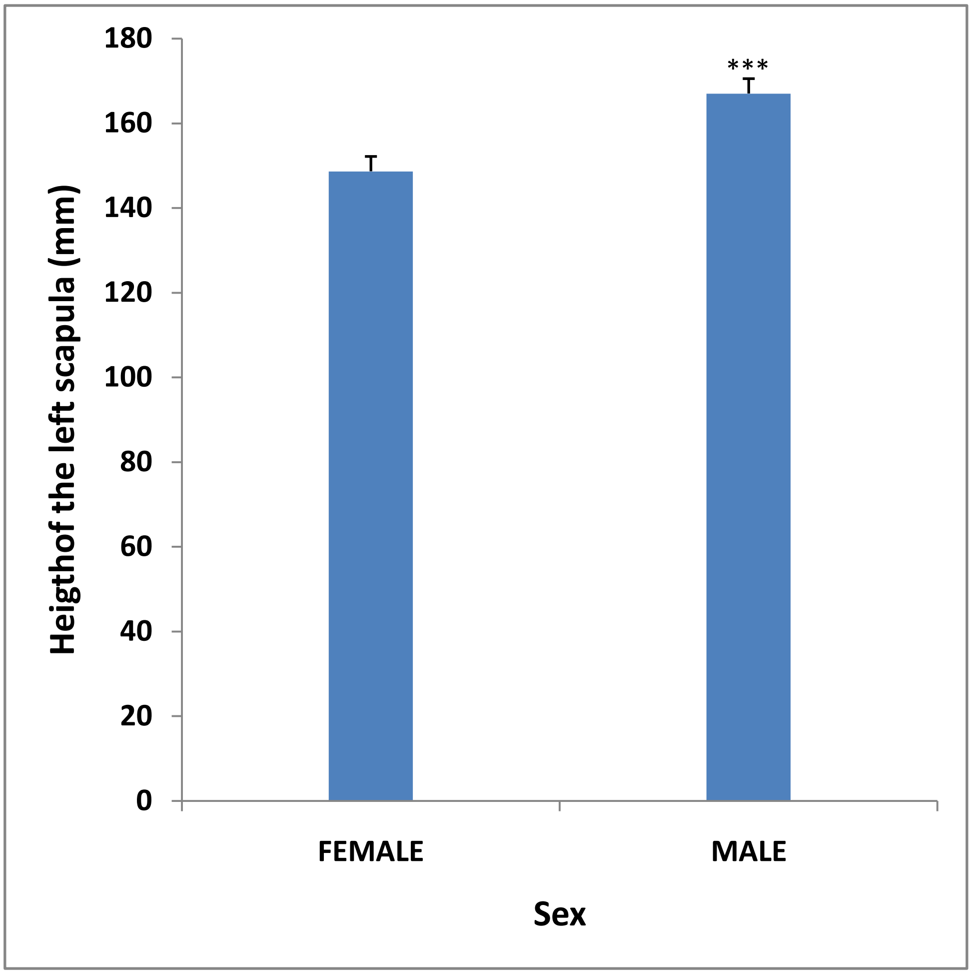


Fig. 4.7: Comparison of height of the left scapula, the significant difference was observed between males and females (t = 166.99 mm – 148.62 mm, ***P<0.001).

Table 4.9: Comparison of the height of left scapula (HLS) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	162.33 ± 20.88 (n = 9)	145.78 ± 8.45 (n = 9)	2.205	<0.05
20 - 29	163.19 ± 13.04 (n = 54)	147.33 ± 12.99 (n = 70)	6.727	<0.001
30 - 39	167.23 ± 16.39 (n = 47)	174.97 ± 12.90 (n = 57)	6.707	<0.001
40 - 49	168.11 ± 13.21 (n = 47)	149.41 ± 12.75 (n = 44)	6.862	<0.001
50 - 59	171.28 ± 10.77 (n = 43)	148.26 ± 11.47 (n = 38)	9.311	<0.001
60 -69	169.58 ± 14.81 (n = 26)	152.91 ± 14.72 (n = 23)	3.942	<0.001
≥ 70	164.23 ± 16.39 (n = 24)	152.44 ± 12.24 (n = 9)	1.937	0.062

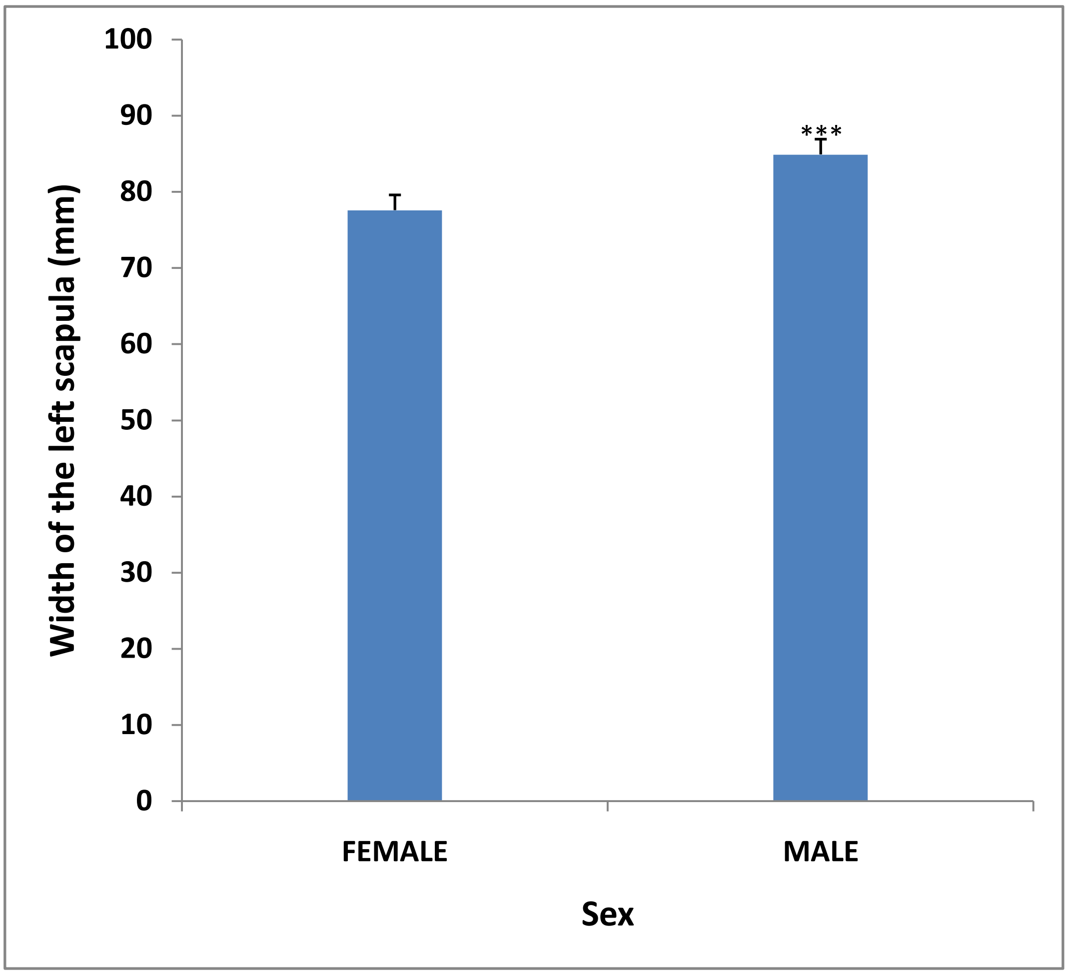


Fig 4.8: Comparison of width of the left scapula, the significant difference was observed between males and females (t = 84.89 mm – 77.57 mm, ***P<0.001).

Table 4.10: Comparison of thewidth of left scapula (WLS) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	80.89 ± 7.66 (n = 9)	79.44 ± 5.68 (n = 9)	0.455	0.656
20 - 29	83.94 ± 10.28 (n = 54)	77.27 ± 7.49 (n = 70)	4.182	<0.001
30 - 39	84.23 ± 7.86 (n = 47)	78.00 ± 7.19 (n = 57)	4.218	<0.001
40 - 49	85.45 ± 9.42 (n = 47)	77.23± 8.05 (n = 44)	4.459	<0.001
50 - 59	86.91 ± 8.85 (n = 43)	76.34 ± 9.67 (n = 38)	5.133	<0.001
60 -69	85.15 ± 9.02 (n = 26)	77.48 ± 5.44 (n = 23)	3.548	<0.001
≥ 70	84.83 ± 6.55 (n = 24)	82.44 ± 13.73 (n = 9)	0.681	0.501

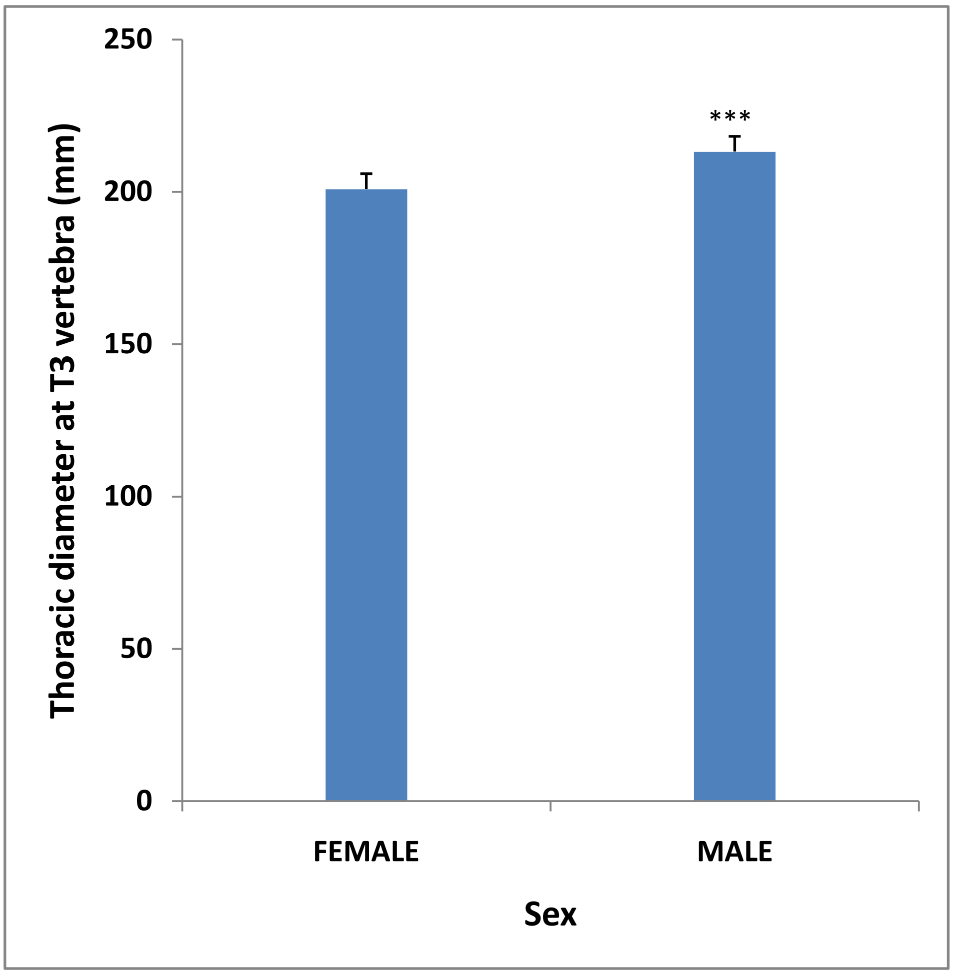


Fig. 4.9: Comparison of thoracic diameter at the level of third thoracic vertebra, the significant difference was observed between males and females (t = 213.16 mm – 200.90 mm, ***P<0.001).

Table 4.11: Comparison of the thoracic diameter at the level of third thoracic vertebra (D- T3) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	212.67 ± 22.30 (n = 9)	200.11 ± 8.33 (n = 9)	1.582	0.133
20 - 29	215.63 ± 16.22 (n = 54)	202.93 ± 17.47 (n = 70)	4.141	<0.001
30 - 39	212.66 ± 15.27 (n = 47)	200.89 ± 15.21 (n = 57)	3.918	<0.001
40 - 49	211.68 ± 18.28 (n = 47)	198.84 ± 15.32 (n = 44)	3.620	<0.001
50 - 59	215.28 ± 16.34 (n = 43)	200.29 ± 16.56 (n = 38)	4.094	<0.001
60 -69	213.50 ± 21.29 (n = 26)	200.35 ± 15.79 (n = 23)	2.429	<0.05
≥ 70	207.46 ± 17.50 (n = 24)	199.89 ± 11.29 (n = 9)	1.201	0.239

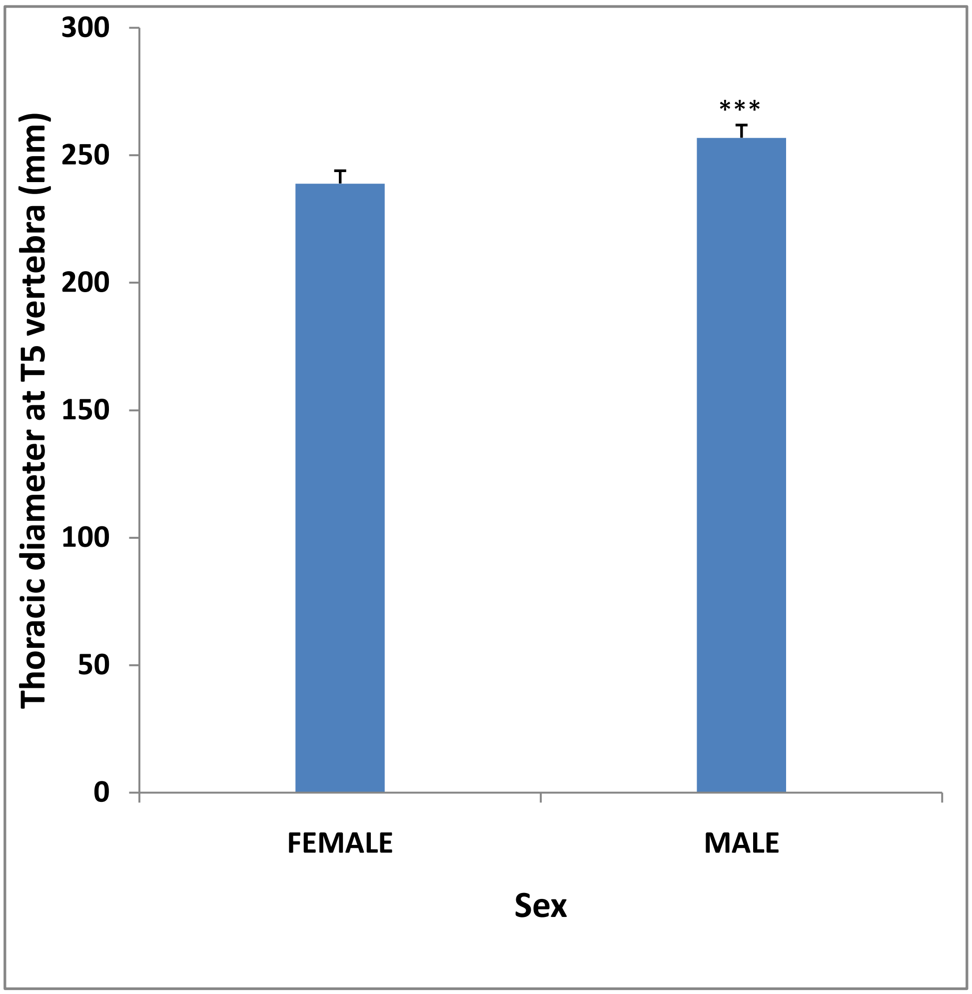


Fig. 4.10: Comparison of thoracic diameter at the level of fifth thoracic vertebra, the significant difference was observed between males and females (t = 256.81 mm – 238.88 mm, ***P<0.001).

Table 4.12: Comparison of the thoracic diameter at the level of fifth thoracic vertebra (D- T5) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	254.33 ± 18.32 (n = 9)	236.44 ± 7.25 (n = 9)	2.724	<0.05
20 - 29	257.61 ± 14.61 (n = 54)	240.99 ± 15.38 (n = 70)	6.098	<0.001
30 - 39	256.49 ± 13.56 (n = 47)	239.53 ± 14.41 (n = 57)	6.136	<0.001
40 - 49	258.70 ± 17.88 (n = 47)	237.91 ± 15.29 (n = 44)	5.941	<0.001
50 - 59	259.12 ± 14.84 (n = 43)	237.66 ± 13.76 (n = 38)	6.866	<0.001
60 -69	254.23 ± 18.61 (n = 26)	236.87 ± 14.68 (n = 23)	3.592	<0.001
≥ 70	251.50 ± 16.28 (n = 24)	236.00 ± 8.06 (n = 9)	2.715	<0.05

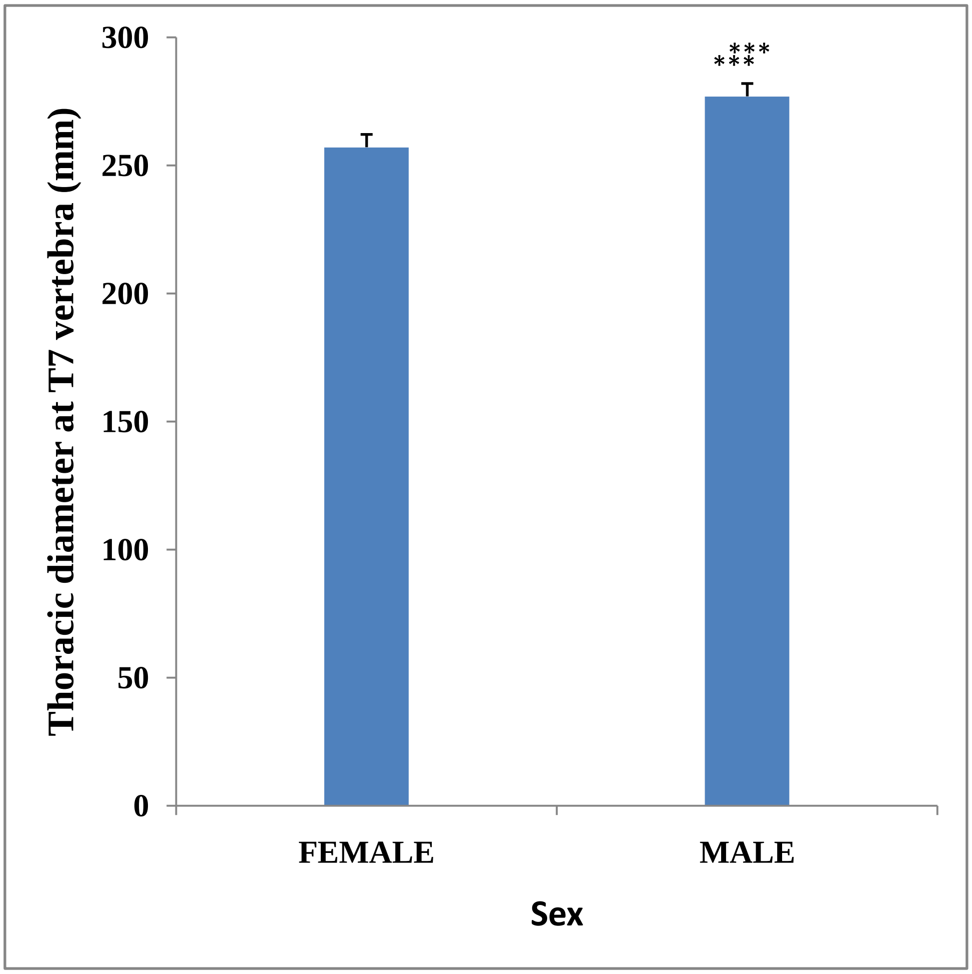


Fig. 4.11: Comparison of thoracic diameter at the level of seventh thoracic vertebra, the significant difference was observed between males and females (t = 276.93 mm – 257.06 mm, ***P<0.001).

Table 4.13: Comparison of the thoracic diameter at the level of seventh thoracic vertebra (D- T7) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	281.89 ± 18.44 (n = 9)	253.00 ± 5.58 (n = 9)	4.491	<0.001
20 – 29	276.56 ± 14.54 (n = 54)	258.60 ± 16.12 (n = 70)	6.416	<0.001
30 – 39	276.57 ± 12.79 (n = 47)	258.35 ± 16.09 (n = 57)	6.295	<0.001
40 – 49	281.19 ± 17.32 (n = 47)	256.84 ± 15.77 (n = 44)	6.998	<0.001
50 – 59	275.88 ± 14.2 (n = 43)	256.29 ± 13.93 (n = 38)	4.862	<0.001
60 -69	274.35± 16.08 (n = 26)	254.65 ± 17.03 (n = 23)	4.163	<0.001
≥ 70	272.96 ± 17.28 (n = 24)	251.56 ± 6.62 (n = 9)	3.589	<0.005

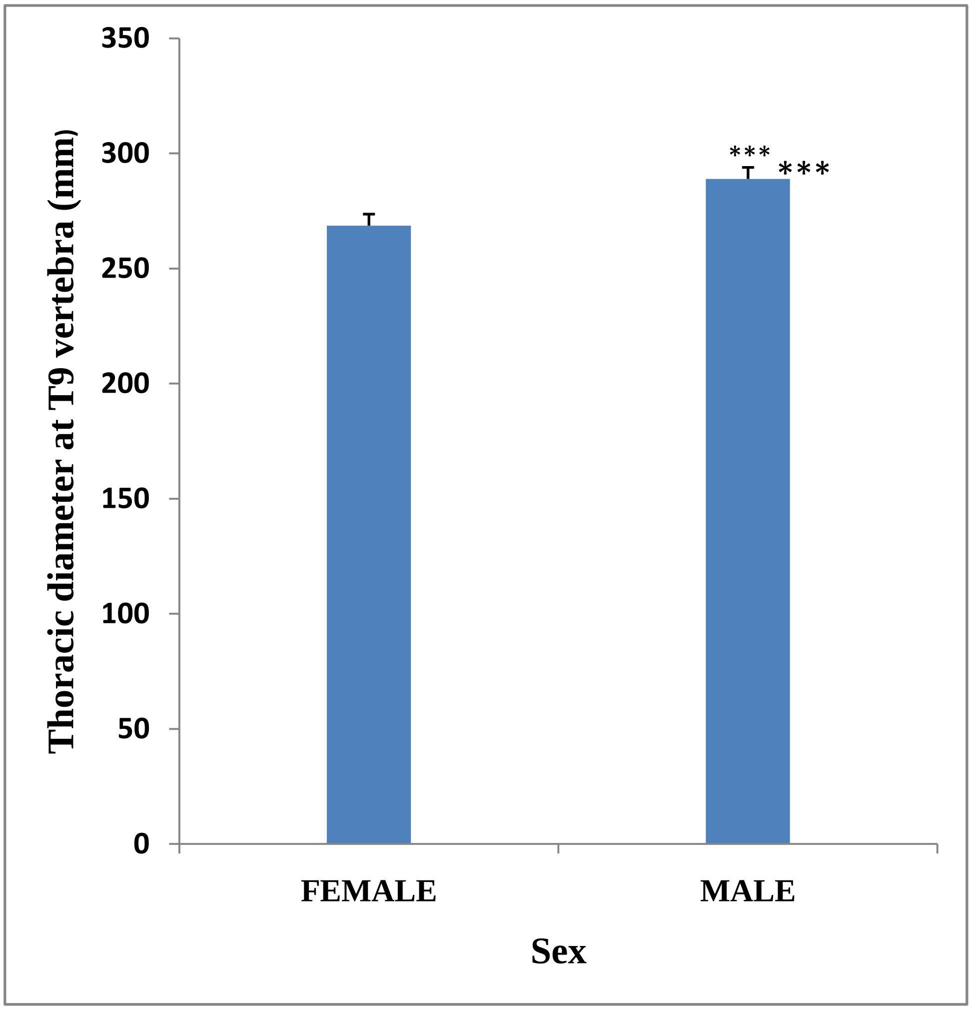


Fig 4.12: Comparison of the thoracic diameter at the level of nineth thoracic vertebra, the significant difference was observed between males and females (t = 288.94 mm – 268.65 mm, ***P<0.001).

Table 4.14: Comparison of the thoracic diameter at the level of ninth thoracic vertebra (D- T9) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	303.67 ± 40.22 (n = 9)	265.00 ± 5.17 (n = 9)	2.861	<0.05
20 – 29	284.65 ± 16.10 (n = 54)	269.93 ± 20.19 (n = 70)	4.387	<0.001
30 – 39	287.92 ± 14.03 (n = 47)	269.77 ± 21.32 (n = 57)	5.007	<0.001
40 – 49	295.00 ± 18.53 (n = 47)	269.68 ± 16.44 (n = 44)	6.876	<0.001
50 – 59	288.86 ± 21.10 (n = 43)	256.29 ± 13.93 (n = 38)	5.540	<0.001
60 -69	285.19 ± 17.88 (n = 26)	265.96 ± 21.76 (n = 23)	3.395	<0.005
≥ 70	287.46 ± 27.58 (n = 24)	263.00 ± 11.53 (n = 9)	2.557	<0.05

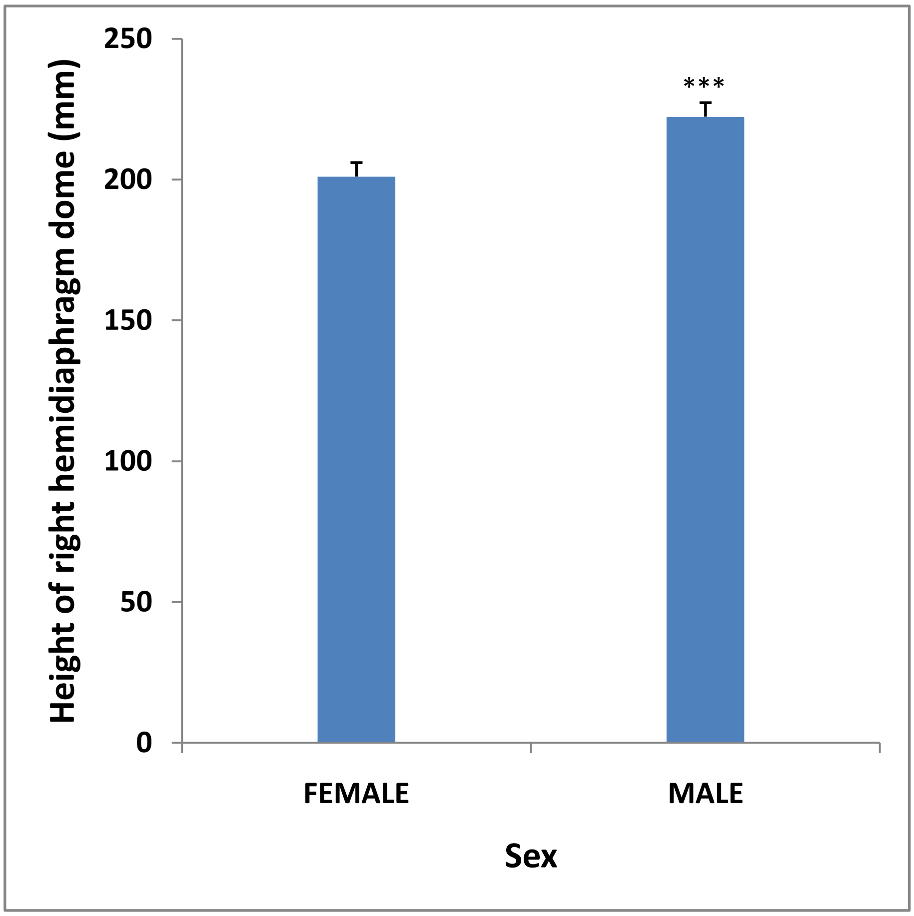


Fig. 4.13: Comparison of the height of right hemidiaphragm dome, the significant difference was observed between males and females (t = 222.34 mm – 201.07 mm, ***P<0.001).

Table 4.15: Comparison of the height of right hemidiaphragm dome (HRHD) between males and females baesd on age groups

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	220.11 ± 6.31 (n = 9)	192.11 ± 14.94 (n = 9)	5.180	<0.001
20 – 29	224.87 ± 20.45 (n = 54)	198.50 ± 16.60 (n = 70)	7.923	<0.001
30 – 39	221.191 ± 19.84 (n = 47)	201.81 ± 19.89 (n = 57)	4.953	<0.001
40 – 49	222.49 ± 19.09 (n = 47)	204.50 ± 18.92 (n = 44)	4.511	<0.001
50 – 59	222.00 ± 22.93 (n = 43)	197.39 ± 14.70 (n = 38)	5.665	<0.001
60 -69	223.73 ± 16.95 (n = 26)	206.74 ± 17.92 (n = 23)	3.409	<0.005
≥ 70	218.54 ± 27.88 (n = 24)	209.67 ± 12.40 (n = 9)	0.915	0.367

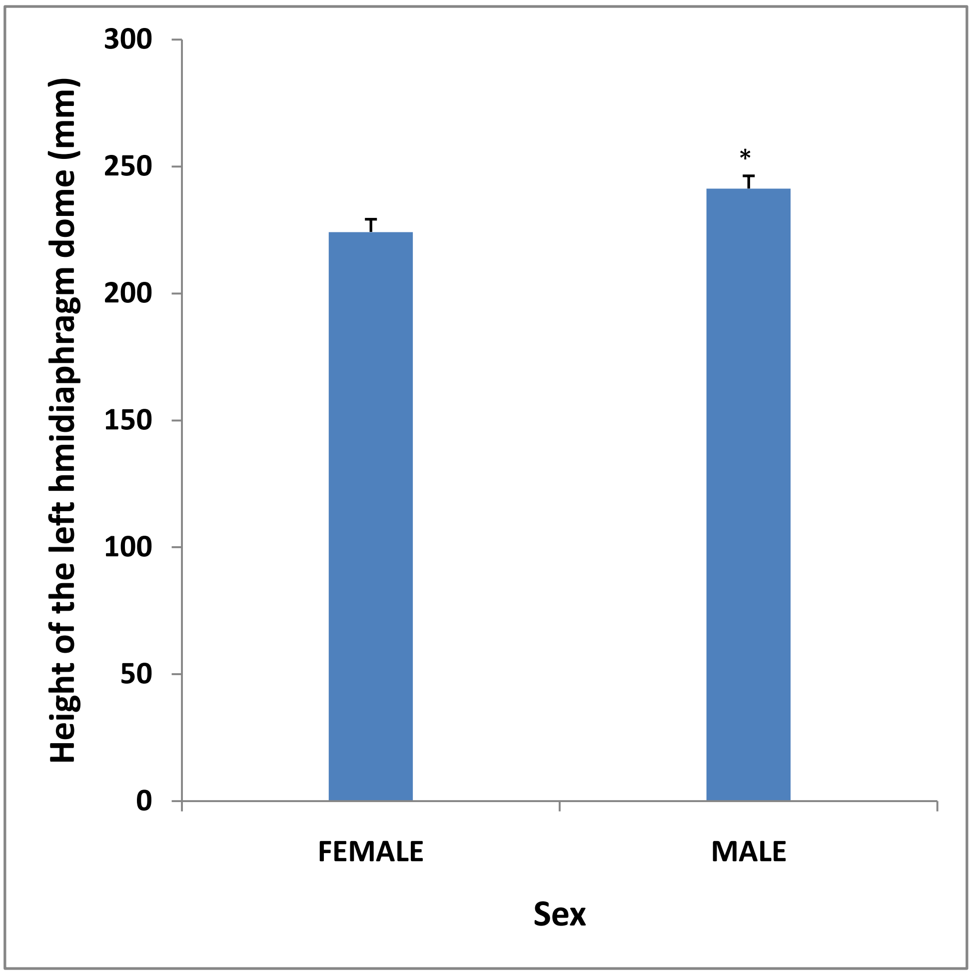


Fig. 4.14: Comparison of height of left hemidiaphragm dome, the significant difference was observed between males and females (t = 241.23 mm – 224.14 mm, *P<0.05).

Table 4.16: Comparison of the height of leftt hemidiaphragm dome (HLHD) between males and females baesd on age groups

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	235.67 ± 10.20 (n = 9)	211.78 ± 11.37 (n = 9)	4.693	<0.001
20 – 29	243.61 ± 18.99 (n = 54)	213.87 ± 16.77 (n = 70)	9.240	<0.001
30 – 39	242.34 ± 18.28 (n = 47)	217. 35 ± 16.34 (n = 57)	7.355	<0.001
40 – 49	241.13 ± 20.46 (n = 47)	217.59 ± 16.99 (n = 44)	5.949	<0.001
50 – 59	242.16± 22.44 (n = 43)	218.13 ± 17.69 (n = 38)	5.837	<0.001
60 -69	236.89 ± 15.87 (n = 26)	223.74 ± 16.49 (n = 23)	2.842	<0.05
≥ 70	239.00 ± 26.95 (n = 24)	222.89 ± 8.98 (n = 9)	1.742	0.091

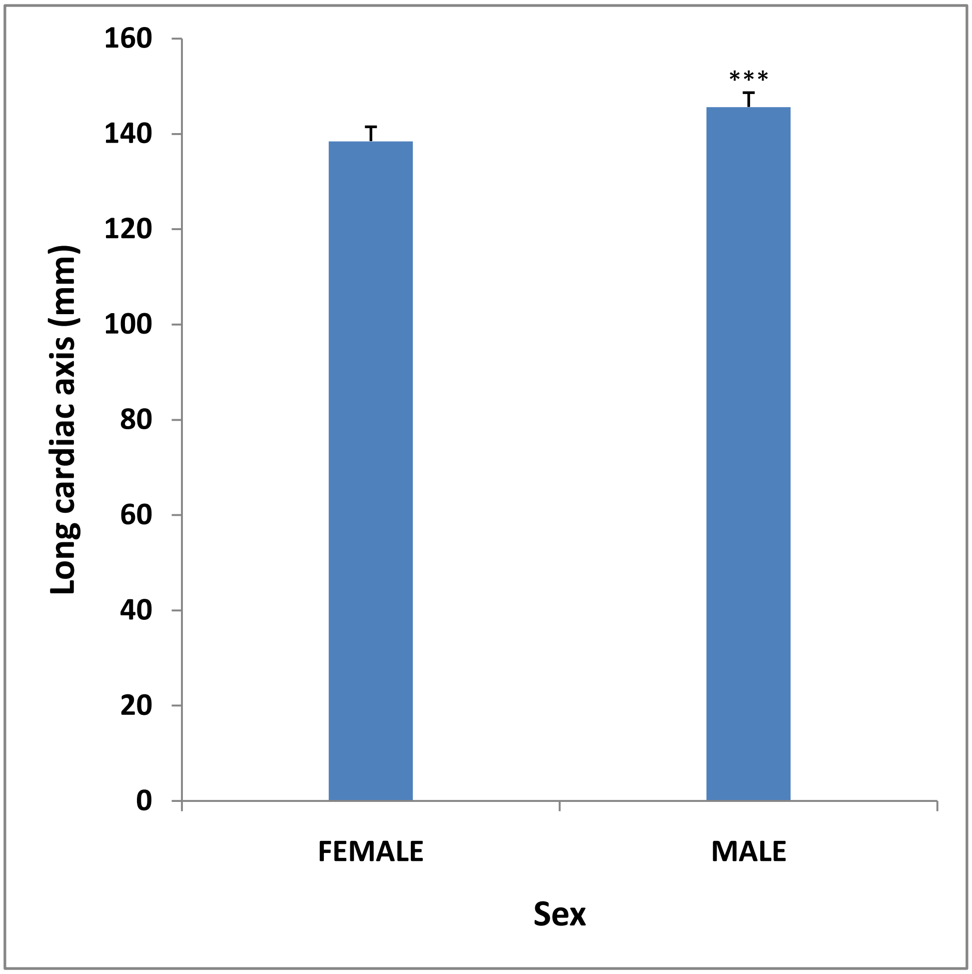


Fig. 4.15: Comparison of length of long cardiac axis, the significant difference was observed between males and females (t = 145.61 mm – 138.44 mm, ***P<0.001).

Table 4.17: Comparison of the length of long cardiac axis (LCA) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	144.56 ± 6.06 (n = 9)	137.44 ± 7.11 (n = 9)	2.283	<0.05
20 – 29	142.46 ± 8.61 (n = 54)	136.36 ± 8.86 (n = 70)	3.853	<0.001
30 – 39	144.96 ± 6.88 (n = 47)	139.72 ± 7.92 (n = 57)	3.562	<0.001
40 – 49	146.87 ± 6.85 (n = 47)	138.91 ± 6.41 (n = 44)	5.719	<0.001
50 – 59	147.77 ± 7.05 (n = 43)	139.18 ± 6.20 (n = 38)	5.782	<0.001
60 -69	147.08 ± 5.18 (n = 26)	137.65 ± 7.84 (n = 23)	5.018	<0.001
≥ 70	146.42 ± 5.34 (n = 24)	140.78 ± 10.93 (n = 9)	2.001	0.05

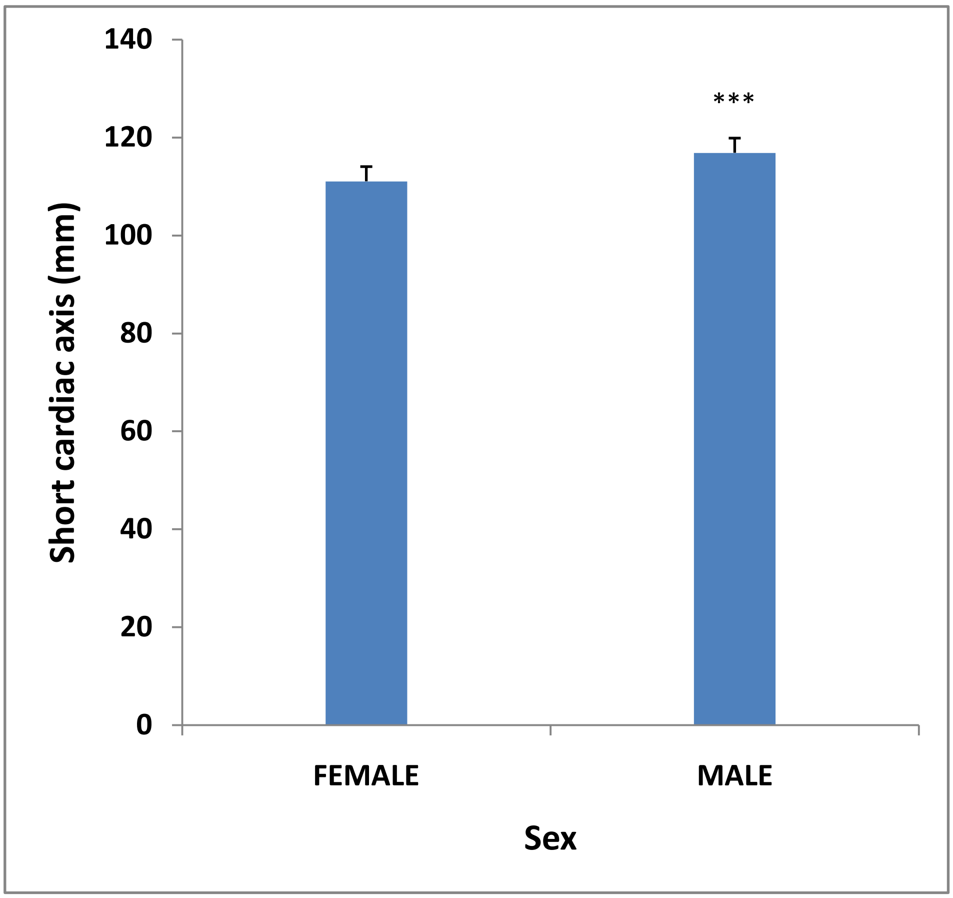


Fig. 4.16: Comparison of length of short cadiac axis, the significant difference was observed between males and females (t = 116.84 mm – 111.02 mm, ***P<0.001).

Table 4.18: Comparison of the length of the short cardiac axis(SCA) between males and females based on age groups.

AGE GROUPS	MALES (MEAN ± SD) (mm)	FEMALES (MEAN ±SD) (mm)	t – Value	p – Value
< 20	144.56 ± 6.06 (n = 9)	137.44 ± 7.11 (n = 9)	2.283	<0.05
20 - 29	142.46 ± 8.61 (n = 54)	136.36 ± 8.86 (n = 70)	3.853	<0.001
30 - 39	144.96 ± 6.88 (n = 47)	139.72 ± 7.92 (n = 57)	3.562	<0.001
40 - 49	146.87 ± 6.85 (n = 47)	138.91 ± 6.41 (n = 44)	5.719	<0.001
50 - 59	147.77 ± 7.05 (n = 43)	139.18 ± 6.20 (n = 38)	5.782	<0.001
60 -69	147.08 ± 5.18 (n = 26)	137.65 ± 7.84 (n = 23)	5.018	<0.001
≥ 70	146.42 ± 5.34 (n = 24)	140.78 ± 10.93 (n = 9)	2.001	0.05

4.3 Study of paired parameters in males and females.

Figure 4.17 shows the graphical representation of paired t-test between the length of right and left clavicles in males and females (LRC and LLC) in which the left are significantly greater in length than right in both males and females with P value <0.001, whereas the paired t-test for the mid-clavicula thickness between right and left clavicles (TRC and TLC) shows the right clavicles are greater in thickness in both males and females with highly significance where the P value are < 0.001 and are represented in Figure 4.18.

Figure 4.19 and 4.20 depicts the paired t-tests for Height and width between right and left (HRS and HLS) and (WRS and WLS) scapula in males and female which shows that the left are greater than right scapulae in both males and females with high significant with P value <0.001 in both height and width.

The paired t-test between height of right and left hemidiaphragm dome (HRHD and HLHD) for males and females are repesented in Figure 4.21 among which left hemidiaphragm dome are significantly greater than right hemidiaphragm dome with P value >0.001 in both males and females.

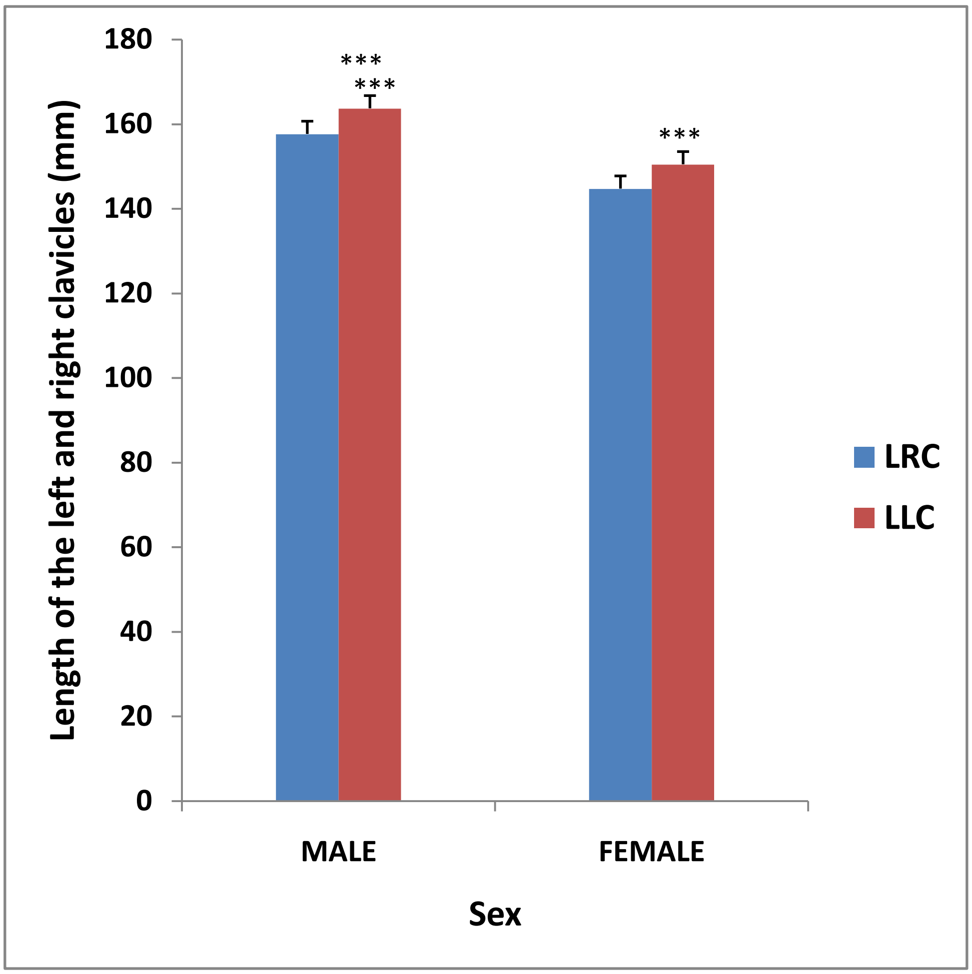


Fig. 4.17: Comparison between length of right and left clavicle, the significant difference was observed for males and females (t = 163.70 mm – 157.65 mm, 150.47 mm – 144.75 mm, ***P<0.001).

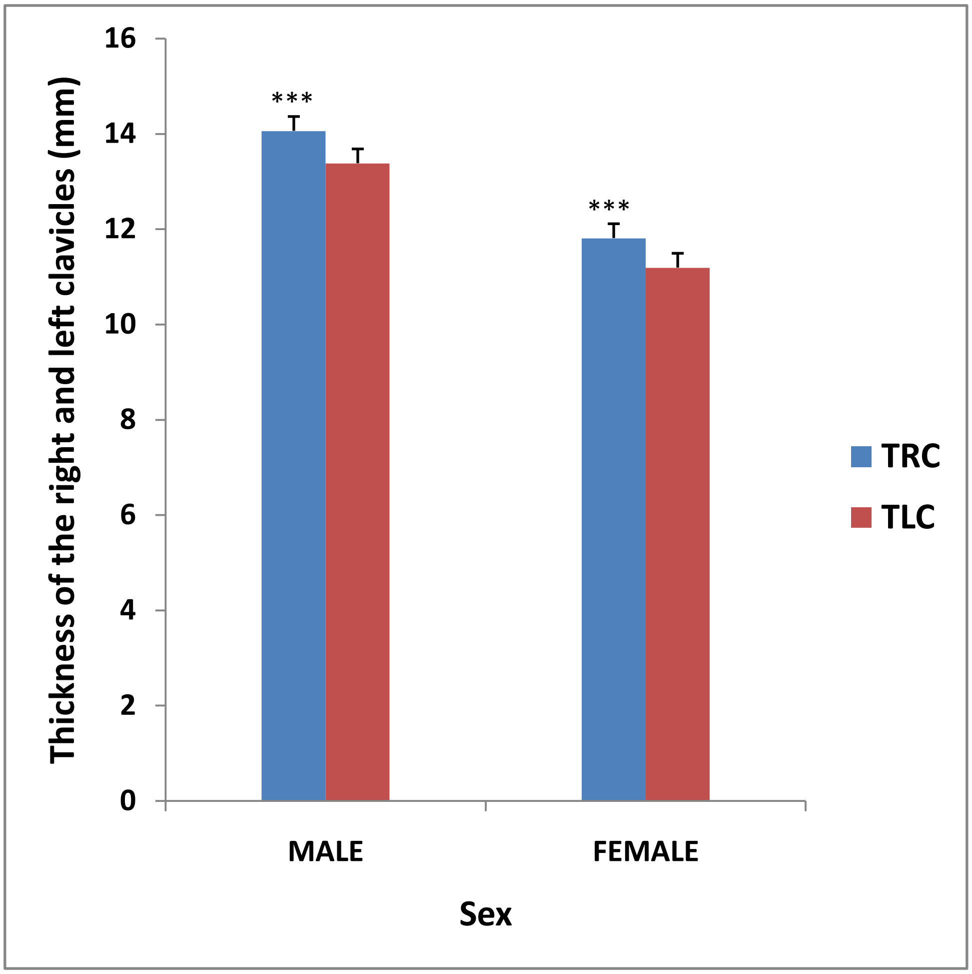


Fig. 4.18: Comparison of the mid - thickness between right and left clavicles, the significant difference was observed for males and females (t = 13.38 mm – 14.06 mm, 11.19 mm – 11.81 mm, ***P<0.001).

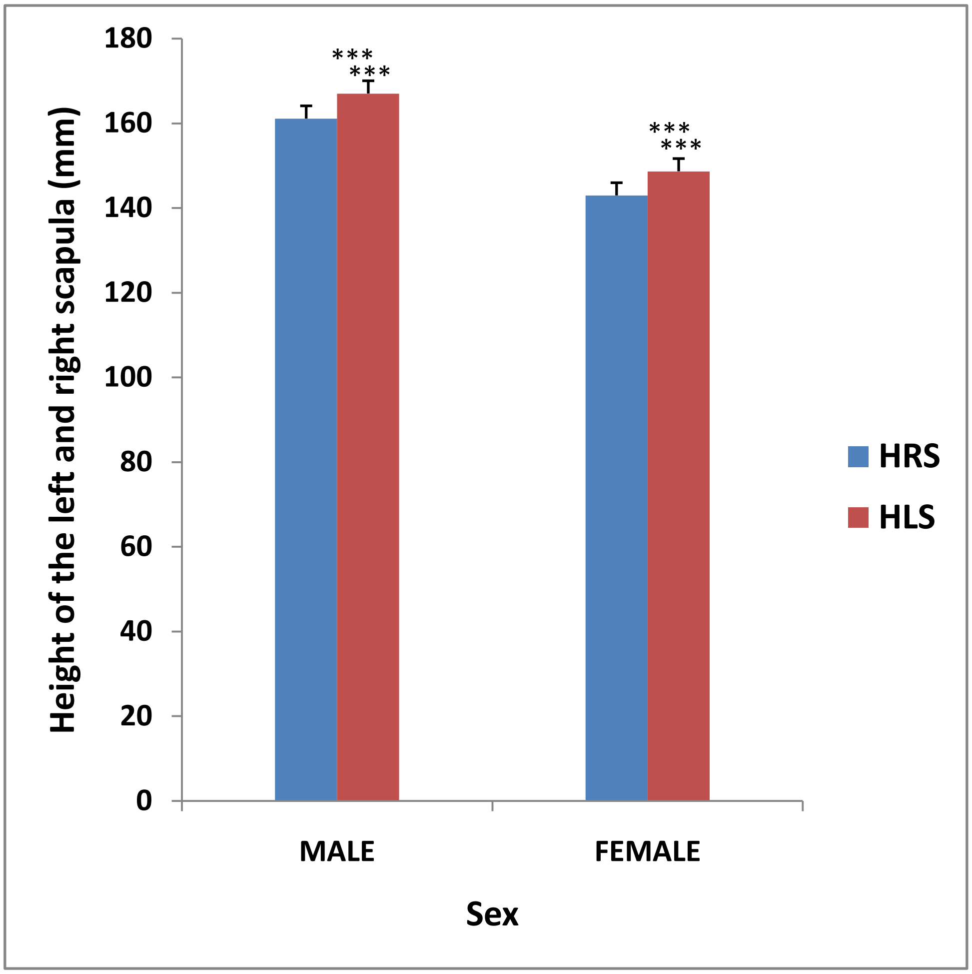


Fig. 4.19: Comparison of the height between left and right scapula, the significant difference was observed for males and females (t = 166.99 mm – 161.07 mm, 148.62 mm – 142.92 mm, ***P<0.001).

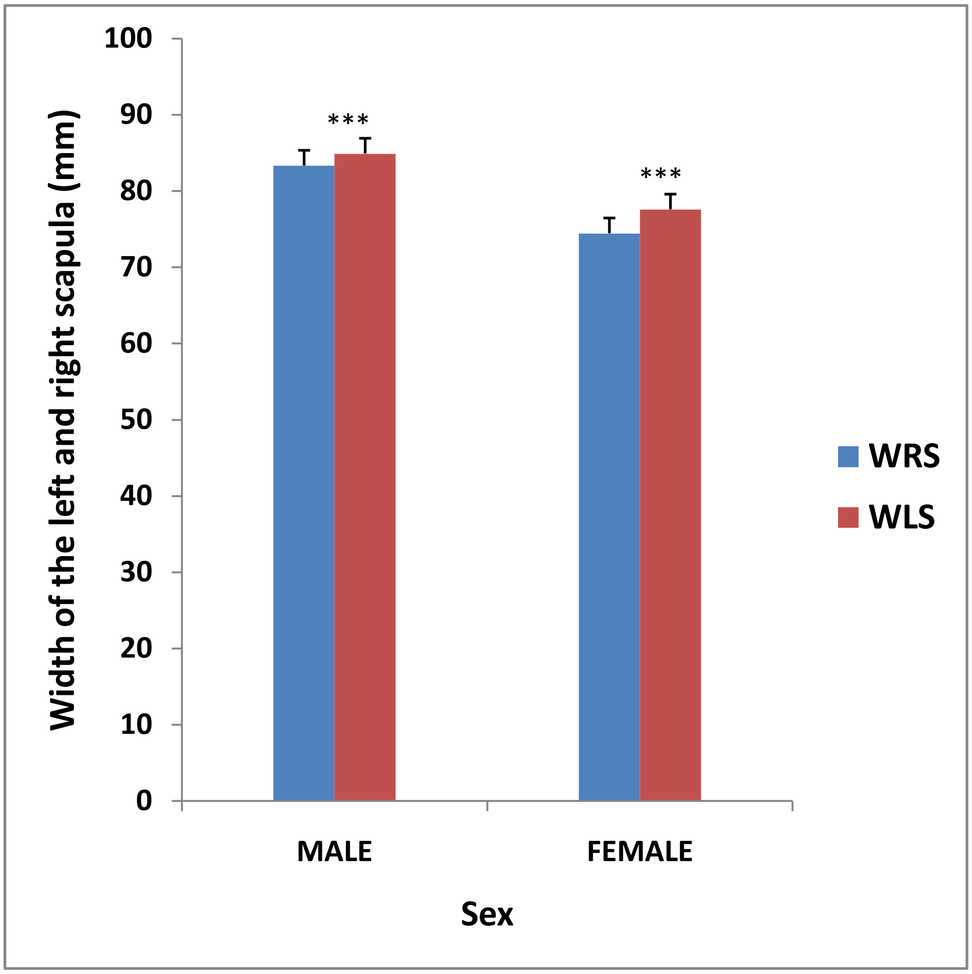


Fig. 4.20: Comparison of the width between left and right scapula, the significant difference was observed for males and females (t = 84.89 mm – 83.32 mm, 77.57 mm – 74.44 mm, ***P<0.001).

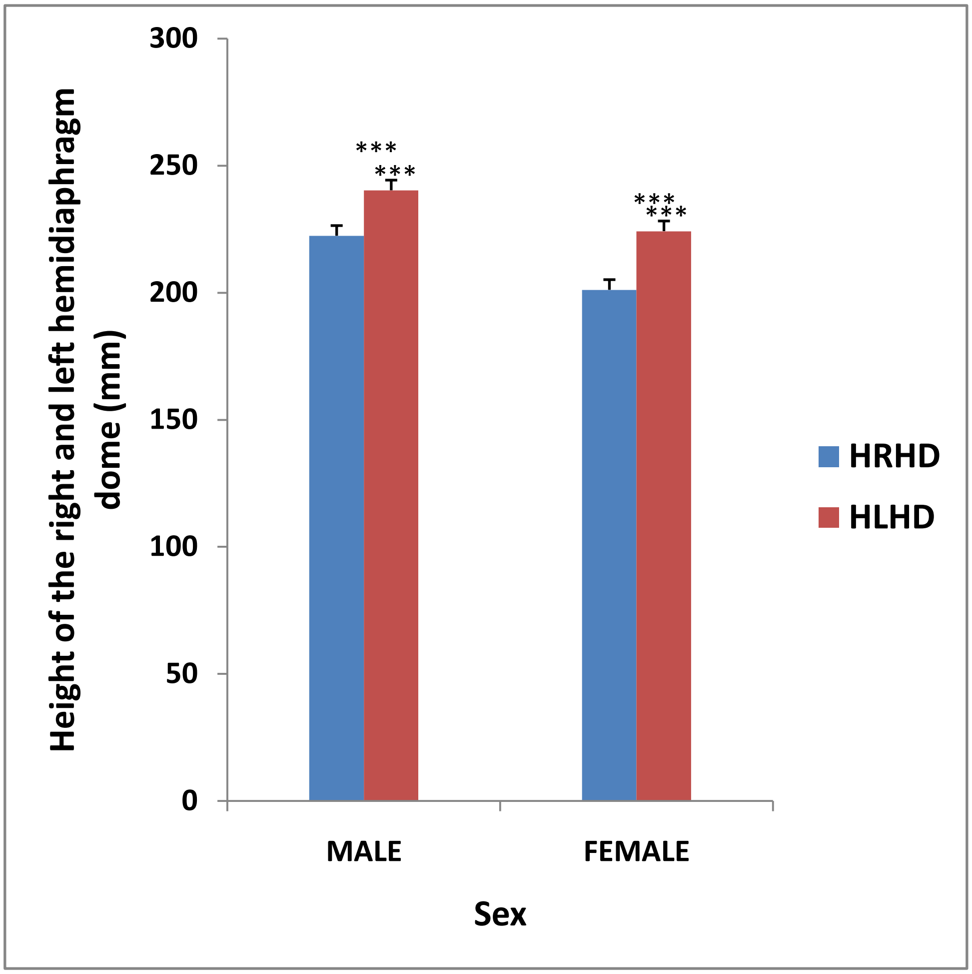


Fig. 4.21: Comparison of the height between left and right hemi- diaphragm dome, the significant difference was observed for males and females (t = 241.23 mm – 222.34 mm, 224.14.47 mm – 201.07 mm, ***P<0.001).

Table 4.19 shows the correlation matrix for all the parameters in both males and females chest radiographs, in which almost all the variables are positively correlated with each other except height of left hemidiaphragm dome correlate wiyh only length of the right clavicle (LRC), length of left clavicle (LLC), width of right scapula (WRS), thoracic diameter at seventh thoracic vertebra (D- T7) and heigth of right hemidiaphragm dome (HRHD), and age which correlated to all but not with width of right scapula (WRS), all the thoracic diameters (D- T3, D- T5, D- T7, D- T9) and height of left hemidiaphragm dome (HLHD). signifying all the varibles play an important in sex determination.

Table 4.20 shows the correlation matrix for all the parameters in males chest radiographs, in which all the variable were positively correlated except height of left and right hemidiaphragm domes HLHD and HRHD), where right hemidiaphragm dome was correlated with legnth of left and right clavicles (LLC and LRC), width of left and right scapula (WLS and WRS) and age which correlated only with thickness of left clavicle (TLC), long and short axis of cardiac ellipsiod (LCA and SCA). But in table 4.21 which is the correlation matrix for the all parameters in fameles, shows positive correlations between all the variables except height of left hemidiaphragm dome which was correlated with only length of left and right clavicles, and age which was correlated with height of right hemidiaphragm dome, long and short axis of cardiac ellipsiod.

Table 4.22 shows the chi- square for all the variables which shows the significance for the variable.

Table 4.19: Correlation matrix of all the parameters in males and females (n=500) chest radiographs of Gombe adults.

Variables	AGE	LRC	TRC	LLC	TLC	HRS	WRS	HLS	WLS	D-T3	D-T5	D-T7	D-T9	HRHD	HLHD	LCA	SCA
AGE	-																
LRC	0.12[a]	-															
TRC	0.17[c]	0.52[c]	-														
LLC	0.09[a]	0.89[c]	0.54[c]	-													
TLC	0.16[c]	0.52[c]	0.92[c]	0.48[c]	-												
HRS	0.16[c]	0.47[c]	0.52[c]	0.50[c]	0.50[c]	-											
WRS	0.08	0.36[c]	0.30[c]	0.36[c]	0.28[c]	0.35[c]	-										
HLS	0.17[c]	0.47[c]	0.53[c]	0.51[c]	0.50[c]	0.88[c]	0.37[c]	-									
WLS	0.10[a]	0.37[c]	0.35[c]	0.41[c]	0.32[c]	0.40[c]	0.72[c]	0.44[c]	-								
D-T3	-0.02	0.45[c]	0.37[c]	0.48[c]	0.36[c]	0.38[c]	0.21[c]	0.45[c]	0.23[c]	-							
D-T5	-0.02	0.60[c]	0.56	0.63[c]	0.54[c]	0.49[c]	0.27[c]	0.55[c]	0.30[c]	0.87[c]	-						
D-T7	0.04	0.58[c]	0.59[c]	0.60[c]	0.59[c]	0.45[c]	0.24[c]	0.51[c]	0.28[c]	0.72[c]	0.91[c]	-					
D-T9	0.03	0.47[c]	0.54[c]	0.50[c]	0.53[c]	0.39[c]	0.19[c]	0.45[c]	0.24[c]	0.60[c]	0.76[c]	0.83[c]	-				
HRHD	0.09[a]	0.42[c]	0.36[c]	0.43[c]	0.34[c]	0.36[c]	0.30[c]	0.37[c]	0.29[c]	0.19[c]	0.33[c]	0.36[c]	0.27[c]	-			
HLHD	0.06	0.15[c]	0.08	0.15[c]	0.06	0.07	0.09[a]	0.06	0.05	0.05	0.08	0.09[a]	0.06	0.21[c]	-		
LCA	0.22[c]	0.39[c]	0.46[c]	0.32[c]	0.48[c]	0.31[c]	0.14[c]	0.32[c]	0.15[c]	0.36[c]	0.44[c]	0.51[c]	0.46[c]	0.36[c]	0.09[a]	-	
SCA	0.20[c]	0.30[c]	0.36[c]	0.27[c]	0.37[c]	0.29[c]	0.10[a]	0.30[c]	0.15[c]	0.29[c]	0.36[c]	0.38[c]	0.35[c]	0.36[c]	0.06	0.57[c]	-

LRC= Length of right clavicle; TRC= Thickness of the right clavicles LLC=length of left clavicle; TLC= Thickness of left clavicle; HRS= Height of right scapula; WRS= width of right scapula; HLS= Height of left scapula; WLS= Width of left scapula; D-T3= Thoracic diameter at level third thoracic vertebra; D- T5= Thoracic diameter at level fifth thoracic vertebra; D- T7= Thoracic diameter at level of seventh thoracic vertebra; D- T9= Thoracic diameter at level of ninth thoracic vertebra; HRHD= Height of the right hemidiaphragm dome; HLHD= Height of lefthemidiaphragm dome; LCA= long cardiac axis; SCA= short cardiac axis. [a]P<0.05, [b]P<0.01, [c]P<0.001

Table 4.20: Correlation matrix of all the parameters in males (n=250) chest radiographs of Gombe adults.

Variables	AGE	LRC	TRC	LLC	TLC	HRS	WRS	HLS	WLS	D-T3	D-T5	D-T7	D-T9	HRHD	HLHD	LCA	SCA
AGE	-																
LRC	0.01	-															
TRC	0.12	0.23^{c}	-														
LLC	-0.03	0.82^{c}	0.26^{c}	-													
TLC	0.15^{a}	0.26^{c}	0.93^{c}	0.19^{c}	-												
HRS	0.11	0.22^{c}	0.28^{c}	0.23^{c}	0.24^{c}	-											
WRS	0.07	0.15^{a}	0.08	0.17^{a}	0.03	0.16^{a}	-										
HLS	0.11	0.22^{c}	0.25^{c}	0.27^{c}	0.23^{c}	0.82^{c}	0.17^{a}	-									
WLS	0.09	0.19^{c}	0.13^{a}	0.23^{c}	0.09	0.22^{c}	0.78^{c}	0.23^{c}	-								
D-T3	-0.08	0.31^{c}	0.27^{c}	0.38^{c}	0.25^{c}	0.24^{c}	0.04	0.34^{c}	0.05	-							
D-T5	-0.07	0.45^{c}	0.37^{c}	0.53^{c}	0.35^{c}	0.29^{c}	0.05	0.38^{c}	0.08	0.88^{c}	-						
D-T7	-0.07	0.43^{c}	0.37^{c}	0.47^{c}	0.38^{c}	0.21^{c}	0.02	0.27^{c}	0.04	0.68^{c}	0.85^{c}	-					
D-T9	-0.01	0.32^{c}	0.35^{c}	0.37^{c}	0.35^{c}	0.16^{a}	-0.05	0.23^{c}	-0.02	0.53^{c}	0.68^{c}	0.74^{c}	-				
HRHD	-0.05	0.19^{c}	-0.03	0.22^{c}	-0.02	0.05	0.1^{a}	0.05	0.15^{a}	-0.02	0.07	0.09	-0.02	-			
HLHD	-0.06	0.22^{c}	0.01	0.28^{c}	-0.04	0.09	0.09	0.05	0.13^{a}	-0.08	0.11	0.11	0.03	0.89^{c}	-		
LCA	0.23^{c}	0.25^{c}	0.32^{c}	0.16^{a}	0.39^{c}	0.12	-0.09	0.11	-0.04	0.24^{c}	0.30^{c}	0.37^{c}	0.35^{c}	0.14^{a}	0.21^{c}	-	
SCA	0.14^{a}	0.09	0.17^{a}	0.06	0.22^{c}	0.06	-0.12^{a}	0.05	-0.06	0.15^{a}	0.18^{c}	0.18^{c}	0.19^{c}	0.20^{c}	0.24^{c}	0.47^{c}	-

LRC= Length of right clavicle; TRC= Thickness of the right clavicles LLC=length of left clavicle; TLC= Thickness of left clavicle; HRS= Height of right scapula; WRS= width of right scapula; HLS= Height of left scapula; WLS= Width of left scapula; D-T3= Thoracic diameter at level third thoracic vertebra; D- T5= Thoracic diameter at level fifth thoracic vertebra; D- T7= Thoracic diameter at level of seventh thoracic vertebra; D- T9= Thoracic diameter at level of ninth thoracic vertebra; HRHD= Height of the right hemidiaphragm dome; HLHD= Height of left hemidiaphragm dome; LCA= long cardiac axis; SCA= short cardiac axis. $^{a}P<0.05$, $^{b}P<0.01$, $^{c}P<0.001$.

Table 4.21: Correlation matrix of all the parameters in females (n=250) chest radiographs of Gombe adults.

Variables	AGE	LRC	TRC	LLC	TLC	HRS	WRS	HLS	WLS	D-T3	D-T5	D-T7	D-T9	HRHD	HLHD	LCA	SCA
AGE	-																
LRC	0.12	-															
TRC	0.10	0.17[a]	-														
LLC	0.09	0.85[c]	0.22[c]	-													
TLC	0.03	0.18[c]	0.74[c]	0.13[a]	-												
HRS	0.09	0.24[c]	0.14[a]	0.33[c]	0.18[a]	-											
WRS	-0.00	0.18[c]	-0.03	0.19[c]	0.02	0.19[c]	-										
HLS	0.12	0.22[c]	0.21[c]	0.31[c]	0.18[c]	0.83[c]	0.21[c]	-									
WLS	0.03	0.18[c]	0.08	0.26[c]	0.08	0.25[c]	0.56[c]	0.34[c]	-								
D-T3	-0.07	0.33[c]	0.08	0.33[c]	0.09	0.24[c]	0.13[a]	0.33[c]	0.18[c]	-							
D-T5	-0.09	0.40[c]	0.28[c]	0.41[c]	0.27[c]	0.28[c]	0.11[c]	0.35[c]	0.18[c]	0.83[c]	-						
D-T7	-0.09	0.37[c]	0.38[c]	0.37[c]	0.37[c]	0.25[c]	0.04[a]	0.33[c]	0.15[a]	0.66[c]	0.90[c]	-					
D-T9	-0.07	0.24[c]	0.32[c]	0.26[c]	0.33[c]	0.23[c]	0.04[a]	0.28[c]	0.15[a]	0.52[c]	0.70[c]	0.82[c]	-				
HRHD	0.14[a]	0.22[c]	0.09	0.20[c]	0.10	0.26[c]	0.14[a]	0.24[c]	0.08	0.09	0.15[a]	0.19[c]	0.13[a]	-			
HLHD	0.09	0.13[a]	0.03	0.13[a]	0.01	0.01	0.06	0.01	-0.01	0.02	0.04	0.04	0.02	0.12	-		
LCA	0.14[a]	0.14[a]	0.21[c]	0.05	0.19[c]	0.08	0.07	0.12[a]	-0.01	0.26[c]	0.28[c]	0.38[c]	0.32[c]	0.27[c]	0.04	-	
SCA	0.19[c]	0.19[c]	0.18[c]	0.14[a]	0.16[a]	0.23[c]	0.03	0.25[c]	0.11	0.25[c]	0.29[c]	0.34[c]	0.27[c]	0.29[c]	-0.06	0.55[c]	-

LRC= Length of right clavicle; TRC= Thickness of the right clavicles LLC=length of left clavicle; TLC= Thickness of left clavicle; HRS= Height of right scapula; WRS= width of right scapula; HLS= Height of left scapula; WLS= Width of left scapula; D-T3= Thoracic diameter at level third thoracic vertebra; D- T5= Thoracic diameter at level fifth thoracic vertebra; D- T7= Thoracic diameter at level of seventh thoracic vertebra; D- T9= Thoracic diameter at level of ninth thoracic vertebra; HRHD= Height of the right hemidiaphragm dome; HLHD= Height of left hemidiaphragm dome; LCA= long cardiac axis; SCA= short cardiac axis. [a]P<0.05, [b]P<0.01, [c]P<0.001.

Table 4.22: Chi- square for the association between shape of C7/T1 and T1/T2 Intervertebral disc and

Variables	MALES (n=250)		FEMALES (n=250)		DF	P-VALUE
	C	P	C	P		
S-C7/T1	250 (50%)	0 (0%)	60 (12%)	190 (38%)	2	<0.001
S-T1/T2	211 (42%)	39 (8%)	19 (4%)	228 (46%)	2	<0.001

Key:-
S- C7/T1= Shape of seven cervical and first thoracic intervetebral disc, S- T1/T2= Shape of first and second thoracic intervertebral disc, C= curved, P= parallel, chi- square= 306.45, Degree of freedom (DF) = 2, P<0.001 for C7/T1, chi-square= 297.07, Degree of freedom (DF) = 2, P<0.001 for T1-/T2.

Table 4.18 show the regression analysis for the all parameters in males, in which the probabilily for all the parameters is $p < 0.001$ in all cases.

Table 4.19 show the regression analysis for the all parameters in females, in which the probability for predicting all the parameters is $p < 0.001$.

Table 4. 23: Regression analysis for all the parameters in males (n = 250).

Variables	Regression formula	R	R^2	SEE	P – value
LRC	= 30.015 + (0.780 x LLC)	0.815	0.665	5.835	<0.001
TRC	= 2.038 + (0.899 x TLC)	0.926	0.857	0.523	<0.001
HRS	= 16.010 + (0.869 x HLS)	0.819	0.671	8.772	<0.001
WRS	= 13.014 + (0.828 x WRS)	0.779	0.607	5.945	<0.001
D- T3	= -21.062 + (1.192 x D –T5) – (0.210 x D-T7) – (0.048 x D-T9)	0.884	0.782	8.149	<0.001
D- T5	= 22.589 + (0.500 x D-T3) + (0.398 x D-T7) + (0.0600 x D-T9)	0.943	0.889	5.278	<0.001
D- T7	= 9.792 - (0.244 x D-T3) + (0.930 x D-T5) + (0.276 x D-T9)	0.951	0.905	4.746	<0.001
D- T9	= 14.266 + (0.192 x D-T3) - (0.592 x D-T5) + (1.390 x D-T7)	0.830	0.689	10.644	<0.001
HRHD	= 3.112 + (0.909 x HLHD)	0.886	0.784	9.577	<0.001
LCA	= 100.340 + (0.387 x SCA)	0.472	0.222	6.354	<0.001

LRC= Length of right clavicle; TRC= Thickness of the right clavicles LLC=length of left clavicle; TLC= Thickness of left clavicle; HRS= Height of right scapula; WRS= width of right scapula; HLS= Height of left scapula; WLS= Width of left scapula; D-T3= Thoracic diameter at level third thoracic vertebra; D- T5= Thoracic diameter at level fifth thoracic vertebra; D- T7= Thoracic diameter at level of seventh thoracic vertebra; D- T9= Thoracic diameter at level of ninth thoracic vertebra; HRHD= Height of the right hemidiaphragm dome; HLHD= Height of lefthemidiaphragm dome; LCA= long cardiac axis; SCA= short cardiac axis.

Table 4.23: Regression analysis for all the parameters in females (n = 250).

Variables	Regression Formula	R	R2	SEE	p – value
LRC	= 19.736 + (0.831 x LLC)	0.852	0.727	4.378	<0.001
TRC	= 5.142 + (0.596 x TLC)	0.736	0.542	0.601	<0.001
HRS	= 27.817 + (0.774 x HLS)	0.827	0.685	6.689	<0.001
WRS	= 16.732 + (0.744 x WLS)	0.557	0.310	8.841	<0.001
D- T3	= -4.059 + (1.467 x D-T5) - (0.677 x D-T7) + (0.106 x D-T9)	0.867	0.751	7.904	<0.001
D-T5	= 10.984 + (0.384 x D-T3) + (0.675 x D-T7) - (0.0855 x D-T9)	0.960	0.922	4.046	<0.001
D-T7	= 9.792 - (0.244 x D-T3) + (0.930 x D-T5) + (0.276 x D-T9)	0.951	0.905	4.746	<0.001
D-T9	= 14.266 + (0.192 x D-T3) - (0.592 x D-T5) + (1.390 x D-T7)	0.830	0.689	10.644	<0.001
HRHD	= 7.193 + (0.0173 x HLHD)	0.118	0.014	17.643	<0.001
LCA	= 65.066 + (0.660 x SCA)	0.566	0.321	6.478	<0.001

LRC= Length of right clavicle; TRC= Thickness of the right clavicles LLC=length of left clavicle; TLC= Thickness of left clavicle; HRS= Height of right scapula; WRS= width of right scapula; HLS= Height of left scapula; WLS= Width of left scapula; D-T3= Thoracic diameter at level third thoracic vertebra; D- T5= Thoracic diameter at level fifth thoracic vertebra; D- T7= Thoracic diameter at level of seventh thoracic vertebra; D- T9= Thoracic diameter at level of ninth thoracic vertebra; HRHD= Height of the right hemidiaphragm dome; HLHD= Height of lefthemidiaphragm dome; LCA= long cardiac axis; SCA= short cardiac axis.

CHAPTER FIVE

5.0 DISCUSSION

5.1 SEX DETERMINATION USING ALL THE PARAMETERS

5.1.1 Sex difference in claviclar measurement

5.1.1.1 Length of clavicles

In the present study, it was discovered that the mean length of left clavicle (LLC) and length of right clavicles (LRC) in males were significantly higher than those of females left and right clavicles (LLC and LRC), which is the same in different age groups, this is because males have broader shoulder than females and the clavicles contribute to the breadth of the shoulder (Olivier, 1951; Shobha *et al*., 2011).

This result is in agreement with that of Patel *et al.* (2009) findings for the people of Gujarat, but their result for males mean length of left and right clavicles were 21.80 mm and 15.55 mm less than those of males of the present study and the female mean length of left and right clavicles were 23.59 mm and 18.82 mm less than those of females of the present study.

These result were supported by the result reported by Shobha *et al.* (2011) for the people of North Karnataka, but the mean length of males left and right clavicles were 19.90 mm and 15.55 mm less than those of males of the present study and the mean length of the females left and right clavicles were 17.77 mm and 13.02 mm less than those of the females of the present study.

These findings were also in agreement with that of (Udoaka and Nwokediuko 2013) for the people of southern Nigeria but their measurement for mean length of male clavicles were

7.88 mm less than the present result, and their measurement for the mean length of the females clavicles were 2.60 mm less than the present result. These variation in these findings marked the racial difference which may be observed even in closed related racial groups (Olivier 1951; Kaur *et al.*, 2002).

5.1.1.2 Mid Shaft - thickness of Clavicle

In the present study, it was found that the mean thickness of overall males left and right mid shaft-clavicles (TLC and TRC) and in different age groups were significantly greater than the mean thickness of the overall females left and right mid-clavicles (TLC and TRC) and in different age groups, these was because males were exposed to physical activities than females (Joseph *et al*., 2008; Patel et al., 2009).

This discovery was supported by that of Patel *et al.* (2009) for the people of Gujarat but their result for the mean thickness of the males left and right mid- clavicles were 1.23 mm and 1.69 mm less than the mean thickness of males left and right mid clavicles of the present study and the mean thickness of the females left and right clavicles were 1.14 mm and 1.66 mm less than those of the females of the present study. The result also agreed with that of Shobha *et al.* (2011) for the people of North Karnataka, in which their findings for the mean thickness of the males left and right clavicles were less than those of the present study with 1.05 mm and 1.68 mm, and their females measurement of mean thickness of left and right clavicles were less than those of present study with 1.09 mm and 1.64 mm repectively.

Udoaka and Nwokediuko (2013) who worked on the mean thickness of mid-clavicles for males and females of the Southern Nigeria also support the present result but their findings for males clavicles were 6.38 mm greater than those of the present findings and females were 3.3 mm greater than those of the present findings. The variation shown in thickness of the mid-clavicle from one group to another also indicated racial difference Kaur *et al.*, (2002).

5.1.2 Sex Evaluation using Scapula Measurement

5.1.2.1 Height of scapula

This study shows that the total and age group mean height of left and right scapulae (HLS and HRS) demonstrate sex difference between males and females whereby they were significantly greater in males than in females. This may be because males are more exposed to physical activities than females Ozer *et al.* (2006) and males have broader shoulder than females and the scapula contribute to the broadness of the shoulder Di Vella *et al*. (1994).

This result was in agreement with the result of Ozer *et al.* (2006) for the East Antolian population, but their measurement for males mean height of the scapula was 12.86 mm less than those of the present study and the females mean height of the scapula was 8.65 mm less than those of the females of the present study. This result is also in line with the work of Shailesh *et al.,* (2013) for the people of Gujarat India, but their result was for males mean scapula height was 28.00 mm less than the mean scapula height of the present study and the females mean scapula height was 26.14 mm less than the mean scapula height of females of the present study. These results were also consistent with the findings of Carter *et al.* (2013) for the White Europeans, but in their finding the mean height of males scapula was 9.10 mm greater than that of the males of the present study, while the females mean length of the scapula was 4.45 mm less than that of the females of the present study. The variation shown by the parameters may indicate racial difference Carter *et al.* (2013).

5.1.2.2 Width of the scapula

This study also identified that the mean width of the left and right scapula shows significant sex difference between males and females, which is also indicated in different age groups, which may be due to more exposure to physical activities by males than females Ozer *et al.* (2006) and males have broader shoulder than females and the scapula contribute to the broadness of the shoulder Di Vella *et al*. (1994).

These results were in agreement with the result of Ozer *et al.* (2006) for the people of East Anatolia, but their results for males and females width of the scapula were 26.51 mm and 19.73 mm greater than those of the present study. The result was also in consistent with findings of Shailesh *et al.* (2013) for the people of Gujarat, but their result was for males and females mean width of scapula was 16.56 mm and 17.51 mm greater than the result found for males and females in the present study. These were also supported by the work of Carter *et al.* (2013) for the population of White Europeans, but their result for males was 23.88 mm greater than that of males of the present study and for females was 19.82 mm greater than that of the females of the present study. The differences between these parameters of all the findings may be due to racial difference (Carter *et al.*, 2013).

5.1.3 Thoracic dimensions

This study identified that in the thoracic diameters at the level of third (D-T3), fifth (D-T5), seventh (D-T7) and ninth (D-T9) thoracic vertebrae showed highly significant difference between males and females. The height of left and right hemidiaphragm dome also demonstrated sex difference between males and females with the males having greater thoracic dimensions in all the age level than females, this may be due to males have greater height than females Hassan *et al.* (2013).

This result is in consistent with the discovery of Theodoros *et al.* (1991) who found that from puberty females have significantly narrower and shorter thorax than that of males which implies that from puberty the females thoracic cage is narrower relative to spinal length than males at most level, this greater slenderness of the females thorax is consistent with the greater slenderness of females which may be because of the greater rotational inertia generated by their larger pelvis.

The result was also in agreement with the work done by Francios *et al.* (2003) who reported that the thoracic dimensions were significantly smaller in females than in males, with height of hemidiaphragm dome significantly shorter in females than males by approximately 9 %, which were associated with a greater anterior- posterior inclination of ribs and during resting breathing.

This result was also in line with the work of Obikili and Okoye, (2006) whose work identify the thoracic diameter for the males in Enugu to be ranged from 233 mm to 350 mm and females thoracic diameter for the females to be ranged from 217 mm to 308 mm, which shows high significance in gender difference which may be due to development of kyphosis in females, which leads to increased in anterior- posterior chest diameter with a resultant change in the thoracic shape and reduction in the transverse diameter.

5.1.4 Cardiac ellipsoid

This study also identified that long cardiac axis (LCA) and short cardiac axis (SCA) were significantly greater in male in all age level than in female, with the P-value (P<0.001), these may be attributed to differences in morphology (body size) and level of physical activities between genders (Zdansky, 1965; Oladipo *et al.,* 2012).

The present result is in line with the work of Carol *et al.* (2002) who discovered that the radiograph measurements of heart volumes were significantly greater (P<0.001) in men than in women.

This result was also in agreement with the work of Oladipo *et al.* (2012) who reported that there was sexual variation in all the parameters measured in heart size, as females showed significantly lower values for both heart and chest diameters than in males.

5.2 COMPARISON OF PAIRED STRUCTURES

5.2.1 Comparison of Left and Right Clavicles

5.2.1.1 Length of left and right clavicles

It was discovered in the present work that the left clavicle is significantly longer than right in both male and female sexes with P value (P<0.001), which is because of greater curves in the right clavicle than left clavicle which may be due to frequent usage of right hand than left (Habir, 1989; Patel *et al.*, 2009).

This result was supported by the work of Kaur *et al.* (2002) who reported that the length of adult left clavicle was more than that of right side. It is in agreement with the work of Patel *et al.* (2009) who found that the difference between each measurement (length) of two clavicles were highly significant in both sexes.

5.2.1.2 Mid shaft - thickness of the left and right clavicles

This study found that the mid-thickness of the right clavicle in both male and female was significantly greater in right clavicles than left clavicles, which may be due to frequent use of the right hand, which leads to shorter and thicker right bone as compared to the left as reported by Kaur *et al.* (2002).

This result is in line with the work of Joseph *et al.* (2008) who discovered that side difference exist in both sexes with right clavicle shorter and thicker than left which may be due to continuous use of right in manual labor than left. This result was also in consistent with the result found by Patel *et al.* (2009) who found the right clavicles in males and females as thicker than left clavicles in the same peoples.

5.2.2 Comparison between Left and Right Scapulae

5.2.2.1 Height of left and right scapulae

This study show that the left scapula is significantly greater in height than right scapula in both male and female sexes with P- value ($P<0.001$), which may be due to frequent use of the right hand, which leads to shorter and thicker right bone as compared to the left (Iscan et al., 1998; Kaur *et al.* 2002).

This was in agreement with the work of Kavita *et al.* (2013) who found the height of the scapula in the left side to be greater than in the right side. The result was also consistent with the result of Singh *et al.* (2013) who discovered that the mean value of the scapular height in the left side was significantly greater than the mean scapula height in the right side.

5.2.2.2 Width of left and right scapulae

This study also found that the width of left scapulae was significantly greater than the width of the right scapula in both sexes, in which the P value <0.001, which may be due to frequent use of the right hand, which leads to shorter and thicker right bone as compared to the left Kaur *et al.* (2002).

This result was in line with the result of Kavita *et al.* (2013) who found the mean width of the left scapulae to be greater than that of right. The result was also supported by the work of Singh *et al.* (2013) who found the mean width of the left scapulae to be significantly greater than the right scapula.

5.2.3 Height of right and left hemidiaphragm dome

The result of the present study discovered that height of left hemidiaphragm dome was significantly greater than right in both sexes, This may be as a result of heart and sub-diaphragmatic organs Ayush and Frank (2013).

This result is in line with the work of Thitiporn *et al.* (2003) who shows that the mean right hemidiaphragm dome position was at 9.7 ± 0.8 vertebral levels. This was slightly above the inferior endplate of the tenth thoracic vertebral body (T10), and 0.9 ±2.3 cm above the right crossing rib level. The mean left hemidiaphragm dome position was 0.5 vertebral levels lower than the right, 0.3 ± 2.4 cm below the left crossing rib level. It was also in line with the work of Hassan *et al.* (2013) who found in their total samples, the right hemi diaphragm dome was shorter than the left hemi diaphragm in 98 sample which was act 98% of the total sample, the left hemi diaphragm dome was shorter in 1 sample which was 1% of the total sample and they was in the same height in also 1 sample which was 1% of the total sample.

5.3 Sex difference in the shape of C7/T1 and T1/T2 intervertebral disc

The finding of the present study show that there were significantly difference between males and females in the shaped of C7/T1 and T1/T2 interveterbral disc in chest radiographs with the P value ($P<0.001$). Male shape of the intervertebral disc at the level of C7/T1 was 50% curved while the female intervertebral disc at that level was 50% parallel, likewise the shaped of the T1/T2 intervertebral disc in male was 42% curved, while the shaped of female intervertebral at the level of T1/T2 was 46% parallel.

These result was supported by the discovery of Lina (2008) who found that the male subjects showed a significantly greater degree of relative flexion mobility in both segment C7/T1 and T1/T2 compared with the female subjects. It was also supported by the work of Leon *et al.* (2008) who reported that there were differences in cervicothoracic angles between males and females when sitting looking straight ahead, when sitting looking down, and in change from looking straight ahead to slump sitting, because there is less neck flexion in females than in males.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

This study revealed sex differences between males and females in all age levels from measurements of normal chest radiographs, which may be due to hormonal secretion during maturity and exposure to the physical activities. Although it is supported by various workers in the past, the difference between their parameters and present parameter indicates racial difference.

It has been shown that the length and mid-clavicular thickness of left and right clavicle differs sexually with males having longer and thicker clavicle than females. It was also found that the length and mid- clavicular thickness of the left and right clavicles varies in each sex with left longer but less thicker than right clavicles in both males and females sexes, which could be due to exposure to physical activities.

This study also identified that the height and width of left and right scapula revealed sexual difference with males having higher and wider scapula than females, also in both sexes; the height and width of the left scapulae are greater than right scapulae.

The thoracic dimensions (diameter) at the level T3, T5, T7 and T9 demonstrated positive sex determination with males having greater thoracic dimensions than females. Additionally, the height of left and right hemidiaphragm dome are greater in males than in females, in which the height of the left hemidiaphragm dome is greater in left side than in right side, which would due to presence of heart and sub- diaphragmatic structures.

It was also discover that the males have significantly greater cardiac dimension than females, which may be attributed to the difference in body size and exposure to physical activities between the sexes.

All these differences are due to hormonal activities , body complexity and exposure to the physical activities by males than females, and more frequently use of right hand than left hand in both sexes.

Lastly the results demonstrated that the shape of C7/T1 and T1/T2 intervetebral disc are mostly curved (inverted V- shaped) in males which differ from that of females which are mostly parallel in shape, this may be due to greater anterior flexion of mobility in males than females.

6.2 Conclusion

The present study has confirmed the accuracy of sex determination using measurements of different structures in the chest radiographs of adult population in Gombe in different age levels.

This work established monogram for sex determination using measurements of some structures such as clavicle, scapula, heart and thoracic cage in posteroanterior chest radiographs of adults in Gombe, which could be applied in the identifying deceases that underwent beyond recognition by physical identification.

It also confirmed the reliability of thoracic parameters for sex determination in case of forensic anthropological investigation where the skull and pelvic bones are fragmented or missing.

It also revealed that sex can be assessed with a high degree of accuracy using other regions of the skeleton.

It was shown that all the structures are greater in males than females. This is in line with the established literature that thoracic region undergoes changes during maturation, with the females mostly having smaller and shorter thoracic region than males, which may be due to hormonal secretion and exposure to physical activities.

6.3 RECOMMENDATIONS

i. There is need for further research for sex determination using normal chest radiographs for the other parts of the country in order to identify the variations in sex determination and ethnicity, since exposure to the physical activities affect the bone size, as the study is done using normal chest radiographs from Federal medical center (Federal Teaching hospital) Gombe.
ii. There is need for further research on chest radiographs in case of disasters and forensic cases, and other circumstances in which other portion typically used to determine sex are not present or not adequately preserved.
iii. There is need for further research to the molecular level on bones around the thoracic region so as to have positive identification of a deceased for his family to have confirmation that is their relative that is dead in cases of manmade mass disasters, genocides or aircraft accidents.
iv. There is need to create Genbank, which may help in identification of individuals, during bio- archaeological and forensic investigations.

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APPENDICES

APPENDIX I

Biodata of Radiograph.

i. Examination ID--------
ii. Sex--------------
iii. Age -------------
iv. State of Origin------------
v. Tribe----------------------------

Anthropometric Parameter Measurements

The parameters that will be recorded		
S/N	THE DATA LIST	MEASUREMENT (MM)
1.	Lateral diameter of rib cage at the level of T3	
2.	Lateral diameter of rib cage at the level of T5	
3.	Lateral diameter of rib cage at the level of T7	
4.	Lateral diameter of rib cage at the level of T9	
5.	Height of right hemidiaphragm dome below T1	
6.	Height of left hemidiaphragm dome below T1	
7.	Maximum length of right clavicle	
8.	Mid- shaft thickness of right clavicle	
9.	Maximum length of left clavicle	
10.	Mid- shaft thickness of left clavicle	
11.	Maximum height of right scapula	
12.	Maximum width of scapula	
13.	Maximum height of left scapula	
14.	Maximum width of left scapula	
15.	Long cardiac axis of cardiac ellipsoid	
16.	Short cardiac axis of cardiac ellipsoid	

SHAPE OF C7/T1 AND T1/T2 INTERVERTEBRAL DISC			
S/N	NAME	Curve	Parallel
1.	C7-T1 Intervertebral disc		

2.	T1-T2 Intervertebral disc		

APPENDIX II

Ethical Certificate

APPENDIX III

Descriptive statistics for the parameters in males radiographs of Gombe adults.

	Males (n=250)			
Variables	**Mean±SD**	**Max**	**Min**	**Range**
AGE	**43.38±16.55**	**80.00**	**18.00**	**62.00**
LRC	**157.65±10.06**	**189.00**	**130.00**	**59.00**
TRC	**14.06±1.38**	**19.50**	**10.05**	**9.00**
LLC	**163.70±10.52**	**193.00**	**126.00**	**67.00**
TLC	**13.38±1.42**	**19.00**	**10.00**	**9.00**
HRS	**161.07±15.27**	**193.00**	**116.00**	**77.00**
WRS	**83.32±9.46**	**114.00**	**62.00**	**52.00**
HLS	**166.99±14.40**	**204.00**	**120.00**	**84.00**
WLS	**84.89±8.90**	**120.00**	**65.00**	**55.00**
D-T3	**213.16±17.36**	**262.00**	**167.00**	**95.00**
D-T5	**256.81±15.76**	**305.00**	**214.00**	**91.00**
D-T7	**276.93±16.64**	**325.00**	**181.00**	**144.00**
D-T9	**288.94±19.50**	**398.00**	**231.00**	**167.00**
HRHD	**222.34±20.57**	**274.00**	**153.00**	**121.00**
HLHD	**241.23±20.04**	**305.00**	**184.00**	**121.00**
LCA	**145.61±7.19**	**169.00**	**118.00**	**51.00**
SCA	**116.84±8.76**	**134.00**	**120.00**	**122.00**

LRC= Length of right clavicle; TRC= Thickness of the right clavicles LLC=length of left clavicle; TLC= Thickness of left clavicle; HRS= Height of right scapula; WRS= width of right scapula; HLS= Height of left scapula; WLS= Width of left scapula; D-T3= Thoracic diameter at level third thoracic vertebra; D- T5= Thoracic diameter at level fifth thoracic vertebra; D- T7= Thoracic diameter at level of seventh thoracic vertebra; D- T9= Thoracic diameter at level of ninth thoracic vertebra; HRHD= Height of the right hemidiaphragm dome; HLHD= Height of left hemidiaphragm dome; LCA= long cardiac axis; SCA= short cardiac axis.

APPENDIX IV

Descriptive statistics for all the parameters in females radiographs of Gombe adults.

		Females (n=250)		
VARIABLES	**Mean±SD**	**Max**	**Min**	**Range**
AGE	**39.28±14.68**	**85.00**	**18.00**	**67.00**
LRC	**144.72±8.36**	**168.00**	**120.00**	**48.00**
TRC	**11.81±0.89**	**15.00**	**9.00**	**6.00**
LLC	**150.47±8.58**	**170.00**	**130.00**	**40.00**
TLC	**11.19±1.09**	**20.00**	**8.50**	**11.50**
HRS	**142.92±11.89**	**173.00**	**99.00**	**74.00**
WRS	**74.44±10.63**	**174.00**	**52.00**	**122.00**
HLS	**148.62±12.70**	**182.00**	**115.00**	**67.00**
WLS	**77.57±7.96**	**107.00**	**46.00**	**61.00**
D-T3	**200.90±15.76**	**241.00**	**158.00**	**83.00**
D-T5	**238.88±14.36**	**272.00**	**201.00**	**71.00**
D-T7	**257.06±15.28**	**294.00**	**215.00**	**79.00**
D-T9	**268.65±18.96**	**361.00**	**219.00**	**142.00**
HRHD	**201.07±17.73**	**281.00**	**154.00**	**127.00**
HLHD	**224.14±12.78**	**209.00**	**169.00**	**94.00**
LCA	**138.44±8.31**	**185.00**	**109.00**	**76.00**
SCA	**111.02±6.73**	**127.00**	**94.00**	**33.00**

LRC= Length of right clavicle; TRC= Thickness of the right clavicles LLC=length of left clavicle; TLC= Thickness of left clavicle; HRS= Height of right scapula; WRS= width of right scapula; HLS= Height of left scapula; WLS= Width of left scapula; D-T3= Thoracic diameter at level third thoracic vertebra; D- T5= Thoracic diameter at level fifth thoracic vertebra; D- T7= Thoracic diameter at level of seventh thoracic vertebra; D- T9= Thoracic diameter at level of ninth thoracic vertebra; HRHD= Height of the right hemidiaphragm dome; HLHD= Height of left hemidiaphragm dome; LCA= long cardiac axis; SCA= short cardiac axis.