RELATIONSHIP BETWEEN SERUM TESTOSTERONE, DIGIT RATIO AND BODY COMPOSITION AMONG ADOLESCENTS OF IGBO ETHNIC GROUP IN NIGERIA

BY

Chikezie Jude OKAMKPA

DEPARTMENT OF HUMAN ANATOMY
FACULTY OF MEDICINE
AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

July, 2015

RELATIONSHIP BETWEEN SERUM TESTOSTERONE, DIGIT RATIO AND BODY COMPOSITION AMONG ADOLESCENTS OF IGBO ETHNIC GROUP IN NIGERIA

BY

ChikezieJude OKAMKPA MB.BS (EBSU) 2006
P13MDHA8013

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (M.Sc) DEGREE IN HUMAN ANATOMY

DEPARTMENT OF HUMAN ANATOMY
FACULTY OF MEDICINE
AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

July, 2015

DECLARATION

I, OKAMKPA, JUDE CHIKEZIE declare that the work in the thesis titled ‘‘**Relationship between serum testosterone, digit ratio and body composition among adolescents of Igbo ethnic group**”was carried out by me in the Department of Human Anatomy, Faculty of Medicine, Ahmadu Bello University, Zaria. The information used for my literature review was fully acknowledged in the text and references. This thesis has not been presented in any scientific gathering, neither has it been presented for another degree or diploma at any University.

_____ _____

CHIKEZIEJUDE OKAMKPASIGNATURE DATE

CERTIFICATION

Dr. S. A. Akuyam (BSc, MSc, PhD, FMLSCN, PGDE) _____ _____
Chairman Supervisory Committee, SignatureDate
Department of Chemical Pathology,
Faculty of Medicine,
Ahmadu Bello University Teaching Hospital, Zaria

Dr B. Danborno (BSc, MSc, PhD) _____ _____
Member Supervisory Committee, SignatureDate
Department of Human Anatomy,
Faculty of Medicine,
Ahmadu Bello University

ProfessorS.S.Adebisi (BSc, MSc, PhD)_____ _____
Head of Department, Signature Date
Department of Human Anatomy,
Faculty of Medicine,
Ahmadu Bello University

Professor Z. A. Hassan _____ _____
Dean School of Postgraduate Studies, SignatureDate
Ahmadu Bello University

DEDICATION

To all the students who volunteered to be part of this study.
To my lovely wife Chiamaka
To Ugo, Amy, andJide.
And my parents, Sir and Lady J.O Okamkpa (KSJ) for their support, encouragement and love

ACKNOWLEDGEMENT

I thank God Almighty through whose guidance and protection this work became a reality. To my family I am deeply indebted.

My profound gratitude goes tomy supervisors, Dr S. A. AkuyamandDr B. Danborno for their support and constructive critics. I'm thankful to have had them and their resources at my disposal.

To Mr Agbon Abel and Mr Nwankwo M., words cannot express how grateful I am for your help and support. Your kind gesturesshall always be appreciated.

I also wish to thank the entire staff of department of Anatomy for their assistance towards the completion of this work..

Special thanks to Dr. A Ibegbu, Dr J.N. Alawa, Dr E. Umana, Dr. W. O. Hamman, Dr S. A. Musa and Dr J. Timbuak for their advice and encouragement.

Of many classmates and colleagues who have been of help in the course of achieving this goal, I particularly wish to thank Col David Solomon my reading partner,Chigeru, Dr Okoye A. E (Consultant haematologist), Dr ArohAdaora and Dr EzeOnyinye for their assistance and love.

I would also like to extend my gratitude to Dr. Maduka I. C. of Chemical pathology department U.N.T.H Enugu for assisting me with the hormonal assay.

To the entire staff of the schools and students who volunteered to be part of this study, I will also remain grateful for your assistance.

Finally, I would like to thank my research assistants; ChukwuebukaAkpati, ChinyereEze, Ijeoma Okonkwo, IfeomaOkoro and ChilotaAnayo without whom I would surely not have collected nearly the sample size that we did.

I sincerely appreciate the contributions of all who for want of space or over sight could not be mentioned, God will bless them for their kindness to me.

ABSTRACT

Digit ratio (2D:4D) is a sexually dimorphic trait, with females having a higher 2D:4D than males. This digit ratio has been associated with numerous behavioural traits and health conditions related to sex hormones. Four hundred and twelve secondary school students (209 males and 203 females) aged 12 to 20 years attending secondary schools within Enugu metropolis, in Enugu state, Nigeria participated in this work after an informed consent was obtained from them and their parents. Detailed information required from subjects was obtained through a standard designed questionnaire. Body fat percentage, weight (kg), Finger length (cm), height (cm), chest, waist and hip circumferences (cm) were measured using standard protocols. Body mass index (BMI), Waist to chest ratio (WCR) and Waist to hip ratio (WHR) were calculated. Blood sample for the estimation of testosterone was also obtained. The variables were studied according to sex and age groups. The data obtained was subjected to statistical analysis using SigmaStat 2.0 for Windows (San Rafael, CA) and statistical values were acceptable at $p<0.05$. Testosterone and all the anthropometric variables considered in this studyshowed statistical significant difference ($p<0.001$ and 0.002) between males and females. The result also indicated a negative significant relationship between 2D:4D of both hands and testosterone in males, while in females testosterone had a positive correlation with 2D:4D of the right hand and a negative correlation 2D:4D of the left hand ($p<0.05$). 2D:4D of both hands had a negative correlation with weight and height in females ($p<0.01$ and $p<0.05$) respectively while in males, 2D:4D did not correlate with height and weight ($p>0.05$). Males had a significant relationship with weight, height, body fat percentage and chest circumference ($p<0.01$) while in females testosterone had a significant relationship with weight, body mass index, body fat percentage, waist to hip ratio, chest, waist and hip circumference ($p<0.05$). In conclusion, the present study confirmed the existence of sexual dimorphism of finger lengths and digit ratios as well as in body composition variables. It also showed a relation between digit ratios and testosterone in the adolescent age group. These findings could be of importance in addressing biological traits and health conditions related to sex hormones.

TABLE OF CONTENT

Title page ----------i

Declaration ---------- ii

Certification ---------- iii

Acknowledgement ----------iii

Dedication----------iv

Table of Contents ---------- vi

List of Tables ---------- xii

List of Figures ---------- xii

Abbreviations ---------- xiii

List of Appendices ---------- xiv

Abstract---------- xv

CHAPTER ONE

Introduction ---------- 1

1.1 Background of Study ----------1

1.2 Statement of Research Problem ----------4

1.3 Justification of study ---------- 5

1.3.1 Research hypotheses ---------- 5

1.5 Significance of study ---------- 5

1.6 Aims and objectives----------6

1.6.1 Aim ----------6

1.6.1 Aims and Objectives of the Study ---------- 6

1.6.2 Objectives ---------- 6

1.7 Limitation of study ---------- 6

CHAPTER TWO

Literature review ----------7

2.1 Finger digit ratio ---------- 7

2.2 Historical view on finger length measurement ---------- 8

2.3 Abnormalities and Disorders Correlated with 2D:4D Ratio ---------- 13

2.4 Testosterone ---------- 14

2.4.1 Testosterone at different stages of development---------- 16

2.4.2 Male Testosterone Levels---------- 17

2.4.3 Female testosterone levels ---------- 18

2.5 Adolescent and growth ---------- 20

2.5.1 Adolescent ---------- 20

2.5.2 Growth at puberty ---------- 20

2.6 Body composition ---------- 23

2.6.1 Body mass index ---------- 26

2.6.2 Waist Circumference---------- 26

2.6.3 Waist-to-Hip Ratio ---------- 27

CHAPTER THREE

Materials and method ---------- 29

3.1 Study location ---------- 29

3.2 Sample size determination----------31

3.3 Research participants---------- 31

3.4 Inclusion criteria. ---------- 32

3.5 Exclusion criteria ----------32

3.6 Methodology ---------- 32

3.7 Anthropometric measurement ----------33

3.7.1 Finger length measurements ---------- 33

3.7.2 Weight and body composition ---------- 33

3.7.3 Height ---------- 33

3.7.4 Chest circumference----------34

3.7.5 Waist circumference ---------- 34

3.7.6 Hip circumference ---------- 34

3.7.8 Body mass index ---------- 35

3.7.8 Blood specimen collection and processing ----------35

3.7.9 Estimation of Serum Testosterone----------35

3.7.10 Principle EIA Procedure----------35

3.7.11 Testosterone EIA Procedure----------36

3.8 Ethical consideration----------43

3.9 Data analysis----------44

CHAPTER FOUR

Results----------45

4.1Analysis of study of population----------45

4.2 Descriptive statistics showing the finger length of the right and left hands of subjects according to sex----------45

4.3 Descriptive statistics showing digit ratios of the right and left hands of subjects according to sex----------47

4.4 Descriptive statistics showing anthropometric variables and body composition of subjects according to sex---------- 47

4.5 Descriptive statistics of anthropometric variables, testosterone and body composition of subjects according to sex in relation to age group----------50

4.6 Correlation matrix of serum testosterone, 2d:4d and body composition in females---
----------57

4.7 Correlation matrix of serum testosterone, 2d: 4d and body composition in males. ---------- 57

4.8 Linear and multiple regression equation for testosterone level in males and females---------- 60

CHAPTER 5

5.1 Discussion ---------- 63

CHAPTER SIX

6.1 Summary and Conclusion ---------- 67

6.2 Recommendation ---------- 67

References ---------- 69

LIST OF TABLES

Table 2.1 Reference Values of Testosterone in humans for age----------19

Table 4.1: Descriptive statistics showing the finger length of the right and left hands of subjects according to sex----------46

Table 4.2: Descriptive statistics showing the digit ratios of the right and left hands of subjects according to sex----------48

Table 4.3: Descriptive statistics showing anthropometric variables and body compositionof subjects according to sex----------49

Table 4.4: Descriptive statistics of anthropometric variables, testosterone and body composition of subjects according to sex in relation to age group----------51

Table 4.5: Correlation matrix of circulating testosterone, anthropometric variables and body composition in females (n=203) ----------58

Table 4.6: Correlation matrix of serum testosterone, anthropometric variables and body composition in males (n=209) ----------59

Table 4.7: Linear and multiple regression of Testosterone from R2D4, L2D4D, R2D4DL2D4D, Body fat in males----------61

4.8: Linear and multiple regression of Testosterone from R2D4, L2D4D, R2D4DL2D4D, Body fat and anthropometric variables in females----------62

LIST OF FIGURES

Figure 3.0: Map of Nigeria showing the study area----------31

Figure 4.1: Mean ± SD of study participants of age groups 12 - 15 and 16 - 19 years ----------52

Figure 4.2: Comparison of study participants' height of age groups 12 - 15 and 16 - 19 years ---------- 53

Figure 4.3: Mean ± SD of testosterone level of study participants according to age group and sex ----------54

Figure 4.4: Comparison of body fat percentage according to sex and age categories----------55

Figure 4.5: Comparison of chest, waist and hip circumferences according to sex and age groups----------56

LIST OF PLATES

Plate I: Demonstration of measurement of finger lengths using a digital calliper----------**37**

Plate II: Body compositionanalyzer from TanitaCorporation used in the measurement of body weight and body fat percentage----------**38**

PlateIII: Demonstration of height measurement----------**39**

PlateIV: Demonstrating Chest circumference measurement----------**40**

Plate V: Demonstrating Hip circumference measurement----------**41**

Plate VI: Blood specimen collection----------**42**

LISTOFAPPENDIX

Appendix I: Consent form ---------- 78

Appendix II: Informed written consent ---------- 79

Appendix III: ABUTH ethical clearance certificate ---------- 80

Appendix IV: Ministry of Health, Enugu State ethical clearance certificate ---------- 81

Appendix V: Questionnaire for the study of relationship between serum testosterone, digit ratio and body composition ---------- 82

ABBREVIATIONS

ADHD Attention Deficit/Hyperactive Disorder

AS Asperger's Syndrome

BMI Body Mass Index

BMR Basal Metabolic Rate

CAR Congenital Adrenal Hyperplesia

EIA Enzyme Immune Assay

HPR Horseradish peroxidase

SD Standard Deviation

SHBG Sex Hormone Binding Globulin

TMB TetramethylBenzidine

WCR Waist Chest Ratio

WHO World Health Organisation

WHR Waist Hip Ratio

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

There are very few parts of the human body in health or disease that provide observation better than the hand. The hand presents excellent opportunities for us, students of human nature and of human anatomy to exercise power of observation and to study the outward form of a portion of the body (Jones, 1942). But more to our purpose is the fact that in probing deeper into the anatomy of the hand we are immediately brought face to face with some of the most important biological problems and some of the most striking exhibitions of general vital principles.

The fingers in the adult human hand differ in length and in distal extent (Jones, 1942). These finger lengths are fixed for life within the first three months of pregnancy (Manning *et al*., 1998;Csatho*et al*., 2003). Contemporary anthropological studies have found that in the clear majority of males, the distal extent of the ring finger tends to be relatively greater (using the middle finger as standard) than the index finger (Manning *et al*., 1998; McFadden and Shubel, 2002). However, the results for females vary considerably with some studies reporting that females show a similar pattern to that of males (Manning *et al*., 1998) while others suggest that the prevalence of a longer index finger is relatively or absolutely more common in females (Danborno *et al*.,2008a).

This shows that the ratio of the index finger (2D) to that of the ring finger (4D) in humans is sexually dimorphic (Ecker, 1875; George, 1930; Phelps, 1952; Manning, 2002). This sexual dimorphic trait is also found in bonoboos (Ecker, 1875; Jones, 1942; Manning *et al;* 2003; Danborno *et al.*, 2008a).

Finger length ratio is historical to what went on in the womb at the time when the brain, heart and other organs were growing (Malas*et al*., 2005; Mclntye, 2005 and Danborno*et al*., 2008b). It suggests that a relatively long ring finger is a sign that certain organs were exposed to higher levels of testosterone while a relatively long index finger points to lower level of male hormone and higher levels of oestrogen (Manning *et al*., 2003 and Danborno *et al*., 2008a).

Exactly how testosterone affects the foetal digit ratio is not clear. One theory is that for a certain time in foetal development, the ring finger which has more testosterone receptors than the index finger tends to grow faster when exposed to higher levels of the hormones (Zheng *and* Cohn, 2011). The patterns of activation of these receptors differ between sexes and affect the growth of specific digits. Androgen receptors appear around the 8^{th} week of gestation and by the 14^{th} week they have disappeared. It may be that there are more receptors on the ring finger than the index finger. Interestingly, when the back of the fingers are observed, it seems that there are more hairs on the middle part between the two joints of the ring finger than other fingers.

This discovery provides a genetic explanation for a raft of studies that link finger digit ratio with traits ranging from sexual dimorphism (Ecker, 1875; George, 1930; Phelps, 1952;Manning, 2002),sperm counts(Manning *et al*., 1998), aggressions(Danborno *et al*., 2008b),sports prowess (Neave *et al.*, 2003), eating disorders in women (Klump*et al*., 2006) to other health related conditions such as cancers and heart related diseases (Manning,*2002*).

There are insufficient studies available on other digit ratios such as 3D:5D, 2D:5D and 3D:4D. Links between the developmental control of the urogenital system and patterns of finger growth may influence digits other than 2D and 4D (Manning *et al*., 2003). In

humans, sexual dimorphism has been reported for 2D:5D and 3D:4D (McFadden and Shubel, 2002) and for 2D:3D and 2D:5D and this sex differences are greater in the right hand than the left hand (Manning *et al.*, 2003). In mice, there is also evidence that 2D:3D is dimorphic (Kyriakidis and Papaioannidou, 2008). This may mean that otherdigit ratios could be correlated to sex-dependent traits such as developmental disorders and susceptibility to disease (example, 2D:3D, 2D:4D and 2D:5D for myocardial infarction (Manning *et al.*, 2003). The stability of these ratios in rapidly growing children is therefore of interest.

Adolescence is a dynamic period of development marked by rapid changes in body size, shape and composition, all of which are sexually dimorphic (Alan *et al.*, 2002). These changes are as a result of rise in sex steroid secretion.

Testosterone is well known for its role during this pubertal period. It promotes the development of secondary sexual characteristics such as growth spurt, increased muscle, bone-mass, the sprouting of body hair (Bassil*et al*., 2009), breast development, deposition of fat and development of sexual libido (Rako*et al*., 1996) in females, thickening of the vocal chords and increase in strength in males. In addition, testosterone is essential for health and well-being of the body (Tuck and Francis 2009).

Body fat distribution is also sexually dimorphic and while the dimorphism in body fat is minimal in infancy, childhood and old age, it is maximal during early reproductive life mediated by sex steroids in combination with heritable genetic factors (Nelson *et al*., 1999). During puberty, males deposit adipose (and also muscle) tissue around the upper body whilst females deposit adipose tissue around the thighs and buttocks. This distribution of body fat is thought to signal the ratio of pubertal/adult oestrogen to testosterone, since the predominance of oestrogen at puberty produces a typical female

body shape (gynoid), while the predominance of testosterone produces a typical male (android) body shape (Bjorntrop, 1997).

It is commonly accepted that pubertal/adult sex hormones are the main regulators of sexually dimorphic physical features (Fink *et al*., 2003). If so, then there should be an association between sexual dimorphism determined in utero and other sexually dimorphic traits which are largely determined at puberty.

1.2 STATEMENT OF RESEARCH PROBLEM

There is accumulating evidence that 2D:4Dwhich is largely determined in-utero, increases with age and is sexually dimorphic (Manning *et al*., 1998; Malas*et al*., 2005; McIntyre *et al*., 2005; Trivers*et al*., 2006 and Galis*et al*., 2009). Thus males tend to show lower values of 2D:4D than do females; that is males have on average longer fourth digits relative to their second than females (Phelps, 1952 and Manning *et al*., 1998). It has been suggested that sex differences in 2D:4D arise from in-utero concentration of sex steroids with 2D:4D negatively related to prenatal testosterone and positively associated with prenatal oestrogen (Manning *et al*., 1998). These sex differences in 2D:4D are robust across a number of ethnic groups and races (Manning *et al*., 1998).

Considering certain problems associated with development of secondary sexual characteristics in adolescents, its relationship with prenatal exposure tosex hormones will be of great interest in medical field. Although the sexual dimorphism in 2D:4D is largely determined in utero, its relationship with sexual dimorphic traits at puberty is not clear. Similarly, data on the relationship between testosterone, digital ratio and body composition among Nigerians are scanty.

1.3 JUSTIFICATION OF THE STUDY

Determining the relationship between serum testosterone, digit ratio (2D:4D) and body composition among adolescents could be of importance in the psycho-social management of this group of individuals. This could therefore improve the understanding of the physical changes that occur in the body during adolescence and could help parents and guardians in guiding this group of individuals during this critical period of life.

1.4 RESEARCH HYPOTHESES

The following hypotheses have been formulated to guide the conduct of this study.

i. There is a correlation between serum testosterone level and body composition for an individual.
ii. There is a correlation between serum testosterone level and digit ratio (2D:4D).
iii. There is a correlation between 2D:4D and body composition variables.
iv. There is a relationship between digit ratio (2D:4D) and age of menarche in females.

1.5 SIGNIFICANCE OF STUDY

This study will provide a reference value on sexual dimorphism of 2D:4D and other digit ratios among the Igbo ethnic group since Manning *et al*. (2003) reported significant ethnic variations in digit ratios (Gwunireama and Ihemelandu, 2010).It will provide an insight on the possibility of using anthropometric measurements and body composition assessment as predictor of risk of diseases in adults.

May be useful in predicting behaviour of individuals and thus guide them towards a definitive career.

1.6AIMS AND OBJECTIVES OF THE STUDY

1.6.1 Aim

The aim of this study was to determine the relationship between serum testosterone, digit ratios and body composition among adolescents in Igbo ethnic group.

1.6.2 Objectives

The objectives of the present study shall be as follows:

i. Determine the relationship between digit ratio (2D:4D) and serum testosterone in adolescents.

ii. Determine the relationship between digit ratio (2D:4D) and body composition variables in adolescents

iii. Determine the relationship between serum testosterone and body composition variables in adolescents

iv. Determine the relationship between digit ratio (2D:4D) and age of menarche in females.

1.7. LIMITATIONS OF THE STUDY

i. The present study was limited by

ii. Inability of the subjects to fill out the questionnaires correctly.

iii. Difficulty in collecting blood samples twice (am and pm) from participants since assessment of androgen status is based on more than a single measurement (Braunstein, 2002).

CHAPTER TWO

LITERATURE REVIEW

2.1. FINGER DIGIT RATIO

Man's place in nature is largely written upon his hand, thus it affords a study in itself, a study that the physician cannot afford to neglect (Jones, 1942). Despite the accumulated work of the past four centuries, much is uncertain and much remains unsolved following the study of the hand, even when we consider the most familiar features in our immediate family member.

Finger digit ratio is the ratio of the lengths of different digits or fingers typically measured from the bottom crease where the finger joins the hand to the tip of the finger (Manning *et al*., 1998). It has been suggested by some scientists that digit ratio (2D:4D in particular) presumably reflects prenatal exposure to sex hormones. This digit ratio is sexually dimorphic and males consistently have a slightly lower value than females (Manning *et al*., 1998 and Danborno *et al*., 2008a). This dimorphism appears to emerge during early development and is consistent across different age groups. It also reflects foetal testosterone and oestrogen levels in-utero (Lutchmaya*et al*., 2004). 2D:4D appear to correlate with a variety of covariates related to sex-dependent behaviour (Manning *et al*., 2001). Although results are not always homogeneous, there are indications that 2D:4D correlate with aggression, dominance, sporting ability (Neave *et al*., 2003), sexual orientation and health status including those related to reproductive success (Manning *et al*., 2003 and Putz*et al*., 2004).

McIntyre *et al.* (2005) believe that the dimorphism in 2D:4D between sexes emerges at the foetal stage and in young children and increases with age. Currently, the prevailing assumption is that 2D:4D mainly reflects prenatal exposure to sex hormones but it is

not clear how stable the individual values of these ratios are which could have important implication for its usefulness as an indicator of health status at different ages. The many results that appear to support this view call for further studies on association between 2D:4D and human characteristics affected by hormone exposure (Fink *et al*., 2003 and Putz*et al*., 2004).

The 2D:4D is calculated by measuring the length of the index finger of the right hand, then that of the ring finger and dividing the former by the latter. A longer index finger will result in a ratio higher than 1 while a longer ring finger will result in a ratio of less than 1 (Manning *et al*., 1998 and Danborno *et al*., 2008a).

2.2.HISTORICAL VIEW ON FINGER LENGTH MEASUREMENT

The scientific studies into the features of the hand began as far back as the time when ideas of evolution in humans were still young. The "Darwinist" ideas were still just beginning to blossom in the scientific world. The first text written about the hand from an anatomical point of view was "*The Hand, its mechanism and vital endowments as evincing design*" published in 1832 by the eminent surgeon Sir Charles Bell in which he sought to demonstrate the perfection of the hand both as a tool and as an instrument as well as being the supreme sense organ available to human beings in its role as the sense organ of touch (Peters *et al*., 2002). He discovered that there were more neural connections between the hand and the brain than between the brain and any other part of the body, a fact which has been widely used by many chirologists to explain how the lines of the hand reveal something of the consciousness of their owner.Professor Wood Jones, in his work, *'The Principles of Anatomy as seen in the Hand'*, first published in 1942 described the anatomy of the hand in considerable details and many of his

findings provided further anatomical and scientific evidence to support the significance of the hand as a valid means of studying human consciousness.

When we speak of finger length, various definitions can be used but the one most easily appreciated concerns the distal extent of the fingertips. An anthropologist and biologist Dr Frank Baker (1888)in his book titled '*Anthropological Notes on the human Hand*'noticed that the index finger is usually shorter than the ring finger. In Casanova's memoirs, where he recounts a conversation with the painter Mengs (Casanova, 1894), Casanova made two clear statements: first, "that the ring finger is relatively longer than the index finger" and second, "that this is the case for both men and women" (Peters *et al*., 2002).

F. Wood Jones, a professor of anatomy at Manchester University in his work "The Principles of Anatomy as seen in the Hand", described the anatomy of the hand in considerable details and many of his findings provided further anatomical and scientific evidence to support the significance of the hand as a valid means of studying human consciousness.

When we speak of finger length, various definitions can be used but the one most easily appreciated concerns the distal extent of the finger tips. Albrecht Du¨ rer, a great renaissance artist who was concerned with the standard proportions of the ideal human body provided a finger length pattern of 3 > 4 > 2 > 5 > 1 for artists in his treatise (Jones, 1942). In his drawing which deals with the hand of a strong man, the middle finger is the longest, followed by ring, index, small finger, and thumb. In contrast, Ecker *et al.*, (1875) claimed that "great artists would not wish to portray a beautiful hand as one in which the index finger is notably shorter than the ring finger" because such a pattern is of the "lower" type (meaning, observations from nonhuman primates)

where the second digit has been found to be considerably shorter than the fourth digit. A compromise was struck by Jones (1942) who cited an anatomy text for art students as suggesting that the middle finger extends farthest while the index and ring fingers are of equal length. The reasoning of Ecker (1875) found a more recent reflection in Schultz (1924) who also focused on the observation that in most primates (especially those with a pronounced arboreal habit), the index finger is not very well-developed while the ring and middle fingers are of considerable length. Like Ecker (1875), Schultz (1924) seemed to accept the proposition that individuals who depart from the subhuman primate pattern of a relatively underdeveloped index finger represent a "higher" finger length pattern type by virtue of an opposite trend. Schultz (1924) went as far as to infer an intermediate status for "Negroes" for whom he claimed a "more simian hand."

It was not until much later that finger length differences were finally recorded and classified (George, 1930). This was when a statistically significant difference between men and women in the length of their index and ring fingers relative to one another was first noted. George noted for the first time that men tended to have the lower 2D:4D, with shorter index fingers and longer ring fingers while women tended to have the higher 2D:4D with the longer index fingers and the shorter ring fingers. Since these findings, 2D:4D has been measured across races and cultures of the world. Manning *et al*(2007) surveyed 255,116 participants worldwide, including those from Whites, Asians, Middle-Eastern, Blacks and Chinese ethnicities. Their data was analyzed for 2D:4D differences across genders and sexual orientations. The results showed that Black and Chinese participants had significantly lower ratios than White, Asian and Middle-Eastern participants. Remarkably, differences were also discovered between

European nationalities surveying people of 11 countries and finding relatively small but significant differences.

For decades after the first cataloguing of 2D:4D, it was not yet known that this relationship between digit lengths was due to differences in prenatal testosterone regulation. In 1983, Psychologist Glenn Wilson introduced the word digit ratio. In his book titled "*Finger Length as an index of assertiveness in women"* he introduced the 2D/4D 'digit ratio' as a maker of exposure to prenatal testosterone.

He was among the first researchers to suggest that this relationship may exist as a result of genetic differences, wherein sex hormones that affect bodily growth are delegated differently with higher levels of the hormones causing the fourth digit to grow more than the index finger and lower levels causing less growth in this finger. He was also the first to begin linking this ratio to personality traits, finding significance in the relationship between the 2D:4D of women and their assertiveness.

Wilson's (1983) findings revealed a wide, unexplored breadth of potential research to be uncovered with these findings. The presence of prenatal testosterone not only accounts for developmental differences between men and women throughout their bodies but also for developmental differences in their brains (Breedlove *et al*., 1999and Harding, 2004). Certain structures in the brain of humans have shown differences in mass between genders. Males have significantly greater volume in the amygdala, which is instrumental in "fight or flight" mechanisms. The females have significantly greater volume in the hippocampus which encodes short-term memory and the striatum which plays a role in reward motivation and executive function (Cavinesset *al.*, 1996 and Lange *et al*., 1997). The male typical difference was cited to be related significantly to circulating testosterone levels while the female-typical development was cited to be

significantly related to circulating oestrogen levels (Naufang*et al*., 2009). Differences in brain structures most likely are related to levels of prenatal hormones. However, we can also find differentiation in behaviour within each gender based on if they had more "masculinised" or "feminized" exposure to hormones in utero. Given that prenatal hormones are responsible for the dichotomy in digit ratios and also tend to affect our sensitivity to circulating hormones later in life (Archer, 2006), it has become reasonable to suppose that some correlations may exist between personality and digit ratio as Manning*et al*(1998) has found. His findings have revealed numerous possibilities for many different dependent variables associated with personality and behaviour to be implemented in studying the relationship between 2D:4D and behavioural phenotypes in humans.

Theories on why 2D:4D should have any correlation with any displayed traits are rooted in the endocrinology of the developing foetus. It has been shown that higher levels of prenatal testosterone are also related to higher levels of prenatal estradiol which plays a significant role in neural development (Harding, 2004). There is still no clear understanding of what happens specifically in the brain during this period of development that may account for all of the sexual dimorphisms. In 1998 2D:4D ratio was linked to sex steroids by the observation that men with lower 2D:4D have higher serum testosterone and lower oestrogen levels (Manning *et al*., 1998). The discovery that sexually dimorphic digit ratios exist in 2-year-old children raised the possibility that 2D:4D is determined early in life (Lutchmaya*et al*, 2004).

Today digit ratios are related to a variety of variables such as fertility and human behaviour (Manning, 2002), body composition (Fink *et al*., 2003, predictor of birth weight (Danborno *et al.*, 2010) aggression and assertiveness (Wilson, 1983.,Peters *et*

al., 2002and Danborno *et al.*, 2008b), personality factor and hand skill. Medical conditions such as breast cancer, autism and congenital adrenal hyperplasia have also been explained with digit ratio study (Brown*et al.*, 2004). Manning *et al*(2003) and Oladipo*et al* (2009) reported significant racial and ethnic variations in digit ratios.

2.3. ABNORMALITIES AND DISORDERS CORRELATED WITH 2D:4D RATIO

Further observations of 2D:4D in individuals with hormonal abnormalities increased the belief that exposure to prenatal androgens in uteroaffects not only the finger length ratio but also certain hormonally-balanced traits. Individuals, both male and female with congenital adrenal hyperplasia (CAH), a disorder known to be associated with abnormally high levels of prenatal and circulating testosterone, exhibited a much lower 2D:4D than control groups (Ökten*et al*., 2002; Brown *et al*., 2002). Further evidence of this relationship's existence came from 33 amniocentesis samples measuring the ratio of foetal testosterone to foetal estradiol and finding a negative correlation between this ratio and 2D:4D at the age of 2 years (Lutchmaya*et al*., 2004).

In addition to CAH, other disorders have also been found to have significant relationship with 2D:4D, vis-à-vis endocrine system and hormone abnormalities. Perhaps the most prominent of hormone-linked disorders to have been found correlated with 2D:4D is autism (Manning *et al*., 2001; Voracek, 2008). While it was already known that autism is a sex-linked disorder with a male-to-female ratio of 4 to 1 Rutter and Schopler,(1978) and Manning *et al* (2001) sought to discover if low 2D:4D could be a potential marker of autism. Their results showed that children with autism had significantly lower ratios on both hands than children with Asperger's syndrome (AS) and control children, and that their siblings and parents who were not afflicted with

autism or AS also had lower ratios than control populations. These findings suggested that exposure to high levels of prenatal androgen may make the foetus more susceptible to autism. Also Attention-deficit hyperactivity disorder(ADHD) in boys is associated with low 2D:4D (Martel *et al;* 2008).

2D:4D has also been studied for correlations with disorders in individuals with female-typical ratios. Aggression for example was found to have some correlation with 2D:4D. Individuals with lower 2D:4D have been found to be prone to greater aggression (Bailey and Hurd, 2005). Danborno *etal* (2008a) in their study 'the relationship between second and fourth digit lengths, digit ratio (2D:4D) and aggression in Nigerians' also found some correlation between digit ratio and aggression. Anxiety was also found to have some correlation with 2D:4D. Another disorder to have a correlation with female-typical 2D:4D is schizophrenia (Aratóet *al*., 2004).Interestingly, schizophrenia is thought to be related to an imbalance of hormones because of its typical onset during the reproductive age (Aratóet *al*., 2004).

Female schizophrenia patients were found to have a significantly higher 2D:4D than control females though males were found to have a lower 2D:4D. Literature suggests that men are prone to a different and more degenerative type of schizophrenia as compared to women (Castle and Murray, 1991) which may account for the difference in 2D:4D. In addition, studies correlating 2D:4D and the eating disorders (bulimia nervosa and anorexia nervosa, two more female-typical disorders) showed that females with lower ratio were less susceptible to these disorders (Klumpet *al*., 2006).

2.4. TESTOSTERONE

Testosterone is a steroid hormone from the androgen group and is found in mammals, reptiles (Cox and John-Alder, 2005), birds (Reed *et al.*, 2006) and other vertebrates. In

mammals, testosterone is primarily secreted in the testes of males and the ovaries of females although small amounts are also secreted by the adrenal glands. It is the principal male sex hormone and an anabolic steroid. In men, testosterone plays a key role in the development of male reproductive tissues such as the testis and prostate as well as promoting secondary sexual characteristics such as increased muscle mass, bone mass and the growth of body hairs (Mooradian*et al.*, 1987). In addition testosterone is essential for health and well-being (Bassil*et al.*, 2009) as well as the prevention of osteoporosis (Tuck and Francis, 2009). On average, in adult human males, the plasma concentration of testosterone is about 7-8 times as great as the concentration in adult human females' plasma (Torjesen and Sandnes, 2004) and as the metabolic consumption of testosterone in males is greater, the daily production is about 20 times greater in men but females are more sensitive to the hormone (Dabbs and Dabbs, 2000).The largest amounts of testosterone (>95%) are produced by the testes in men. It is also synthesized in far smaller quantities in women by the thecal cells of the ovaries, by the placenta, as well as by the zonareticularis of the adrenal cortex and even skin (Zouboulis and Degitz, 2004) in both sexes. In the testes, testosterone is produced by the leydig cells (Brooks, 1975). The male generative glands also contain sertoli cells which require testosterone for spermatogenesis. Like most hormones, testosterone is supplied to target tissues in the blood where much of it is transported bound to specific plasma proteins called sex hormone binding globulin (SHBG).

Testosterone is observed in most vertebrates. Fish make a slightly different form called 11-ketotestosterone (Nelson and Randy, 2005). Its counterpart in insects is ecdysone (De Loof, 2006). These ubiquitous steroids suggest that sex hormones have an ancient evolutionary history (Mechoulam, *et al*., 1984).

2.4.1. Testosterone at Different Stages of Development

In the prenatal period, androgens first kick into action during the embryonic stages of life. At about the fourth to sixth week of development an embryo is anatomically defined. Before this, the human foetus is essentially sexless, possessing a set of "indifferent" genitalia. One interpretation of this is that all embryos begin as female and testosterone makes the difference. Under the influence of testicular testosterone, the Wolffian system develops and the Mullerian inhibiting substances causes the Mullerian system to degenerate. But in the absence of foetal testosterone the Mullerian system develops into female reproductive ducts and the Wolffian system fails to develop. By the eighth week, testosterone causes midline fusion, phallic enlargement, scrotal thinning and rugation with development of the prostate and seminal vesicles (Mooradian*et al*., 1987).

During the 2nd trimester androgen levels are associated with gender identity. This period affects the femininization or masculinization of the foetus and can be a better predictor of feminine or masculine behaviours. The gonadal testosterone which further drives the process of male differentiation will then lead to organizational effects on the genitalia, brain and other organ systems. Thus male differentiation is partly dependent on the formation of the foetal testes. Androgen receptors are also very important in determining the finger length pattern of an embryo. Although correlation studies suggest that digit ratios reflect prenatal exposure to androgen, the developmental mechanism underlying sexually dimorphic digit development remains unknown (Manning *et al*., 1998).

By the early infancy around the first week of life for male infants, testosterone level rises (Forest *et al*., 1973). The levels remain in a pubertal range for a few months but

usually reach the barely detectable levels of childhood by fourth to sixth months of age (Corbier*et al*., 1992). The function of this rise in humans is unknown.

Pre- Peripubertal effects are the first observable effects of rising androgen levels at the end of childhood occurring in both boys and girls. Adult-type body odour, increased oiliness of skin and hair, appearance of pubic hair, axillary hair growth spurt, accelerated bone maturation and fat distribution are all the effect of testosterone at that stage of life (Alan *et al*., 2002).

Puberty is a dynamic period of development marked by rapid changes in body size, shape and composition all of which are sexually dimorphic. It is characterized by the greatest sexual differentiation since foetal life and the most rapid rate of linear growth since infancy (Alan *et al*., 2002). Effects of testosterone at this stage begin to occur when androgen has been higher than normal for an adult. The effect is basically the maturation and establishment of secondary sexual characteristics (Bhasin*et al*., 1996). Adult testosterone effects are more clearly demonstrable in males than in females but are likely important to both sexes. Some of these effects may decline as testosterone levels decrease in the later decades of adult life.

2.4.2. Male Testosterone Level

Normal testosterone levels in males vary significantly with age. For the first few months after birth, levels range from 75 - 400 ng/dL, then drops below 20ng/dL until around 10 years, as measured at Mayo Clinic Laboratories (Pardridge et al; 1985). With the onset of puberty, the levels rise gradually through the teen years to as high as 1200 ng/dL. Normal adult values are then from 240 - 950 ng/dL, with an individual's testosterone level dropping slowly within this range beginning sometime after the age

30 years (Pardridge*et al*; 1985). Different laboratories may have slightly different normal values depending on the test method used.

2.4.3. Female Testosterone Level

Testosterone in women shows a similar but more subdued pattern of age-related changes. Levels are highest in the first few months after birth, ranging from 20 to 80ng/dL(Pardridge et al; 1985). As in males, testosterone then drops to less than 20 ng/dL until the onset of puberty at which time the hormone increases again to as high as 75 ng/dL. The level then stabilizes as an adult at between 8 and 60 ng/dL(Pardridge et al; 1985).

Table 2.1 Reference Values of Testosterone in humans for age

Male		Female	
Age	T Level (ng/dL)	Age	T Level (ng/dL)
0-5 months	75-400	0-5 months	20-80
6 mths-9 yrs.	<7-20	6 mths-9 yrs.	<7-20
10-11 yrs.	<7-130	10-11 yrs.	<7-44
12-13 yrs.	<7-800	12-16 yrs.	<7-75
14 yrs.	<7-1,200	17-18 yrs.	20-75
15-16 yrs.	100-1,200	19+ yrs.	8 – 60
17-18 yrs.	300-1,200		
19+ yrs.	240-950		
Adult Male	270-1,070	Adult Female	15-70
30+ yrs.	-1% per year		

Mayo clinic, mayo medical laboratories Testosterone, Total, Bio available, and Free, Serum (TTFB)

2.5 ADOLESCENT AND GROWTH

2.5.1 Adolescent

Adolescence is a transitional period of psychological, social, physical and mental development occurring between childhood and adulthood.It is associated with teenage years. Chronological age provides only a rough marker of adolescence and scholars have found it difficult to agree upon a precise definition (Zukauskaitė*et al*., 2005). During this time, a child will go through many changes in his/ her physical, psychological (mental and emotional) and social growth.

In studying adolescent development, adolescence (derived from a Latin a*dolescentia*, a*dolescere,* which means to grow up) can be defined as a transitional stage of psychological, social, physical and mental human development, generally occurring between puberty and age of maturity (Larson and Wilson; 2004 andArnett , 2007). It is the transmission from child to adulthood.

2.5.2 Growth at Puberty

Puberty is a dynamic period of development marked by rapid changes in body size, shape and composition all of which are sexually dimorphic. The average onset of puberty is at 10 or 11 for girls and age 11 or 12 for boys (Palo Alto medical foundation, 2009).Every person's individual timetable for puberty is influenced primarily by heredity, although environmental factors such as diet and exercise also exert some influence (Kaplowitz*et al.*, 2001). These factors can also contribute to precocious and delayed puberty.

Puberty begins with a surge in hormone production which in turn causes a number of physical and physiological changes in individuals' height, weight, bodycomposition and circulatory and respiratory systems (Alan *et al*., 2002). It is also the stage of life in

which a child develops secondary sex characteristics (for example, a deeper voice and larger adam's apple in boys and development of breasts, more curved and prominent hips in girls) as his or her hormonal balance shifts strongly towards an adult state. This is triggered by the pituitary gland which secretes a surge of hormonal agents into the blood stream initiating a chain reaction. The male and female gonads are subsequently activated which puts them into a state of rapid growth and development. The triggered gonads now commence the mass production of the necessary chemicals. The testes primarily release testosterone and the ovaries predominantly dispense oestrogen. The production of these hormones increases gradually until sexual maturation is met. Some boys may develop gynecomastia due to an imbalance of sex hormones tissue responsiveness or obesity (Niewoehner and Schorer,2008).

Puberty is preceded by adrenarche, marking an increase of adrenal androgen production between ages 6-10. The major landmark of puberty for males is the first ejaculation which occurs on average, at age 10-13 (Kaplowitz*et al*., 2001). For females it is menarche (the onset of menstruation) which occurs between ages 12 and 13 (Zuckerman, 2009).The age of menarche is influenced by heredity, diet, environment and lifestyle (Kaplowitz, *et al*., 2001). Regardless of genes, a girl must have certain proportion of body fat to attain menarche (Kaplowitz, *et al*., 2001). Consequently, girls who have a high-fat diet and who are not physically active begin menstruating earlier than girls whose diet contains less fat and whose activities involve fat reducing exercise (e.g. ballet and gymnastics) (Kaplowitz, *et al*., 2001). Girls who experience malnutrition or are in societies in which children are expected to perform physical labour also begin menstruating at later ages(Zukerman, 2009, Kaplowitz, *et al*., 2001).

The timing of puberty can have important psychological and social consequences. Early maturing boys are usually taller and stronger than their friends (Abbassi, 1998). Late maturing boys can be less confident because of poor body image when comparing themselves to already developed friends and peers. However, early puberty is not always positive for boys. Early sexual maturation in boys can be accompanied by increased aggressiveness due to the surge of hormones that affect them (Abbassi, 1998 andZuckerman, 2009). For girls early maturation can sometimes lead to increased self-consciousness, though a typical aspect in maturing females(Zuckerman, 2009). Because of their bodies' developing in advance, pubescent girls can become more insecure (Alan *et al*., 2002and Palo Alto medical foundation, 2009). Consequently, girls that reach sexual maturation early are more likely than their peers to develop eating disorders (Alan *et al*., 2002). Nearly half of all American high school girls' diet is to lose weight.

During puberty, bones become harder and more brittle. There can be ethnic differences in these skeletal changes. For example, in the United States of America, bone density increases significantly more among African-American than white adolescents. This might account for decreased likelihood of African-American women developing osteoporosis (Gilsanz, *et al*., 1991).

Another set of significant physical changes during puberty happen in bodily distribution of fat and muscle. This process is different for females and males (Alan *et al*., 2002). Before puberty, there are nearly no sex differences in fat and muscle distribution. During puberty, boys grow muscle much faster than girls although both sexes experience rapid muscle development. In contrast, though both sexes experience an increase in body fat, the increase is much more significant in girls. Frequently, the increase in fat for girls happens in their years just before puberty. The ratio between

muscle and fat among post-pubertal boys is around three to one, while for girls it is about five to four. This may help explain sex differences in athletic performance (Alan *et al*., 2002).

Pubertal development also affects circulatory and respiratory systems as an adolescents' heart and lungs increase in both size and capacity. These changes lead to increased strength and tolerance for exercise. Sex differences are apparent as males tend to develop larger hearts and lungs, higher systolic blood pressure, a lower resting heart rate, a greater capacity for carrying oxygen to the blood, a greater power for neutralizing the chemical products of muscular exercise, higher blood haemoglobin and more red blood cells (Peterson and Taylor, 1980 and Alan *et al*., 2002).

Despite some genetic sex differences, environmental factors play a large role in biological changes during adolescence. For example, girls tend to reduce their physical activity in preadolescence (Savage and Scott, 1998) and may receive inadequate nutrition from diets that often lack important nutrients such as iron (Johnson *et al*., 1994). These environmental influences in turn affect female physical development.

2.6. Body Composition

Sex differences in composition of body fat are evident even at the foetal stage but they become much more pronounced during puberty (Wells, 2007). Women have substantially more total adipose tissue than men and these whole-body sex differences are complemented by major differences in tissue distribution. Men have greater arm muscle mass, larger and stronger bones, less limb fat and a relatively greater central distribution of fat. Women have a more peripheral distribution of fat in early adulthood (Alan *et al*., 2002). These differences continue throughout adult life. Sex differences in

body composition are primarily attributable to the action of sex steroid hormones which drive the dimorphisms during pubertal development. Derby *et al,* (2006) in their study found an association between total and free testosterone levels with obesity. They found that a reduction in free testosterone levels was associated with an increase in fat mass and reduction in muscle mass in men.

The ever-increasing worldwide problems associated with obesity pose increased risk for coronary heart disease, hypertension, abnormal cholesterol, diabetes mellitus, sleep apnoea and certain cancers (Hainer*et al*., 2008). However, the increased risks associated with obesity are of greater concern depending on the pattern of fat distribution in the body (Srikanthan*et al*., 2009). Torso and abdominal fat referred to as visceral, central or intra-abdominal fat is related to health abnormalities including insulin resistance and abnormal blood lipid levels. This escalates the risk of diabetes mellitus and cardiovascular disease respectively (Ness-Abramof and Apovian, 2008). Presently, body mass index (BMI), waist circumference and waist-to-hip ratio are employed for classifying obesity and the risks of abdominal fat accumulation.

In the human body, fat can be divided into two main compartments: visceral (torso) and subcutaneous (under the skin). Fat is also stored in smaller amounts in the heart, pancreas, liver and within muscles (intramuscular fat which is used for fuel during exercise). Visceral body fat helps to maintain free fatty acid (free fatty acids are the triglyceride molecules separated from their glycerol 'backbone') levels in the blood and facilitates in the regulation of blood insulin (Ness-Abramof and Apovian, 2008). Visceral fat may be infiltrated by specific immune cells (known as macrophages) which will trigger insulin resistance, a precursor for pre-diabetes and diabetes (Attie and Scherer, 2009).

Fat cells which were once considered to be solely energy depots are now known to be busy endocrine organs. They secrete a number of specialized proteins known as cytokines which regulate responses to infection, immune reactions, inflammation and trauma. In regards to inflammation regulation (the response of the body to injury or irritation) fat cells secrete pro-inflammatory cytokines (Dinarello, 2000). Some of the cytokines promoting inflammation are tumour necrosis, interlukin-6 and C-reactive protein. These pro-inflammatory cytokines can damage arterial walls when chronically elevated in the circulatory system such as from high blood pressure and become the starting point for atherosclerotic plaque build-up.

The measurement of body composition has assumed an important role in endocrine and metabolic research studies as well as in the clinical practice of endocrinology. Body compositional changes including the regional distribution of body fat are especially expressed during the pubertal transition and markedly sexually dimorphic (Alan *et al*., 2002).

Changes in body composition including alterations in the relative proportions of water, muscle, fat and bone are hallmarks of pubertal maturation and the result of typical sex differences (Alan *et al*., 2002). Under the influence of testosterone, boys have a significant increase in the growth of bone and muscle with a simultaneous loss of fat in the limbs (Tanner *et al*., 1989). Testosterone is also implicated in pubertal growth spurt in females (Rako, 1996). The increase in skeletal size and muscle mass leads to increased strength in males. Increase in both height and weight are the strongest correlates of skeletal mineralization during childhood and adolescence (Slemenda*et al*., 1994). Boys have a marked age-related delay in skeletal mineralization compared to girls. The former continue to deposit substantial bone mineral between the ages of 15

and 18 years (Slemenda*et al*., 1994and Alan *et al*., 2002). This increase in bone mineral density continues after the pubertal growth spurt.

2.6.1.The Body Mass Index(BMI)

The Body mass index (BMI) is a measure of body mass corrected for height which is used to assess the extent of weight deficit or excess. BMI also provides a practical indicator of adiposity and hence overweight or obesity. It is calculated as weight in kilogram (kg) divided by the square of height in meters (Eknoyan, 2007).Another simple BMI calculation is body weight in pounds multiplied by 703 and then divided by height in inches. The World Health Organization (WHO) has established guidelines for normal (18.5 - 24.9 kg/m^2), overweight (25-29.9 kg/m^2) and obese (>30 kg/m^2) adults (Dietz *et al*., 2009). One of the drawbacks of BMI use in fitness populations is that a muscular person will score higher, producing an inaccurate assessment of overweight or obese. Ness-Abramof and Apovian (2008) also indicated that older populations tend to have a loss in muscle mass, possibly leading to an underestimate of the BMI.

The body mass index varies between individuals (Fink *et al*., 2003) and is a weak predictor of weight related health problems among some racial and ethnic groups such as African-American and Hispanic-American women (National Institute of Diabetes and Digestive and Kidney Diseases, 2008).

2.6.2. Waist Circumference

Generalized and abdominal obesity are associated with increased risk of morbidity and mortality. Cardio vascular disease are the main cause of death related to obesity and abdominal obesity is a major predisposing factor (WHO, 2008). The precise

measurement of visceral fat requires the use of magnetic resonance imaging or tomography which is scientific techniques that visually depict the internal tissue compositions. Waist circumference is a substitute technique for these scientific assessments (WHO, 2008). Landmarks used for waist measurement include the umbilicus, the midpoint between the lowest rib and the iliac crest and just above the iliac crest. According to the WHO (2008), the waist circumference should be measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest, using a stretch-resistant tape that provides a constant 100 g tension. The United States national institutes of health and the national health and nutrition examination survey used results obtained by measuring at the top of the iliac crest. Waist measurements are usually obtained by lay persons by measuring around the waist at the umbilicus but study has shown that these measurements may underestimate the true waist circumference. The measurement is usually taken at the end of expiration, when the diaphragm is in its neutral position. During an inspiration, the diaphragm descends into the abdominal cavity, enlarging the waist circumference measurement. A waist circumference >35 inches (88 cm) in women and >40 inches (102 cm) in men is associated with higher cardiometabolic risk (Ness-Abramof and Apovian, 2008). Welborn and Dhaliwal (2007) indicate that waist circumference is superior to BMI in predicting cardiovascular disease risk.

2.6.3. Waist-to-Hip Ratio

Waist–hip ratio or waist-to-hip ratio (WHR) is the ratio of the circumference of the waist to that of the hips. The WHR has been used as an indicator or measure of the health of a person, and the risk of developing serious health conditions (Welborn and Dahlia, 2007). Research shows that people with "apple-shaped" bodies (with more weight around the waist) face more health risks than those with "pear-shaped" bodies

who carry more weight around the hips (Srikanthan*et al*., 2009). WHR is used as a measurement of obesity which in turn is a possible indicator of other more serious health conditions. WHO (2008) states that abdominal obesity is defined as a waist–hip ratio above 0.90 for males and above 0.85 for females or a body mass index (BMI) above 30.0. The National Institute of Diabetes, Digestive and Kidney Diseases (NIDDK) stated that women with waist–hip ratio of more than 0.8 and men with more than 1.0 are at increased health risk because of their fat distribution. Although there are age-specific table cut-offs for youth with waist circumference, waist is measured at the narrowest point of one's midsection between the bottom rib and the top of the hipbone. A WHR of 0.7 for women and 0.9 for men has been shown to correlate strongly with general health and fertility. Women within the 0.7 range have optimal levels of oestrogen and are less susceptible to major diseases such as diabetes, cardiovascular disorders and ovarian cancers (WHO, 2008). Women with high WHR (0.80 or higher) have significantly lower pregnancy rates than women with lower WHR (0.70–0.79) independent of their BMI (Singh, 1994). Men with WHR around 0.9 similarly have been shown to be more healthy and fertile with less prostate cancer and testicular cancer (WHO, 2008).

WHR has been found to be a more efficient predictor of mortality in older people than waist circumference or BMI threefold (WHO, 2008) and if obesity is redefined using WHR instead of BMI, the proportion of people categorized as at risk of heart attack worldwide increases (WHO, 2008).

CHAPTER THREE

MATERIALS AND METHODS

3.1. STUDY LOCATION

The study was carried out in six secondary schools (Queens School Enugu, Holy Rosary College, New Heaven Girls, College of Immaculate Conception, Urban Boys Secondary School and Uwani Secondary School) within Enugu metropolis in Enugu state, south- Eastern part of Nigeria.

Enugu State is one of the 36 States in Nigeria, apart from the Federal Capital Territory, located between latitude 5° $56^{'}$ N and 7º 00' N and longitude 7º 00' E and 7º$55^{'}$ E of the Greenwich meridian (fig. 3.1). The State is bounded in the northeast by Ebonyi State, on the north by Benue and Kogi States and to the west by Anambra State from which it was carved out in 1991. In the south it borders with Abia State. Enugu State has a total land area of 7660.166 square kilometres with a population of 3,267,837 persons (National population census, 2006) and therefore a population density of 427 persons per square kilometre with an area code of 042. Administratively, Enugu State is divided into 19 Local Government Areas. But politically, there are three zones, namely: Enugu North, Enugu South and Enugu Central. About 85% of the rural population are engaged in the agriculture. The State capital is located at the hilly city of Enugu, an old seat of government. Enugu was the capital of the former East Central State from which present Anambra, Enugu, Imo, Abia, and Ebonyi States were carved out. It is a highly cosmopolitan town. Enugu boasts of a couple of industries. The state is called the Coal City State because of the discovery of coal in commercial quantity in Enugu urban in 1909 (Enete and Alabi, 2012).

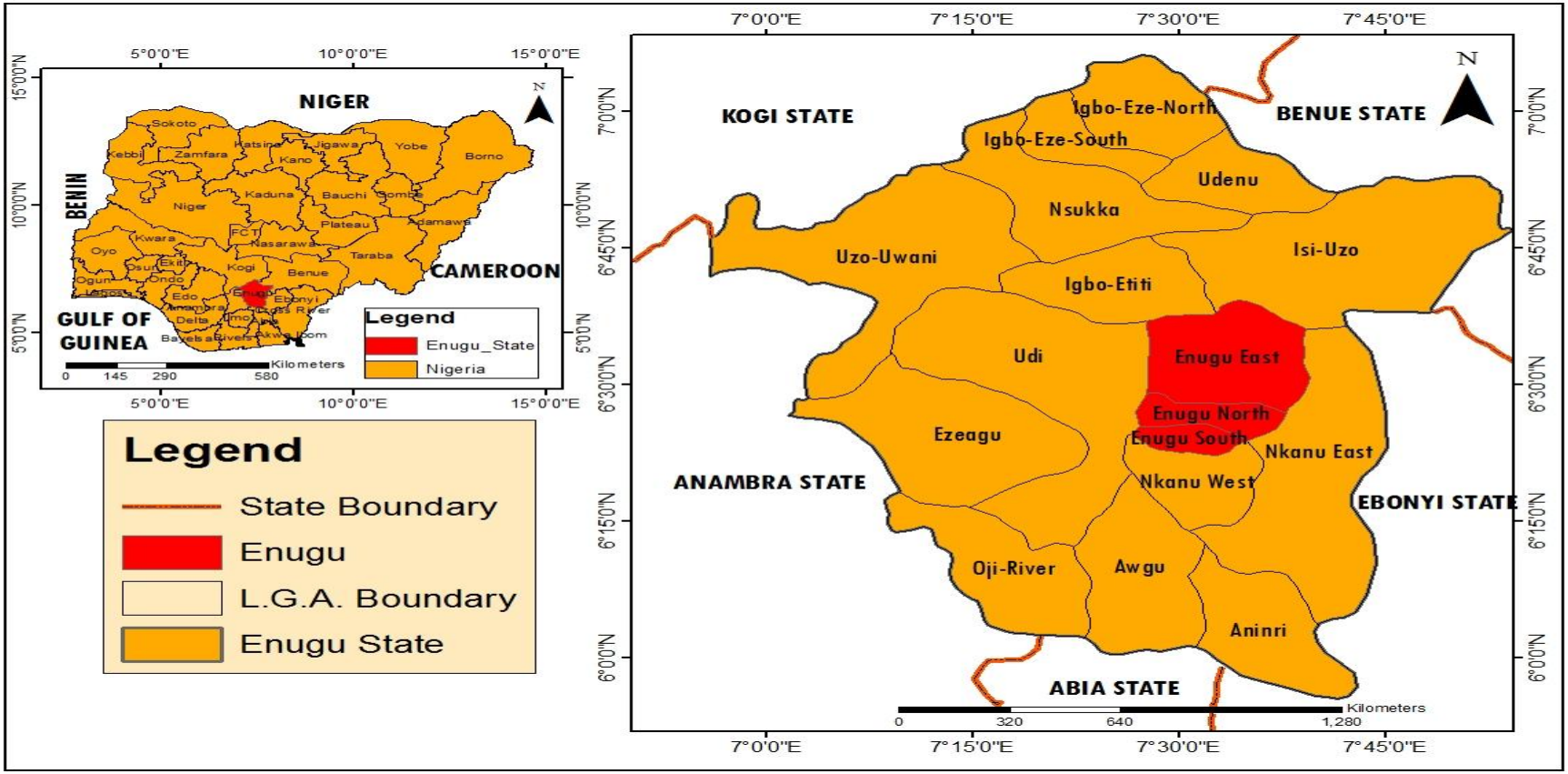


Figure 3.0: Map of Nigeria showing the study area

Source: Geographic information systems

3.2. SAMPLE SIZE DETERMINATION

The sample size for this study was determined using the formula:

n = $z^2 pq/d^2$((Naing, 2006)

Where:

n = the desired sample size

z = the standard normal deviate, usually set at 1.96 (≈ 2.0)

p = the proportion in the target population having the particular trait (when no estimate 50% is used, i.e. 0.50)

q = 1.0 ─ *p*

d = degree of accuracy desired, usually set at 0.05

Thus *n* = *(*$1.96)^2$ (0.5) (0.5)/ $(0.05)^2$

= 384

As calculated, the minimum sample size for the study was 384. However, 10% was used as attrition (to accommodate refusal and non response by some participants). Thus, a total of about 422 participants were recruited for the purpose of this study out of which 412 was reported.

3.3. RESEARCH PARTICIPANTS

The data required for the study was obtained from 412 adolescents (209 males and 203 females) aged 12 to 20 years attending secondary schools within Enugu metropolis and are from the Igbo ethnic group.

3.4. INCLUSION CRITERIA

i. Adolescent subjects within the age group of 12 to 20 years

ii. Participants were from the Igbo ethnic group in Nigeria

iii. Participants were mentally fit and had no body deformities

3.5. EXCLUSION CRITERIA

i. Participants with structural deformities that could hinder accurate anthropological assessment

ii. Those with obvious sign of anaemia were excluded from the study.

iii. All subjects who declined to give consent for inclusion in the study were also excluded.

3.6. METHODOLOGY

Data were collected from adolescents in the public secondary schools used for this study. Informed consent was also obtained from participants and their parents and guardians before their inclusion into the study using consent forms (Appendices I and II). In this case, the nature of the study was explained to the participants in the appropriate languages best understood by them. Brief medical assessments were carried out on the subjects followed by anthropometric measurements and blood collection. Information required from participants were obtained through questionnaires (appendix V) distributed to the participants. Questionnaires were filled with any writing material and mistakes were corrected before collecting them. Other anthropometric data were collected through direct measurement on the subjects using the methods described below:

3.7 ANTHROPOMETERIC MEASUREMENT

3.7.1Finger Length Measurements

The length of each finger on both hands of each subject was measured using electronic venire calipers(precision 0.01 mm) as described by Fink *et al* (2003). The length of each finger was defined as the distance from the ventral proximal crease of the digit to the tip. If there was a band of creases at the base of the digit, measurements were made from the most proximal of these. Measurements were performed twice. Finger lengths were calculated as the mean values of the first and second measurement of the length of each digit.(Plate 3.1)

3.7.2Weight and Body Composition

Weight and body composition values were obtained using the innerscan body composition monitor (Plate 3.2). The body monitor was set as described in the manual. Weight values were taken with subjects on light clothes and barefoot. Values for weight, body fat percentage, visceral fat rating, estimated muscle mass and bone mass for all the subjects were recorded accordingly.

3.7.3 Height

Height was measured using a standiometer with subjects standing without shoes and with heels together, toes apart, ensuring that weight was evenly distributed on both feet and the head held in the Frankfort plane to the nearest 0.1cm. The arms were made to hang freely by the sides and the head, back, buttocks and heels were positioned vertically so that the buttocks and the heels was in contact with the vertical board(Plate 3.3).

3.7.4 Chest Circumference (cm)

This measurement was taken at the level of the middle of the sternum (breast-bone), with a standard tailor tape passing under the arms. After the tape was put in position, the arms werethen relaxed by the side and the measurement taken at the end of a normal expiration (Plate 3.4).

3.7.5 Waist Circumference(cm)

Standard tailor measuring tape, maximum length 150 cm was used for this measurement. The subjects were dressed as for the weight measurement and made to stand with feet close together, arms at the side and body weight evenly distributed. The hip area was palpated and a measurement reference point to identified. The measurements were taken at the midpoint between the lowest rib and the iliac crest. The measuring tape was placed perpendicular to the long axis of the body and horizontal to the floor, with sufficient tension to avoid slipping off but without compressing the skin. The measurement was made at the end of a normal expiration to the nearest 0.1cm. Each measurement was repeated twice. The measurements that were within 1 cm of one another, the average were calculated. Those whose differencebetween the two measurements exceeded 1 cm, the two measurements were repeated WHO, 2008).

3.7.6 Hip Circumference

The subjects stood erect with the weight evenly distributed on both feet then the tape was placed at the maximum extension of the buttocks, horizontal to the floor, with sufficient tension to avoid slipping off. The tape was held a bit tighter but without compressing the buttocks. The zero end of the tape was held under the measurement and the value was recorded to the nearest 0.1cm (Plate 5)

*3.7.7*Body Mass Index(BMI)

The BMI also known as "Quetelet's index" is an index that uses the variables weight and height to measure body fat and protein stores. It was calculated as the rapport of weight in kilogram by square of height in meters (m^2).BMI (kg/m^2) = weight (kg)/height (m^2).

3.7.8 Blood Specimen Collection and Processing

Blood specimens (about 2ml each) were taken into plain tubes by venepuncture (plate VI). This was performed using a syringe and needle after sterilizing the site with methylated spirit. A tourniquet was applied a few centimetres above the site to distend the veins and blood taken using a sterilized 2 ml syringe and 22 G needle. The blood specimens in the plain tubes were centrifuged at 2000 r.p.m for 20min ($30^{o}C$) and the sera carefully drawn into sample bottles and then analyzed immediately for testosterone.

3.7.9Estimation of Serum Testosterone

Serum testosterone was estimated using Enzyme Immunoassay (EIA) technique as described by Johnson and Korenam (1987) in the laboratory using BioCheck, Inc testosterone EIA test kit.(BioCheck Inc., Foster City, CA).

3.7.10 PrincipleEnzyme Immunoassay

The testosterone EIA is based on the principle of competitive binding between testosterone in the test specimen and testosterone-HRP conjugate for a constant amount of rabbit-anti testosterone.

3.7.11Enzyme ImmunoassayProcedure

The desired number of coated wells in the holder was secured. 10ul of standards, specimen and controls were dispensed into the appropriate wells. Also 100ul and 50ul of the testosterone-HRP conjugate reagent and rabbit anti testosterone reagent were put into the wells respectively. The contents of the wells were thoroughly mixed for 30 seconds and then incubated at 37^{oc} (for 90 minutes). The microwells were then rinsed 5 times with distilled water. 100ul of Tetramethylbenzidine(TMB) reagent was dispensed into each well and gently missed for 10 seconds. The mixture was incubated at room temperature for 20 minutes. The reaction was stopped by adding 100ul of stop solution to each well and gently mixed for 30 seconds. The absorbance value was read at 450 nm with a microtiter well reader (Syntron MSR-1000) within 15 minutes.



Plate I: Demonstration of measurement of finger lengths using a digital calliper



Plate II: Body compositionanalyzer from TanitaCorporation used in the measurement of body weight and body fat percentage



PlateIII: Demonstration of height measurement



PlateIV: Demonstrating Chest circumference measurement



Plate V: Demonstrating Hip circumference measurement



Plate VI: Blood specimen collection

3.8 Ethical Consideration

A letter of introduction addressed to all principals of the various schools where the study was conducted was obtained from the Department of Anatomy, Ahmadu Bello University, Zaria, Kaduna State.Informed consent was obtained from parents and guardians of each participant recruited for this study and from each participant as well using standard informed consent formats (Appendices 1andII). Ethical approval was obtained from the Ethical Committee of Ahmadu Bello University Teaching Hospital (ABUTH), Zaria and that of Enugu State Ministry of Health in accordance with the Helsinki declaration(Appendices III and IV).

3.9 Data Analysis

Data were presented as descriptive statistics; Mean ± standard deviation.Student t-test was applied to test for difference in mean of all variables in males and females.The statistical analyses of the data weredone using SigmaStat 2.0 for Windows (San Rafael, CA,Statsoft, 1995).Pearson correlation was used to test the relationship between each of measured anthropometric parameters.Statistical significant difference was deemedacceptable at $p<0.05$for all analysis. Linear and multiple regression equations were used to generate predictive equations.

CHAPTER FOUR

RESULTS

4.1.ANALYSIS OF STUDY OF POPULATION

A total of Four hundred and twelve students 412 aged 12 to 20 years old comprising of two hundred and nine (209) males (mean age 15.65 ± 1.23) and two hundred and three (203) females (mean age 15.65 ± 1.04) were considered for this study.

4.2.DESCRIPTIVE STATISTICS SHOWING THE FINGER LENGTH OF THE RIGHT AND LEFT HANDS OF SUBJECTS ACCORDING TO SEX

The mean digit lengths of all digits of the right and left hand in both sexes with the characteristics of their values (minimum and maximum) are represented in Table 4.1. The mean values of all the finger digits are lower in females than inmales.

The result therefore shows a strong sexual dimorphism in finger digit length as shown in table 4.1 with statistical significant difference in males and females$P<0.001$.

Table 4.1: Descriptive statistics showing the finger length of the right and left hands of subjects according to sex

	MALES (n=209)				FEMALES (n=203)					
Variables	**Mean± SD**	**Maximum**	**Minimum**	**Range**	**Mean± SD**	**Maximum**	**Minimum**	**Range**	**t**	**P**
Right 1D	67.67±4.77	83.25	55.02	28.23	62.18±4.15	74.43	48.70	25.73	12.43	<0.001
Right 2D	75.08±5.02	91.32	59.13	32.19	70.18±3.91	80.41	59.23	21.18	11.04	<0.001
Right 3D	83.68±5.24	98.77	67.04	31.73	77.12±4.49	88.85	66.63	22.22	13.62	<0.001
Right 4D	76.77±5.12	91.24	60.02	31.22	70.60±4.08	82.88	59.13	23.75	13.53	<0.001
Right 5D	60.50±4.58	75.43	45.28	30.15	55.55±4.47	68.26	35.30	32.96	11.10	<0.001
Left 1D	67.32±4.52	82.51	56.29	26.22	61.40±4.12	71.31	44.75	26.56	13.89	<0.001
Left 2D	75.08±5.10	91.12	58.83	32.29	70.18±3.09	80.72	59.08	13.46	10.96	<0.001
Left 3D	83.68±5.21	98.54	70.05	28.49	77.31±4.45	89.06	66.60	22.46	13.56	<0.001
Left 4D	76.78±5.22	91.02	60.01	31.01	70.60±4.11	83.11	58.99	24.34	13.29	<0.001
Left 5D	60.92±4.75	75.06	46.20	28.89	55.80±4.25	68.09	43.74	25.35	11.52	<0.001

n = sample size, SD = standard deviation, 2D = 2nd digit (index finger), 3D = 3rd digit (middle finger), 4D = 4th digit (ring finger), 5D = 5thdigit (little finger). Length is expressed in mm.

Table 4.1 indicates strong sexual dimorphism in finger digit length P<0.001

4.3.DESCRIPTIVE STATISTICS SHOWING DIGIT RATIOS OF THE RIGHT AND LEFT HANDS OF SUBJECTS ACCORDING TO SEX

Table 4.2 presents the means and standard deviations of all the digit ratios studied.

Females had higher 2D: 4D (0.99±0.01) than males (0.98 ±0.01) in both hands. This difference was statistically significant at P<0.001.

The result also revealed statistical significant difference (P<0.001) in other digit ratios. 3D:5D and3D:4D were not significantly different.

4.4.DESCRIPTIVE STATISTICS SHOWING ANTHROPOMETRIC VARIABLES AND BODY COMPOSITION OF SUBJECTS ACCORDING TO SEX

Table 4.3 presents the means and standard deviations of anthropometric variables, testosterone and body composition studied. Student's t-test analyses indicated significant difference in all the variables($p < 0.001$), however the difference in hip circumference was statistically significant ($p = 0.002$). Age was not significantly different. Males had higher mean value of testosterone level (0.80±0.60) than females (0.193±0.10) while females had higher mean value of percentage body fat (18.603±7.93) than males (8.46±2.88).

Table 4.2: Descriptive statistics showing the digit ratios of the right and left hands of subjects according to sex

	MALES (n=209)				FEMALES (n=203)					
Variables	**Mean± SD**	**Maximum**	**Minimum**	**Range**	**Mean± SD**	**Maximum**	**Minimum**	**Range**	**t**	**P**
Right 2D:4D	0.98±0.01	1.04	0.92	0.12	0.99±0.01	1.01	0.97	0.04	15.29	<0.001
Left 2D:4D	0.98±0.01	1.02	0.97	0.05	0.99±0.01	1.02	0.97	0.05	16.17	<0.001
Right 2D:3D	0.90±0.02	0.97	0.77	0.20	0.91±0.03	1.01	0.81	0.20	5.18	<0.001
Left 2D:3D	0.90±0.02	0.97	0.82	0.15	0.91±0.03	1.03	0.82	0.81	4.67	<0.001
Right 2D:5D	1.24±0.05	1.42	1.11	0.31	1.27±0.08	1.93	1.12	0.81	3.71	<0.001
Left 2D:5D	1.24±0.05	1.42	1.10	0.32	1.26± 0.07	1.48	1.11	0.37	4.43	<0.001
Right 3D:5D	1.39±0.07	1.63	1.20	0.43	1.39±0.09	2.04	1.13	0.91	0.94	0.35
Left 3D:5D	1.38±0.7	1.64	1.23	0.41	1.38±0.07	1.63	1.15	0.48	1.55	0.12
Right 3D:4D	1.09±0.03	1.27	1.02	0.25	1.09±0.03	1.24	0.97	0.27	0.72	0.47
Left 3D:4D	1.09±0.03	1.19	1.03	0.16	1.09 ± 0.03	1.22	0.95	0.27	1.09	0.28

n = sample size, SD = standard deviation,

Table 4.2 showing statistical significant difference in digit ratios (P<0.001). 3D:5D and 3D:4D of both hands were not significantly different.

Table 4.3:Descriptive statistics showing anthropometric variables and body composition of subjects according to sex

	MALES (n=209)				FEMALES (n=203)					
Variables	**Mean± SD**	**Maximum**	**Minimum**	**Range**	**Mean± SD**	**Maximum**	**Minimum**	**Range**	**T**	**P**
Age (yrs)	15.82±1.23	19.00	13.00	6.00	15.65±1.04	20.00	13.00	7.00	-1.54	0.125
Weight (kg)	60.32±8.70	82.50	36.00	46.50	51.19±8.72	74.10	30.70	33.40	10.64	<0.001
Height (cm)	169.29±8.02	1.96	1.48	0.48	162 ±9.19	1.78	1.47	0.31	-9.83	<0.001
BMI (kg/m^2)	20.98±2.20	28.500	16.20	12.30	19.63±3.16	28.50	13.00	15.50	-5.09	<0.001
Body fat (%)	8.46±2.88	5.90	5.00	0.90	18.603±7.93	35.40	5.00	30.40	-11.26	<0.001
Testosterone (ng/ml)	0.80±0.60	16.50	0.1	16.40	0.193±0.10	0.40	0.00	0.40	17.36	<0.001
Chest circumference (cm)	81.91±5.91	98.00	66.00	32.00	85.68±6.24	107.10	68.00	39.10	6.29	<0.001
Waist circumference (cm)	76.71±4.83	92.00	65.00	27.00	78.75±5.92	98.00	64.00	34.00	3.83	<0.001
Hip circumference (cm)	88.03±6.29	103.00	67.00	36.00	92.02±6.30	113.00	76.00	37.00	6.43	<0.001
Waist: hip	0.87±0.05	1.16	0.78	0.28	0.86±0.06	1.07	0.70	0.37	-3.06	0.002
Waist : chest	0.94±0.06	1.080	0.82	0.26	0.92±0.05	1.04	0.76	0.28	-3.59	<0.001

n = sample size, SD = standard deviation, BMI= Body mass index.

Student's t-test of anthropometric and body composition variables of subjects according to sex is presented in this table. Sex difference in waist to hip ratio was significant at P=0.002 while other variables had statistically significant differences between sexes (P<0.001) except for age P=0.125.

4.5.DESCRIPTIVE STATISTICS OF ANTHROPOMETRIC VARIABLES, TESTOSTERONE AND BODY COMPOSITION OF SUBJECTS ACCORDING TO SEX IN RELATION TO AGE GROUP

Table 4.4 presents the means and standard deviations of anthropometric variables, testosterone and body composition of males and females in different age groups(age group 12–15 and age group 16–19). For the age group 12–15(n= 78 males, 86 females) a statistical significant difference was observed in weight (Fig 4.1), height (Fig 4.2), BMI, testosterone (Fig 4.3), body fat percentage Fig (4.4), waist to hip ratio, waist to chest ratio as well as in hip and waist circumferences(Fig 4.5). However, waist circumference was not significantly different (P=0.221). For the 16–19 (n= 131 males, 117 females) the result showedsignificant sexes differences in weight (Fig 4.1), height (Fig4.2), testosterone (Fig 4.3), body fat percentage Fig (4.4) and all body circumferences studied (4.5). These differences werestatistically significant (P<0.001).BMI, waist to hip ratio and waist to chest ratio were not significantly different (P= 0.582, 0.181 and 0.327) respectively.

Table 4.4: Descriptive statistics of anthropometric variables, testosterone and body composition of subjects according to sex in relation to age group

	13-15 years				16-19 years(n=131)			
	Male (n=78)	Female (n=86)			Male (n=131)	Female (n=117)		
Variable	Mean± SD	Mean± SD	T	P	Mean± SD	Mean± SD	**T**	**P**
Weight (kg)	58.30± 7.76	51.05± 8.28	5.79	<0.001	61.53± 9.03	51.29± 9.09	8.89	<0.001
Height (cm)	167.23 ± 8.22	161.33±5.91	5.32	<0.001	170.52± 7.67	160.68±11.01	8.24	<0.001
BMI (kg/m^2)	20.8 ±2.13	19.6±3.06	-2.86	0.005	21.1 ±2.14	20.6± 10.35	-0.55	0.582
Body fat (%)	0.74 ±0.58	19.3±7.47	21.92	<0.001	19.3 ±7.47	18.1 ±8.24	23.65	<0.001
Testosterone (ng/ml)	8.03 ±2.57	0.18±0.10	-28.14	<0.001	8.17 ±3.02	0.20 ±0.11	-30.49	<0.001
Chest circumference (cm)	80.8 ± 5.69	84.9±6.11	4.43	<0.001	82.6 ±5.98	86.2 ±6.30	4-72	<0.001
Waist circumference (cm)	75.9 ± 4.49	76.9±5.26	1.23	<0.221	77.2± 4.98	80.1± 6.02	4.22	<0.001
Hip circumference (cm)	87.2 ± 5.60	91.1±5.65	4.50	<0.001	88.5 ±6.64	92.7± 6.70	4.87	<0.001
Waist: hip	0. 87 ± 0.04	0.84±0.04	-4.42	<0.001	0.87 ±0.05	0.87± 0.04	-1.34	0.181
Waist : chest	0. 94 ± 0. 06	0.91±0.04	-4.48	<0.001	0.94 ±0.54	0.93± 0.05	-0.98	0.327

n = sample size, SD = standard deviation, BMI= Body mass index.

Table 4.4 shows sexual dimorphism in weight, height, body fat percentage and testosterone in males and females different age groups

P<0.001

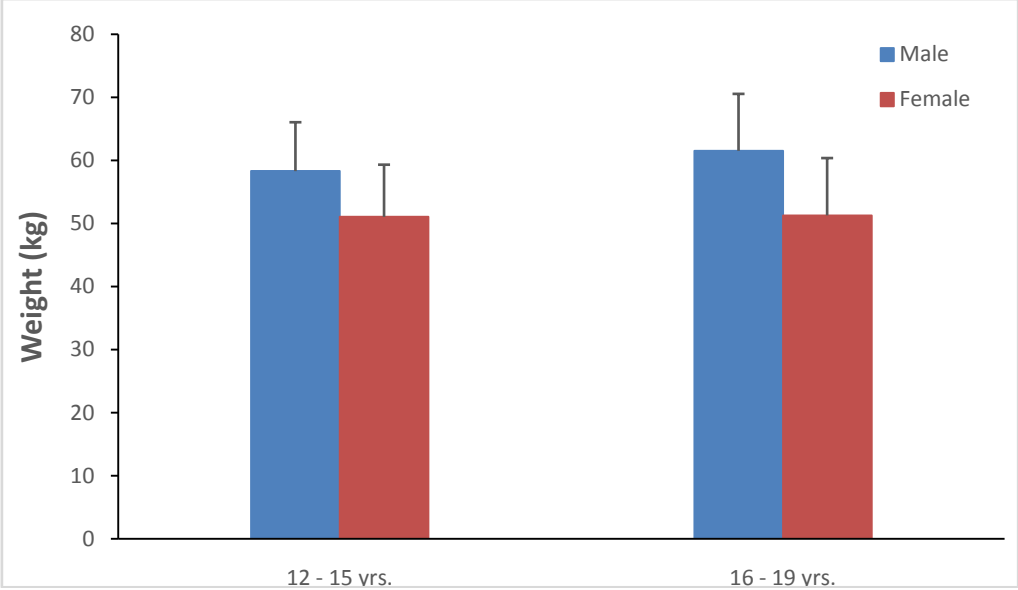


Fig 4.1: Sex difference in weight at different age groups. Student's t-test showed statistical significant sex difference in weight $P < 0.001$.

The males are heavier than females in the different age groups.

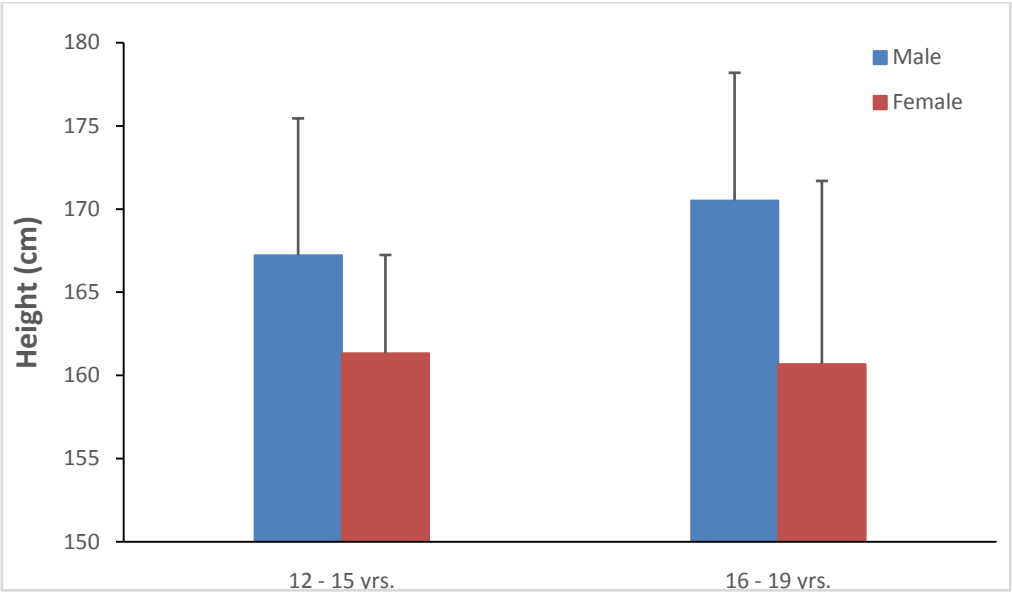


Fig 4.2: Sex difference in height of participants within the ages of 12–15 and 16–19.Student's t-test showed statistical significant sex difference in height P< 0.001. Males in the different age groups studied were taller than females.

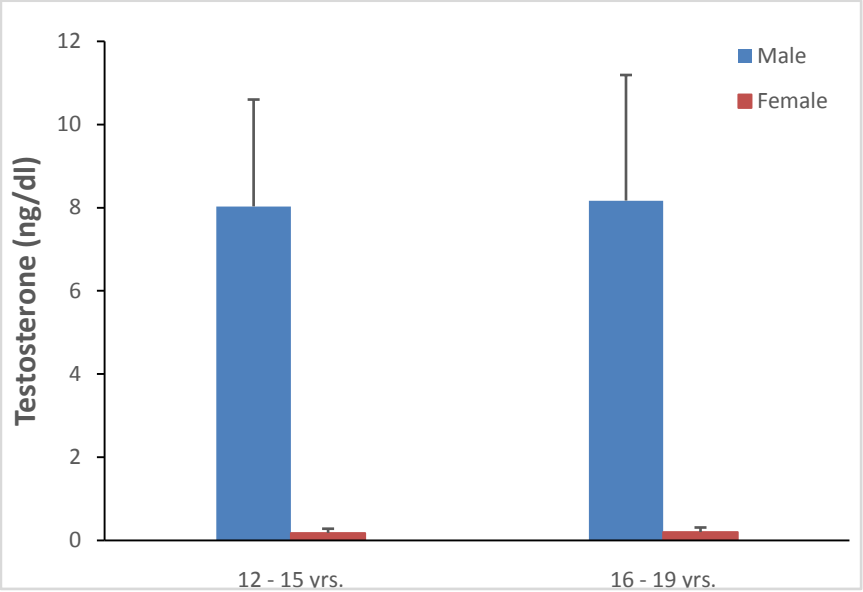


Fig 4.3:Mean± SD of testosterone in males and females of different age groups.

Student's t-test indicates statistical significant sex difference in testosterone level with age P< 0.001. Males had higher mean value for testosterone than females.

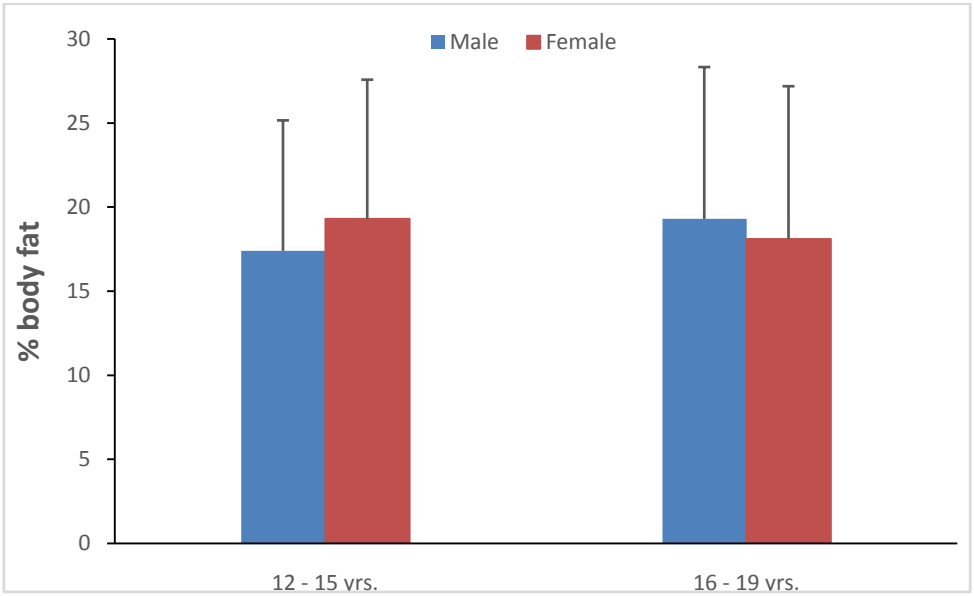
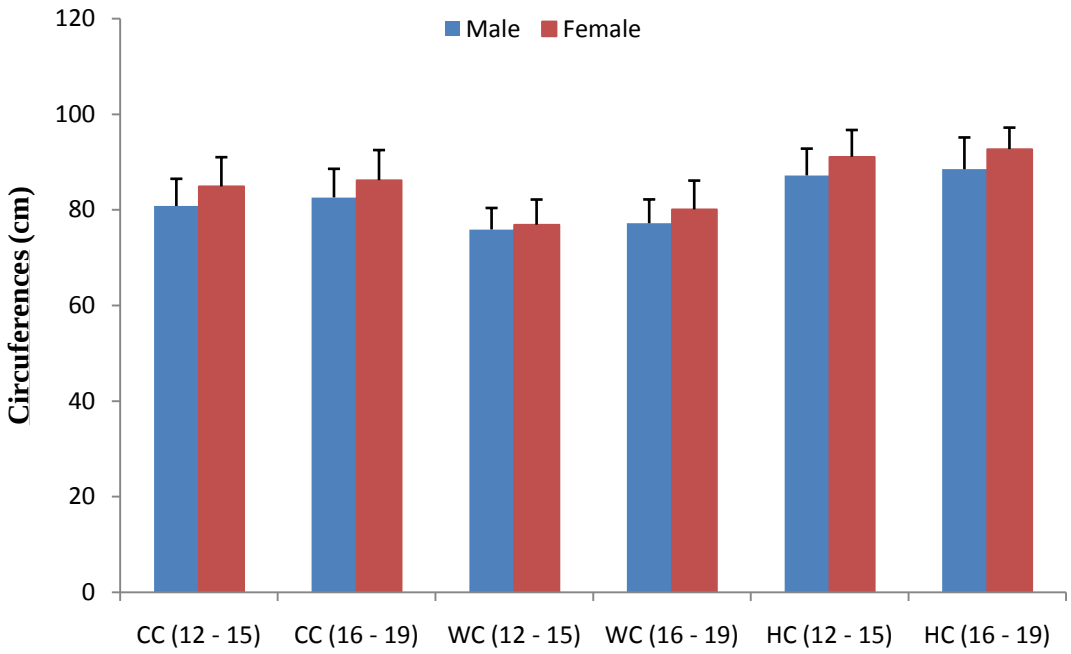


Fig. 4.4: Mean± SD of body fat percentage in males and females of different age groups.

Student's t-test showed statistical significant sex difference in body fat percentage P< 0.001. Males in the different age groups studied had lower body fat percentage than females.



CC = chest circumference, WC = waist circumference, HC = hip circumference

Fig 4.5:Sex difference inchest, waist and hip circumference at age groups 12–15 and 16–19. Females had higher chest, waist and hip circumferences than males for both age groups P< 0.001. However waist circumference was not significantly different in the age group 12–15(P=0.221)

4.6.CORRELATION MATRIX OF SERUM TESTOSTERONE, 2D:4D AND BODY COMPOSITION IN FEMALES.

2D:4D, testosterone and anthropometric variables were correlated to investigate the relationship the variables. Table 4.5showedthat in the female population, serum testosterone correlated positively with weight, body mass index, body fat percentage, 2D:4D of the right hand, chest circumference, waist circumference and hip circumference $P<0.01$, but an inverse correlation with 2D:4D of the left hand $P<0.01$.

The table also demonstratedpositive significant correlation in waist to chest ratio for 2D:4D of both handsbut height and weighthad inverse relationshipwith 2D:4D of both hands. An inverse correlation with chest circumference for 2D:4D of the right and a positive correlation for 2D:4D of the left hand ($P<0.01$) was also observed.

4.7.CORRELATION MATRIX OF SERUM TESTOSTERONE, 2D: 4D AND BODY COMPOSITION IN MALES.

Table 4.6showedan inverse correlation in testosterone for 2D:4D ratio of both hands $P<0.01$ but a positive correlation in testosterone for weight ($P<0.05$), height($P<0.05$), body fat percentage and body fatpercentage $P<0.01$. Digit ratio of left hand correlates negative with chest circumference $p < 0.01$.

Table 4.5: Correlation matrix of circulating testosterone, anthropometric variables and body composition in females (n=203)

Variables	T	Age	WT	HT	BMI	%BF	R2D4D	L2D4D	CC	WC	HC	WHR	WCR
T	-	0.08	0.31[b]	0.04	0.31[b]	0.30[b]	0.46[b]	-0.50[b]	0.24[b]	0.18[b]	0.32[b]	0.18[b]	-0.07
Age		-	0.05	0.04	0.03	-0.09	0.02	0.03	0.18[a]	0.36[b]	0.19[b]	0.36[b]	0.26[b]
Weight			-	0.34[b]	0.89[b]	0.82[b]	-0.15[b]	-0.26[b]	0.51[b]	0.55[b]	0.74[b]	0.55[b]	0.07
Height				-	-0.12	-0.04	-0.16[a]	-1.18[a]	0.29[b]	0.29[b]	0.37[b]	0.29[b]	0.03
BMI					-	0.90[b]	-0.08	-0.13	0.40[b]	0.44[b]	0.60[b]	0.44[b]	0.06
Body fat						-	-0.09	-0.13	0.30[b]	0.31[b]	0.52[b]	0.31[b]	0.01
R2D4D							-	0.90[b]	-0.18[b]	-0.04	-0.10	-0.04	0.17[a]
L2D4D								-	0.20[b]	-0.06	-0.06	-0.06	0.17[a]
CC									-	0.72[b]	0.73[b]	0.72[b]	-0.34[b]
WC										-	0.76[b]	1.00[b]	0.41[b]
HC											-	0.76[b]	0.05
WHR												-	0.41[b]
WCR													-

a=p<0.05, **b**=p<0.01.c=p<0.001.T = Testosterone, BMI = Body Mass Index, **%BF**= percentage body fat, CC = chest circumference, WC = waist circumference, HC = hip circumference, WHR = waist-hip ratio, WCR = waist-chest ratio.

Table 4.6: Correlation matrix of serum testosterone, anthropometric variables and body composition in males (n=209)

Variables	Testosterone	Age	Weight	Height	BMI	%BF	R2d4D	L2D4D	CC	WC	HC	WHR	WCR
Testosterone	-	0.13	0.16[a]	0.16[a]	0.07	0.15[a]	-0.31[b]	-0.37[b]	0.20[b]	0.12	0.10	0.03	-0.12
Age (yrs)		-	0.27[b]	0.31[b]	0.09	0.17[a]	-0.01	-0.02	0.20[b]	0.12	0.14[a]	-0.03	-0.11
Weight			-	0.73[b]	0.76[b]	0.59[b]	-0.06	-0.01	0.74[b]	0.63	0.75[b]	-0.26[b]	-0.26[b]
Height				-	0.07	0.21[b]	0.03	0.00	0.47[b]	0.45[b]	0.45[b]	-0.07	-0.11
BMI					-	0.61[b]	-0.11	-0.13	0.62[b]	0.48[b]	0.66[b]	-0.31[b]	-0.26[b]
%BF						-	-0.12	-0.16[a]	0.56[b]	0.46[b]	0.64[b]	-0.30[b]	-0.21[b]
R2d4D							-	0.87[b]	-0.03	0.03	-0.21	0.04	0.61
L2D4D								-	-0.06	-0.01	-0.01	0.04	0.67
CC									-	0.64[b]	0.04[b]	-0.22[b]	-0.57[b]
WC										-	0.68[b]	0.24[b]	-0.2[b]
HC											-	-0.55[b]	0.27[b]
WHR												-	-0.55[b]
WCR													-

a=p<0.05, **b**=p<0.01. T = Testosterone, BMI = Body Mass Index, (**%)** BF= percentage body fat, CC = chest circumference, WC = waist circumference, HC = hip circumference, WHR = waist-hip ratio, WCR = waist-chest ratio.

4.8.LINEAR AND MULTIPLE REGRESSION EQUATION FOR TESTOSTERONE LEVEL IN MALES AND FEMALES.

Tables (4.7 and 4.8) showed linear and multiple regression equations of testosterone in males and females respectively.

In males, linear and multiple regression equations of testosterone from right 2D: 4D, left 2D: 4D, right 2D: 4D and left 2D: 4D, weight and height was demonstrated. From the table, right 2D: 4D and left 2D: 4D is a stronger possible predictor of testosterone level than the other variablesin the population studied. Left 2D: 4D is also a strong predictor of testosterone level in males.

In females, linear and multiple regression equations of testosterone from right 2D: 4D, left 2D: 4D, right 2D: 4D and left 2D: 4D, and body circumferences (chest circumference, waist circumference and hip circumference) was demonstrated. From the table, right 2D: 4D and left 2D: 4D is a stronger possible predictor of testosterone level than the other variablesin the population studied.

Table 4.7: Linear and multiple regression of Testosterone from R2D4, L2D4D, R2D4DL2D4D, Body fat (%) in males

Parameters	Predictive equation	R	R^2	SEE	p
R2D4D	T = 12.954 + (-12.455) * R2D4D	0.307	0.094	0.464	0.0001
L2D4D	T = 17.509+ (-17.110) * L2D4D	0.365	0.133	0.454	0.0001
R2D4D,L2D4D	T = 1.085* R2D4D + (-18.931)L2D4D+17.525	0.365	0.133	0.454	0.0001
Body fat (%)	T = 0.556+ 0.026* Body fat (%)	0.152	0.023	0.481	0.0001
Weight (kg)	T = 0.235+ 0.009* WT	0.160	0.025	0.481	0.315
Height (cm)	T = -0.907 + 0.010*HT	0.164	0.027	0.481	0.198

HC = hip circumference, WC = waist circumference, CC = chest circumference, R = right, L = left

Table 4.8: Linear and multiple regression of Testosterone from R2D4, L2D4D, R2D4DL2D4D, Body fat and anthropomertic variables (%) in females

Parameters	Predictive equation	R	R^2	SEE	p
R2D4D	T = 5.156 + (-4.991) * R2D4D	0.456	0.208	0.093	0.0001
L2D4D	T = 5.451+ (-5.289) * L2D4D	0.496	0.242	0.903	0.0001
Body fat (%)	T = 0.120+ 0.004* Body fat (%)	0.301	0.091	0.099	0.0001
R2D4D,L2D4D	T = -0.461* R2D4D + (-4.883)L2D4D+5.506	0.496	0.246	0.905	0.002
CC,WC,HC	T = 0.001*CC + (-0.003)WC+0.006*HC+(-0.274)	0.333	0.111	0.098	0.001

HC = hip circumference, WC = waist circumference, CC = chest circumference, R = right, L = left

CHAPTER FIVE

DISCUSSION

The 2D:4D ratio in the sample of the Igbo population that was studied was found to be significantly higher in females than in males, a finding that is consistent with other studies of 2D:4D in other ethnic groups in Nigeria (Danborno*et al* 2008a, Oladipo*et al*, 2009; Gwunireama and Ihemelandu, 2010).Manning (2002) observed sex difference in digit ratio in British andFinnish population while McFadden *et al*(2005) reported sex difference in United States of America.Kyriakidis*et al*, 2008 also established sex difference in 2D:4Din Greek population.

Our study also confirmed sexually dimorphismin other digit ratios. It showed statistical significant difference in 2D:3D and 2D:5D of right and left hands ($P<0.01$). Thesedigit ratios were lower in malesthan in females hence concurring with previous reports of Manning *et al*(2003), McFadden *et al*, (2005), who reported sexual dimorphism in 2D:5D, 3D:4D and, 2D:3D,2D:5D respectively.Kyriakidis*et al*, (2008) also reported sex difference in 2D:3D,2D:5D but with a lateralizing character. Our result showed dimorphism in both left and right hand. The differences in these findings may be attributed to the difference in ethnic groupsand geographical location as well as the method used to obtain finger digit measurement.

Finger digit lengths have also been reported to be sexually dimorphic (Manning *et al*2003;Danborno*et al* 2008a), our study also established sexual dimorphism in finger digit length. The mean values of all the finger digits were lower in females than inmales($P<0.001$).

Puberty begins with a surge in hormone production which in turn causes a number of physical and physiological changes in individuals' height, weight, and body composition (Alan *et al*., 2002).These differences are attributed to the effect of sex hormones during the adolescent age group.This study presented anthropometric measurement andexistence of sexual dimorphism in adolescents with males having higher mean values for weight and height while females had higher mean values for chest, waist and hip circumferences. Females also had higher mean value for percentage body fat compared to males while males had higher mean value for testosterone than females (Table 4.3). These differences were statistically significant P<0.001. This confirms the reports by Nelson *et al*, 1999, Alan *et al*, 2002 and Wells, 2007 who also reported sexual dimorphism in anthropometric variables.

Our study observed sexual dimorphismat different age groups. Males were taller and weighed morethan females in all the age groups studied (fig 4.1, 4.2). This is consistent with the study of Agu*et al*, (2014) who reported that after the age of 12, males are taller and weighed more than the females.Height growth spurt in girls begin around 9-10 years reach maximum velocity around 12 years, growth rate then slows, but growthcontinues to about 16-18 years(Malina, andBouchard, 1991).Our study also observed that females had more body fat than males. This confirms the assertion Malina, and Bouchard, (1991).uring the interval of maximum growth in height (about 11-13 years in girls and 13-15 years in boys) girls gain on average, more fat than boys during the interval of their growth spurt.Our study also observed a slight decline in weight and height in females at age group 16-19(fig 4.1, 4.2) respectively. The probable reason may be attributed to the fact that on the average, females usually complete pubertal growth spurt earlier than boys by ages 15–17 (Alan *et al*, 2002,). This also corresponds with the periodof epiphyseal maturation and closure in girls

(Alan *et al*, 2002).Drop in weight may be due to social pressure to be thin.The early-maturing girls develop a negative view of their body image

Previous studies (Manning *et al*, 1998,McIntyre*et al*, 2007)have shown that testosterone is related negatively to 2D:4D.Lutchmaya*et al* (2004) also showed a relationship between 2D:4D measured in children and testosterone concentration measured in samples of amniotic fluid collected during their gestation.

Consequently our study, which is one of the few studies on digit ratios and serum testosterone in Igbo population in Nigeria, observed a negative correlation between testosterone level and digit ratio. In males, testosterone was found to have a negative significant relationship with left 2D:4D and right 2D:4D. This could mean that 2D:4D may be sensitive to the effect of relative circulating testosterone and that a high concentration of testosterone leads to a low digit ratio. In the female population testosterone had a negative relationship with left 2D:4D and a positive relationship with right 2D:4D.This may explain the possible effect of oestrogen which is also in largely secreted in females during adolescence.

Serum testosterone correlated positively with weight, body mass index, body fat percentage, chest circumference, waist circumference and hip circumference in female while in males testosterone correlated positively with weight, height and chest circumferences. This agrees with the works of (Evans *et al*1983 andSair*et al*, 2005. Lukas*et al* (2004) found a significant relationship between BMI and salivary testosterone in a sample of men from United States of America whileEvans*et al*, (1983) demonstrated a positive relationship between testosterone and WHR in a group of premenopausal women.

Relationship between testosterone and body composition has also been established in previous studies (Kaufman 2008).This study showedthat in males, serum testosterone had positive correlation with body fat percentage. This relationship with body fat percentage may be attributed to the age,environmental and nutritional influence on the participants used for this study.

Digit ratio has also been reported to correlate with body composition(Fink *et al;*2003,Neave *et al,*2003, Manning *et al,* 2003). Our study demonstrated that 2D:4D has a positive significant relationship with waist to chest ratiobut inverse relationshipwith chest circumference, height and weight in females. It also showed that age of menarche correlated positively with 2D:4D of left hand though the correlation was not significant.

Fink *et al* (2003) hypothesized that 2D:4D would correlate with BMI, WHR and WCR. Like in the study of Fink *et al* (2003) our dataprovided some further evidence that this supposition holds true, though we must report that the strongest associationswere found between 2D:4D and WCR in females and not in males. We did not find any relationship between digit ratios and WHR or BMI. This is consistent with results from Neave *et al* (2003)and Fink *et al* (2003) but in contrast to that of Manning *et al* (2003) who reported positive relationship between 2D:4D with Waist, hip circumferences, WHR and BMI. The relationship between 2D:4D and WCR could be associated with the fact that oestrogens should largely influence female chest circumference (Fink *et al*., 2003).

Linear regression equations for predicting testosteronewere formulated from anthropometric variables and 2D:4D obtained from this study.

CHAPTER 6

6.1.SUMMARY AND CONCLUSION

In conclusion, the present study confirmed the existence of sexual dimorphism in finger length, digit ratio and body composition variables in males and females. These differences in sex may be attributed to the influence of sex hormone in the adolescent age group.

Digit ratio (2D:4D) in males and females were found to have an inverse correlation with testosterone. Testosterone also had a significant relationship body composition and other anthropometric variables.

A positive relationship was also found to exist between 2D:4D and weight, height, body fat percentage and chest circumference in males while in females 2D: 4D showed a positive significant relationship with waist to chest ratiobut inverse relationshipwith chest circumference, height and weight.

6.2.RECOMMENDATION

It could be recommended that:

i. Certain anthropometric variables can serves as biomarkers for disease conditions

ii. There is need to conduct genetic studies so as to ascertain if there are genetic influences with respect to sexual dimorphism in digit ratio.

iii. The anthropometric measurements may be important in establishment of reference standards for clinicians and researchers.

iv. There is need to establish absolute cut-off points for these anthropometric indices with respect to sex; age, geographical location and ethnic group in Nigeria. The cut-off points can be used as reference standards.

v. Information provided by this study can be used to assess of genetic, environmental and nutritional statures of adolescents.

vi. The study will create awareness on the importance of use of digit ratio and body composition monitoring as a pointer to some biological traits and behaviours that are related to sex hormones in humans.

vii. Since digit ratio can predict testosterone level, 2D: 4D, the predictive equation generated from this study can be used to predict behaviour and health conditions related to sex hormones.

REFERENCES

Abbassi, V. (1998). "Growth and normal puberty"; *Paediatrics*102: 507–11.

Agu, A.Anyanwu,U., Ezugworie,G. E.,Obikili,O. J. and Nebeuwa,E., (2014)."Anthropometric Measurements And Sexual Dimorphism In School Children And Adolescents In Enugu-Nigeria" Science Journal of Medicineand Clinical Trials, Volume 2014, Article ID sjmct-119, 5 doi: 10.7237/sjmct/119

Alan, D. Rogol, M.D., James, N., Roemmich, Pamela, A. and Clark, M.D. (2002). Growth at Puberty, *Journal of Adolescent Health*; 31:192–200.

Archer, J. (2006). Testosterone and human aggression: An evaluation of the challenge hypothesis. *Neuroscience andBiobehavioural Reviews*, *30*(3): 319-345.

Arató, M., Frecska, E., Beck, C., A, M., and Kiss, H. (2004). Digit length pattern in schizophrenia suggests disturbed prenatal hemispheric lateralization. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *28*(1): 191-194.

Arnett, J. J. (2007). "Emerging Adulthood: What Is It, and What Is It Good For?" *Child Development Perspectives*1 (2): 68–73.

Attie, A.D. and Scherer, P.E. (2009).Adopocyte metabolism and obesity; *Journal of Lipid Research,* 50: S395-S399.

Bassil, N., Alkaade, S. and Morley, J.E. (2009)."The benefits and risks of testosterone replacement therapy: a review". *Journal of Therapeutics and Clinical Risk Management* 5 (3): 427–48.

Bailey, A. and Hurd, P. (2005). Finger length ratio (2D:4D) correlates with physical aggression in men but not in women. *Biological Psychology*, *68*(3): 215-222.

Baker, F. (1888). Anthropological notes on the human hand. *American Anthropology* 1:51–76.10.1525/aa.**1888**.**1**.**1**.02a00040.

Bhasin,S., Storer, T.W., Berman, N., Callegari, C., Clevenger, B., Phillips, J., Bunnell, T.J., Tricker, R., Shirazi, A. and Casaburi, R. (1996). "The effects of supraphysiologic doses of testosterone on muscle size and strength in normal men". *New England Journal of Medicine*335 (1): 1–7.

Bjorntrop, P., (1997). Body fat distribution, insulin resistance, and metabolic diseases *Journal of Nutrition*, 13: 795–803.

Braunstein, G.D. (2002). Androgen insufficiency in women: summary of critical issues. FertilSteril; 77 4:S94-99.

Breedlove, S., Cooke, B., and Jordan, C. (1999). The orthodox view of brain sexual differentiation. *Brain, Behaviour and Evolution*, *54*(1), 8-14.

Brooks, R.V. (1975). "Androgens". *Clinical Endocrinology and Metabolism*4 (3): 503–20. .

Brown, W.M., Hines, M., Fane, B.A. and Breedlove, S.M. (2002); Masculinized finger length patterns in human males and females with congenital adrenal hyperplasia. *Hormones and Behaviour 42* (4): 380–386.

Castle, D.J. and Murray, R.M. (1991). The neurodevelopmental basis of sex differences in schizophrenia. *Psychological Medicine. A Journal of Research in Psychiatry and the Allied Sciences, 21*(3), 565– 575.

Casanova, J. (1894). The memoirs of Jacques Casanova de Seingalt, volume 6 New York: G.P. Putnam's Sons

Caviness, V.S. Jr, Kennedy, D.N., Richelme, C., Rademacher, J., and Filipek, P.A. (1996). The human brain age 7-11 years: A volumetric analysis based on Magnetic resonance images. *Cerebral Cortex, 6,* 726-736.

Corbier, P., Edwards, D.A and Roffi, J. (1992). "The neonatal testosterone surge: a comparative study". *Archives Internationales de Physiologie, de Biochimieet de Biophysique (Liege)* 100 (2): 127–31.

Cox, R.M. and John-Alder, H.B. (2005). "Testosterone has opposite effects on male growth in lizards (Sceloporus spp.) with opposite patterns of sexual size dimorphism". *Journal of Experimental Biology*208 (Pt 24): 4679–87.

Csathó, A., Osváth, A., Bicsák, E., Karádi, K., Manning, J. and Kállai, J. (2003). "Sex role identity related to the ratio of second to fourth digit length in women". *Biological Psychology*62 (2): 147–56.

Dabbs, M, and Dabbs, J.M. (2000).Heroes, rogues, and lovers: testosterone and behaviour. New York: McGraw-Hill. ISBN 0-07-135739-4

Danborno, B., Adebisi, S.S., Adelaiye, A.B. and Ojo, S.A. (2008a). Sexual dimorphism and relationship between chest, hip and waist circumference with 2D, 4D and 2D:4D in Nigerians. *International Journal of Biological Anthropology* 1:2.

Danborno, B., Adebisi, S.S., Adelaiye, A.B. and Ojo, S.A. (2008b). Relationship between second and fourth digit lengths, digit ratio (2D:4D) and aggression in Nigerians. *Journal of Environmental Neuroscience Biomed* 2(1): 229-234.

Danborno, B., Adebisi, S.S., Adelaiye, A.B. and Ojo, S.A. (2010). Relationship between digit ratio (2D:4D) and birth weight in Nigerians. *Anthropologist* 12: 127-130.

Derby, C.A., Zilber, S. andBrambilla, D. (2006). Body mass index, waist circumference and waist to hip ratio and change in sex steroid hormones: the Massachusetts Male Ageing Study. *ClinicalEndocrinology,* 65(1):125‐131.

De Loof, A. (2006). "Ecdysteroids: the overlooked sex steroids of insects? Males: the black box". *Insect Science*13 (5), 325–338.

Dietz, W., Story, M., and Leviton, L. (2009). Introduction to issues and implications of screening, surveillance, and reporting of children's BMI. *Pediatrics, 124*, S1 S2.

Dinarello C.A. (2000). "Proinflammatory cytokines". *Chest***118** (2): 503–8. doi:10.1378/chest.118.2.503. PMID 10936147.

Enete, I. C. and Alabi, M. O.(2012). Observed urban heat island characteristics in Enugu urban during the dry season. Global journal of human social science geography and environmental geosciences, volume 12:10.

Ecker, A. (1875). Some remarks about a varying character in the hands of humans. *Archives of Anthropology.* 8, 68–74.

Eknoyan, G. (2007). "AdolpheQuetelet (1796–1874)—the average man and indices of obesity". *Nephrology Dialysis Transplantation*23: 47–51.

Evans, D. J., Hoffmann, R. G., Kalkhoff, R. K., and Kissebah, A. H. (1983). Relationship of androgenic activity to body fat topography, fat cell morphology and metabolic aberrations in premenstrual women. *Journal of Clinical Endocrinologyand Metabolism*, 57, 304–310.

Fink, B., Neavez, N. and Manning, J. T. (2003). Second to fourth digit ratio, body mass index, waist-to-hip ratio, and waist-to-chest ratio: their relationships in heterosexual men and women *Annals of Human Biology*, 30: 728-738.

Forest, M.G., Cathiard, A.M. and Bertrand, J.A. (1973). "Evidence of testicular activity in early infancy", *Journal of Clinical Endocrinology and Metabolism*37 (1): 148–51.

Galis, F.T., Broek, C.M., Van Dongen, S. and Wijnaendts, L.C. (2009). "Sexual Dimorphism in the Prenatal Digit Ratio (2D:4D)". *Archives of Sex Behaviour*38 (1), 57–62.doi:10.1007/s10508-009-9485-7.

George, R. (1930). Human finger types.*Anatomical Records* 46:199–204.doi: 10.1002/ar.1090460210

Gilsanz, V., Roe, T., Mora, S., Costin, G. and Goodman, W. (1991). "Changes in vertebral bone density in Black girls and White girls during childhood and puberty" *New England Journal of Medicine*325 (23): 1597–1600.

Gwunireama, I. U. and Ihemelandu, E. C. (2010). Geographical influence on digit ratio (2D:4D): a case study of Andoni and Ikwerre ethnic groups in Niger delta, Nigeria. *Journal of Applied Biosciences* 27: 1736 – 1741.

Hainer, V., Toplak, H, and Mitrakou, A. (2008). Treatment modalities of obesity: what fits whom? Diabetes Care, 31(Supplement 2), S269-S277.

Harding, C. (2004). Hormonal modulation of singing: Hormonal modulation of the songbird brain and singing behaviour. *Annals of the New York Academy of Science, 1016*: 524–539.

Jones, W. (1942). The Principles of Anatomy as seen in the Hand. *Williams and Wilikins company,* Baltimore.

Johnson, R., Johnson D., Wang M., Smiciklas-Wright, H. and Guthrie,H. (1994). "Characterizing nutrient intakes of adolescents by socio demographic factors". *Journal of Adolescent Health*15 (2), 149–154.

Kaplowitz, P.B., Slora, E.J., Wasserman, R.C, Pedlow, S.E. and Herman-Giddens, M.E. (2001).Earilest onset of puberty in girls: relation to increased body mass index and race. *Journal of Pediatrics*108 (2), 347–53.

Klump, K., Gobrogge, K., Perkins, P., Thorne, D., Sisk, C., and Breedlove, S. (2006). Preliminary evidence that gonadal hormones organize and activate disordered eating. *Psychological Medicine*, *36*(4), 539-546.

Kaufman, J. (2008). "Testosterone and body fat are controlled by the same genes." http://www.physorg.com/news137173251.html.

Kyriakidis, I. and Papaioannidou,P. (2008). Epidemiologic Study of the Sexually Dimorphic Second to Fourth Digit Ratio (2D:4D) and Other Finger Ratios in Greek Population. *Journal of Antropology* 32 4: 1093–1098.

Lange, N., Giedd, J.N., Castellanos, F.X., Vaituzis, A.C., andRapoport, J.L., (1997). Variability of human brain structure size: Ages 4-20 years. *Psychiatry Research: Neuroimaging*, *74*, 1-12.

Larson, R.and Wilson, S., (2004). Adolescence across place and time: Globalization and the changing pathways to adulthood. *In R. Lerner and L. Steinberg Handbook of adolescent psychology* New York: Wiley

Lukas, W., Campbell, B.C.andEllisonP.T., (2004). Testosterone, aging, and body composition inman from Harare, Zimbabwe, *Annals of Human Biology*,16:704- 712

Lukaski H. C. (1987). Methods for the assessment of human body composition: Traditional and new. *American Journal of Clinical Nutrition*, 46, 537–556.

Lutchmaya, S., Baron-Cohen, S., Raggatt, P., Knickmeyer, R. and Manning, J.T. (2004). 2^{nd} to 4^{th} digit ratios, fetal testosterone and estradiol, *Early Human Development* 77 (1/2), 23–28

Malas, A.M., Dogan, S., Evcil, E.H. and Desdicioglu, K., (2005). Fetal development of the hand, digit, and digit ratio (2D:4D). *Early Human* Development, DOI: 10.1016/j.earlhumdev. 2005.12.002

Malina, R.M., and Bouchard C., (1991). *Growth, Maturation, and Physical Activity.* Champaign, IL: Human Kinetics Publishers, Examines the effects of physical activity on child and adolescent growth

Manning, J.T., Scutt, D., Wilson, J. and Lewis-Jones, D.I. (1998). The ratio of 2nd to 4thdigit length: a predictor of sperm numbers and levels of testosterone, LH and oestrogen. *Journal of Human Reproduction* 13: 3000-3004.

Manning, J., Baron-Cohen, S., Wheelwright, S., and Sanders, G. (2001). The 2nd to 4th digit ratio and autism. *Developmental Medicine and Child Neurology*, *43*(3): 160-164.

Manning, J. T. (2002). Digit ratio. A pointer to fertility, behaviour and health. New Jersey: Ruters university press,pp 24-40.

Manning, J. T., Callow, M., and Bundred, P. E. (2003). Finger and toe ratios in humans and mice: Implications for the aetiology of diseases influenced by HOX genes. *Medical Hypotheses* 60:340-343.

Manning, J.T., Henzi, P., Venkatramana, P., Martin, S. and Singh D. (2003). Second to fourth digit ratio: ethnic differences and family size in English, Indian, andSouth African populations. *Annals of Human Biology* 2003; 30:579-88

Manning, J., Churchill, A., and Peters, M. (2007). The effects of sex, ethnicity, and sexual orientation on self-measured digit ratio (2D:4D). *Archives of SexualBehaviour*, *36*(2), 223-233.

Martel, M., Gobrogge, K., Breedlove, S.andNigg, J. (2008). Masculinized finger length ratios of boys, but not girls, are associated with attention deficit/hyperactivity disorder.*Behavioural Neuroscience*,*122*(2), 273-281. doi:10.1037/0735 7044.122.2.273.

McFadden D. and Shubel E. (2002). "Relative lengths of fingers and toes in human males and females". *Hormones and Behaviour*42 (4): 492–500.

McFadden, D., Loehlin, J. C., Breedlove,M. C., Lippa, R. A., Manning, J. T., and Rahman, Q. (2005). A reanalysis of five studies on sexual orientation and the relative length of the 2nd and 4th fingers (the 2D:4D ratio). *Archives of Sexual Behavior*, *34*, 341–356.

McIntyre, M.H., Ellison, F.T., Lieberman, D.E., Demerath, E. and Towne, B. (2005). The development of sex differences in digital formula from infancy in the Fels longitudinal study, *Proceedings of Royal Society B*, 272: 1473–1479

McIntyreM. H.,Chapman J. F., Lipson, F., and Ellison P. T.(2007). Index-to-Ring Finger Length Ratio (2D:4D) Predicts Levels of Salivary Estradiol, But Not Progesterone, Over theMenstrual Cycle American journal of human biology 19:434–436

Mechoulam, R., Brueggemeier, R.W., and Denlinger, D.L. (1984). "Estrogens in insects" *Journal Cellular and Molecular Life Sciences*40 (9): 942–944.

Mooradian, A.D., Morley, J.E.and Korenman, S.G. (1987). "Biological actions of androgens" *Endocrine Review* 8 (1): 1–28. doi:10.1210/edrv-8-1-1. PMID 3549275.

Naing, L., Winn, T., and Rusli, B. N., (2006). Medical statistics: Archives of Orofacial Sciences, 1: 9-14.

National Institute of Diabetes and Digestive and Kidney Diseases, (2008). Weight and waist measurement: Tools for adults: (http://win.niddk.nih.gov/publications/tools.htm#circumf) Retrieved June 26, 2010

National Population Commission on the (2006). Report of Nigeria's National Population Commission on the 2006 Census *Population and Development Review;* Vol. 33, No. 1 pp. 206-210 http://www.jstor.org/stable/25434601

Neufang, S., Specht, K., Hausmann, M., Güntürkün, O., Herpertz-Dahlmann, B. Fink,G. and Konrad K. (2009). Sex differences and the impact of steroid hormones on the developing human brain, *Cerebral Cortex, 19*: 464-473

Neave N, Laing S, Fink B. and Manning J.T. (2003).Second to fourth digit ratio, testosterone and perceived male dominance.*Proceedings of Biological Sciences* 270: 2167–72.

Nelson and Randy, F. (2005). An introduction to behavioural endocrinology. Sunderland, Mass: Sinauer Associates. p. 143 ISBN 0-87893-617-3

Nelson, T. L., Vogler, G. P., Pederson, N. L., and Miles, T. P. (1999). Genetic and environmental influences on waist-to-hip ratio and waist circumference in an older Swedish twin population. *International Journal of Obesity*, 23: 449–455.

Ness-Abramof, R. and Apovian, C. M. (2008). Waist circumference measurement in clinical practice.*Nutrition in Clinical Practice*, 23: 397-404.

Niewoehner, C.B. andSchorer, A.E. (2008). Gynaecomastia and breast cancer in men. *British medical journal,*336: 709-713.

Oladipo, S., Fawehinmi, B., Hakeem, I. Edibamode, E., Osunwoke, E. and Ordu, K.S (2009).Second to fourth digit ratio in Nigerian Igbos and Yorubas. Scientific Research and Essay Vol. 4 (10), pp. 1146-1148,

Ökten, A., Kalyoncu, M. and Yariş, N. (2002). The ratio of second- and fourth-digit lengths and congenital adrenal hyperplasia due to 21-hydroxylase deficiency, *Early Human Development*, *70*(1-2), 47-54. doi:10.1016/S0378 3782(02)00073-7.

Palo Alto Medical Foundation (2009). Teenage Growth and Development.Archived Retrieved 2009-02-20

PardridgeWM, andCefaluW, (1985). Bioavailabilityof albumin boundtestosterone. *Journal ofClinincalEndocrinologyand Metabolism*;61:705.

Peters, M., Mackenzie, K. and Bryden, P. (2002). Finger Length and Distal FingerExtent Patterns in Humans.*American Journal of Physical Anthropology* 117:209–217 DOI 10.1002/ajpa.10029

Peterson, A. and Taylor, B. (1980). The biological approach to adolescence: Biological change and psychological adaptation. *Inernational Journal. Adelson (Ed.),Handbook of adolescent psychology,* pp.129. New York: Wiley.

Phelps, V. R. (1952). Relative index finger length as a sex-influenced trait in man,*American Journal of Human Genetics,* 4: 72–89.

Putz, D.A., Gaulin, S.J.C., Sporter, R.J. and McBurney, D.H. (2004). Sex hormones and finger length. What does 2D:4D indicate? *Evolution of Human Behaviour,* 25: 182-199.

Rako, S. (1996). The Hormone of deseire: The Truth about Sexuality, menopause and testosterone. *Harmony Books (division of Crown Publishers),* New York

Reed, W.L., Clark, M.E., Parker, P.G., Raouf, S.A., Arguedas, N., Monk, D.S., Snajdr, E., Nolan, V. and Ketterson, E.D. (2006). Physiological effects on demography: a long-term experimental study of testosterone's effects on fitness. *American Society of Naturalists.*167: 667–83.

RossR., Tina B., Bradshaw,A. J.,Henry S.,Katzmarzyk, P. T., Kuk,J. L., Seidell,J. C., Snijder, M. B.and Després, J. (2008). Does the relationship between waist circumference, morbidity and mortality depend on measurement protocol for waist circumference? *Obesity Reviews,* 9:312-25.

Rutter M. and Schopler E., (1978).Diagnosis and definition. Autism: A Reappraisal of Concepts and Treatment.*New York: Plenum Press*, P 1–26.

Sari, M.V., Anders M.A. and Elizabeth, H.(2005).Waist-to-Hip Ratio Is PositivelyAssociated With Bioavailable Testosterone but Negatively Associated with Sexual Desire in Healthy Premenopausal Women; *Journal of behavioural Medicine,67:246-250.*

Savage, M. and Scott, L. (1998) Physical activity and rural middle school adolescents. *Journal of Youth and Adolescence*,27: 245–253.

Schultz, A.H., (1924). Growth studies on primates bearing upon man's evolution. *American Journal of Physical Anthropology*, 7:149–164.

Singh, D.(1994). Ideal female body shape: role of body weight and waist-to-hip ratio. *International Journal of Eating Disorders,* 16: 283–288.

Slemenda, C.W., Reister, T. K. and Hui, S. L. (1994). Influence on skeletal mineralization in children and adolescents: Evidence for varying effects of sexual maturation and physical activity. *Journal of Paediatrics.* 125:201–7.

Srikanthan, P., Seeman, T.E., and Karlamangla, A.S. (2009). Waist-hip-ratio as a predictor of all-cause mortality in high-functioning older adults. Annals of Epidemiology, 19: 724-731.

Sizonenko, P.C.andPaunier, L. (1975). Hormonal changes in puberty III: correlation of plasmdehydroepiandrosterone, testosterone, FSH and LH with stages of puberty and bone age in normal boys and girls and in patients with Addison's disease or hypogonadism or with premature or late adrenarche. *Journal of Clinical Endocrinology and Metabolism*, 41:894-904

Swaab, D.F.andGarcia-Falgueras, A. (2009). Sexual differentiation of the human brain in relation to gender identity and sexual orientation. *Functional Neurology*,24: 17–28.

Tanner J.M. (1989). Foetus into Man, Physical Growth from Conception to Maturity. Cambridge, MA: Harvard University Press.

Torjesen, P.A. and Sandnes, L. (2004). Serum testosterone in women as measured b an automated immunoassay and a RIA. *Journal of Clinical Chemistry*, 50: 678 - 9.

Trivers, R., Manning, J.T. and Jacobson, A. (2006). A longitudinal study of digit ratio (2D:4D) and other finger ratios in Jamaican children. *Journals of Hormones and Behaviour* 49: 150-156.

Tuck, S. P. and Francis, R.M. (2009). Testosterone, bone and osteoporosis".Frontiers of Hormone Research 37: 123–32. doi:10.1159/000176049. ISBN 978-3-8055 8622-1. PMID 19011293.

Voracek, M. (2008). Digit ratio (2D:4D) as a marker for mental disorders. Low (masculinized) 2D:4D in autism-spectrum disorders, high (feminized) 2D:4D in schizophrenic-spectrum disorders. *Behavioural and Brain Sciences31*:283 284.

Wells, J.C. (2007). Sexual dimorphism of body composition.Best Practice and Research*Clinical Endocrinology and Metabolism,*21(3):415‐430.

Welborn, T.A. and Dhaliwal, S.S. (2007). Preferred clinical measures of central obesity for predictingmortality.*European Journal of Clinical Nutrition*, 61:1373‐1379.

WHO expert consultation; (2008). Waist circumference and waist–hip ratio: WHO Library Cataloguing-in-Publication Data; Geneva.ISBN 978 92 4 150149 1 (NLM classification: QU 100

Wilson, G.D. (1983). Finger-length as an index of assertiveness in women. *Personality and Individual Differences*4: 111–2

Zheng, Z. and Cohn, M. J. (2011). "Developmental basis of sexually dimorphic digit ratios". *Proceedings of the National Academy of Sciences of the United States of America*108: 16289–16294.

Zouboulis, C.C. and Degitz, K. (2004). "Androgen action on human skin from basic research to clinical significance". *Journal Expermental Dermatology.*134:5 10.

Zuckerman, Diana (2009). "Early Puberty in Girls" National Research Centre for Women and Families. Retrieved 2010-07-13

Žukauskaitė, S., Lašienė, D., Lašas, L., Urbonaitė, B and Hindmarsh, P. (2005). "Onset of breast and pubic hair development in 1231 preadolescent Lithuanian school girls". *Archives of Disease in Childhood.*90: 932–6.

\

APPENDIX I

CONSENT FORM

Research No …….

Age ……

Consent form to participate in a study.

1. This study is about "Relationship between serum testosterone, digit ratios and body composition among adolescents in Igbo ethnic group". The procedure involves collection of blood specimen.
2. The result from the study will be treated with strict confidentiality.

3. You are free to participate or decline in this study without any consequence.

4. The study will hopefully improve your present health status and that of others in the future.

If you desire to participate in this study, kindly sign the written consent form.

Thank you.

APPENDIX II

INFORMED WRITTEN CONSENT

I…….. Of (address)……. agree, to participate in the study of "Relationship between Serum Testosterone, Digit Ratios and Body composition among adolescents of Igbo ethnic group". The full procedure and probable benefits where explained to me. I understand that a sample of my child's blood will be taken for tests and that if I so wish the results will be communicated to me in confidence.

I made this consent willingly without being subjected to any pressure.

Participants

Name……. Signature……

Witness Name…… Signature…….....

Researchers Name…… Signature…….....

APPENDIX III

Ahmadu Bello University Teaching Hospital

P.M.B. 06, Shika - Zaria, Kaduna State. Nigeria. 069-876305

website: www.abuth.org abuthshika@yahoo.com Abuthshika@gmail.com

Chairman of Board:

Chief Medical Director: DR. LAWAL KHALID, *MBBS, FMCS, FWACS, FRCS(ED) mni*

Chairman, Medical Advisory Committee: DR. ABDULLAHI MOHAMMED, *MBBS, FWACP FICS*

Director of Administration: BARR. ISHAK BELLO, *LL.B, BL, LL.M. PGDM, AHAN, FCAI*

Our Ref:

ABUTH/HREC/TRG/36 10th July,2012

Dr Okamkpa Chikezie Jude
Dept of Chemical Pathology
ABU Teaching Hospital
Zaria.

ETHICAL CLEARANCE

Your application for ethical clearance on the research proposal titled. "**RELATIONSHIP BETWEEN SERUM TESTOSTERONE, DIGIT RATIOS AND BODY COMPOSITION AMONG ADOLESCENTS OF IGBO ETHICS GROUP**" refers.

This is to convey ethical approval for you to commence the study. The ABUTH Scientific and Health Research Ethics Committee requires an annual update from the principal investigator.

Prof. J. U. Okpapi
Chairman, ABUTH HREC

APPENDIX IV

REF: MH/ MSD/

Ethical Committee on Research
Ministry of Health,
Enugu, State.
11th April 2012.

The Researcher
Dr. Okamkpa Chikezie Jude
Department of Human Anatomy
Faculty of Medicine,
Ahmadu Bello University,
Zaria,
Kaduna, State.

Sir,

RE: THE RELATIONSHIP BETWEEN SERUM TESTOSTERONE, DIGIT RATIO AND BODY COMPOSITION AMONG ADOLESCENTS OF THE IGBO ETHIC GROUP.

I refer to your request for permission to carry out a study / research on the above health issue and to inform you that approval has been granted to you for the study.

ETHICAL GUIDELINES

(1) You are to keep to the principles of the informed consent by obtaining a signed / thumb printed informed consent of the subjects, parents/ legally accepted representative.
(2) You are to deposit two copies of the result of your study to the ethical committee of the Enugu state ministry of health.

Dr. Ejeh M.N.
Chairman, ethical committee on research

OFFICE OF THE DIRECTOR
PUBLIC HEALTH SERVICES
MINISTRY OF HEALTH
ENUGU.
DATE 19/4/12

APPENDIX V

QUESTIONAIRE FOR THE STUDY OF RELATIONSHIP BETWEEN SERUM TESTOSTERONE, DIGIT RATIO AND BODY COMPOSITION

Biodata of respondent

Research ID (optional)..... Gender..... Age: .....
Date of birth: ..... State of origin..... Handedness.....
Ethnic background: ..... Mother's tribe.....
Father's tribe.....
Socioecomic background
Father's occupation: ..... Mother's occupation: .....
Fathers level of education..... Mother's level of education.....
For Female respondent: age of menarche: .....

Birth order (e.g. 2nd, 3rd etc).....
Number of siblings: Males..... Females: .....
Family history of cancer..... (Specify)

BP..... Pulse rate..... Temp.....
Height (cm): ..... Waist circumference (cm).....
Chest circumference (cm)..... Hip circumference (cm).....
Weight (kg): ..... Body fat%.....
Total body water%..... visceral fat rating.....
Bone mass..... Muscle mass.....

Hand anthropometry

Length of digits (mm)

Hand	**Fingers**				
	I	**II**	**III**	**IV**	**V**
Right					
Left					

Serum testosterone level (ng/ml) .....