

**RELATIONSHIP BETWEEN SOMATOTYPES AND
HEPATOBIILIARY DIMENSIONS, BODY COMPOSITION, AND
SOME ANTHROPOMETRIC VARIABLES OF STUDENTS IN
AHMADU BELLO UNIVERSITY, ZARIA**

BY

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AHMADU BELLO UNIVERSITY, ZARIA**

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FEBRUARY, 2017

DECLARATION

I Mustapha, Musa hereby declare that the work in this Dissertation titled “***Relationship between Somatotypes and Hepatobiliary Dimensions, Body Composition, and some Anthropometric Variables of Students in Ahmadu Bello University, Zaria***” was performed by me in the Department of Human Anatomy, Faculty of Medicine, ABU, Zaria, under the supervision of Dr AA Adamu and Dr WO Hamman. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree at any institution.

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CERTIFICATION

The thesis entitled “*Relationship between Somatotypes and Hepatobiliary Dimensions, Body Composition, and some Anthropometric Variables of Students in Ahmadu Bello University, Zaria*” by Musa MUSTAPHA meets the regulations governing the award of the degree of Master of Science in Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literacy presentation.

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DEDICATION

Specially dedicated to my Creator who gave me the wisdom and inspiration in completing this work. Also to my family and those who believed in me when I was crossing from clinical arm of medicine to academics.

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ABSTRACT

Previous studies have suggested an association of somatotype with body composition and the organ dimensions among individuals and populations. However, the relationship of somatotypes of medical students of Ahmadu Bello University (ABU), Zaria with body composition, organ dimensions and some anthropometric variables has not been evaluated. This cross-sectional study consisted of 350 apparently healthy medical students of ABU, Zaria (175 males and 175 females) aged 18-35 years. Stature, four skinfold sites, body mass, two bone breadths and two girths were measured according to the International Society for the Advancement of Kinanthropometry (ISAK). The body composition variables were computed using the Durnin and Wormersely method and hepatobiliary dimensions were measured with an ultrasound machine. Chi-square test, independent sample t-test, one-way Analysis of variance (ANOVA), somatotype analysis of variance (SANOVA), Pearson's correlation, partial correlation and multiple linear regression were used. $P < 0.05$ was set at the level of significance. The mean somatotype was 1.61-4.28-3.04 (ectomorphic-mesomorph) for the males and 1.75-4.21-1.96 (balanced mesomorph) for the females and were significantly different ($F=30.06$, $p<0.001$). Seven major somatotype categories were found irrespective of the sexes: endomorphic-mesomorph, balanced-mesomorph, ectomorphic-mesomorph, mesomorph-ectomorph, mesomorphic-ectomorph, balanced-ectomorph and central. There was a significant association for male and female subjects based on the somatotype categories ($\chi^2 = 44.87$, $p < 0.05$). The height, body mass index (BMI), body surface area (BSA), skin folds, bone breadth and body composition variables showed significant sexual dimorphism based on the dominant somatotypes ($p < 0.05$). The BMI, BSA, gall bladder width, common bile duct diameter (CBDD) and body composition variables indicated significant differences according to the age groups in the dominant mesomorphs and

ectomorphs ($p < 0.05$). Dominant endomorphy was positively correlated with some skin folds and body composition variables in both sexes. Mesomorphy correlated positively with upper arm girth, calf girth, BBH and BBF in both sexes. Ectomorphy showed more sparing correlation with other variables, i.e., it showed a significant positive correlation with BBH and BBF in male subjects only. No significant correlations were observed in blood pressure and hepatobiliary dimensions with the dominant somatotypes. Tricep skin fold, subscapular skin fold, and medial calf skin fold were the joint best predictors of percent body fat in both sexes ($R^2 = 0.999$). In conclusion, the relationship between dominant somatotypes with body composition, hepatobiliary dimensions and some anthropometric variables have been established.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The interest in the classification and analysis of human physique or body types of individuals and populations has a long history going back to the ancient Greeks, Hippocrates (460-377 BC). Over the centuries, various systems for classifying physique have been proposed, leading to the system called somatotyping as proposed by Sheldon *et al.* (1940), and subsequently modified by others, notably Parnell (1958), Heath and Carter (1967) and Carter and Heath (1990). Sheldon believed that somatotype was immutable i.e., it relies solely on genetic basis, but the present view is that the somatotype is phenotypical and thus amenable to change under the influence of both internal and external factors such as growth (Carter and Heath, 1990), aging (Gakhar and Malik, 2002; Bhasin and Jain, 2007), sex (Kalichman and Kobliansky, 2006), nutrition (Chakrabarty *et al.*, 2008), physical activity (Chandel and Malik, 2012), occupation (Singh and Singh, 2006), socioeconomic differences (Rahmawati *et al.*, 2004; Singh, 2011) and pathological conditions (Williams *et al.*, 2000; Eiben *et al.*, 2004; Kalichman *et al.*, 2004).

The technique of somatotyping is used to appraise body shape and composition (Bailey *et al.*, 2009). The resulting somatotype gives a gestalt or quantitative summary of the physique as a unified whole (Carter, 1996; Rajajeyakumar, 2015). Somatotyping is defined as the quantification of the present shape and composition of the human body independent of the body size (Carter and Heath, 2002; Zorka and Dragan, 2013). According to Carter and Heath (2002), the somatotype is usually expressed in a three

number rating representing endomorphy (relative adiposity), mesomorphy (relative musculoskeletal robustness) and ectomorphy (relative linearity or slenderness of a physique) respectively, always in that order. For example, a 3-5-2 rating is recorded in this manner and is read as three, five, and two. These numbers give the magnitude of each of the three components. Ratings on each component of 2 to 2.5 are considered low, 3 to 5 are moderate, 5.5 to 7 are high, and 7.5 and above are very high (Carter and Heath, 1990). Theoretically, there is no upper limit to the ratings, and values of 12 or more occur in very rare instances. Because the components are rated relative to stature, the somatotype is independent of, or normalized for stature.

There are three methods of obtaining the somatotype: (a) the photoscopic method, in which ratings are made from a standardized photograph; (b) the anthropometric method, in which anthropometry is used to estimate the criterion somatotype; and (c) the criterion method, which combines anthropometry and ratings from a photograph (Carter and Heath, 2002). Because most people do not get the opportunity to become criterion raters using photographs, the anthropometric somatotype has proven to be the most useful for a broad range variety of applications. It can be used in the field or laboratory, requires little equipment and calculation, and measurements can be made with relative ease on subjects dressed in minimal clothing.

Neither Sheldon *et al.* (1940, 1954) nor Parnell (1954, 1958) attempted to describe the components of somatotype in terms of body composition. However, the selection of the anthropometric dimensions for the Parnell method covertly proposed a relationship between the components of body composition (fat mass and lean body mass) and the components of somatotype. The skin fold thickness measurements imply a relationship between endomorphy and relative fatness, and the muscle girth and the bone breadth

measurements imply a relationship between mesomorphy and relative lean body mass. However, the third component, ectomorphy, was described by the linearity of physique, a morphological characteristic without reference to body composition.

It is not surprising, then, that many studies have attempted to relate somatotype and body composition variables (Dupertius *et al.*, 1951; Tanner *et al.*, 1960; Wilmore, 1970; Slaughter and Lohman, 1976; Bulbulian, 1984; Bolonchuk *et al.*, 1989, 2000). These studies revealed that, on average, endomorphs were fatter, heavier and taller than mesomorphs or ectomorphs; the mesomorphs had greater fat-free weights and were shorter than endomorphs or ectomorphs and ectomorphs had lower bodyweights and less fat than mesomorphs or endomorphs. Thus, these findings suggest a general association between body somatotype and structure.

Similarly, two people of the same sex and body weight may look completely different from each other because they have a different body composition (Wells *et al.*, 2006) and body type (Chaplygina *et al.*, 2013). To further support this logic, Singh (2007) emphasized that it is highly unlikely that persons of different body types have a similar body composition or body organ dimensions (Adamu *et al.*, 2007). Thus, individuals at the top or bottom of the ladder of body habitus cannot share the same range of values for a given organ. For instance, Adamu *et al.* (2007) reported that endomorphic subjects have larger dimensions of internal organs than the ectomorphic subject. A positive correlation was observed in the evaluated data of ultrasound examination of the thyroid gland in relation to the body types (Zmeev, 2010; Chaplygina and Kuchieva, 2012). Similarly, Chaplygina and Guber (2014) observed significant differences in the values of the linear dimensions of the liver in patients with different somatotypes. In another study, the liver

volume was found to be dependent on the variability of the macroscopic structure of the body (Chaplygina *et al.*, 2013).

1.2 Statement of the Problem

In literature, there are some studies on the Caucasians about the dependence of the morphological and functional characteristics of individual organs and body composition on the human dominant somatotype components (Slaughter and Lohman, 1976; Bolonchuk *et al.*, 1989; Bolonchuk, 2000; Gorbonov, 2001; Adamu *et al.*, 2007; Marek and Aneta, 2013; Chaplygina and Guber, 2014). However, a thorough literature search yielded dearth of documented reports of such kind of studies on the Negroid especially in Nigeria. Hence, this underscores the importance of conducting this cross-sectional study in our surroundings.

1.3 Justification and Significance of the Study

There is a need for baseline anthropological data among medical students of Ahmadu Bello University, Zaria, especially with respect to somatotype profiles, body composition and sonographic hepatobiliary dimensions. Extraction of various forms of variables associated with somatotype, body composition and hepatobiliary dimensions will enrich the information regarding the three profiles, hence serve as database and reference information as the need may arise. Establishment of the relationship of dominant somatotype with body composition, organ dimensions and other anthropological variables has received less attention in the literature with little or no such attempt among a Nigerian population. Thus, the need to conduct this study on our population.

The evaluation of the data of ultrasound of hepatobiliary system, taking into account the somatotype of the individual gives the clinician the ability to differentiate the

constitutional norm, detect early subclinical pathologic changes in the body and institute preventive measures (Chaplygina *et al.*, 2014).

Information about the individual typological characteristics of both sexes, i.e., the study population, can be used by the medical institution of the University in the selection of preventive measures to protect high somatotype risk group, selection of athletes for sports and will also help government defense agencies in the survey of young men of military age.

Finally, this work will bring the subject matter to the limelight, especially in the science community and will also serve as an impetus in stimulating the interest of researchers to explore this crucial area that has enjoyed little attention so that this important lacuna in knowledge can be filled.

1.4 Hypothesis

There is a relationship between somatotypes and hepatobiliary dimensions, body composition, and some anthropometric variables of students in Ahmadu Bello University, Zaria.

1.5 Aim and Objectives of the Study

1.5.1 Aim of the Study

The aim of the study was to determine the relationship between somatotypes and hepatobiliary dimensions, body composition, and some anthropometric variables of students in Ahmadu Bello University, Zaria.

1.5.2 Objectives of the study

- i. To determine the somatotype profiles of medical students of Ahmadu Bello University Zaria, using the Heath and Carter method.
- ii. To investigate sexual dimorphism in hepatobiliary dimensions (liver, caudate lobe, common bile duct, and gallbladder), body composition and other anthropometric variables according to the dominant somatotype.
- iii. To examine the age variations in hepatobiliary dimensions, body composition and other anthropometric variables according to the dominant somatotype.
- iv. To study the relationship between dominant somatotypes with hepatobiliary dimensions, body composition and some anthropometric variables.
- v. Prediction of body composition variables (% body fat BF% and fat mass FM) from anthropometric variable (height) and somatometric variables (subscapular skin fold, triceps skin fold and medial calf skin fold).

1.6 Scope of the Study

This research work focussed on the determination of the relationship between somatotypes and hepatobiliary dimensions, body composition, and some anthropometric variables of students in Ahmadu Bello University, Zaria. Anthropometric somatotype was used in the field. To calculate the anthropometric somatotype, ten anthropometric dimensions were needed, these include the: body mass, stretch stature (height), four skin folds (subscapular, medial calf, triceps and supraspinal), two bone breadths (bicipital breadth of the humerus and femur) and two limb girths (calf, tensed and arm flexed). Blood pressure was measured, and the dimensions of the liver, caudate lobe common bile duct and gallbladder were determined sonographically.

1.7 Limitations

The following limitations were considered while interpreting the result:

- i. One of the limitations in our study is the smaller sample size. The sample size must be large enough to detect the clinically important relationship between dominant somatotype and organ dimensions (Altman, 1980). However, because of cost implication study with an overlarge sample is not necessary as it seems unethical to involve unnecessary extra subjects (Kirby *et al.*, 2002).
- ii. Although percent body fat can be assessed more objectively with greater precision by the use of such sensitive methods such as, underwater weighing or hydrostatic, ultrasonography, Computed Tomography Scan, Lunar Prodigy DXA scanner, and Magnetic Resonance Imaging; only skin fold measurement was used to estimate percent body fat in this study because it is simple and easy to use.
- iii. In order to avoid inter observer error and establish a standardized techniques, all anthropometric measurement should be done by one person. However, considering the cultural background of the study area, male subjects were all measured by a trained anthropometrist and female subjects by a trained female anthropometrist.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Historical Background of Somatotype

The study of the human body and the different types associated with it has been of great interest for a very long period. Physicians have been prominent in the history of constitutional investigations, particularly in studies of interrelations of morphology and susceptibility to disease (Carter and Heath, 2003).

2.1.1 Hippocrates

The earliest classification of body type was that of Hippocrates (460-377 BC) who classified human body into two types – the ‘phthisic habitus’, an individual dominated by the vertical dimension possessing a long, thin body, and the ‘apoplectic habitus’, a horizontally dominated individual, short and thick set. Hippocrates correlated the physical appearance of an individual with the psychology of an individual and almost all researchers followed this trend in the later years (Comas, 1960).

2.1.2 Rostan

Comas (1960) identified the work of Leon Rostan done in 1826 as one of the earliest attempts of typological classification, which included four distinct types, namely respiratory, muscular, digestive and cerebral. He used a mathematical combination of stature, arm span, chest circumference, sternum height and abdominal height to come up with the four different types of body types as mentioned above.

Numerous researchers worked on body type classification during the nineteenth century and early twentieth century and all their body type classification were basically vertical, horizontal or a combination of both. The body parts used for classification include thorax, neck, curvature of the back, musculature, and skin of an individual.

2.1.3 Viola

At the beginning of the twentieth century, an Italian anthropologist, Viola, did significant work in the field of Biotypology. His findings included three body types, namely 'Normosplanchnic', 'Macrosplanchnic', and 'Microsplanchnic'. Viola took into consideration ten body measurements, five of which were horizontal girths and five were vertical heights. They included Sternum length, Upper abdominal height, Lower abdominal height, Length of the arm, Length of the leg, Transverse thoracic diameter, Antero-posterior thoracic diameter, Transverse hypochondriac diameter, Antero-posterior hypochondriac diameter, and Bi-iliac or transverse pelvic diameter. In addition, he took three compound measurements - Stature, Trunk height, Total abdominal height and also the weight of the individual (Salusso-Deonier, 1982).

Viola came up with four indices (see Table 1) using the measurements and studied the relationship between them by comparing them using two columns (as shown in Table 2) to determine the constitution or body type of the individual.

Table 2.1: Viola's Indices

1.	Thoracic Index – Sternum Length X Chest Breadth X Chest Depth
2.	Upper Abdominal Index – Upper Abdominal Height X Upper Abdominal Breadth X Abdominal Depth
3.	Lower Abdominal Index – Lower Abdominal Height X Lower Abdominal Breadth X Abdominal Depth
4.	Total Abdominal Index – Upper Abdominal + Lower Abdominal Indices
5.	Trunk Value – Thoracic + Total Abdominal Index
6.	Limb Value – Length of the Arm + Length of the Leg

(Comas, 1960, pp. 330)

Table 2.2: Viola's Comparison of Indices to Determine the Body Type of an Individual

I	II
Trunk Value	Limbs Value
Trunk Value	Suprasternal Pubic Height
Antero-posterior diameters	Transverse diameters
Total Abdominal Index	Thoracic Index

(Comas, 1960, pp. 330)

For example, when the value of the indices was equal in column I and II of Table2, then the body type was classified as Normosplanchnic when the values in column I were greater, the body constitution was Macrosplanchnic or brachymorphic – lateral type, and when the indices in column II were greater, then the body constitution was Microsplanchnic or Doliochomorph – Linear. If all four combinations followed the same way, Viola called them pure types. If a person had three relationships going in one way and one, the other way, the classification was based on the three relationships. If there were two relationships in the same way, and if they were trunk value vs. limb value and trunk value vs. suprasternal pubic height, a diagnosis could still be made. If the

values did not fit into any of the above categories, then Viola called them mixed and unclassifiable. In Viola's study, 40% of the subjects fell into the mixed category (Comas, 1960).

2.1.4 Barbara

Another Italian anthropologist, Barbara, used trunk-limb relationships in classifying body types. His classification included Linear, Lateral and Proportionate body types. When the trunk was proportionally smaller than the limbs, then the body type was Linear ($T < L$), if the trunk was proportionally larger than the limbs ($T > L$), the body type was lateral and if the trunk and limb proportions were proportionally similar and balanced, then the body type was Proportional ($T = L$). He used a combination of the three fundamental trunk-limb relationships and came up with the body types listed in Table 2.3.

Table 2.3: Barbara's Typology for Body Type and Size Variation

Body Type	Size Variation				
	Underdeveloped	Intermediate	Fundamental	Intermediate	Overdeveloped
Linear Types	$T - < L -$	$T - < L o$	$T - < L +$	$T o < L +$	$T + < L +$
Lateral Types	$T - > L -$	$T - > L -$	$T + > L -$	$T + > L o$	$T + > L +$
Proportionate	$T - = L -$		$T o = L o$		$T + = L +$

(Salusso-Deonier, 1982)

Barbara was able to classify 100% of the subjects using his classification method. He interpreted body proportions, which were proportionate but overdeveloped as lateral and those, which were proportionate but underdeveloped as linear (Salusso-Deonier, 1982).

2.1.5 Kretschmer

During the 20th century, Ernst Kretschmer, a German psychiatrist classified human body into three distinct types – Asthenic, Athletic and Pyknic. These types were found in both

men and women even though the prominent characteristics were found distinctly in men. Among women, there exist many indefinite and a-typical forms (Kretschmer, 1926).

Kretschmer believed that 'ideal types' were a rare occurrence and the prominent characteristics were found in every person in a blurred form, and these prominent characteristics were found from a collection of values. The rationale behind his three physique types was:

“When a fairly large number of morphological similarities can be followed through a correspondingly large number of individuals, then we pause and register the measurement. From this we reckon the average value and thus the outstanding common characteristics come out clearly, while those peculiar marks which only occur in isolated cases, disappear in the average value. Only those characteristics which become sharply marked in the average values are described as 'typical' (Kretschmer, 1926).

An asthenic person was characterized by a fragile and narrowly built body, with normal height and small bones and belonging to a vertical or linear structure. The individual would not gain weight and would remain slender throughout his life. Kretschmer (1926) defined an asthenic person as having “a deficiency in thickness combined with an average unlesened length” (Kretschmer, 1926). This person looked taller than he truly was and had a thin stomach and delicately boned arms. When it came to asthenic women, their height to weight ratio was smaller. They differ from asthenic men by the fact that they had an overall lesser growth of the body and hence they could be classified as asthenic-hypoplastic - that is, thin in size with an overall under development of the body with reference to height.

An athletic person was muscular with average to tall height, and a well-developed bone and muscle structure. Kretschmer found that the athletic type person was apparent only until middle age, but were very distinct. A female with an athletic profile was characterized by distinct musculature in face and body with accentuated shoulders and strong male features. Comas (1960) observed that Kretschmer removed the athletic type from his books in the later editions.

Kretschmer described a pyknic individual as plump with medium height, round and stocky with larger horizontal dimensions than vertical dimensions. This type of person was in perfect form during middle age and had more weight distribution in the trunk. A pyknic woman had fat distribution concentrated along her bust and hips.

In addition to his three distinct types, Kretschmer described another type namely dysplastic. A dysplastic person was one who didn't fall into any category and possessed mixed traits. Kretschmer's classification was well established till the 1930s, after which it became obsolete. This was due to his erroneous assumption that individuals could be classified into separate discrete types except for a few as found by the researchers after him (Harrison *et al.*, 1977).

2.1.6 Sheldon

The next important body type classification which is widely in use today was by the American psychologist, William Sheldon, named his body type classification as 'Somatotyping'. Even though his system proved to be flawed, his somatotyping methodology is the foundation for all research done since. Sheldon classified human body into three different types – Endomorph, Ectomorph and Mesomorph. An individual may possess all three qualities, but on different scales. From his study, Sheldon took the back,

front and side views of 4000 male college students, irrespective of the body size of the individual. He discovered that their physiques were made up of a combination of three fundamental elements and worked out a mathematical way to measure these elements. He used a scale of one to seven to describe the degree of the three traits in an individual, one being the least and seven being the most prominence of that trait. He called the mathematical expression that represented the three components, the 'somatotype' of an individual (Harrison *et al.*, 1977).

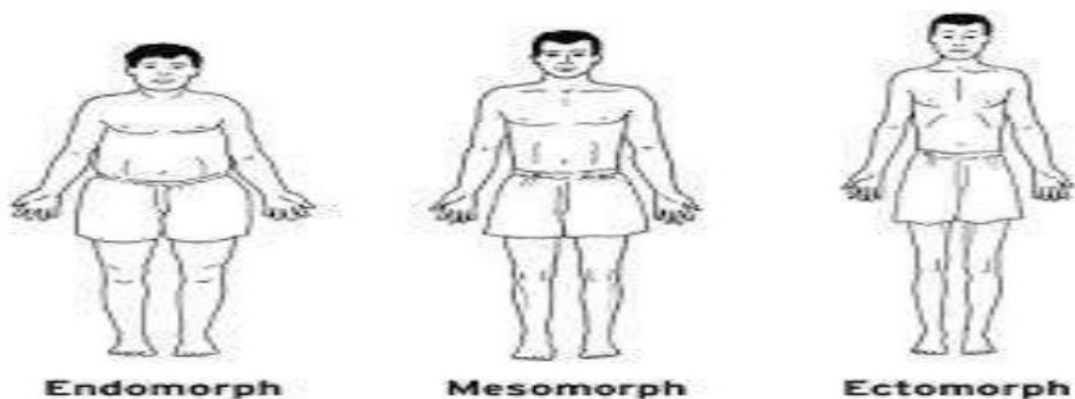


Figure 2.1: Sheldon's Perfect Endomorph, Perfect Mesomorph, and Perfect Ectomorph (Heath and Carter, 1990).

Sheldon described a mesomorph as an individual who was square with well-defined muscles and large bones, which gave him a squareness and hardness of the body. This person had well developed upper arms and legs, with broad shoulders and chest. A perfect mesomorph would have a somatotype of 1-7-1. When mesomorphy was extended towards women, on the whole women tended to be more endomorphic than mesomorphic. Thus women do not have a number of 6 or 7 in their mesomorphic scale (Harrison *et al.*, 1977).

A perfect ectomorph was a person with a somatotype of 1-1-7 and looked delicate, with thin bones and slight muscles. This person tended to be more linear with a thin, narrow

chest, and abdomen, and wiry arms and limbs. Endomorphs are characterised by relative fatness and a rounded shapely figure which seem to be the consequence of the predominance of digestive viscera. A perfect endomorph has a somatotype of 7-1-1.

There were no perfect endomorphs, ectomorphs or mesomorphs in the population, but people with a fair amount of each component. Harrison *et al.* (1977) stated that the common somatotypes among people were the 3-4-4, 4-3-3 or 3-5-2. A permutation and combination of the three numbers could result in 343 somatotypes among which Sheldon found that 76 of them effectively represented the female population.

Sheldon's work mainly centred on somatotyping of men. When extended to women or children, his methodology encountered difficulties due to the unavailability of a complete strategy or published atlas of women (Harrison *et al.*, 1977). In the case of children, it was difficult to predict the longitudinal growth that would occur during their adolescent years when they were young. Sheldon's work differed from the work of other researchers in the manner he classified body types – not as distinct types, but as a combination of the different traits he identified. Sheldon also found that when somatotyping was extended to women, they exhibited 76 of the 343 types that were found in men. He also found that endomorphy was common and women with strong endomorphic and ectomorphic components were commonly found while mesomorphy and a combination of endomorphy and mesomorphy were common in men (Sheldon, 1954).

2.1.7 Heath and carter

Heath and Carter devised a somatotype method, which was a three number rating of the human physique according to the present shape and body composition of an individual. The three number rating was the same as Sheldon – endomorphy, mesomorphy, and

ectomorphy except that according to them, the somatotype of a person might vary over time and their rating could be used for both men and women. Heath found flaws with Sheldon's somatotype since many subjects in her research work couldn't fit into the 7-point scale proposed by Sheldon. She also believed that ethnicity, growth, aging, nutrition, sport, physical performance, and occupational choice all made an impact on the somatotype of an individual. Also, Sheldon's method did not prove effective with children, who according to Heath had varying somatotypes during varying ages.

Heath modified Sheldon's somatotype method by replacing the 7-point scale of Sheldon's method with a rating scale that started at zero and had equal intervals. The restrictions that the sum of the three components should be between 9 and 12 were removed. A table that comprised a logical linear relationship between somatotype rating and height-weight ratios was constructed and a single table of Height-weight ratio and somatotypes were adopted for both male and females (Carter and Heath, 1990). Heath thus predicted a series of somatotypes for an individual based on the subsequent changes in the physical features of the individual (Carter and Heath, 1990).

Heath and Carter further modified Heath's somatotype method by modifying Parnell's M.4 technique and using it in their method. Parnell's M.4 technique made use of bone diameters, muscle girths, and skin folds or subcutaneous fat measurements (Heath and Carter, 1967). According to Heath and Carter, somatotype was the 'present morphological conformation' expressed in a three-number scale. The first numeral indicated the endomorphy of a person, that is, the fatness or leanness, while the second number referred to the muscular development of a person relative to his height and the third number corresponded to the ectomorphy or the relative linearity of the person. In addition to the height/weight ratio of the person, this number revealed the 'stretched outness' of the other

two values (Heath & Carter, 1967). The Heath Carter rating required an anthropometric somatotype, the somatotype photograph and the height-weight ratios, while a skilled somatotyper could rate using the photograph and the height-to-weight ratio table (Heath and Carter, 1967).

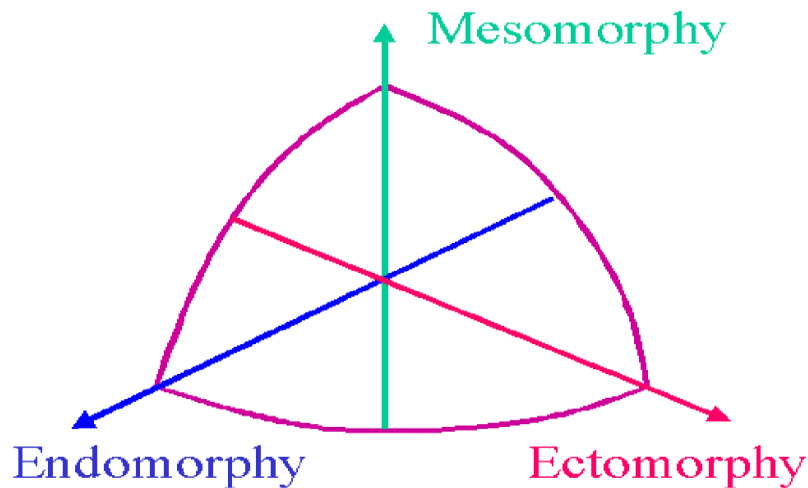


Figure 2.2: Graph showing three components of the Heath-Carter anthropometric somatotype (Rajajeyakumar, 2015).

The Heath-Carter Anthropometric Somatotype Method” requires the following anthropometric measurements to obtaining the somatotype: Weight, subscapular skin fold, height, supraspinale skin fold, triceps skin fold, calf skin fold, femur biepicondylar diameter, biceps girth, humerus biepicondylar diameter and calf girth.

2.2 Sexual Dimorphism in Somatotype Components

A number of studies involving the Chuvasa of Russian (Pavlovsky and Kobylansky, 1997; Kalichman and Kobylansky 2006), Czechoslovakian infants (Parizkova *et al.*, 1984), Indian adolescents (Gaur *et al.*, 2008, 2014), Italian and Estonian (Ventrella, 2008), Nigerian (Toriola and Igbokwe, 1985), Belgian (Hebbelinck *et al.*, 1995), South

African (Makgae *et al.*, 2007; Amusa *et al.*, 2011), children Spanish (Rebato *et al.*, 1996), young Americans and (Malina *et al.*, 2005; Arce *et al.*, 2012) have reported significant endomorphic differences between boys and girls, with the girls being more endomorphic compared to boys and boys being more mesomorphic than girls.

However, studies by Goon *et al.* (2013) on the somatotypes of Andibila rural children based on gender and age revealed no gender differences among Andibila children concerning their somatotype components. Their result conformed with other studies (Monyeki *et al.*, 1994, 2002) on South African children where sexual dimorphism in somatotype components was not apparent. Ethnic differences, type of study and methodological inconsistencies may have affected such differences in comparisons with studies from other countries.

As for the ectomorphic component Carter and Heath (1990), Rebato *et al.* (1996) Jurimae *et al.* (1999), Kalichman and Kobylansky (2006), Gaur *et al.* (2008, 2014), Yang *et al.*, (2015), all noted fewer differences in general in ectomorphy between males and females ($P > 0.05$) compared with the other two components, with higher mean values for males.

2.3 Body Composition

The body composition is a key component of health in both individuals and populations. It is defined as the ratio of fat and fat-free mass in the body, i.e., it illustrates the percentages of fat, bone, water and muscle in human bodies. A number of methods have been used to assess body composition: underwater weighing, air displacement plethysmography, dual-energy X-ray absorptiometry (DXA), among others, and are regarded as reference methods because of their accuracy of body composition estimation at the individual level (Wells *et al.*, 1999; Fields and Goran, 2000; Parker *et al.*, 2003). At

the present time, reference or laboratory methods are still not suitable enough for field and clinical use. Therefore, anthropometry and bioelectrical impedance (BIA) are the most widely used methods when population size is big, when no economic resources are available or when a quick measure is required (Wang *et al.*, 2000).

2.3.1 Dimorphism in body composition

The simplest model of body composition divides body weight into two components: the fat and lean masses. Adjusting these components for size can be undertaken in different ways, many of which fail to achieve their purpose (Goran *et al.*, 1995). They are now conventionally adjusted for height by dividing by height squared, producing two indices: the lean mass index (lean mass/height²) and the fat mass index (fat mass/height²). These indices have the advantage that they provide discrete indices for the two components of weight, each adjusted for an independent component of size. In most cases, they provide sufficient adjustment for size, although in some cases more complex approaches are required (Van Itallie *et al.*, 1990; Wells *et al.*, 2002).

Relatively, therefore, females are fatter than males at birth, and tend to have slightly higher mean skin-fold thicknesses (Akinyinka *et al.*, 1999; Rodriguez *et al.*, 2005). Consequently, even at this early age, the two sexes seem to have differing developmental strategies, and these differences may be related to greater male vulnerability in the new born period (Well, 2000). The two sexes show broad consistency over the first decade in terms of lean mass (Fomon *et al.*, 1982; Van der Sluis *et al.*, 2002) but vary in their accumulation of fat (Arfai *et al.*, 2002; Taylor *et al.*, 2002). Both sexes show relative drop off in body fat between 1 and 6 years of age; yet, the girls begin to

increase fatness again while the boys are primarily attributable to lean mass and increase in weight.

These contrasting growth patterns diverge further during adolescence, with girls gaining considerable amounts of fat but relatively little lean, and boys showing the opposite strategy (Haschke, 1989; Maynard *et al.*, 2001; Hattori *et al.*, 2004). These changes are mainly hormonally driven; however, reduced energy expenditure in girls during puberty may also be important.

The end result by early adulthood is that while the sexes have relatively similar weight for height (BMI), the ratio of lean to fat is much greater in males than females. These data illustrate the inadequacy of BMI as an index of body composition during growth. Whereas increases in BMI are generally attributed to greater fatness in females while age-associated increase in BMI, in boys, can be ascribed to gain in lean mass rather than fat (Hattori *et al.*, 2004).

The realization of adulthood is therefore marked by significant dimorphism in total body composition, with women having considerably greater mean percentage fat and relatively less lean mass. This sex difference cut across all ethnic groups and has been observed in all populations, although its magnitude is influenced by environmental conditions and ethnic genetic factors. Percentage fat averages 10–15% of males in most populations, but can attain 30% in some Polynesian populations. The typical range in females is 20–30%, but up to 45% in Polynesians (Norgan, 1990; Goran *et al.*, 1998; Wells, 2006). Complementing these population differences in percentage fat are differences in relative lean mass; however, despite their importance for functional work capacity and long-term health these have generally received much less attention.

The main source of evidence concerning skeletal size and bone mass is DXA. This is a two-dimensional imaging method which measures the length and width of bones but not their depth (Seeman, 2001). The degree of attenuation of photons during their transmission through bone is a function of the bone mineral content. Larger bones with greater volume attenuate more photons, but this does not imply greater bone density. Young adult males therefore have greater bone mass due to their larger body size, but their bone density is similar to that in females, and this applies likewise to earlier developmental periods (Lu *et al.*, 1996; Maynard *et al.*, 1998). The sex difference in bone mineral mass and size emerges during puberty (Nguyen *et al.*, 2001) and can be attributed to several factors, including the longer prepubertal growth period of boys compared to girls, and the inhibitory effect of oestrogen on periosteal apposition in girls (Seeman, 2001).

Recent studies indicate that gender differences in bone mass emerge at around 15–17 years, with the larger size of male bones then conferring greater strength (Schoenau *et al.*, 2003). Thus whereas mineral mass is very similar between the sexes at birth (Fomon *et al.*, 1982) by the start of adulthood skeletal weight is around 4 kg in men and 2.8 kg in women (Malina, 1996).

Dimorphism in total body composition does not remain stable in adulthood. Therefore, due to both hormonal changes and decline in activity levels Males maintain their lean mass into the fifth decade of life, but then begin to lose muscle mass (Pichard *et al.*, 2003). Females show a similar decline in lean mass, but often illustrate greater gains in fatness, even when weight-stable (Zamboni *et al.*, 2003). Such changes continue into old age (Viser *et al.*, 2003), but are strongly influenced by the quality of the environment. Whereas those from industrialized populations tend to gain weight with age, in non-

industrialized populations the elderly are frequently malnourished (Strickland and Ulijaszek, 1994; Ahmed *et al.*, 1998). Since the decline in lean mass is relatively universal, weight gain with age in all populations can be attributed primarily to fat.

Bone size and content are influenced in contrasting ways by the processes of growth and development. The effect of growth is to increase the size of the bone, whereas that of ageing is to resorb bone from the cortex while offsetting this process with periosteal apposition which enlarges the bone (Seeman, 2001). The process of trabecular bone loss can occur either by thinning or by loss of connectivity, and the influence of these two processes differs between the sexes, which can be attributed to the effect of oestrogen deficiency occurring at menopause.

Age-associated periosteal bone formation also differs between the sexes, being greater in men. The net effect of these two sex differences is to confer greater strength on male bones in old age, and hence predispose to a marked sex difference in the risk of fracture (Seeman, 2001).

Recent research has emphasized the influence of reproductive maturity on the profile of female fatness. The timing of onset of puberty is itself associated with baseline body fatness (Slyper, 1998), while those entering puberty earlier tend to maintain high levels of fatness throughout adulthood (Pierce and Leon, 2005).

Pregnancy is associated with marked gains in lean mass and body fat, and fatness also increases and becomes more central with parity, since postpartum fat accretion occurs disproportionately in the abdomen (Sidebottom *et al.*, 2001). Thus the magnitude of sexual dimorphism can be related to patterns of reproductive maturation and fertility. However, calcium depletion related to lactation is only temporary.

Sexual dimorphism in total tissue masses is of importance in several contexts: for example, when calculating energy requirements or the dosages of some drug treatments and dialysis. It also exerts strong effects on some aspects of function, such as work capacity. However, it is a regional body composition that is most strongly implicated in sex differences in the risk of diseases.

2.4 Role of Imaging in Measurement of Organ Size

2.4.1 Methods of measurement

Modern medical science is characterized by rapid development and introduction into clinical practice of new technological methods and diagnostic features with the possibility of their use for the study of normal anatomy and variants of the structure of various organs and systems of the human body (Chaplygina and Gubar, 2014). In this regard, anatomists began to actively use new medical technologies: ultrasonography, computed tomography, magnetic resonance imaging and other radiological techniques that allowed in vivo study of the organs and systems of the human body (Chaplygina *et al.*, 2014).

2.4.1.1 Radiography

Radiography is usually performed first in most cases as it is relatively cheap and easy to do. Radiography allows a global view of the abdomen and it is often as easy (or easier) to determine size and position of organs on radiographs with more advanced imaging techniques. The abdominal radiograph allows assessment the abdominal boundaries and vertebrae which may be involved in abdominal pathology e.g. metastases of prostatic tumors. The main problems with abdominal radiography are poor soft tissue contrast and difficulties with interpretation due to superimposition. In the presence of significant ascites, radiography is usually unhelpful due to complete loss of serosal detail; the same

is often true for severely emaciated animals. Many diseases involving the small organs such as adrenal glands, pancreas, lymph nodes are not visible radiographically. Despite relatively poor soft-tissue contrast, radiographs are good at showing relatively small volumes of free abdominal gas and alterations of gas patterns within the gastrointestinal tract. Radiographs are also reasonably good for demonstrating areas of mineralization e.g. ureteric calculi and radiopaque foreign bodies.

2.4.1.2 Ultrasound (US)

Diagnostic ultrasound, also called Sonography, uses pulses and high-frequency sound waves to form images of the body. The speed of sound depends on the type and interfaces between tissues which act as total or partial reflectors of the ultrasound waves. The travel time of the ultrasound waves is interpreted by using a range of frequencies, distance to the different interface, pulse and amplitudes in conjunction with advanced signal processing, two-, three- and even four-dimensional image data can be reconstructed (Von-Herby *et al.*, 2004). Health risks associated with exposure to diagnostic ultrasound are unknown, but thanks to its real-time imaging capacity with high temporal and spatial resolution used in most areas of the body (Furuse *et al.*, 2003). Though, the image quality is partial by total reflection via air- or gas-containing organs, skeletal or other calcified structures and by the depth of the object to examine. Diagnostic ultrasound is considered more operator-dependent than other modalities. In upper abdominal imaging, it is an efficient means of examining the pancreas, gallbladder, liver and biliary ducts. The introduction of ultrasound contrast media in the last decade has increased its accuracy and applications, e.g. in liver characterization and lesion detection, especially where small lesions are undetected by MRI or CT (Furuse *et al.*, 2003). Contrast-enhanced ultrasound (CEUS) adds functional information on pathological and normal vascular structures on tissue

perfusion in real time, which MR and CT cannot provide at temporal resolution or equal spatial (Morin *et al.*, 2007).

2.4.1.3 Computed tomography (CT)

In 1971, Hounsfield developed the Computed tomography (CT) from producing one 2-dimensional image slice in several minutes to almost instantly delivering time-resolved three-dimensional image datasets amounting to thousands of images (Hounsfield, 1973). The CT equipment consists of a rotating ring-like frame carrying the x-ray tube which delivers a fan-shaped radiation to the opposite side, where an array of small detector elements is located. The frame rotates continuously in its housing (gantry) around the patient table, which moves through the gantry opening. The detector array samples the radiation that has passed through the patient in and this data is then processed to form a three-dimensional representation of the body. The image elements contain an *attenuation value* corresponding to the density or opacity to x-ray radiation, measured on the Hounsfield (HU) unit scale that defines the attenuation of air as -1000 HU and that of water as 0 HU. Thus, there are typical attenuation values of all tissues and direct comparisons between examinations can therefore be made. While many organs are well delineated by CT, the contrast between soft tissues is low. Therefore, contrast media based on iodine are frequently used to improve the conspicuity of vessels and parenchymal organs. Computed tomography is a generally available modality in many parts of the world and is typically the first choice in examinations of the abdomen with a focus on malignancies. Modern multi-detector CT (MDCT) equipment (Kalender *et al.*, 1990) combined with contrast medium power injectors provide reliable imaging at high resolution in several phases of vessel enhancement, which makes it possible to image the liver in 1–2 arterial-dominant phases, portal venous phase and later phases if needed.

Examinations including several phases can however, lead to a considerable dose of ionizing radiation, especially for those patients who are referred for regular follow-up, e.g. during or after chemotherapy. Specifically for biliary imaging purposes, ordinary contrast-enhanced MDCT image data from a portal venous or later phase can be processed with the Minimum Intensity Projection (MinIP) technique. This will highlight the lowest-intensity parts of the image data, which normally corresponds to the bile-filled biliary ducts and gallbladder (Kim *et al.*, 2006). Although not available in all countries, an intravenous cholangiographic contrast medium that is excreted by the biliary system – meglumine iotroxate (Biliscopin®, Bayer Schering Pharma, Berlin, Germany) – can be used for contrast enhancement of the biliary ducts in MDCT (Hashimoto *et al.*, 2008 and Persson *et al.*, 2005).

2.4.1.4 Nuclear medicine (NM)

Nuclear medicine uses detectors sensitive to ionizing radiation from radioactive isotopes that have been introduced into the body. The isotopes or rather the molecules – *tracers* – they are part of having different affinity for different organs or tissues. Organs and functions can be targeted by specific tracers to produce image data and quantitative measures of tracer uptake and elimination. In hepatobiliary imaging, the Hepatobiliary Iminodiacetic Acid (HIDA) scan is used to evaluate the elimination of HIDA, which mainly takes place in the liver (Jonas *et al.*, 2001). Positron Emission Tomography (PET) combined with CT in the same machine – CT/PET or PET-CT – has become more available during recent years. Tracer compounds containing positron-emitting isotopes are introduced into the patient and detected by the PET equipment, which gives higher resolution images than other NM techniques. These are then easily fused with morphological images obtained from the CT part of the CT/PET-machine. The role of

CT/PET in hepatobiliary imaging is so far limited. In some cases, it may assist in finding distant metastases of primary liver tumors that have tracer uptake (Delbeke *et al.*, 2005).

2.4.1.5 Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) is based on the electromagnetic interactions of the hydrogen nuclei – protons – in the body (Warnjtes *et al.*, 2005). All protons exhibit magnetic properties due to their electrical charge and spin. The MRI unit consists of a main superconducting electromagnetic coil producing a very strong stationary magnetic field, gradient coils providing additional and weaker but highly variable magnetic fields and antennas for sending and receiving radiofrequency waves to/from the body being examined. Very simplified, images are formed from weak radio waves emitted from the protons in the body, their frequency and phase representing different locations. To receive the proper signals, a great number of physical parameters need to be defined correctly in the MRI machine, so that the relevant tissues are imaged with the intended characterization or so-called weighting. The MR imaging process can be tuned to show different tissues with varying contrast, highlighting and suppressing structures in numerous ways. There is, however, no reference tissue or any well-defined range of signals from different tissues. In each experiment or scan, a grayscale image is finally formed, but the underlying values in the image pixels lie on a unique scale for that scan. It is possible to perform MRI with a quantitative approach, but the methods used have been time-consuming and difficult to use. With newly developed MRI sequences this is becoming more practical, and quantitative comparison of tissue signals (instead of just visual judgment) can be applied (Warnjtes *et al.*, 2008).

2.4.2 Sonographic Assessment of the Liver, Caudate Lobe, Gallbladder and Common Bile Duct

Diagnostic ultrasound, which operates within a frequency range of 1-20 megahertz (MHz), is generated by transducers that transform electrical energy into ultrasonic energy and vice versa. Ultrasound can penetrate soft tissues, and can also be partly reflected at tissue interfaces. The reflected signals can be recorded and from the information received, a spatial reconstruction of the deep tissues can be built up and displayed on a viewing monitor. To produce pulses of ultrasound electrically, the transducer is rocked to and fro or moved over the skin to obtain echoes from underlying tissues of interest. These echoes are detected by the transducer as in-coming information. This information is processed and displayed as a gradation of shadows from near white to nearly black (grey scale) depending on the strength of these echoes from different tissues.

2.4.2.1 Liver

The examination of the liver should include long-axis and transverse views. The liver parenchyma should be evaluated for focal and/or diffuse abnormalities. If possible, the echogenicity of the liver should be compared with that of the right kidney. In addition, the following should be imaged:

- a. The major hepatic and perihepatic vessels, including the inferior vena cava (IVC), the hepatic veins, the main portal vein, and, if possible, the right and left branches of the portal vein.
- b. The hepatic lobes (right, left, and caudate) and, if possible, the right hemidiaphragm and the adjacent pleural space.
- c. For vascular examinations of the native or transplanted liver, Doppler evaluation

should be used to document blood flow characteristics and blood flow direction. The structures that may be examined include the main and intrahepatic arteries, the hepatic veins, the main and intrahepatic portal veins, the intrahepatic portion of the IVC, collateral venous pathways, and transjugular intrahepatic portosystemic shunt stents.

2.4.2.2 Gallbladder and biliary tract

A routine gallbladder examination should be conducted on an adequately distended gallbladder whenever possible. In most cases, fasting before elective examination will permit adequate distension of a normally functioning gallbladder. In infants and children, fasting may not be necessary in all cases. The gallbladder evaluation should include long-axis and transverse views obtained in the supine position. Other positions such as left lateral decubitus, erect, and prone may be helpful to evaluate the gallbladder and its surrounding areas completely. Measurements may aid in determining gallbladder wall thickening. If the patient presents with pain, tenderness to transducer compression should be assessed.

The intrahepatic ducts can be evaluated by obtaining the views of the liver demonstrating the right and left branches of the portal vein. Doppler imaging may be used to differentiate hepatic arteries and portal veins from bile ducts. The intrahepatic and extrahepatic bile ducts should be evaluated for dilatation, wall thickening, intraluminal findings, and other abnormalities.

The bile duct in the porta hepatis should be measured and documented. When visualized, the distal common bile duct in the pancreatic head should be evaluated.

2.5 Somatotype, Body Composition, Organ Dimensions and Other Anthropometric Variables

2.5.1 Relationship between somatotype and body composition

Several investigators examined the relationship between body composition and the components of somatotype. Dupertuis *et al.* (1951) found a high negative correlation between endomorphy and specific gravity and low positive correlations between mesomorphy, ectomorphy, and specific gravity.

Wilmore (1970) investigated the claim of Heath and Carter (1967) that the endomorphic and mesomorphic components represent the degree of fatness and lean body weight, respectively. Because of low correlations ($r = .16$ and $.41$ for females and males, respectively) between lean body weight and the mesomorphic component, he seriously questioned the validity of referring to the mesomorphic component as representing lean body weight. Higher correlation coefficients ($r = .58$ for females and $.72$ for males) supported the relationship between percent fat and the endomorphic component. Wilmore also concluded that there was a lack of differentiation between the mesomorphic component and the ectomorphic component.

Slaughter and Lohman (1976) reported significant correlations ($r = .74$, $.45$, and $-.66$) between percent fat and endomorphy, mesomorphy, and ectomorphy, respectively. Correlations between lean body mass and the somatotype components were not significant ($r = .25$, $.20$, and -0.34 , respectively). These findings are compatible with Wilmore's (1970) conclusions and the findings of Bolonchuk *et al.* (2000) for the female subjects. Apparently, the Heath and Carter somatotype procedure for rating female mesomorphy is unrelated to fat-free weight. However, the relationship between the fat-

free weight and mesomorphy, in the study by Bolonchuk *et al.* (2000) and in Wilmore's study, was significant for men.

Bolonchuk *et al.* (2000) reported a relationship between body composition and each of the components of somatotype. The measurements from several different tests and the estimates of body composition established this relationship. Fat and fat-free weight were positively correlated with the endomorphic and mesomorphic components and negatively correlated with the ectomorphic component. The relationship between fat and the endomorphic component was generally greater than the relationship between fat and the mesomorphic component. The relationship between fat-free weight and the mesomorphic component was generally greater than the relationship between fat-free weight and the endomorphic component for males. There was no correlation between fat-free weight and the mesomorphic component for females.

2.5.2 Relationship between somatotype and blood pressure

Herrera *et al.* (2004) observed the correlation between ectomorphy and both Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP). It was shown that as ectomorphy increased the blood pressure decreased, except for the oldest age group. Malina *et al.* (1997) investigated 642 apparently healthy adults particularly on blood pressure (SBP and DBP), fasting glycaemia and blood fats. The results showed that the correlation ranged from - 0.20 to + 0.30 in women, and 0.23 to + 0.23 in males. Groups with older age had a stronger correlation, in women with high total skinfold thickness showed a positive correlation with risk factors, whereas in males showed a negative correlation. Kalichman *et al.* (2004) observed that individuals of robust physique (with

high endomorphy and mesomorphy) showed high mean values of SBP and DBP, whereas the smallest persons had the lowest BP values.

According to Badenhorst *et al.* (2003), somatotype and elevated blood pressure showed correlation which indicated that the blood pressure of the endomorphic boys was the highest which increased with physical activity levels. Rahmawati (2012) reported that in females, correlations between somatotype and blood pressure tended to be stronger in 31-40 and 41-50 age groups, while in males this pattern was less consistent. In general, for males and females correlation between blood pressure and endomorphy were positive, however between blood pressure and ectomorphy were negative. This suggested that ponderosity and muscularity have the opposite effect; however linearity of physique could offer an adaptive advantage.

Kalichman and Kobylansky (2004) concluded from their work on the relationship between somatotypes and blood pressure in adult Chuvasa population that dominant endomorphs and mesomorphs tend to have a higher mean value for systolic and diastolic blood pressure compared to the ectomorphs. The disparity in blood pressure was attributed to the high subcutaneous fat and large muscle mass present in the endomorphs and mesomorphs respectively. In another study by Makgae *et al.* (2007) on rural south African children, ectomorphs had the highest value for both systolic and diastolic blood pressure while endomorph and mesomorphy had similar mean values. This inverse finding was attributed to the high prevalence of malnutrition reported by the sampled children during the research exercise.

2.5.3 Relationship between somatotype and organ sizes

Several investigators have reported a relationship between somatotype and organ sizes among the Caucasians. For instance, Adamu *et al.* (2007) reported that endomorphic subjects have larger dimensions of internal organs than the ectomorphic subject. A positive correlation was observed in the evaluated data of ultrasound examination of the thyroid gland in relation to the body types (Zmeev, 2010; Chaplygina and Kuchieva, 2012). Similarly, Chaplygina and Guber (2014) observed significant differences in the values of the linear dimensions of the liver in patients with different somatotypes. In another study, the liver volume was found to be dependent on the variability of the macroscopic structure of the body (Chaplygina *et al.*, 2013).

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Study Location

This cross-sectional study was carried out in the Department of Human Anatomy, Ahmadu Bello University and also in the Radiology Department of Ahmadu Bello University Teaching Hospital, Zaria.

3.2 Data Collection

In order to achieve the objectives, we identified the following stages: Stage I involved field data collection: biodata, medical history and anthropometry were collected from the subjects using a questionnaire in the Department of Human Anatomy; Stage II involved the formation of electronic database of the anthropometric variables and computation of somatotype using the Heath and Carter method and body composition using the Durnin and Wormersely method; Stage III involved the conveying of the somatotyped subjects on the subsequent day to the Radiology Department of Ahmadu Bello University Teaching Hospital, Zaria for abdominal ultrasound; and Stage IV is the final phase, which involved the analyses of sonographic anthropometric variables, somatotypes and body composition.

3.3 Sample Size Determination

The study group was chosen from amongst a cross-sectional sample of one thousand nine hundred and sixteen (1916) undergraduate students of Faculty of Medicine, Ahmadu Bello University, Zaria, Kaduna State (ABU, 2013). The number of subjects included in the study was calculated using the finite population correction formula (n_f).

$$n_f = \frac{n}{1 + (n/N)} \quad (\text{Araoye, 2004})$$

Where:

n_f = the desired sample size when the population is less than 10,000

N = the estimate of the population size

n = the desired sample size when the population is more than 10,000; determined from the formula $n = \frac{z^2 pq}{d^2} = 384$ (Araoye, 2004)

n = the desired sample size when the population is greater than 10,000

z = Value of normal standard deviates corresponding to 1.96

p = Proportion of the target population estimated to have a particular characteristic (if there no reasonable estimate, 50% i.e.; 0.05 is used.

q = Complimentary probability $1 - p$

d = Degree of accuracy (0.05 or 5%)

Thus $n_f = \frac{384}{1 + (384/1918)} = \mathbf{318}$

Hence, a minimum number of 318 subjects would have been used in the study in order to draw valid conclusions from it. However, a total of three hundred and fifty (350) subjects were recruited for the study (after calculating for 10% non-response rate); 175 males and 175 females.

3.4 Sampling Technique

A multistage sampling technique was employed involving the following stages:

3.4.1 Stage 1 (Selection of faculty)

Faculty of Medicine was conveniently sampled. All the Departments and levels were included in the sampling.

3.4.2 Stage 2 (Selection of students)

By using proportionate allocation, the number of students sampled from each department was determined.

Table 3.1: Determination of Number of Students to be Sampled in Each Department

Departments	Total No. of students	Proportion	No. of students to be sampled
MBBS	525	$525/1916 = 0.3$	$0.3 \times 350 = 105$
Human Anatomy	396	$396/1916 = 0.2$	$0.2 \times 350 = 70$
Human Physiology	413	$413/1916 = 0.2$	$0.2 \times 354 = 70$
Nursing Sciences	582	$582/1916 = 0.3$	$0.3 \times 350 = 105$
Total	1916		350

From the above table 105, 70, 70 and 105 number of students were sampled from MBBS, Human Anatomy, Human Physiology and Nursing Sciences respectively.

Also, by using equal allocation, the number of students sampled from each level of each Department was determined as illustrated in the table below.

Table 3.2: Determination of Number Students in each Level from each Department

Departments	No. of students to be sampled	No. of levels	No. of students at each level
MBBS	105	6	$105/6 = 18$
Human Anatomy	70	4	$70/4 = 18$
Human Physiology	70	4	$70/4 = 18$
Nursing Sciences	105	5	$105/5 = 21$

A list of all students in each level was made and by using simple random sampling (Balloting), the number of each student from each level as calculated above was sampled.

3.5 Inclusion Criteria

- i. Inclusion of the data in the present study was dependent on somatotype dominance. Only those subjects (age: 18 - 35 years and medical students of Ahmadu Bello University, Zaria) who demonstrated somatotype dominance, defined as a somatotype component rating at least 0.5 points higher than either of the other two component ratings, were selected.
- ii. Apparently healthy subjects.
- iii. Voluntary participation

3.6 Exclusion Criteria

- i. All subjects with equal ratings for the highest somatotype component, non-medical students and age outside 18-35 years.
- ii. Subjects with known or suspected clinical evidence of liver or gallbladder disease, and cardiovascular disease.
- iii. Subjects with clinical evidence of lymphadenopathy, sickle cell disease or

pregnancy.

- iv. Subjects with imaging evidence of liver parenchymal mass lesion or cyst and gall stone.
- v. Subjects that did not fast overnight before the scanning.

3.7 Ethical Approval

The ethical approval for the study was sought according to World Health Organization (WHO, 2002) and the Helsinki Declaration (The World Medical Association) from the Ethics Committee of Faculty of Medicine, Ahmadu Bello University, Zaria (Appendix I).

3.8 Informed Consent

All participants were informed about the aim and procedure of the study, and about the right of voluntary withdrawal from participation. Subjects were required to sign the consent form before participating (see the form in Appendix II).

3.9 Methodology

3.9.1 Materials

- i. Luftkin flexible tape
- ii. Harpenden skin fold caliper with measuring accuracy of 0.05mm
- iii. Stadiometer with measuring accuracy of 0.1cm
- iv. Precision (SECA™) weighing Scales with measuring accuracy of 50g
- v. Small sliding caliper with measuring accuracy of 0.05cm (Rosscraft, Canada, Ltd)
- vi. Mercury Sphygmomanometer (ACCUSON)

- vii. Mindray diagnostic Ultrasound system (Model DC-3, 2010/2012, Nanshan, Shenzhen, PR China) plus 2.5-6 MHz curvilinear probe.

3.9.2 Anthropometry

The following anthropometric measurements were taken according to the standard protocol reported by International Society for Advancement of Kinanthropometry (ISAK, 2001).

- a. **Stature (Height).** Height was measured against the stadiometer with the subject standing straight, against an upright, touching the instrument with heels, butt and back. The head was oriented in the Frankfort plane (the upper edge of the ear orifice and the lower edge of the eye socket along a horizontal line) and the heels together. The subject was then instructed to stretch upward and to acquire and hold a full breath and the headboard was lowered until it firmly touched the vertex.
- b. **Body mass (weight).** The weight was measured in kilograms using a digital weighing scale while the participant is in light clothes. The participant was asked to remove any heavy objects and take off his or her shoes and all accessories and the scale was then put on a perfectly flat surface with no obstructions. The participant was then asked to stand on the scale and remain still until the readings appear. The weight in kilogram was then read to the nearest decimal place.
- c. **Skinfolds.** A fold of skin and subcutaneous tissue was lifted firmly between thumb and index finger of the left hand and away from the underlying muscle at the marker site. The edge of the plates was applied to the caliper branches 1 cm under the fingers of the left hand and allowed to exercise their full pressure before reading at 2 Sec the thickness of the fold. All skin folds on the right side of the

body were taken. The subject stood relaxed, except for the calf skinfold, which was done with the subject seated.

- i. **Triceps skin fold.** With the subject's arm hanging loosely in the anatomical position, fold at the back of the limb at a level halfway on a communication channel connecting the acromion and the olecranon processes was taken.
- ii. **Bicep skin fold:** with the subject assuming anatomical position, the skin fold site was marked over the most anterior part of biceps when viewed from the side at the marked mid-acromiale radiale level.
- iii. **Subscapular skin fold.** The subscapular skinfold was raised on a course from the inferior angle of the scapula in a way that is obliquely downwards and laterally at 45 degrees.
- iv. **Supraspinale skin fold.** A fold 5-7 cm (depending on the size of the subject) above the anterior superior iliac spine on a line to the anterior axillary border and on a diagonal line going downwards and medially at 45 degrees was raised.
- v. **Medial calf skin fold.** A vertical skinfold on the medial position of the leg was raised, at the point of the maximum girth of the calf.



A



B



C

Plate I: procedures for taking tricep skin fold (A), bicep skin fold (B) and subscapular skin



D



E

Plate II: procedures for taking supraspinal skin fold (D) and medial calf skin fold (E)

d. **Bony landmarks and dimensions:**

- i. **Biepicondylar breadth of the humerus, right (BBH).** The width between the medial and lateral epicondyles of the humerus, with the shoulder and elbow, flexed to 90 degrees. The caliper was applied at an angle approximately bisecting the angle of the elbow. Firm pressure was put to compress the subcutaneous tissue.
- ii. **Biepicondylar breadth of the femur, right (BBF).** The subject was seated with knees, bent at a right angle. The greatest distance between the lateral and medial epicondyles of the femur was measured with firm pressure on the crossbars to compress the subcutaneous tissue.



F



G

Plate III: procedure for taking BBH (F) and BBF (G)

e. **Girth:**

- i. **Upper arm girth, elbow flexed and tensed, right.** The subject was asked to flex the shoulder to 90 degrees and the elbow to 45 degrees, clenched the hand, and maximally contract the elbow flexors and extensors. The measurement of the greatest girth of the arm was taken.
- ii. **Calf girth, right.** The subject stood with feet slightly apart and the tape put on the calf and the maximum circumference was measured.



H



I

Plate IV: procedure for taking arm girth (H) and calf girth (I)

3.9.3 Body mass index (BMI) and Body surface area (BSA)

The BMI and BSA were computed using the formula below:

$$\text{BMI} = \frac{\text{Weight (kg)}}{\text{Height (m}^2\text{)}} \quad (\text{Mosteller, 2004})$$

$$\text{BSA} = \left(\frac{\text{Weight X Height}}{3600} \right)^{\frac{1}{3}} \quad (\text{Mosteller, 2004})$$

3.9.4 Fat Mass Index (FMI), Fat-free Mass Index (FFMI), Fat-Free Mass (FFM) Total Body Potassium (TBK) and Body Cell Mass (BCM)

The FMI, FFMI, BMD, TBK and BCM were computed from the fomulae below:

$$\text{FMI} = \text{fat mass (kg)} / \text{Height}^2 \text{ (m}^2\text{)} \quad (\text{Schutz } et al., 2002)$$

$$\text{FFMI} = \text{fat-free mass (kg)} / \text{Height}^2 \text{ (m}^2\text{)} \quad (\text{Schutz } et al., 2002)$$

$$\text{FFM (Kg)} = 0.001999 (\text{Height})^2 \text{ m}^2 + 1.67 \quad (\text{Slaughter and Christ, 1995})$$

$$\text{TBK (g)} = (5.52 - 0.014 \times \text{Age (years)}) \times \text{Weight}^{0.5} \text{ (kg)} \quad (\text{Ellis } et al., 1974)$$

$$\text{BCM (kg)} = \text{TBK} \times 0.00833 \quad (\text{Moore } et al., 1963)$$

3.9.5 Blood pressure (BP)

BP was measured to the nearest 2 mm Hg as the first (systolic) and the fifth (diastolic) Korotkoff phases using a standard mercury sphygmomanometer. Three measurements were taken at 1-minute intervals in the sitting position after the participant had been sitting for 5 minutes. The mean of the two last readings was calculated. Participants were asked whether they had been told by a doctor or nurse that they had high BP and whether they were currently taking prescribed medication for hypertension. Participants were

considered to have hypertension if they answered “yes” to both of these questions or had systolic BP ≥ 140 mm Hg and/or diastolic BP ≥ 90 mm Hg.

3.10 Equations for Somatotype Analysis

The following equations are used in calculation and analysis of somatotype data. Items 3.10.1 and 3.10.2 are for calculating and plotting the somatotype.

3.10.1 The anthropometric somatotype

$$\text{Endomorphy} = -0.7182 + 0.1451 (X) - 0.00068 (X^2) + 0.0000014 (X^3)$$

$$\text{Mesomorphy} = (0.858 \text{ HB} + 0.601 \text{ FB} + 0.188 \text{ CAG} + 0.161 \text{ CCG}) - (0.131 \text{ H}) + 4.5$$

Ectomorphy:

$$\text{If HWR} > 40.75, \text{ then Ectomorphy} = 0.732 \text{ HWR} - 28.58$$

$$\text{If HWR} < 40.75 \text{ and } > 38.25, \text{ then Ectomorphy} = 0.463 \text{ HWR} - 17.63$$

$$\text{If HWR} \leq 38.25, \text{ then Ectomorphy} = 0.1 \text{ (or recorded as } \frac{1}{2} \text{)}$$

Where: X = (sum of triceps, subscapular and supraspinale skinfolds) multiplied by (170.18/height in cm); HB = humerus breadth; FB = femur breadth; CAG = corrected arm girth; CCG = corrected calfgirth; H = height; HWR = height / cube root of weight.

CAG and CCG are the girths corrected for the triceps or calf skinfolds respectively as follows: CAG = flexed arm girth - triceps skinfold/10; CCG = maximal calf girth - calf skinfold/10.

3.10.2 Plotting somatotypes on the 2-D somatochart

X-coordinate = ectomorphy - endomorphy

Y-coordinate = 2 x mesomorphy - (endomorph + ectomorph)

3.11 Scanning Technique

Before the ultrasound examination, the participants were requested to fast overnight in order to maximise the distension of the gall bladder and reduce food residue and gas in the upper gastrointestinal tract, which may reduce image quality or preclude liver imaging. The subjects were also encouraged not to smoke for 6–8 h prior to the ultrasound examination, since there is some evidence that smoking can reduce image quality to scan the upper abdominal structures and some chemicals in tobacco may cause contraction of the gall bladder, even after fasting. Afterwards, the participants underwent physical examination to rule out any clinically visible disease that could modify the hepatobiliary dimensions. All the sonographic examinations were done by a single trained sonologist in order to avoid inter-observer error. And all measurements were taken in duplicate with their mean values as the real measurement; this is in order to avoid intra-observer error. A pilot study was carried out where the examiner measured repeatedly the hepatobiliary dimensions of ten different subjects.

Examinations were done with each subject lying supine according to the agreed scanning techniques described by American institute of ultrasound in medicine proceedings, 2007 (AIUM). The following organs were measured:

3.11.1 Liver and the caudate lobe

Following application of coupling gel on the area of interest, longitudinal scan image of the liver was done at deep arrested inspiration and with a relaxed abdominal wall. In order to have better access to the liver, subjects were instructed to raise their right hand behind their head, thus increasing the intercostal spaces and the distance from the lower costal margin to the iliac crest. The size of the liver was measured in the right mid-clavicular line (MCL) (with a measurement from the hepatic dome to the inferior hepatic tip) (see plate V). The caudate lobe of the liver was seen posterior to fissure for ligamentum venosum and the cranio-caudal length and anterior posterior lengths were measured (see plate VI).

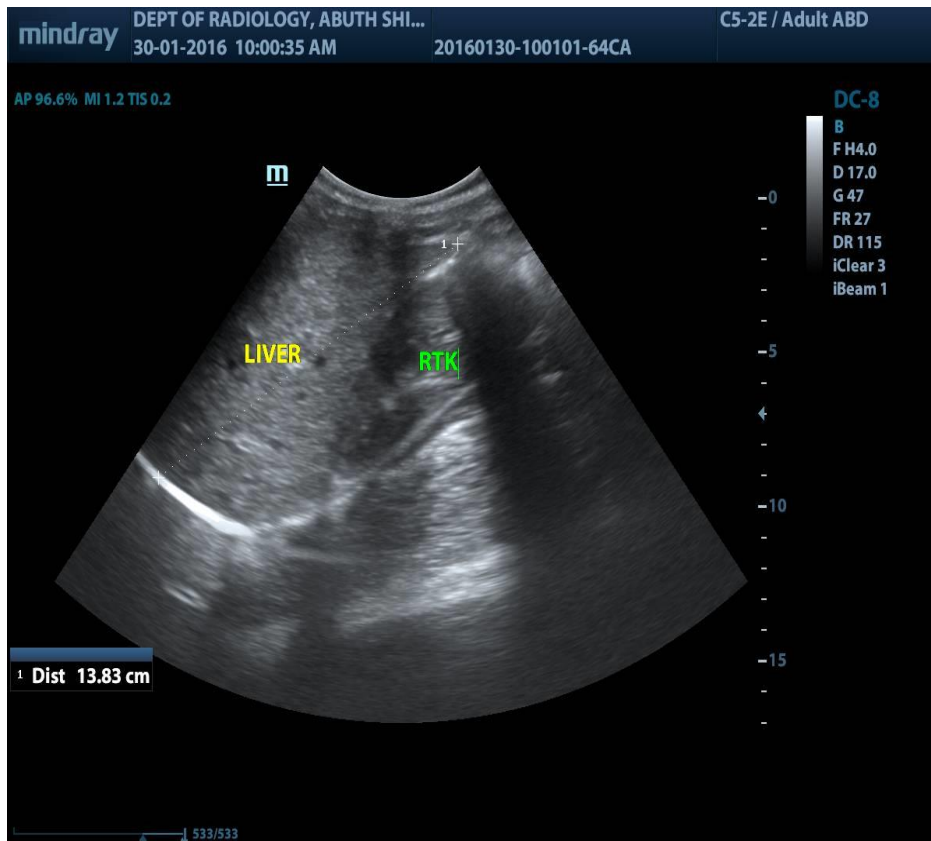


Plate V: imaging procedure for measuring the length of liver in MCL

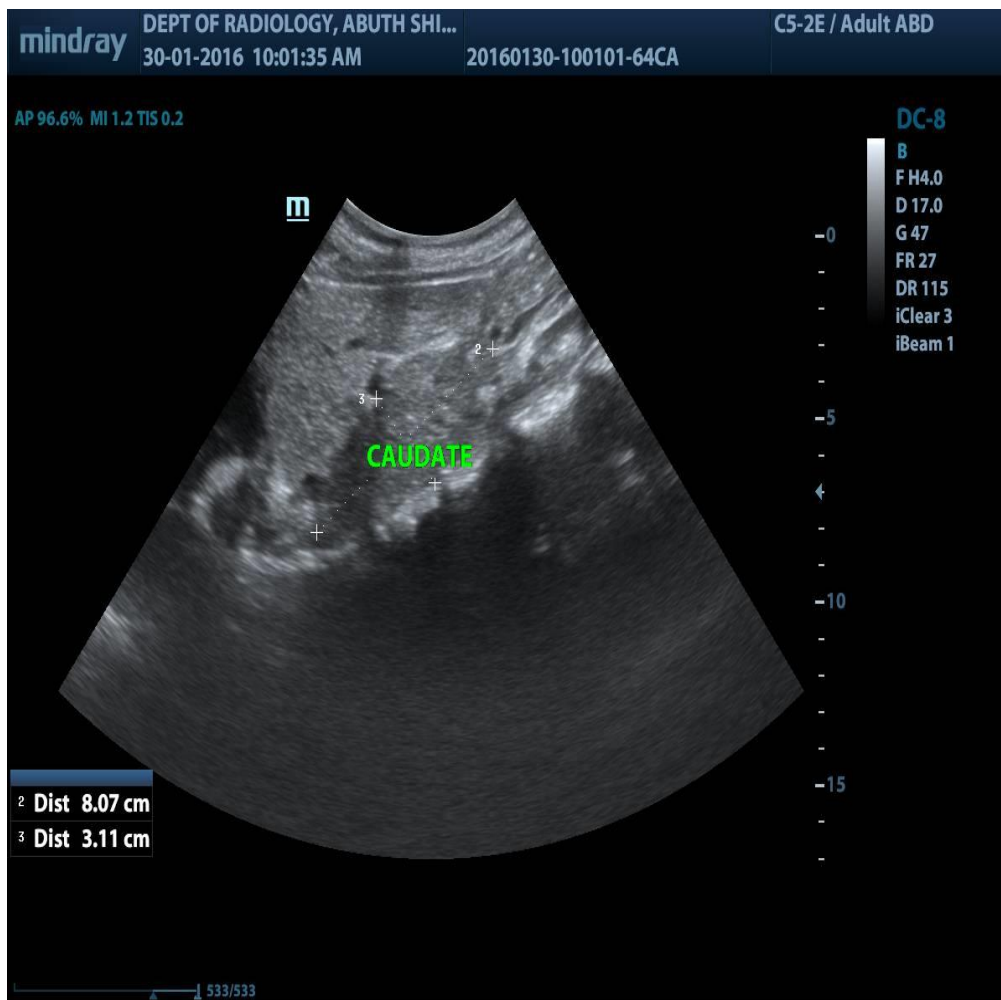


Plate VI: imaging procedure for measuring the cranio-caudal length and anterior posterior diameter of caudate lobe

3.11.2 Gall bladder

Useful landmarks used for the location of the gallbladder were the edge of the right hepatic lobe and the liver hilum. In the right subcostal oblique section, the landmark structure was also used was the interlobar fissure and the gallbladder was found by aligning the probe with the fissure and then tilting it according to the method described by Popescu and Sporea, (2010). The gallbladder was located inferiorly or laterally to the fissure (between liver segments IV and V). The cranio-caudal length of the gall bladder was identified as the maximum length from the neck to the fundus of the gall bladder and the anterior posterior diameter was the distance from the anterior to the posterior end of the body of the gall bladder. The normal gallbladder will have an anechoic content, with thin (1-3 mm) echoic walls. If the patient was not fasting the gallbladder will be partially contracted, and the walls will appear thicker (see plate VII).

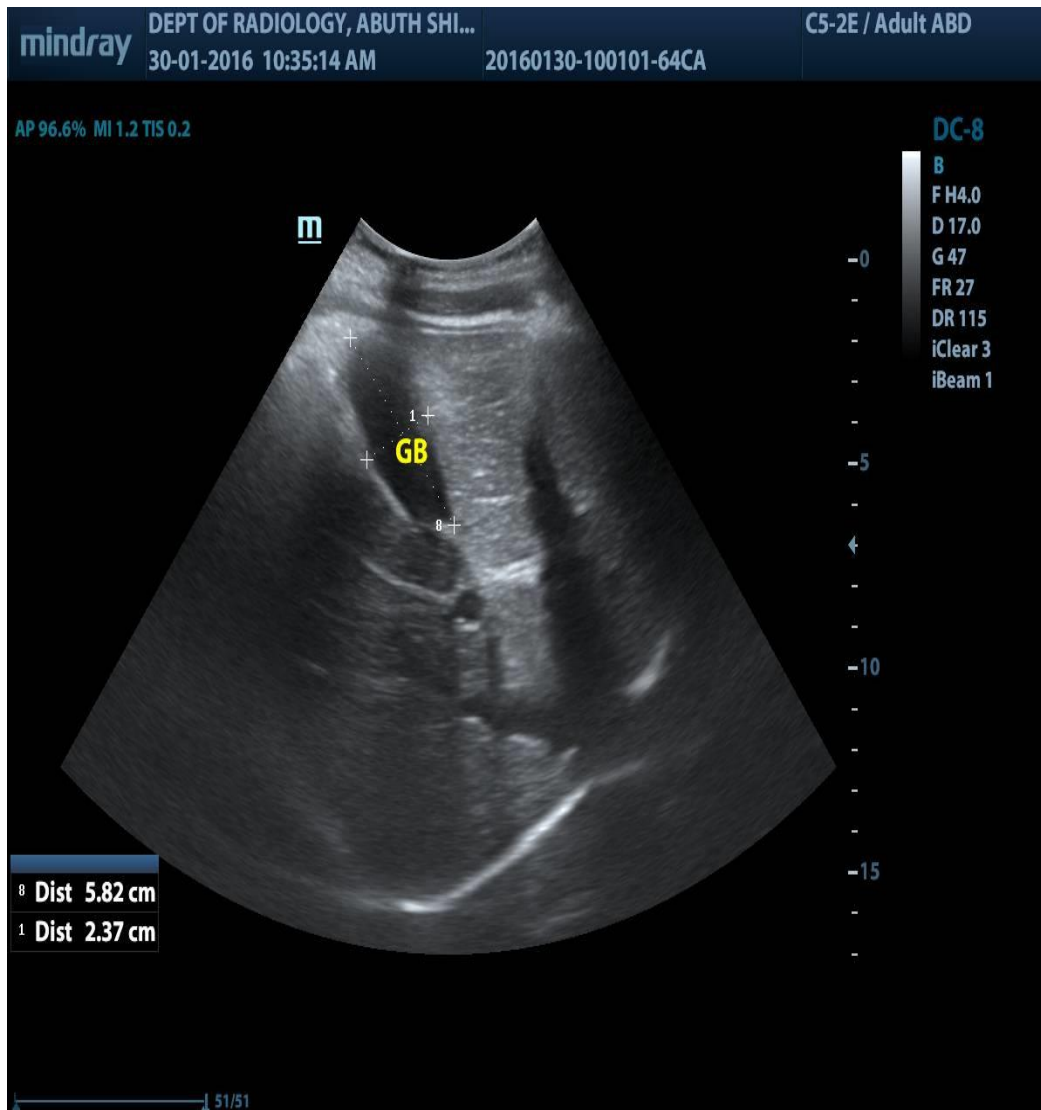


Plate VII: imaging procedure for measuring the gall bladder cranio-caudal length and anterior posterior diameter.

3.11.3 Common bile duct

The last step in the evaluation of the hepabiliary system was the visualization of the common biliary duct (CBD). It was demonstrated with the patient in the supine or lateral decubitus position by using a perpendicular line from the rib section in the right hypochondrium. The common biliary duct would appear as a tube situated in front of the portal vein. In the same section, the hepatic artery will appear as a round structure between the CBD and the portal vein. Once located, the portal triad was then interrogated with color doppler in order to distinguish the CBD from the vessels. The hepatic artery and portal vein demonstrated flow whereas the CBD did not. The common bile duct luminal diameter was measured from the inner wall to the inner wall in the tranverse plane.

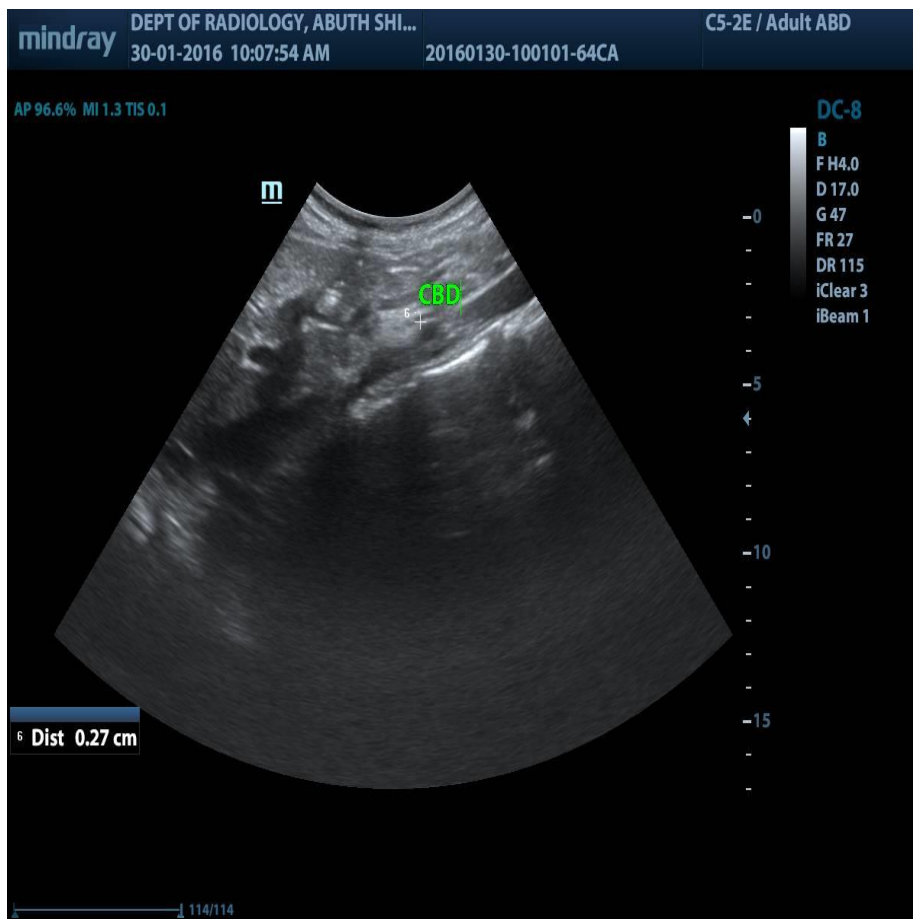


Plate VIII: imaging procedure for measuring common bile duct luminal diameter

3.12 Data Analyses

The quantitative and qualitative data were expressed as mean $\pm$ SD. Frequency/percentages respectively were used to determine somatotype categories from somatochart areas. Chi-square followed by post-hoc test was used to test for significance of the differences between distributions of somatotypes by categories. Independent sample t-test was used to test for sex differences in the variables. One –way analysis of variance was used to compare means of variables. Somatotype analysis of variance (SANOVA) was used to compare the distances between the somatotype means in terms of somatotype attitudinal distance (SAD). Partial correlation was used to establish relationship between dominant somatotypes with body composition, organ dimensions and some anthropometric variables after statistically adjusting for the contributions of the other two somatotype components. Pearson's correlation analyses were also used for the relationship between body composition and anthropometric variables. Linear multiple regression analysis was used to predict percent body fat (BF%) from skin fold thickness and height.

Statistical Package for Social Sciences (SPSS) version 20 (IBM Corporation, for Windows) statistical software was used for the statistical analysis and $p < 0.05$ was set as the level of significance. Somatotype calculation and analysis software was used to compute somatotype (Carter, 2002). Body tracker linear software was used to compute body composition.

CHAPTER FOUR

4.0 RESULTS

4.1 Descriptive Statistics of Study Population

The mean, standard deviation (SD) and range of anthropometric, somatometric, physiologic and sonographic variables were summarized in Tables 4.1, 4.2 and 4.3. That of the overall study subject was presented in a column. From the results, the male students were older, taller, heavier and had a higher body surface area than their female counterpart. However, weight did not indicate significant differences ($P > 0.05$). On the contrary, female subjects had higher BMI than the male subjects ($p < 0.001$) as shown in Table 4.1. Somatometric, physiologic and sonographic variables indicated significant differences ($P < 0.001$) between male and female subjects except for upper arm girth, liver length, caudate lobe length, gallbladder length, gall bladder width and Common bile duct diameter ($P > 0.05$) as shown in Tables 4.2 and 4.3.

Table 4.1: Descriptive statistics of the anthropometric variables (mean $\pm$ standard deviation and ranges)

	All sample (n=350)	Female (n=175)		Male (n=175)	
	Mean $\pm$ SD	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
Age (yrs.)	22.19 $\pm$ 3.35	21.54 $\pm$ 3.29	18 – 35	22.85 $\pm$ 3.30	18 – 35
Weight (kg)	60.61 $\pm$ 10.47	60.27 $\pm$ 12.08	40.00 – 97.00	60.94 $\pm$ 8.56	46.00 – 86.00
Height (cm)	165.44 $\pm$ 7.84	161.65 $\pm$ 7.05	146.00 – 180.00	169.28 $\pm$ 6.66	157.00 – 191.00
BMI (kgm ⁻²)	22.16 $\pm$ 3.49	22.99 $\pm$ 3.89	15.81 – 36.13	21.33 $\pm$ 2.81	16.90 – 33.34
Body Surface Area (m ²)	1.66 $\pm$ 0.16	1.64 $\pm$ 0.18	1.31 – 2.14	1.69 $\pm$ 0.14	1.43 – 2.03

BMI; Body Mass Index, BSA; Body Surface

Table 4.2: Descriptive statistics of Somatometric variables (mean $\pm$ standard deviation and ranges)

	All sample (n=350)	Female (n=175)		Male (n=175)	
	Mean $\pm$ SD	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
<i>Somatometric variables</i>					
Tricep skinfold (mm)	6.10 $\pm$ 1.41	5.94 $\pm$ 1.03	3.20 – 9.60	6.27 $\pm$ 1.70	0.20 – 9.90
Subscapular skinfold (mm)	7.90 $\pm$ 1.14	7.73 $\pm$ 1.10	5.40 – 9.80	8.06 $\pm$ 1.16	5.50 – 9.90
Supraspinal skinfold (mm)	3.40 $\pm$ 1.03	2.75 $\pm$ 0.61	1.30 – 4.20	4.06 $\pm$ 0.96	1.90 – 7.00
Medial calf skinfold (mm)	3.73 $\pm$ 1.38	2.71 $\pm$ 0.83	1.00 – 5.80	4.76 $\pm$ 1.00	0.40 – 7.20
Upper arm girth (cm)	28.86 $\pm$ 3.51	28.96 $\pm$ 3.56	23.00 – 40.00	28.75 $\pm$ 3.46	13.30 – 35.10
Calf girth (mm)	33.89 $\pm$ 3.71	35.08 $\pm$ 3.50	27.00 – 46.00	32.67 $\pm$ 3.52	13.15 – 38.50
BBH (mm)	6.46 $\pm$ 0.64	6.05 $\pm$ 0.52	4.70 – 8.20	6.87 $\pm$ 0.47	5.30 – 7.90
BBF (mm)	8.98 $\pm$ 0.69	8.80 $\pm$ 0.77	5.40 – 11.00	9.17 $\pm$ 0.54	8.10 – 10.50
BBH; Biepicondylar Breadth of Humerus, BBF; Biepicondylar Breadth of Femur					

Table 4.3: Descriptive statistics of physiologic and sonographic variables (mean $\pm$ standard deviation and ranges)

	All sample (n=350)	Female (n=175)		Male (n=175)	
	Mean $\pm$ SD	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
<i>Physiologic parameters</i>					
Systolic blood pressure (mm Hg)	111.07 $\pm$ 8.66	109.01 $\pm$ 8.33	90.00 – 130.00	113.16 $\pm$ 8.50	100.00 – 130.00
Diastolic blood pressure (mm Hg)	73.49 $\pm$ 7.37	74.26 $\pm$ 7.45	60.00 – 90.00	72.70 $\pm$ 7.22	60.00 – 90.00
<i>Sonographic variables</i>					
Liver length (cm)	14.18 $\pm$ 1.55	14.07 $\pm$ 1.67	10.41 – 18.80	14.44 $\pm$ 2.21	11.67 – 18.52
Caudate lobe length (cm)	6.12 $\pm$ 0.79	6.05 $\pm$ 0.94	3.78 – 8.09	6.19 $\pm$ 0.59	5.06 – 7.69
Caudate lobe APD (cm)	2.47 $\pm$ 0.62	2.39 $\pm$ 0.58	1.29 – 4.25	2.55 $\pm$ 0.65	1.54 – 5.33
Gall bladder length (cm)	5.33 $\pm$ 0.89	5.30 $\pm$ 0.88	3.26 – 7.80	5.36 $\pm$ 0.91	2.28 – 7.39
Gall bladder width (cm)	2.22 $\pm$ 0.51	2.19 $\pm$ 0.57	1.12 – 6.40	2.22 $\pm$ 0.52	1.11 – 3.23
Common bile duct diameter (cm)	0.33 $\pm$ 0.17	0.32 $\pm$ 0.24	0.18 – 0.33	0.33 $\pm$ 0.06	0.21 – 0.49

APD; Anterior Posterior Diameter

4.2 Somatotype Profile of the Study Participants

Table 4.4 presents a somatotype analysis of variance (SANOVA) table for the study population which compares the somatotype of each group by using the somatotype attitudinal distances (SAD) within and between the groups. The females had a low endomorphic rating of 1.75, though greater than the male ratings (1.61). The males, on the other hand, had moderate mesomorphic (4.82) and ectomorphic ratings (3.04) which were greater than the ones in females (mesomorphic = 4.21 and ectomorphic = 1.96). The SANOVA test showed a significant difference based on the sex ($F= 30.65$, $p< 0.001$). The females had significantly higher endomorphic component (female: 1.75 vs male: 1.61) while male on the other hand, had higher ectomorphic component (male: 3.04 vs female: 1.96), and mesomorphic component (male: 4.85 vs female: 4.22) (Figure 4.1)

When the subjects were evaluated collectively (Figure 4.2), the majority of the somatotypes means clustered on the North Axis with few in the North East and South East Axis of the boundary of the somatochart. Also, On the Somatochart, the mean somatotype for all the profiles in the document is shown by the profile marker inside an empty circle. Thus, the mean somatotype for all the male and female profiles was ectomorphic-mesomorph (1.68-4.25-2.5). In terms of the distribution of the subjects according to the regions in the somatochart, it was found (figure 4.3) that 77 (22%) of the subjects were endomorphic-mesomorph, 70 (20%) balanced-mesomorph, 100 (28%) ectomorphic-mesomorph, 48 (14%) mesomorph-ectomorph, 34 (10%), mesomorphic-ectomorph, 17 (5%) balanced-ectomorph and 4 (1%) central.

Figure 4.4 contains somatocharts showing the somatotype distribution of the male and female subjects respectively. For the males, the majority of the somatotypes means

clustered on the North Axis with few in the North East and South East Axis of the boundary of the somatochart. Also, On the Somatochart, the mean somatotype for all the profiles in the document is shown by the profile marker inside an empty circle. Thus, the mean somatotype for all the male profiles was ectomorphic-mesomorph (1.61-4.28-3.04). For the females, the majority of the somatotype means clustered on the North Axis and near equal distribution on the North West and North East axis of the boundary of the somatochart. Hence the mean profile marker inside an empty circle on the somatochart was balanced-mesomorph (1.75-4.21-1.96). In terms of the distribution of the subjects according to the regions in the somatocharts (Figure 4.3), it was found that ectomorphic-mesomorphs had the highest frequency among male subjects 56 (32%), followed by mesomorph-ectomorph 34 (19%) and the least was central 3 (2%). However, among the female subjects, endomorphic-mesomorphs had the highest frequency 50 (29%) followed by balanced-mesomorph 49 (28%) and the least was also central 1 (1%).

Figure 4.4 is a chart comparing the somatotypes categories according to the sex. There was a statistically significant association for male and female subjects ($\chi^2 = 44.87$, $P < 0.05$) based on the somatotype categories. Following a chi-square post hoc test, the significant difference seen were mainly contributed by ectomorphic mesomorph, mesomorph ectomorph and balanced mesomorph with all the frequencies higher in male subject.

Table 4.4: Somatotype Analysis of Variance (SANOVA) for the Study Population Based on their Sex

Group	Count	Mean	SD
Male	175	1.61-4.82-3.04	0.4-4.82-1.24
Female	175	1.75-4.21-1.96	0.32-1.44-1.36
ANOVA	F= 30.65	p= < 0.001	

SD: Standard Deviation

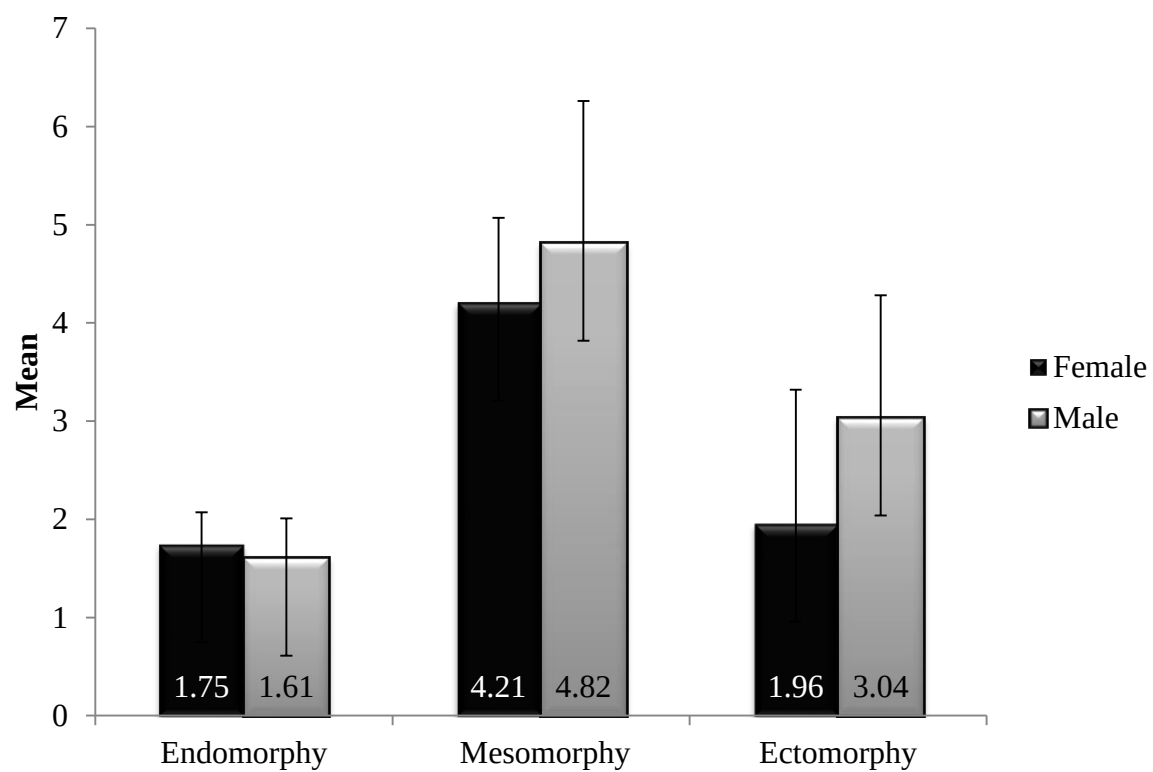


Figure 4.1: Sexual dimorphism in the dominant somatotype components (* $P < 0.05$)

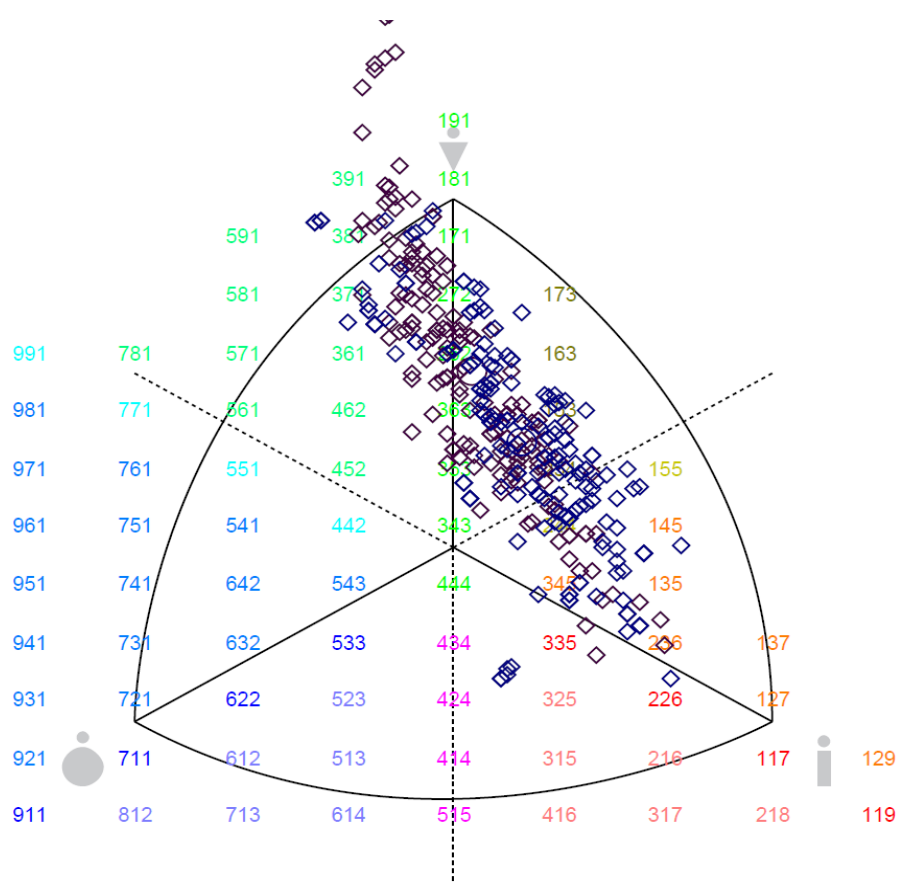


Figure 4.2: Somatotype distribution of the overall study population

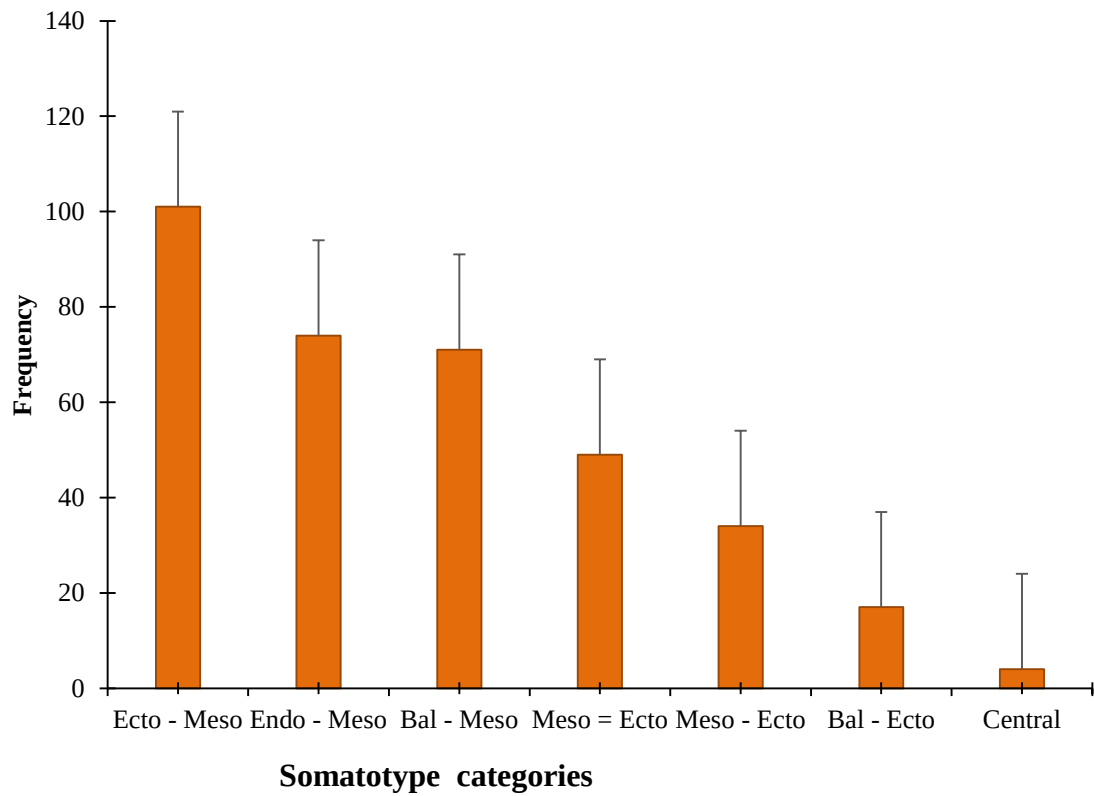


Figure 4.3: The distribution of somatotypes for the combined population analysed according to the region in the somatochart.

Ecto - Meso: ectomorphic-mesomorph, Endo - Meso: endomorphic-mesomorph: Bal - Meso: balanced-mesomorph, Meso = Ecto: mesomorph =ectomorph, Meso - Ecto: mesomorphic =ectomorph Bal - Ecto: balanced-ectomorph

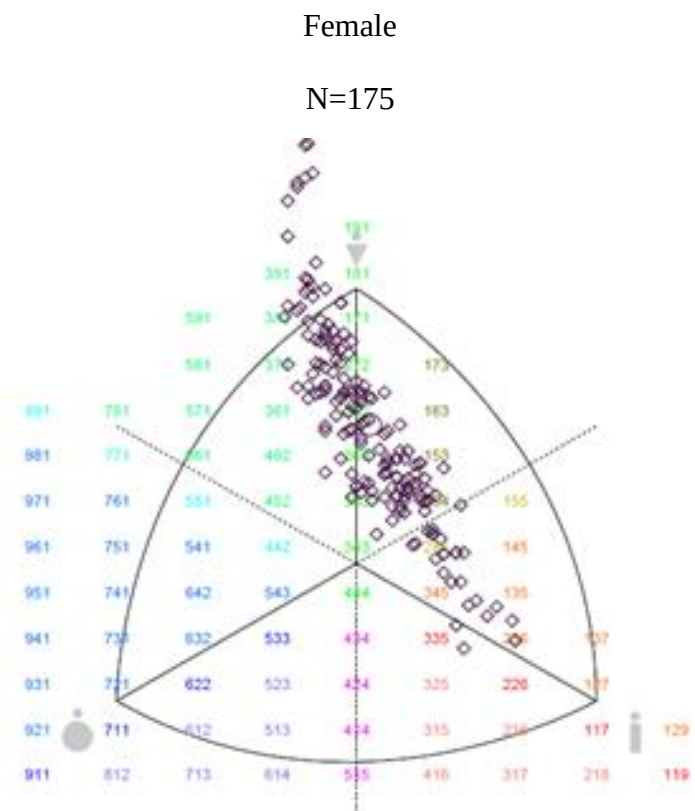
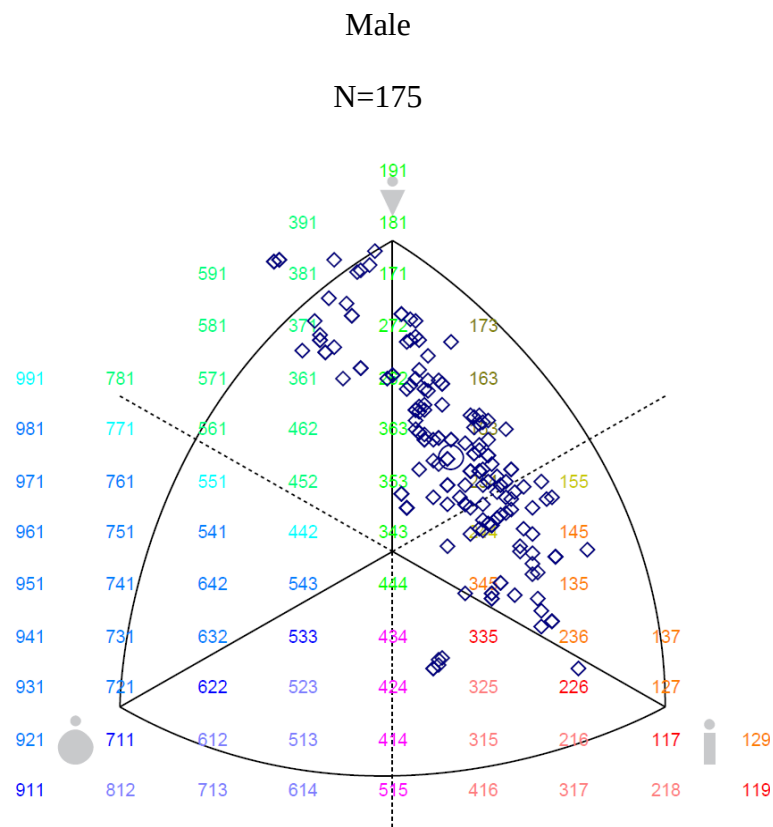


Figure 4.4: the somatotype distribution of study population according to sex

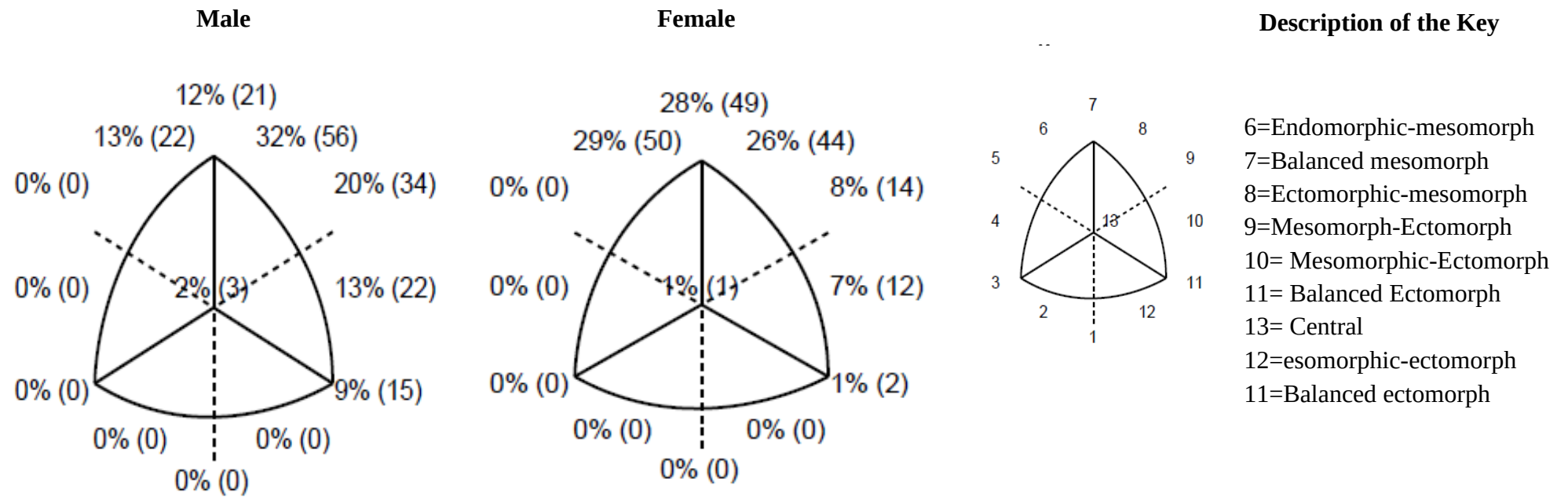


Figure 4.5: A category chart showing the percentage/frequency profile of the major somatotype categories based on sex

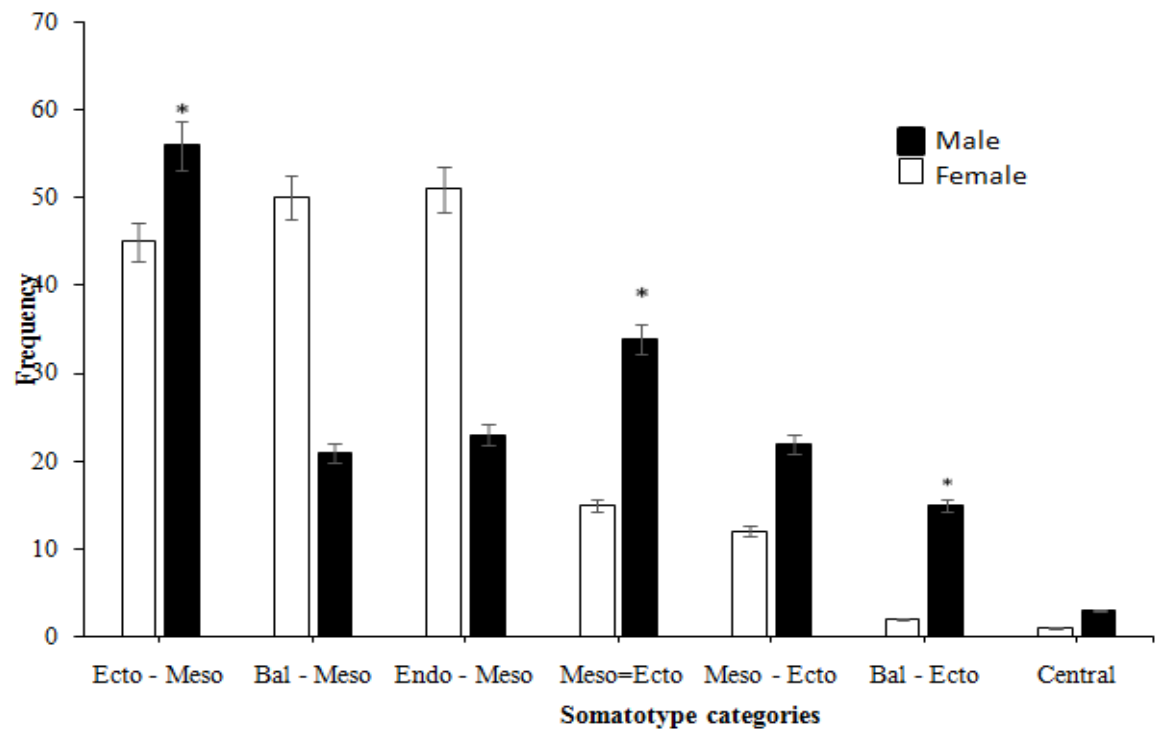


Figure 4.6: Comparison of somatotype categories according to sex ($\chi^2 = 44.87$, $*P < 0.05$)

Ecto-Meso: Ectomorphic-mesomorph; Bal-Meso: Balanced-Mesomorph; Endo-Meso: Endomorphic-Mesomorph; Meso=Ecto: Mesomorph Ectomorph; Meso-Ecto: Mesomorphic-Ectomorph; Bal-Ecto: Balanced-Ectomorph.

Association between somatotypes categories and sex based on age groups is presented in table 4.5. In the age group 18-23, there was statistically significant association between the somatotype categories and sex ($\chi^2 = 35.38$, $p < 0.001$). Balanced mesomorph (male = 16 & female = 42) and balanced ectomorph (male = 11 & female = 0) contributed most to the significance seen following a post hoc test done. In the other age groups (23-29 and 30-35), no statistically significant association was found ($p > 0.001$). However, females had higher values of endomorphic-mesomorph, mesomorph-ectomorph compared to their male counterpart in the age group of 24-29, while male had higher values of ectomorphic-mesomorph and mesomorphic-ectomorph in the same age group. In the age group 30-35, females had higher values of endomorphic-mesomorph, balanced mesomorph and balanced ectomorph, while males had higher values of ectomorphic-mesomorph and mesomorph-ectomorph compared with their male counterpart.

Table 4.5: Association between Somatotype Categories and Sex Based on Age Group

AGE GRP	SEX				
	Somatotype	Male	Female	X ²	P-value
18-23	Endomorphic-mesomorph	18 (30)	42 (70)	35.38	<0.001
	Balanced mesomorph*	16(27.6)	42 (2.4)		
	Ectomorphic-mesomorph	42(53.2)	37 46.8)		
	Mesomorph-ectomorph	17(60.7)	11(39.3)		
	Mesomorphic-ectomorph	16(59.3)	11(40.7)		
	Balanced ectomorph*	11 (100)	0 (0)		
	Central	2 (100)	0 (0)		
24-29	Endomorphic-mesomorph	5(38.5)	8(61.5)	13.83	0.032
	Balanced mesomorph	5(50)	5(50)		
	Ectomorphic-mesomorph	11(64.7)	6(35.3)		
	Mesomorph-ectomorph	13(92.9)	1(7.1)		
	Mesomorphic-ectomorph	6(85.7)	1(14.3)		
	Balanced ectomorph	4(100)	0(0)		
	Central	1(50)	1(50)		
30-35	Endomorphic-mesomorph	0(0)	1(100)	5.797	0.325
	Balanced mesomorph	1(33.3)	2(66.7)		
	Ectomorphic-mesomorph	3(60)	2(40)		
	Mesomorph-ectomorph	3(60)	2(40)		
	Mesomorphic-ectomorph	1(50)	1(50)		
	Balanced ectomorph	0(0)	2(100)		
	Central	1(50)	1(50)		

Tables 4.6, 4.7 and 4.8 present a comparison of anthropometric dimensions, physiologic and sonographic variables based on the dominant somatotypes components. The value of height (168.61 ± 8.46) for ectomorph somatotype is significantly higher ($P < 0.001$) than that of endomorphic and mesomorphic somatotypes. The sequel to this, triceps skinfold, medial calf skinfold, upper arm girth, calf girth and biepicondylar breadth of femur indicated various statistically significant levels. Mesomorph values of triceps skinfold, upper arm girth, calf girth and biepicondylar breadth of the femur are higher than those of endomorphs and ectomorphs. In contrast, ectomorph's value of medial calf skinfold is higher than those of endomorphs and mesomorphs. All physiologic and sonographic variables did not indicate significant differences ($P > 0.05$).

Table 4.6: Comparison of Anthropometric Variables of Subjects Based on the Dominant Somatotypes

	Endomorphs	Mesomorphs	Ectomorphs	Total		
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	F	<i>P-value</i>
N	34	246	66	346		
Weight (kg)	61.31 $\pm$ 10.18	60.17 $\pm$ 10.74	62.15 $\pm$ 9.79	60.66 $\pm$ 10.51	1.00	0.374
Height (cm)	164.62 $\pm$ 7.19 ^a	164.72 $\pm$ 7.59 ^a	168.61 $\pm$ 8.46 ^b	165.45 $\pm$ 7.85	6.81	<0.001
Body Mass Index (kgm ⁻²)	22.69 $\pm$ 4.01	22.19 $\pm$ 3.55	21.88 $\pm$ 3.06	22.18 $\pm$ 3.50	0.59	0.553
Body Surface Area	1.67 $\pm$ 0.15	1.65 $\pm$ 0.16	1.70 $\pm$ 0.16	1.66 $\pm$ 0.16	2.10	0.124

APD: anterior posterior diameter

Table 4.7: Comparison of Anthropometric Variable (skinfolts) of Subjects Based on the Dominant Somatotypes

	Endomorphs	Mesomorphs	Ectomorphs	Total		
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	F	<i>P-value</i>
N	34	246	66	346		
Tricep skinfold	5.48 $\pm$ 1.29 ^a	6.20 $\pm$ 1.45 ^b	5.91 $\pm$ 1.13 ^{ab}	6.07 $\pm$ 1.39	4.67	0.010
Subscapular skinfold	7.54 $\pm$ 1.27	7.90 $\pm$ 1.14	7.98 $\pm$ 1.03	7.88 $\pm$ 1.13	1.89	0.153
Supraspinal skinfold	3.31 $\pm$ 1.01	3.36 $\pm$ 1.09	3.57 $\pm$ 0.81	3.40 $\pm$ 1.04	1.19	0.307
Medial calf skinfold	3.79 $\pm$ 1.38 ^a	3.52 $\pm$ 1.31 ^a	4.38 $\pm$ 1.36 ^b	3.71 $\pm$ 1.36	11.02	<0.001
Sum of skinfolts	21.48 $\pm$ 3.73	21.00 $\pm$ 3.64	21.13 $\pm$ 3.73	21.07 $\pm$ 3.66	0.27	0.766
Upper arm girth (cm)	26.65 $\pm$ 2.25 ^a	30.00 $\pm$ 3.00 ^b	25.90 $\pm$ 3.56 ^a	28.89 $\pm$ 3.51	57.23	<0.001
Calf girth (cm)	30.87 $\pm$ 2.59 ^a	35.07 $\pm$ 3.11 ^b	31.19 $\pm$ 4.01 ^a	33.92 $\pm$ 3.72	53.66	<0.001
Biepicondylar Breadth Humerus (mm)	6.37 $\pm$ 0.71	6.47 $\pm$ 0.65	6.46 $\pm$ 0.60	6.46 $\pm$ 0.64	0.33	0.719
Biepicondylar Breadth Femur (mm)	8.78 $\pm$ 0.80 ^a	9.05 $\pm$ 0.71 ^b	8.88 $\pm$ 0.53 ^a	8.99 $\pm$ 0.69	3.59	<0.029

APD: anterior posterior diameter

Table 4.8: Comparison of Physiological and Sonographic Variables of Subjects Based on the Dominant Somatotypes

	Endomorphs	Mesomorphs	Ectomorphs	Total	F	<i>P-value</i>
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD		
N	34	246	66	346		
Physiologic parameters (mm Hg)						
Systolic Blood Pressure	110.00 $\pm$ 8.53	110.81 $\pm$ 8.85	112.65 $\pm$ 8.19	111.08 $\pm$ 8.71	1.46	0.235
Diastolic Blood Pressure	73.24 $\pm$ 8.43	73.78 $\pm$ 7.34	72.58 $\pm$ 6.64	73.50 $\pm$ 7.32	0.73	0.483
Sonographic variables (cm)						
Liver length	14.25 $\pm$ 1.57	14.18 $\pm$ 1.83	14.56 $\pm$ 2.56	14.26 $\pm$ 1.97	0.97	0.379
Caudate lobe length	5.90 $\pm$ 0.84	6.13 $\pm$ 0.81	6.17 $\pm$ 0.68	6.12 $\pm$ 0.79	1.47	0.232
Caudate lobe APD	2.39 $\pm$ 0.42	2.46 $\pm$ 0.61	2.56 $\pm$ 0.75	2.47 $\pm$ 0.63	0.96	0.385
Gall bladder length	5.33 $\pm$ 0.86	5.33 $\pm$ 0.89	5.31 $\pm$ 0.89	5.32 $\pm$ 0.89	0.02	0.983
Gall bladder width	2.26 $\pm$ 0.50	2.22 $\pm$ 0.53	2.19 $\pm$ 0.48	2.22 $\pm$ 0.51	0.21	0.809
Common bile duct diameter	0.31 $\pm$ 0.06	0.33 $\pm$ 0.20	0.33 $\pm$ 0.05	0.33 $\pm$ 0.17	0.15	0.858

APD: anterior posterior diameter

Table 4.9 shows the comparison of body composition according to the dominant somatotype. Ectomorphs had significantly higher values of bone mineral content ($p < 0.001$) than the endomorphs and mesomorphs. Dominant mesomorphs had a significantly higher fat percentage than endomorphs and ectomorphs. Fat mass and fat-mass index were significantly greater for dominant mesomorph than for endomorphs and ectomorphs. Lean body mass was significantly greater for dominant ectomorphs than for endomorphs and mesomorphs. However, fat-free mass, fat-free mass index, and body cell mass were not significantly different by dominant somatotype.

Table 4.9: Comparison of Body Composition of all Sample Population According to the Dominant Somatotype

	Endomorphs	Mesomorphs	Ectomorphs		
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	F	<i>P-value</i>
BMC (g)	2419.00 $\pm$ 96.73 ^a	2042.77 $\pm$ 106.63 ^a	2646.73 $\pm$ 10.95 ^b	9.57	<0.001
Body Fat (%)	10.17 $\pm$ 2.79 ^a	12.13 $\pm$ 2.46 ^b	10.69 $\pm$ 2.17 ^a	16.03	<0.001
Fat Mass (kg)	6.27 $\pm$ 2.10 ^a	7.30 $\pm$ 2.02 ^b	6.66 $\pm$ 1.18 ^a	5.71	<0.001
Fat Free Mass (kg)	55.04 $\pm$ 8.97	52.88 $\pm$ 9.53	55.48 $\pm$ 8.69	2.49	0.084
Fat Mass Index (kgm ⁻²)	2.33 $\pm$ 0.84 ^a	2.70 $\pm$ 0.73 ^b	2.35 $\pm$ 0.65 ^a	8.27	<0.001
Fat Free Mass Index (kgm ⁻²)	20.36 $\pm$ 3.47	19.45 $\pm$ 3.03	19.50 $\pm$ 2.67	1.36	0.258
Lean Body Mass (kg)	38.71 $\pm$ 15.39 ^a	31.45 $\pm$ 16.93 ^b	42.94 $\pm$ 15.83 ^a	13.80	<0.001
Body Cell Mass (kg)	30.08 $\pm$ 6.13	30.54 $\pm$ 7.41	31.68 $\pm$ 8.20	0.75	0.475
Body Cell Mass g/cm	0.18 $\pm$ 0.03	0.18 $\pm$ 0.04	0.19 $\pm$ 0.04	0.30	0.742

BMC: Bone mineral content

4.3 Sexual Dimorphism in Organ Dimensions, Body Composition and Other Anthropometric Variables According to the Dominant Somatotype

Table 4.10 presents results of sexual dimorphism in anthropometric variables and the organ dimensions according to the dominant somatotype. In the endomorphs, the height, body mass index, supraspinal skinfold, medial calf skin fold, upper arm girth, calf girth, biepcondylar breadth of humerus and femur showed significant sexual dimorphism ($p < 0.05$) with males having higher values than the females with the exception of BMI which was only higher in females. In the same endomorphs, weight, body surface area, tricep and subscapular skinfold, blood pressure and sonographic variables did not show sexual dimorphism ($p > 0.05$), even though, organ dimensions, BSA and subscapular skin fold were higher in males while BP and tricep skin fold were higher in females.

Similarly, in the mesomorphs significant sexual dimorphism was noticed in the height, BMI, BSA, the skin folds, calf girth, bone breadth, organ dimensions and SBP ($p < 0.05$) with all the values higher in males except BMI and calf girth which were only higher in females. The upper arm girth, liver length, gall bladder length and DBP did not show statistically significant level ($p > 0.05$), however, the values were in males except for DBP that was only higher in females.

Also, in the ectomorphs males had statistically significant higher values in height, the skin folds and bone breadth than their female counter part ($p < 0.05$). The blood pressure, organ dimensions, weight, BMI, BSA, upper arm and calf girth did not show sexual dimorphism ($p > 0.05$) even though all the values were higher in males with the exception of the DBP and gall bladder length which were only higher in females.

Table 4.10: Sexual Dimorphism in Anthropometric Variables, Blood Pressure and Hepatobiliary Dimensions According to the Dominant Somatotype

Variables	ENDOMORPH			MESOMORPH			ECTOMORPH		
	Male	Female	t-value	Male	Female	t-value	Male	Female	t-value
	Mean±SD	Mean±SD		Mean±SD	Mean±SD		Mean±SD	Mean±SD	
	N=22	N=12		N=101	N=146		N=51	N=18	
Weight kg	60.14±7.48	61.67±14.27	-0.41	60.32±8.67	59.94±11.80	0.28	62.53±8.72	62.09±13.28	0.16
Height m	1.67±0.07	1.59±0.05	3.61*	1.69±0.06	1.62±0.07	8.91*	1.70±0.08	1.64±0.08	3.03*
BMI kg/m ²	21.52±2.37	24.38±5.60	-2.09*	21.16±2.93	22.88±3.76	-3.86*	21.59±2.77	22.99±3.72	-1.69
BSA	1.67±0.13	1.64±0.18	0.49	1.68±0.14	1.63±0.18	2.19*	1.71±0.14	1.67±0.20	0.91
TRP SF mm	5.48±1.56	6.04±1.15	-1.1	6.58±1.85	5.95±1.04	3.41*	6.00±1.24	5.82±0.95	0.56
SUB SF mm	7.67±1.42	7.61±1.18	0.13	8.09±1.17	7.77±1.10	2.16*	8.19±1.00	7.53±1.03	2.39*
SUP SF mm	3.76±0.97	2.65±0.59	3.63*	4.20±1.08	2.78±0.62	13.07*	3.90±0.60	2.63±0.50	7.98*
MC SF mm	4.64±0.90	2.51±1.01	6.31*	4.67±1.07	2.73±0.79	16.46*	5.00±0.85	2.67±1.06	9.37*
UG cm	27.35±2.00	25.58±2.17	2.38*	30.30±2.58	29.73±3.30	1.45	26.29±3.82	24.98±2.09	1.39
CG cm	31.03±3.00	30.71±1.66	0.34	33.96±2.43	35.77±3.36	-4.64*	30.84±4.39	32.44±1.87	-1.49
BBH cm	6.80±0.55	5.68±0.22	6.74*	6.96±0.44	6.12±0.53	13.10*	6.72±0.44	5.72±0.29	9.03*
BBF cm	9.20±0.64	7.93±0.23	6.59*	9.25±0.52	8.90±0.78	4.04*	8.98±0.50	8.58±0.56	2.82*
SBP mmHg	109.55±8.99	110.00±7.39	-0.15	113.76±8.56	108.84±8.51	4.46*	113.53±7.96	109.72±7.76	1.76
DBP mmHg	71.82±9.07	75.00±9.05	-0.98	73.37±7.25	74.11±7.40	-0.78	71.76±6.23	75.00±7.07	-1.83
LL cm	14.45±1.31	13.98±1.74	0.89	14.29±2.08	14.07±1.64	0.96	14.72±2.72	14.20±1.92	0.76
CLL cm	5.92±0.50	5.96±1.25	-0.13	6.26±0.60	6.04±0.92	2.09*	6.17±0.58	6.20±0.88	-0.15
CLAP cm	2.41±0.40	2.28±0.46	0.87	2.56±0.63	2.39±0.59	2.15*	2.58±0.78	2.48±0.65	0.53
GBL cm	5.53±1.03	5.08±0.64	1.36	5.37±0.93	5.31±0.86	0.55	5.26±0.80	5.41±1.10	-0.62
GBW cm	2.24±0.52	2.34±0.47	-0.54	2.11±0.40	2.30±0.59	-2.74*	2.16±0.49	2.22±0.43	-0.4
CBDD cm	0.31±0.06	0.29±0.05	1.19	0.34±0.06	0.32±0.26	0.42	0.33±0.05	0.32±0.04	0.11

t: * $p < 0.05$; SF: skin fold; BMI: body mass index; BSA: body surface area; SUB: subscapular; SUP: supraspinal; MC: medial calf; UG: upper arm girth; CG: calf girth; BBH: biepicondylar breadth of humerus; BBF: biepicondylar breadth of femur; SBP: systolic blood pressure; DBP: diastolic blood pressure; LL: liver length; CLL: caudate lobe length; CLAP: caudate lobe anterior posterior diameter; GBL: gall bladder length; GBW: gall bladder width; CBDD: common bile duct diameter.

Table 4.11 presents results of sexual dimorphism in body composition according to the dominant somatotypes. In the endomorphs, BMC and LBM were significantly higher among males than female subjects ($p < 0.05$). Even though FFM was higher in males than in females, it did not reach any level of statistical significance ($p > 0.05$). The BF percentage, FM, FMI and FFMI were significantly higher in female than in their male counterparts ($p < 0.05$) in the dominant endomorph. BMC and LBM were significantly higher in male subjects than female subjects in dominant mesomorphs and ectomorphs ($p < 0.05$). FFM in dominant mesomorph and ectomorph was higher in males than in females, though not statistically significant ($p > 0.05$). In contrast, BF percentage, FM, FMI, and FFMI were significantly higher in female than in male subjects in dominant mesomorphs and ectomorphs ($p < 0.05$).

Table 4.11: Sexual Dimorphism in Body Composition According to the Dominant Somatotype

	Endomorphs		Mesomorphs		Ectomorphy	
	Females	Males	Females	Males	Females	Males
N	12	22	146	101	18	51
BMC (g)	1227.31 ± 25.99	3069.01 ± 42.52*	1207.20 ± 27.95	3262.70 ± 40.82*	1137.59 ± 21.68	3170.31 ± 49.11*
Body Fat (%)	12.88 ± 1.38	8.69 ± 2.18*	13.27 ± 1.56	10.46 ± 2.58*	12.94 ± 1.42	9.91 ± 1.82*
Fat Mass (kg)	7.98 ± 1.62	5.34 ± 1.74*	7.95 ± 1.85	6.35 ± 1.90*	8.06 ± 2.00	6.18 ± 1.48*
Fat Free Mass (kg)	54.40 ± 12.70	55.39 ± 6.45	51.97 ± 10.28	54.20 ± 8.19	54.10 ± 11.94	55.96 ± 7.34
Fat Mass Index (kgm ⁻²)	21.45 ± 5.02	19.76 ± 2.16	19.82 ± 3.28	18.91 ± 2.54*	20.04 ± 3.27	19.31 ± 2.43*
Fat Free Mass Index (kgm ⁻²)	3.14 ± 0.66	1.89 ± 0.56*	3.03 ± 0.61	2.21 ± 0.61*	2.99 ± 0.66	2.13 ± 0.48*
Lean Body Mass (kg)	18.93 ± 4.46	49.50 ± 4.04*	17.97 ± 4.29	51.12 ± 4.88*	17.99 ± 3.86	51.68 ± 5.65*

BMC: Bone mineral content

**t-value significant at $P < 0.05$

4.4 Age Variations in Hepatobiliary Dimensions, Body Composition and Other Anthropometric Variables According to the Dominant Somatotype

The values for the comparison for age variations in hepatobiliary dimensions, body composition and other anthropometric variables according to the dominant endomorph are presented on table 4.12. All anthropometric, body composition and hepatobiliary variables did not indicate significant differences according to the age groups ($p > 0.05$).

Table 4.13 presents age variations in anthropometric, hepatobiliary variables and body composition based on the dominant mesomorphs. The mean values for the weight, BMI, BSA, gall bladder width, CBDD, FFM and FFMI in the different age categories were significantly higher in subjects in the age group of 30-35 years than in subjects in the age groups 18-23 and 24-29 years ($p < 0.05$). Subscapular skin fold, supraspinal skin fold and caudate lobe anterior posterior diameter were significantly higher among subjects in the age group 24-29 years than those in 18-23 and 30-35 years ($p < 0.05$). Other parameters were not significantly different based on the age categories ($p > 0.05$).

Table 4.14 presents age variations in anthropometric, hepatobiliary variables and body composition based on the dominant ectomorphs. The mean values for the weight, BMI, BSA, FFM, FFMI, FM, and FMI in the different age categories were significantly higher in subjects in the age group of 30-35 years than in subjects in the age groups 18-23 and 24-29 years ($p < 0.05$). However, other variables were not significantly different based on the age categories ($p > 0.05$).

Table 4.12: Age Variations in Anthropometric, Somatometric, Sonographic Variables and Body Composition Based on the Dominant Endomorphs

Variables	Age Groups (Years)			F-value	p-value
	18-24 (n=26)	25-29 (n=7)	30-35 (n=1)		
	Mean±SD	Mean±SD	Mean±SD		
Weight kg	61.58±11.16	58.71±5.47	51.00±0.00	0.67	0.52
Height m	1.65±0.08	1.62±0.06	1.67±0.00	0.44	0.65
Body mass index kg/m ²	22.74±4.39	22.36±2.00	18.29±0.00	0.59	0.56
Body surface Area	1.67±0.16	1.62±0.09	1.54±0.00	0.60	0.55
Tricep SF mm	5.53±0.96	6.41±2.55	4.20±0.00	1.63	0.21
Subscapular SF mm	7.56±1.21	7.90±1.81	8.20±0.00	0.26	0.77
Supraspinal SF mm	3.31±0.92	3.63±1.36	3.20±0.00	0.29	0.75
Medial calf SF mm	3.82±1.48	4.24±1.08	3.10±0.00	0.41	0.67
Upper arm girth cm	26.84±2.09	26.43±2.86	25.80±0.00	0.18	0.84
Calf girth cm	31.00±2.41	31.06±3.29	27.80±0.00	0.74	0.49
Biepicondylar Breadth Humerus cm	6.31±0.70	6.69±0.75	6.80±0.00	0.94	0.40
Biepicondylar Breadth Femur cm	8.75±0.83	8.69±0.87	9.10±0.00	0.11	0.90
Systolic BP mmHg	111.15±8.64	105.71±5.35	100.00±0.00	1.98	0.16
Diastolic BP mmHg	73.85±8.04	70.00±12.91	70.00±0.00	0.54	0.59
Liver length cm	14.21±1.38	14.64±1.93	13.74±0.00	0.29	0.75
Caudate lobe length cm	5.94±0.83 ^a	5.91±0.94 ^a	6.01±0.00 ^b	0.01	0.99
Caudate lobe APD cm	2.38±0.46	2.32±0.27	2.50±0.00	0.09	0.91
Gallbladder length cm	5.31±0.93	5.74±0.88	4.26±0.00	1.37	0.27
Gallbladder width cm	2.25±0.53	2.49±0.18	1.54±0.00	1.90	0.17
Common Bile Duct Diameter cm	0.30±0.06	0.32±0.06	0.24±0.00	1.05	0.36
Bone mineral content	2368.55±1020.64	2838.52±575.24	2920.90±0.00	0.78	0.47
% Body fat	10.38±2.36	11.11±4.88	8.27±0.00	0.43	0.65
Free fat mass	55.14±9.76	52.25±6.14	46.78±0.00	0.62	0.55
Free fat mass index	20.34±3.74	19.92±2.46	16.77±0.00	0.51	0.60
Fat mass	6.44±1.99	6.47±2.79	4.22±0.00	0.51	0.61
Fat mass index	2.39±0.82	2.45±1.06	1.51±0.00	0.52	0.60

SF: skinfold; AP: anterior posterior diameter; BP: blood pressure

Table 4.13: Age Variations in Anthropometric, Somatometric, Sonographic Variables and Body Composition Based on the Dominant Mesomorphs

Variables	Age Groups (Years)			F-value	p-value
	18-24 (n=198)	25-29 (n=40)	30-35 (n=9)		
	Mean±SD	Mean±SD	Mean±SD		
Weight kg	59.72±10.54 ^a	59.87±0.48 ^a	69.22±9.73 ^b	3.53	0.03
Height m	1.64±0.07	1.67±0.08	1.65±0.10	2.27	0.11
Body mass index	22.19±3.61 ^a	21.35±2.68 ^a	25.51±3.51 ^b	5.26	0.01
Body surface Area	1.65±0.16 ^a	1.66±0.18 ^a	1.78±0.15 ^b	2.96	0.05
Tricep SF mm	6.17±1.43	6.40±1.65	6.01±1.17	0.48	0.62
Subscapular SF mm	7.85±1.13 ^a	8.27±1.13 ^b	7.24±1.08 ^a	3.86	0.02
Supraspinal SF mm	3.31±0.98 ^a	3.71±1.43 ^b	2.88±1.49 ^a	3.14	0.05
Medial calf SF mm	3.48±1.31	3.76±1.36	3.46±1.38	0.77	0.47
Upper arm girth cm	29.92±3.08	30.21±2.54	29.90±4.22	0.15	0.86
Calf girth cm	35.05±3.11	34.87±2.93	35.13±4.72	0.06	0.94
Biepicondylar Breadth Humerus cm	6.44±0.66	6.52±0.56	6.73±0.73	1.04	0.36
Biepicondylar Breadth Femur cm	9.02±0.74	9.15±0.48	9.03±0.75	0.50	0.61
Systolic BP mmHg	110.96±9.14	111.00±8.10	107.78±4.41	0.56	0.57
Diastolic BP mmHg	73.48±7.30	74.75±7.84	76.67±5.00	1.21	0.30
Liver length cm	14.18±1.85	14.30±1.67	13.03±1.98	1.86	0.16
Caudate lobe length cm	6.14±0.80	6.14±0.94	5.92±0.66	0.32	0.73
Caudate lobe APD cm	2.42±0.59 ^a	2.68±0.72 ^b	2.44±0.37 ^a	3.08	0.05
Gallbladder length cm	5.30±0.90	5.40±0.88	5.74±0.61	1.14	0.32
Gallbladder width cm	2.21±0.46 ^a	2.21±0.42 ^a	2.66±1.45 ^b	3.33	0.04
Common Bile Duct Diameter cm	0.31±0.06 ^a	0.34±0.09 ^a	0.65±1.01 ^b	12.67	0.00
Bone mineral content	2005.18±1080.29	2332.94±926.64	1592.58±1005.73	2.46	0.09
% Body fat	12.12±2.52	12.14±2.41	11.99±1.79	0.01	0.99
Free fat mass	52.47±9.25 ^a	52.66±9.75 ^a	60.98±9.12 ^b	3.59	0.03
Free fat mass index	19.43±3.04 ^a	18.78±2.53 ^a	22.47±3.24 ^b	5.68	0.00
Fat mass	7.25±2.09	7.21±1.72	8.24±1.53	1.07	0.35
Fat mass index	2.70±0.77	2.58±0.56	3.04±0.55	1.51	0.22

SF: skinfold; AP: anterior posterior diameter; BP: blood pressure; a and b superscript mean $p < 0.05$

Table 4.14: Age Variations in Anthropometric, Somatometric, Sonographic Variables and Body Composition Based on the Dominant Ectomorphs

Variables	Age Groups (years)			F-value	p-value
	18-24 (n=41)	25-29 (n=20)	30-35 (n=8)		
	Mean±SD	Mean±SD	Mean±SD		
Weight kg	59.86±9.77 ^a	64.60±7.48 ^a	70.06±12.51 ^b	4.59	0.01
Height m	1.67±0.08	1.72±0.09	1.69±0.08	2.62	0.08
Body mass index kg/m ²	21.44±2.95 ^a	21.95±2.37 ^a	24.60±4.19 ^b	3.82	0.03
Body surface Area	1.66±0.16 ^b	1.75±0.13 ^a	1.80±0.18 ^a	4.15	0.02
Tricep Skin Fold mm	5.96±1.10	5.99±1.24	5.81±1.45	0.06	0.94
Subscapular Skin Fold mm	7.90±1.11	8.24±0.93	8.06±0.96	0.73	0.49
Supraspinal Skin Fold mm	3.56±0.89	3.67±0.68	3.39±0.63	0.34	0.71
Medial calf Skin Fold mm	4.26±1.59	4.75±0.89	4.21±1.07	0.92	0.40
Upper arm girth cm	25.74±3.63	26.20±3.65	26.39±2.48	0.18	0.83
Calf girth cm	30.86±4.74	31.59±2.22	32.49±2.52	0.66	0.52
Biepicondylar Breadth Humerus cm	6.41±0.63	6.56±0.56	6.46±0.57	0.41	0.66
Biepicondylar Breadth Femur cm	8.86±0.58	8.90±0.41	8.90±0.72	0.05	0.95
Systolic BP mmHg	112.32±8.67	113.50±7.45	111.25±6.41	0.26	0.78
Diastolic BP mmHg	71.71±7.04	73.50±5.87	75.00±5.35	1.11	0.34
Liver length cm	14.41±2.98	15.12±1.38	14.18±2.30	0.64	0.53
Caudate lobe length cm	6.17±0.71	6.18±0.59	6.22±0.71	0.01	0.99
Caudate lobe APD cm	2.49±0.69	2.60±0.79	2.79±0.93	0.58	0.56
Gallbladder length cm	5.23±1.03	5.27±0.50	5.70±0.83	0.96	0.39
Gallbladder width cm	2.17±0.53	2.21±0.40	2.16±0.36	0.05	0.95
Common Bile Duct Diameter cm	0.32±0.04	0.33±0.06	0.32±0.05	0.26	0.77
Bone mineral content	2597.55±1036.30	2908.62±780.75	2158.41±1229.07	1.71	0.19
% Body fat	10.79±1.92	10.44±1.95	11.55±3.72	0.73	0.48
Free fat mass	53.40±8.82 ^a	57.87±6.92 ^a	61.80±10.34 ^b	4.21	0.02
Free fat mass index	19.12±2.63 ^a	19.59±2.33 ^a	21.65±3.12 ^b	3.15	0.05
Fat mass	6.45±1.52 ^a	6.73±1.44 ^a	8.26±3.25 ^b	3.51	0.04
Fat mass index	2.32±0.54 ^a	2.27±0.42 ^a	2.95±1.24 ^b	3.88	0.03

AP: anterior posterior diameter; BP: blood pressure; a and b superscript mean $p < 0.05$

4.5 Relationship Between Dominant Somatotype with Organ Dimensions, Body Composition and Anthropometric Variables

Dominant somatotype, statistically adjusted for the contributions of the other two somatotype components, was significantly related to some measures of body structure (Tables 4.15 and 4.16). The magnitude of the correlation coefficients, however, was variable, with numerous significant relationships identified. Table 4.15 presents the partial correlation for the combined population. Endomorphy was directly related to height, body surface area, BF percentage, FM, FMI, all skin folds except their sum. Endomorphy was also inversely related to FFMI, upper arm girth and calf girth. Still on Table 4.15, mesomorphy was directly correlated significantly with sum of skin folds, upper arm girth, calf girth and biepicondylar breadth of humerus. In contrast, mesomorphy was inversely related to BF percentage, FM, FMI, triceps skin fold, and subscapular skin fold. Ectomorphy was directly related to supraspinal skin fold, medial calf skin fold, upper arm girth, calf girth, and biepicondylar breadth of humerus and inversely related to BF percentage and triceps skin fold. There was no statistically significant correlation between any of the somatotype components with blood pressure and organ dimensions.

Table 4.16 presents partial correlation coefficients of somatypes after controlling for the contributions of the other two somatotype components according to sex. Endomorphy was positively correlated with BF percentage, FM, FMI, triceps skinfold, subscapular skinfold and supraspinal skin fold in females while in males it was also positively correlated with weight, height, BSA, BF %, FM, FMI and all the skin folds. However, upper arm girth, calf girth, BBH and BBF and were significantly negatively correlated

with endomorphy among female subjects. No statistically significant correlation was observed between endomorphy with blood pressure and organ dimensions in both sexes.

Mesomorphy correlated positively with upper arm girth, calf girth, BBH and BBF in both sexes. However, triceps skin fold, suprascapular skin fold and BF % inversely correlated significantly with mesomorphy among females while, in males it was BF %, FM and FMI that significantly correlated negatively with endomorphy. Blood pressure and organ dimensions did not show statistically significant correlation with mesomorphy in both sexes.

Ectomorphy shows more sparing correlation with other variables. It showed significantly positive relation with BBH and BBF in male subjects only. A statistically significant negative correlation was observed between ectomorphy in females with BF %, supraspinal skin fold, upper arm girth, calf girth and BBH while in males, and the significant negative correlation was only seen with common bile duct diameter. Blood pressure and other organ dimensions did not show significant statistical correlation between the sexes.

Table 4.15: Summary of Partial Correlations Relating Somatotype Components and Body Composition, Sonographic Parameters, Anthropometric Variables and Physiologic Parameters for all Sample Population

	Endomorphs	Mesomorphs	Ectomorph
Body structure			
Weight (kg)	0.08	-0.04	0.02
Height (cm)	0.23 [‡]	-0.03	0.09
BMI (kgm ⁻²)	-0.03	-0.03	-0.03
Body Surface Area	0.14 [†]	-0.04	0.04
Fat (%)	0.56 [‡]	-0.27 [‡]	-0.39 [‡]
Fat Free Mass (kg)	-0.01	-0.01	0.08
Fat Free Mass Index (kgm ⁻²)	-0.14 [‡]	0.02	0.04
Fat Mass (kg)	0.46 [‡]	-0.21 [‡]	-0.26 [‡]
Fat Mass Index (kgm ⁻²)	0.38 [‡]	-0.19 [‡]	-0.28 [‡]
Skinfolds (mm)			
Tricep skinfold	0.74 [‡]	-0.21 [‡]	-0.13 [†]
Subscapular skinfold	0.66 [‡]	-0.21 [‡]	-0.08
Supraspinal skinfold	0.62 [‡]	-0.08	0.11 [†]
Medial calf skinfold	0.35 [‡]	0.01	0.26 [‡]
Sum of skinfolds	0.10	0.55 [‡]	-0.10
Upper arm girth (cm)	-0.17 [‡]	0.46 [‡]	-0.18 [‡]
Calf girth (cm)	-0.23 [‡]	0.41 [‡]	0.39 [‡]
BBH (cm)	0.02	0.44 [‡]	0.27 [‡]
BBF (cm)	-0.04	-0.08	-0.07
Physiologic parameters (mm Hg)			
Systolic Blood Pressure	0.08	0.01	0.05
Diastolic Blood Pressure	-0.01	-0.05	-0.06
Organ dimensions			
Liver length (cm)	0.072	-0.006	0.005
Caudate Lobe Length (cm)	0.038	0.023	-0.004
Caudate Lobe APD (cm)	0.067	-0.003	-0.014
Gall Bladder Length (cm)	0.05	0.088	-0.025
Gall Bladder Width (cm)	-0.06	-0.038	-0.043
Common Bile Duct Diameter (cm)	0.027	0.035	-0.051

APD: Anterior Posterior Diameter; BBH: Biepycondylar Breadth of Humerus; BBF: Biepycondylar Breadth of Femur. [‡] $P < 0.01$; [†] $P < 0.05$;

Table 4.16: Summary of Partial Correlations Relating Somatotype Components and Body Composition, Sonographic Parameters, Anthropometric Variables and Physiologic Parameters Based on Sex

	Females			Males		
	Endo	Meso	Ecto	Endo	Meso	Ecto
Body structure						
Weight (kg)	0.01	0.02	0.04	0.18 [†]	-0.11	0.03
Height (cm)	0.07	-0.03	-0.05	0.17 [†]	-0.15	-0.13
BMI (kgm ⁻²)	-0.03	0.04	0.08	0.09	-0.05	0.07
Body Surface Area	0.02	0.01	0.02	0.21 [‡]	-0.14	-0.01
Fat (%)	0.74 [‡]	-0.37 [‡]	-0.19 [†]	0.90 [‡]	-0.19 [†]	-0.02
Fat Free Mass (kg)	-0.07	0.04	0.05	0.01	-0.10	0.03
Fat Free Mass Index (kgm ⁻²)	-0.11	0.07	0.09	-0.10	-0.02	0.11
Fat Mass (kg)	0.38 [‡]	-0.13	-0.03	0.82 [‡]	-0.22 [‡]	0.02
Fat Mass Index (kgm ⁻²)	0.41 [‡]	-0.13	-0.01	0.83 [‡]	-0.18 [†]	0.08
Skinfolds (mm)						
Tricep skinfold	0.56 [‡]	-0.25 [‡]	-0.13	0.81 [‡]	-0.03	0.01
Subscapular skinfold	0.55 [‡]	-0.22 [‡]	-0.12	0.73 [‡]	-0.21 [‡]	-0.02
Supraspinal skinfold	0.45 [‡]	-0.25 [‡]	-0.16 [†]	0.69 [‡]	-0.03	-0.11
Medial calf skinfold	0.29 [‡]	-0.11	-0.08	0.25 [‡]	-0.12	0.03
Sum of skinfolds	0.06	-0.02	-0.04	0.13	-0.14	-0.08
Upper arm girth (cm)	-0.43 [‡]	0.47 [‡]	-0.25 [‡]	-0.05	0.69 [‡]	-0.02
Calf girth (cm)	-0.32 [‡]	0.44 [‡]	-0.16 [†]	-0.06	0.53 [‡]	0.02
BBH (cm)	-0.27 [‡]	0.45 [‡]	0.17 [†]	-0.11	0.44 [‡]	0.26 [‡]
BBF (mcm)	-0.30 [‡]	0.45 [‡]	0.09	0.10	0.41 [‡]	0.29 [‡]
Physiologic parameters (mm Hg)						
Systolic Blood Pressure	0.02	-0.04	-0.04	0.03	0.01	-0.03
Diastolic Blood Pressure	-0.08	-0.08	-0.02	0.09	0.07	0.02
Organ dimension						
Liver Length(cm)	-0.003	0.033	0.02	-0.091	0.029	0
Caudate Lobe Length (cm)	-0.043	-0.002	0.035	0.019	0.015	-0.061
Caudate Lobe APD (cm)	0.079	0.027	0.008	0.064	0.001	-0.07
Gall Bladder Length (cm)	0.007	0.115	-0.089	0.055	0.119	0.031
Gall Bladder Width(cm)	0.034	-0.051	-0.029	0.032	0.017	0.045
Common Bile Duct Diameter (cm)	0.045	0.007	0.002	0.025	0.09	-0.173 [†]

Endo: Endomorphs; Meso: Mesomorph; Ecto: Ectomorph; APD: Anterior Posterior DiameterBBH: Biepycondylar Breadth of Humerus; BBF: Biepycondylar Breadth of Femur

[†] $P < 0.05$;

[‡] $P < 0.01$

Various correlation coefficient levels between component parameters are shown in Tables 4.17 and 4.18. Correlation coefficients for the combined population are illustrated in Table 4.17. Results in the table revealed that 83% of the variables are significantly correlated while the remaining 17% are weakly correlated. From the same table, fat percentage directly associated with triceps skinfold, subscapular skinfold, calf girth, fat mass and fat-mass index. In contrast, it inversely correlated with height, medial calf skinfold, biepicondylar breadth of humerus, body mineral component, lean tissue mass, ponderal index, and fat-free mass. Correlations between fat percentage and all the various body components are generally strong at $P<0.01$. Height also showed strong significant direct correlation with all the various body components except for fat-mass index that it inversely correlated with. Fat mass and fat-mass index both generally showed strong direct and inverse correlation with all other variables. Medial calf skinfold also strongly correlated significantly ($P<0.01$) with all other variables except fat-free mass ($P>0.05$). Biepicondylar breadth of humerus significantly related with all other variables (at $P<0.01$ and $P<0.05$) but calf girth and subscapular skinfold. Triceps skinfold, subscapular skinfold, calf girth, lean tissue mass, ponderal index, and fat-free mass also correlated significantly with some other variables.

Table 4.18 depicts correlation matrix of body composition for both male and female subjects separately. The correlation matrix for female subjects revealed that 30.77% of the variables are significantly correlated while the remaining 69.23% variables were weakly correlated. Similarly, the correlation matrix for male subjects shows that 44.87% of the variables are significantly correlated while the remaining 55.13% are not significantly associated. Comparison of the significance level for individual sex (30.77% vs 44.87%) and for the combined population (83%) in Table 4.17 suggests that the

magnitude of correlation decreases (weakens) with a decrease in the sample population. For both male and female subjects, fat percentage was strongly associated significantly ($P<0.01$) with triceps skinfold, subscapular skinfold, medial calf skinfold, fat mass, and fat-mass index. In contrast, fat percentage showed a significant positive relationship with height among male subjects only. The Fat-mass index also showed significant linear and a negative association with triceps skinfold, subscapular skinfold, fat-free mass, fat mass and fat percentage of both male and female subjects. Medial calf skinfold however, showed a significant linear relationship with fat-mass index among male subjects only. Height was strongly significantly related to fat-free mass and fat mass ($P<0.01$) among female subjects while among male subjects, it was strongly related with triceps skinfold, fat percentage, subscapular skinfold, fat-free mass and fat mass ($P<0.01$). Triceps skinfold was strongly directly related to fat percentage, fat mass and fat-mass index among females while among the males, it was directly related to fat percentage, height, subscapular skinfold, medial calf skinfold, fat mass and fat-mass index and inversely related to fat-free mass. Subscapular skinfold was positively related to fat percentage, medial calf skinfold, bone mineral content, fat mass and fat-mass index among females. Likewise, among males, subscapular skinfold was directly related to fat percentage, height, triceps skinfold, fat mass and fat-free mass and inversely related to biepicondylar breadth of humerus and bone mineral content. The varying magnitude of relationships at numerous significant levels was identified among the other variables for both male and female subjects as illustrated in the same table.

Table 4.17: Pearson's Product-moment Correlation Coefficients of Fat Percent and Body Composition for all Sample Population

	Fat%	HT	TSF	SSF	MCSF	CG	BBH	BMC	LBM	PI	FFM	FM	FMI
Fat%	1	-0.21 [†]	0.61 [‡]	0.53 [‡]	-0.26 [‡]	0.26 [‡]	-0.40 [‡]	-0.59 [‡]	-0.58 [‡]	-0.25 [‡]	-0.16 [‡]	0.77 [‡]	0.83 [‡]
HT		1	0.15 [‡]	0.16 [‡]	0.39 [‡]	-0.20 [‡]	0.31 [‡]	0.44 [‡]	0.45 [‡]	0.26 [‡]	0.49 [‡]	0.13 [†]	-0.21 [‡]
TSF			1	0.36 [‡]	0.30 [‡]	0.04	0.11 [†]	0.08	0.09	0.06	-0.12 [†]	0.47 [‡]	0.40 [‡]
SSF				1	0.28 [‡]	-0.01	0.03	0.12 [†]	0.16 [‡]	0.02	-0.01	0.45 [‡]	0.39 [‡]
MCSF					1	-0.20 [‡]	0.59 [‡]	0.71 [‡]	0.72 [‡]	0.31 [‡]	-0.01	-0.22 [‡]	-0.35 [‡]
CG						1	0.08	-0.27 [‡]	-0.29 [‡]	-0.20 [‡]	0.01	0.17 [‡]	0.22 [‡]
BBH							1	0.63 [‡]	0.61 [‡]	0.23 [‡]	0.57 [‡]	-0.32 [‡]	-0.42 [‡]
BMC								1	0.97 [‡]	0.23 [‡]	0.10	-0.45 [‡]	-0.59 [‡]
LBM									1	0.26 [‡]	0.10	-0.44 [‡]	-0.58 [‡]
PI										1	0.11 [†]	-0.15 [‡]	-0.23 [‡]
FFM											1	0.49 [‡]	0.32 [‡]
FM												1	0.94 [‡]
FMI													1

HT: Height (m), TSF: Triceps skinfold (mm), SSF: subscapular skinfold (mm), MCSF: Medial calf skinfold (mm), CG: Calf girth (mm), LBM: Lean Body mass (kg), PI: Ponderal index = height(cm)/(body weight(kg))^{0.33}, FFM: Free fat mass (kg), FM: Fat mass (kg), FMI: Fat mass index (kgm⁻²), BMC: Bone mineral content.

[†]P<0.05

[‡]P<0.01

Table 4.18: Pearson's Product-moment Correlation Coefficients of Fat Percent and Body Composition for Female (top of the diagonal) and Male (below the diagonal)

	BF %	HT	TSF	SSF	MCSF	CG	BBH	BMC	LBM	PI	FFM	FM	FMI
Fat%	1	0.04	0.73 [‡]	0.77 [‡]	0.36 [‡]	0.06	-0.03	0.11	0.14	-0.05	-0.11	0.50 [‡]	0.55 [‡]
HT	0.19 [†]	1	0.01	0.05	-0.04	-0.05	0.03	-0.10	-0.12	0.15	0.51 [‡]	0.46 [‡]	0.10
TSF	0.91 [‡]	0.17 [†]	1	0.12	0.11	-0.01	-0.09	-0.01	0.02	0.02	-0.14	0.32 [‡]	0.35 [‡]
SSF	0.81 [‡]	0.51 [†]	0.50 [‡]	1	0.41 [‡]	0.09	0.03	0.16 [†]	0.17 [†]	-0.08	-0.03	0.43 [‡]	0.47 [‡]
MCSF	0.37 [‡]	0.11	0.45 [‡]	0.13	1	0.04	0.17 [†]	0.14	0.16 [†]	-0.12	-0.20 [‡]	0.05	0.07
CG	0.10	-0.06	0.14	0.01	0.11	1	0.48 [‡]	0.07	0.04	-0.05	-0.05	0.01	0.01
BBH	-0.01	-0.04	0.14	-0.20 [‡]	0.28 [‡]	0.30 [‡]	1	0.02	0.01	-0.01	-0.04	-0.06	-0.08
BMC	-0.17 [†]	-0.02	-0.13	-0.17 [†]	0.02	0.15 [†]	0.16 [†]	1	0.94 [‡]	-0.57 [‡]	-0.13	-0.06	-0.02
LBM	-0.09	0.01	-0.12	-0.03	-0.06	0.10	-0.01	0.59 [‡]	1	-0.65 [‡]	-0.14	-0.05	0.01
PI	0.01	-0.01	0.02	-0.02	0.17 [†]	-0.12	-0.09	-0.38 [‡]	-0.26 [‡]	1	0.10	0.06	0.01
FFM	-0.12	0.46 [‡]	-0.15 [†]	-0.03	-0.08	-0.08	-0.11	-0.05	0.01	0.01	1	0.80 [‡]	0.67 [‡]
FM	0.87 [‡]	0.41 [‡]	0.78 [‡]	0.72 [‡]	0.29 [‡]	0.06	-0.05	-0.16 [†]	-0.07	0.01	0.37 [‡]	1	0.92 [‡]
FMI	0.89 [‡]	0.13	0.79 [‡]	0.74 [‡]	0.29 [‡]	0.07	-0.04	-0.17 [†]	-0.08	0.01	0.26 [‡]	0.96 [‡]	1

HT: Height (m), TSF: Triceps skinfold (mm), SSF: subscapular skinfold (mm), MCSF: Medial calf skinfold (mm), CG: Calf girth (mm), LBM: Lean Body mass (kg), PI: Ponderal index, FFM: Free fat mass (kg), FM: Fat mass (kg), FMI: Fat mass index (kgm⁻²), BMC: Bone mineral content.

† $P < 0.05$

‡ $P < 0.01$

4.6 Linear and Multiple Regression Equations

Table 4.19 presents the linear and multiple regression equations for estimating fat percentage and fat mass for male and female subjects. The Pearson's product-moment coefficient of regression, coefficients of determination, and standard error of the estimate were also depicted. In the first step, equations for predicting fat percentage (outcome variable) using triceps skin fold, subscapular skin fold, medial calf skin fold, and fat mass as explanatory variables were presented. In the second and third step, these variables were combined to obtain their combined influence. The regression model revealed strong relationships between the outcome and explanatory variables. Subscapular skin fold and triceps skin fold showed the strongest positive significant relationship with a fat percentage among female and male subjects respectively. To assess the goodness of fit of the regression models, estimated percent variation of fat percentage and fat mass (outcome variables) of subjects accounted for by the explanatory variables, given by the value of the coefficient of determination (R^2) was used.

Triceps skin fold, subscapular skin fold, medial calf skin fold, and fat mass yielded respectively coefficient of determination (r^2) of 0.527, 0.591, 0.127, and 0.249 accounting for 52.7%, 59.1%, 12.7%, and 24.9% of the variance in fat percentage among female subjects. Height yielded a coefficient of determination of (r^2) of 0.213 accounting for 21.3% of the variance in fat mass among female subjects. In the second step, triceps skin fold, subscapular skin fold and triceps skin fold, medial calf skin fold were used to estimate fat percentage. In the third step, triceps skin fold, subscapular skin fold, and medial calf skin fold were used to estimate percentage skin fold. Triceps skin fold and subscapular skin fold yielded a joint coefficient of multiple regression (R^2) of 0.999

accounting for 99.9% of the variance in fat percentage among female subjects. Triceps skin fold, subscapular skin fold, and medial calf skin fold accounted for the same jointly contributed to the same variance in fat percentage (99.9%) among female subjects. Therefore, to estimate fat percentage, triceps skin fold, subscapular skin fold, and/or medial calf skin fold are the best estimators to use.

For the male subjects, triceps skin fold, subscapular skin fold, medial calf skin fold, and fat mass yielded coefficient of determination (R^2) of 0.832, 0.652, 0.134, and 0.758 accounting for 83.2%, 65.2%, 13.4%, and 75.8% respectively of the variance in fat percentage among male subjects. When compared to the percent variability's obtained for female subjects, these values are higher indicating a better goodness of fit of the regression model (hence triceps skinfold, subscapular skinfold, medial calf skinfold, and fat mass are better estimators fat percent in males than in females). The pattern of variability obtained in the second and third steps in male subjects were similar to that in the female subjects.

Table 4.19: Prediction Equations for Estimating Percent and Average Fat Composition in Adults Based on Skinfolds, Fat Mass and Height

Explanatory variables	Prediction equations	SEE	r	R ²	P-value
<i>Females</i>					
TSF (mm)	$\text{Fat\%} = 6.814 + (1.079) \times \text{TSF}$	1.058	0.726	0.527	<0.0001
SSF (mm)	$\text{Fat\%} = 4.898 + (1.076) \times \text{SSF}$	0.984	0.769	0.591	<0.0001
MSF (mm)	$\text{Fat\%} = 11.440 + (0.658) \times \text{MCF}$	1.438	0.356	0.127	<0.0001
Fat Mass (kg)	$\text{Fat\%} = 9.893 + (0.418) \times \text{FM}$	1.33	0.499	0.249	<0.0001
Height (m)	$\text{FM} = (-11.459) + (12.016) \times \text{HT}$	1.631	0.462	0.213	<0.0001
TSF, SSF (mm)	$\text{Fat\%} = 0.052 + (0.956) \times \text{TSF} + (0.969) \times \text{SSF}$	0.043	1.000	0.999	<0.0001
TSF, MSF (mm)	$\text{Fat\%} = 5.697 + (1.033) \times \text{TSF} + (0.514) \times \text{MSF}$	0.972	0.777	0.604	<0.0001
SSF, MSF (mm)	$\text{Fat\%} = 4.867 + (0.095) \times \text{MSF} + (1.047) \times \text{SSF}$	0.985	0.770	0.593	<0.0001
TSF, SSF, MSF (mm)	$\text{Fat\%} = 0.052 + (0.956) \times \text{TSF} + (0.967) \times \text{SSF} + (0.004) \times \text{MSF}$	0.043	1.000	0.999	<0.0001
<i>Males</i>					
TSF (mm)	$\text{Fat\%} = 1.941 + (1.310) \times \text{TSF}$	1.001	0.912	0.832	<0.0001
SSF (mm)	$\text{Fat\%} = -3.522 + (1.695) \times \text{SSF}$	1.443	0.807	0.652	<0.0001
MSF (mm)	$\text{Fat\%} = 5.882 + (0.895) \times \text{MCF}$	2.276	0.366	0.134	<0.0001
Fat Mass (kg)	$\text{Fat\%} = 2.794 + (1.186) \times \text{FM}$	1.203	0.871	0.758	<0.0001
Height (m)	$\text{FM} = (-12.274) + (10.914) \times \text{HT}$	1.640	0.406	0.165	<0.0001
TSF, SSF (mm)	$\text{Fat\%} = (-3.929) + (0.988) \times \text{SSF} + (0.975) \times \text{TSF}$	0.064	1.000	0.999	<0.0001
TSF, MSF (mm)	$\text{Fat\%} = (-3.929) + (0.975) \times \text{TSF} + (0.988) \times \text{MSF}$	0.064	1.000	0.999	<0.0001
SSF, MSF (mm)	$\text{Fat\%} = (-6.026) + (1.623) \times \text{SSF} + (0.648) \times \text{MSF}$	1.296	0.849	0.721	<0.0001
TSF, SSF, MSF (mm)	$\text{Fat\%} = (-3.957) + (0.972) \times \text{TSF} + (0.989) \times \text{SSF} + (0.007) \times \text{MSF}$	0.064	1.000	0.999	<0.0001

Linear and multiple-regression analysis [potential predictive/explanatory variables: skinfolds (mm), fat mass (kg), and height (m)]. SEE: Standard error of the estimate, r: Pearson's correlation coefficient, R² = Coefficient of determination; TSF: Triceps skinfold, SSF: subscapular skinfold, MSF: Medial calf skinfold.

Table 4.20: Comparison Between Observed %BF and Estimated %BF using Height, Tricep Skin Fold, Subscapular Skin Fold and Medial Calf Skin Fold

	Female						Male					
	*Fat%		**Fat%		***Fat%		*Fat%		**Fat%		***Fat%	
	SSF		TSF & SSF		TSF, SSF & MCF		TSF		TSF & MCF		TSF, SSF & MCF	
	Obs	Est	Obs	Est	Obs	Est	Obs	Est	Obs	Est	Obs	Est
1.	16.09	15.44	10.77	10.85	13.76	13.74	6.63	6.31	8.38	8.36	11.81	11.78
2.	11.99	12.48	14.90	14.89	12.49	12.46	8.07	10.38	7.25	7.26	9.97	9.92
3.	11.79	12.32	10.77	10.86	12.09	12.09	11.24	12.07	7.66	7.65	7.66	7.66
4.	12.69	12.54	11.89	11.90	13.67	13.64	8.07	7.33	13.32	13.35	14.42	14.52
5.	13.96	15.33	13.96	13.92	11.79	11.80	11.91	12.75	9.48	9.42	9.08	9.02
6.	11.69	11.89	14.15	14.12	14.53	14.49	9.28	8.34	9.48	9.42	12.76	12.76
7.	13.67	13.08	11.99	12.00	12.09	12.09	7.56	11.06	9.28	9.25	7.46	7.47
8.	12.59	12.64	11.38	11.42	11.38	11.41	9.28	10.72	7.46	7.47	2.25	2.70
9.	14.81	14.58	14.53	14.52	14.05	14.00	9.48	8.68	7.46	7.47	12	11.97
10.	13.28	12.00	17.14	17.29	14.99	14.98	14.15	11.06	11.62	11.60	7.66	7.65
	r = 0.859		r = 0.999		r = 0.999		r = 0.633		r = 0.999		r = 0.999	
	P = 0.001		P = 0.001		P = 0.001		P = 0.049		P = 0.001		P = 0.001	

CHAPTER FIVE

5.0 DISCUSSION

Body sizes and shapes vary extensively among living human populations (Ruff, 2002). In the present studies, the female medical students had a low endomorphic rating, though greater than the male medical students' ratings and this implies marked lean physique with minimum subcutaneous fat. The males, on the other hand, had moderate mesomorphic ratings greater than their female counter part and this denotes moderate muscle mass, bone mass plus moderate bone diameters relative to stature. Also, the ectomorphic ratings in males were moderate as compared with their female counterpart (low rating). This characterizes the males as having little mass relative to stature plus relatively elongated limb segments while the females as having greater mass relative to stature. The previous studies also agreed that the mesomorphy was higher in males and endomorphy in females in younger American individuals (Malina *et al.*, 2005; Arce *et al.*, 2012). The main reason is that boys may be more involved in recreational games associated with high levels of physical activity and vigorous activity, which tend to favour musculoskeletal development (mesomorphy). The females on the hand tend to have higher fat mass and percentage body fat, i.e., endomorphic component compared to males. The studies on the native Chuvash of Russian Federation in the age range of 18-80 years also reported that sex differences in somatotypes appear to be the strongest for endomorphy, with generally higher values in females (Pavlovsky and Kobylansky, 1997; Kalichman and Kobylansky 2006). Similarly, another study on North Indian Rajput adolescents by Gaur *et al.* (2014) revealed significant sexual dimorphism in endomorphy (higher in females) and mesomorphy (higher in males).

According to Carter and Heath (1990), there are fewer differences in general in ectomorphy between males and females. Rebato *et al.* (1996) noted that in a sample of Basque boys and girls, ectomorphy values were closer in both sexes compared with the other two components, with higher mean values for males. Several other researchers also found no difference in ectomorphy between boys and girls (Jurimae *et al.*, 1999; Kalichman and Kobylansky, 2006; Gaur *et al.*, 2008, 2014; Yang *et al.*, 2015). The disparity in our study could stem from genetic, nutritional, hormonal, environmental and sociocultural influence on our study population as the previous studies were carried out on Caucasians in a markedly dissimilar environment. However, Ajayi *et al.* (2016) who worked on the medical students of Lagos University, Nigeria had a similar conclusion with ours with respect to the ectomorphic component which perhaps gives credence to the above argument.

As a whole, the mean somatotype of the medical students of Ahmadu Bello University, Zaria was ectomorphic-mesomorph (1.61-4.4.82-3.04) for males and balanced mesomorph for females (1.75-4.21-1.96). This is contrasting with the findings of Ajayi *et al.* (2016) who found the mean somatotypes of male and female medical students of Lagos University to be balanced mesomorphs and mesomorphic endomorphs respectively. The morphological variation seen may be attributable to some measure of genetic factors, nutrition, geographical location, physical activities, hormonal and other socio-cultural or environmental factors. However, consistent with our result are the findings of Adamu *et al.* (2007) and Chaplygina (2009) who worked with medical students of the Rostov Medical University, Russia. The mesomorphic component was dominant in both sexes. In a similar study by Haronian and Sugerman (1965) who worked on the somatotype of American medical students of Yale university, found their mean

ratings to be 3.74-4.27-3.34 respectively (mesomorphy dominant). The Oxford medical students had a similar dominant mesomorphic rating like the Americans (Tanner, 1952). Even though our findings are similar, the somatotyping methodology employed by the latter was different.

In terms of distribution of the students in the somatochart, seven major categories were identified irrespective of the sexes: ectomorphic-mesomorph, endomorphic-mesomorph, balanced mesomorphy, mesomorph-ectomorph, mesomorphic-ectomorph, balanced ectomorphy and central. However, in the work of Adamu *et al.* (2007) on the medical students of Russia, five major categories were identified on the somatoplot of Dorokhov and Petrukhin: microsomatic, micromesosomatic, mesosomatic, mesomacrosomatic and macrosomatic. Also, Ajayi *et al.* (2016) on the medical students of Lagos University identified the thirteen major somatotype categories from the somatoplot. The disparity in our findings could be attributable to the somotyping methodology and software used for the analysis of the data.

The age differences in somatotype categories based on the sex were more pronounced in the age group of 18-23years. The females were more balanced-mesomorphic than males in that age group while the males, on the other hand, were more balanced ectomorphic than the females. Other somatotype categories in that age group were also different based on the sex. However, the higher age groups 24-29 and 30-35 years showed a relative stability in the somatotype categories between the sexes i.e., no significant change was observed between the sexes as the age increases. This agrees with the findings of Yang *et al.* (2015) on Han's population, China who observed a relative stability in somatotype from the age of 30 and above and also with the work of Kalichman and Kobliansky (2006). This could be the result of the decline in metabolic activity in both sexes as the

age advances. Katzmarzyk and Malina (1999) observed a reverse trend from our findings i.e., the somatotype categories between sexes continue to change until the age of 60 years and above. The reason for the discrepancy could be from the large sample size used by the latter.

The structural dimensions associated with the dominant somatotype groups in this study identified standing height as a dependent variable in the determination of somatotype. The highest mean value of standing height and medial calf skin fold was recorded in the dominant ectomorphs ($p < 0.05$). Dominant mesomorphs had the highest mean values for triceps skin fold, upper arm girth, calf girth and biepicondylar breadth of the femur. This agrees with the report of Carter (2002) who described mesomorphs as generally having broad bones with well-developed muscles and peripheral fat distribution and ectomorphs, being taller and slender. Also, from the literature, it has been emphasized that differences in body dimensions among different populations and are as a result of differences in nutrition, the level of physical activity and genetics (Malina, 1994).

Kalichman and Kobylansky (2004) concluded from their work on the relationship between somatotypes and blood pressure in an adult Chuvash population that dominant endomorphs and mesomorphs tend to have a higher mean value for systolic and diastolic blood pressure compared to the ectomorphs. The disparity in blood pressure was attributed to the high subcutaneous fat and large muscle mass present in the endomorphs and mesomorphs respectively. In another study by Makgae *et al.* (2007) in rural South African children, ectomorphs had the highest value for both systolic and diastolic blood pressure while endomorph and mesomorphy had similar mean values. This inverse finding was attributed to the high prevalence of malnutrition reported by the sampled children during the research exercise. However, in the present study, no statistically

significant differences in the blood pressure by dominant somatotypes were noted. The reason for this discrepancy could be ascribed to genetics, environment and the somatotyping technique used. Also, lifestyle and cultural practice may be considered as an additional factor that may play a role in this regard.

Also in the present study organ sizes did not significantly vary by dominant somatotypes. This disagrees with previous works by Adamu *et al.* (2007) and Chaplygina *et al.* (2013) who observed that dominant endomorphs and mesomorphs tend to have larger dimensions of viscera compared to the ectomorphs. They argued that ectomorphy has large surface area, thin muscles, and subcutaneous tissue, and slightly developed digestive viscera, as contrasted with endomorph and mesomorph. This reason for the disagreement with our work could be tied to the somatotyping technique employed, sample size and genetics.

According to Boileau and Lohman (1977), physique is characterized by three distinct and complementary components, including body size, structure, and composition. Body size refers to the physical magnitude of the body and its segments. Body structure alludes to the distribution of body parts expressed as ratios of stature. The composition is the amount of the various chemical components of the body.

In the present study dominant mesomorphs had a significantly higher BF %, FM, FMI than the endomorphs and ectomorphs. The reason for this trend in mesomorphs could be from the fact they had the highest number of subjects by dominant somatotype (246) compared to endomorphs (34) and ectomorphs (66). Previous reports have documented that the endomorphs have higher BF%, FM, and FMI compared to the other two somatotype components (Wells, 2012). The LBM and BMC were significantly higher in

the dominant ectomorphs than in the mesomorphy and endomorphs. This agrees with previous finding that ectomorphs are characterized by linearity and a predominance of connective tissue with LBM (Maynard *et al.*, 1998; Singh, 2007).

For the present study, males with dominant endomorphy, mesomorphy and ectomorphy had higher mean values for height, supraspinale skin fold, arm and calf girth, BBH and BBF compared to their female counterpart. Previous reports have shown that males tend to store fat around the abdomen and have larger bone dimensions with well-developed muscle than the females while females on the hand have a higher BMI (attributed to greater body fatness) than the males (Wells, 2007). The blood pressure and organ dimensions among the dominant somatotypes did not exhibit significant sexual dimorphism even though males had higher mean values than the females. At the molecular level, differences in sex chromosome may result in different type of gene expression that may influence a particular trait in favour of male compared to female or vice versa (Wells, 2007).

The attainment of adulthood is marked by considerable dimorphism in total body composition, with women having substantially greater mean percentage fat and relatively less lean mass. This sex difference holds across all ethnic groups and has been observed in all populations, although its magnitude is influenced by ethnic genetic factors and environmental conditions (Wells, 2007). Percentage fat averages 10–15% of males in most populations but can attain 30% in some Polynesian populations. The typical range in females is 20–30%, but up to 45% in Polynesians (Norgan, 1990). These changes are primarily hormonally driven; however, reduced energy expenditure in girls during puberty may also be important. The end result by early adulthood is that while the sexes

have a relatively similar weight for height (BMI), the ratio of lean to fat is much greater in males than females (Well, 2006).

The sex difference in bone mineral mass and size emerges during puberty and can be attributed to several factors, including the longest prepubertal growth period of boys compared to girls, and the inhibitory effect of oestrogen on periosteal apposition in girls (Seeman, 2001). Recent studies indicate that gender differences in bone mass emerge at around 15–17 years, with the larger size of male bones, then conferring greater strength (Schoenau *et al.*, 2001). Thus, whereas mineral mass is very similar between the sexes at birth (Arfai *et al.*, 2002), by the start of adulthood skeletal weight is around 4 kg in men and 2.8 kg in women.

In our study, irrespective of the dominant somatotypes, BF%, FM, FMI, and FFMI were significantly higher in the females than in men while LBM and BMC were higher in males than in females. This is in keeping with the previous literature on sexual dimorphism in body composition (Well, 2006).

Aging is a process that has deleterious effects on nearly every facet of human body composition. While the pattern and magnitude of these changes are likely influenced by gender, race or ethnicity, and body constitution (Kotani *et al.*, 1994; Kyle *et al.*, 2001), aging is generally associated with increases in adiposity and fat deposition in skeletal and cardiac muscle, liver, and bone marrow (Meunier *et al.*, 1971; Kotani *et al.*, 1994; Kyle *et al.*, 2001; Slawik and Vidal-Puig, 2006; Rabkin, 2007).

In the present study, dominant mesomorphs and ectomorphs had mean values for the weight, BMI, BSA, gall bladder width, CBDD, FFM and FFMI in the different age categories significantly higher in subjects in the age group of 30-35 years than in subjects

in the age groups 18-23 and 24-29 years. This implies that as the age increases the values for the aforementioned parameters also increases. This agrees with a previous report that total fat mass, FFM, and FFMI also increases with age in White men and women. In men, this increase may approach 1% per year throughout the lifespan (Zamboni *et al.*, 2003; Ding *et al.*, 2007) independent of corresponding changes in body weight (Gallagher *et al.*, 2000). White women also have increased until at least age 60–70 (Gallagher *et al.*, 2000; Zamboni *et al.*, 2003), but may begin to lose it thereafter (Visser *et al.*, 2003; Raguso *et al.*, 2006).

However, in the dominant endomorphs all anthropometric, body composition and hepatobiliary variables did not indicate significant differences according to the age groups. This observation could be linked to the least sampled subjects recorded by dominant endomorphs (34).

One speculation is that somatotype reflects differences in body composition. This hypothesis rests on observed correlations between body composition determinations and somatotype ratings. Dupertius *et al.* (1951) found a significant negative correlation between specific gravity and endomorphy and nonsignificant correlations between specific gravity, mesomorphy, and ectomorphy. Wilmore (1970) evaluated the hypothesis that the endomorphic and mesomorphic components represent the degree of fatness and FFW, respectively. Because of low correlations ($r = 0.16$ and 0.41 for females and males, respectively) between FFM and mesomorphy, Wilmore questioned the validity of considering the mesomorphic component as the fat-free body. Wilmore observed greater correlation coefficients between percent body fat and the endomorphic component among women and men ($r = 0.58$ and 0.72 , respectively).

Slaughter and Lohman (1976) reported significant correlations between percent body fat and endomorphy, mesomorphy and ectomorphy ($r = 0.74, 0.45, \text{ and } -0.66$, respectively). Correlation coefficients relating FFW and the somatotype components were not significant ($P > 0.05$; $r = 0.25, 0.20, \text{ and } -0.34$, respectively). Participant in these studies only included college students. Bolonchuk *et al.* (1989) reported similar findings in samples of men ($n=4220$) and women ($n = 4200$) ranging in age from 17 ± 74 years. Endomorphy was significantly correlated with densitometrically determined percent fat in men and women $r = 0.80 \text{ and } 0.87$, respectively. Ectomorphy was negatively correlated with percent body fat $r = -0.56 \text{ and } -0.68$ for men and women. FFW correlated significantly with mesomorphy $r = 0.36$ and ectomorphy $r = -0.62$ only in men.

Generalizations regarding the specificity of somatotypic ratings with body composition measurements should be restricted. In previous studies (Dupertius *et al.*, 1951; Wilmore, 1970; Slaughter and Lohman, 1976; Bolonchuk *et al.*, 1989), the highest component of the somatotype rating was clear. These somatotypes, however, tended toward midline ratings, not extremes or dominant somatotypes. Moreover, the dominance of the rating was modified by a second component. Thus, the relationship of the dominant component to a body composition variable may be diminished by the association of the modifying component to the same variable. Bulbulian (1984) demonstrated a significant correlation between endomorphy and percent body fat among individuals with extreme endomorphic ratings. Bolonchuk *et al.* (1990) discussed this effect of the modified somatotype on body composition.

In the present study, the impact of dominant somatotype, after statistically adjusting for the modifying somatotype components, on body composition, organ dimensions, and anthropometric variables was investigated. Dominant endomorphy was significantly

correlated with height, BSA, BF%, FM and FMI; and inversely related to FFMI and upper arm and calf girth. Significant positive relationships were identified for mesomorphy and bone breadth, arm and calf girth. However, mesomorphy had a significant inverse relationship with BF%, FM, FMI, triceps skin fold and subscapular skin fold. Ectomorphy, however, was significantly and inversely correlated with BF% and triceps skin fold respectively.

All the dominant somatotypes did not show significant correlation with blood pressure and organ dimensions. This disagrees with previous works by Kalichman and Kobylansky (2006), Adamu *et al.* (2007) and Chaplygina *et al.* (2013). The reason for the discrepancy could be attributed to somatotyping technique, race, and genetics. Thus, endomorphy, mesomorphy, and ectomorphy are strong predictors of body composition, but cannot predict blood pressure and organ dimensions.

Another consideration of the relationship between somatotype and body composition is the impact of stature on this relationship. Stature is one discriminating factor among individuals with different somatotypes. Mesomorphs generally are shorter than endomorphs and ectomorphs. Because the relationship between somatotype and function may depend on fat-free weight, or more importantly muscle weight, it is important to normalize body composition data for stature. Van Itallie *et al.* (1990) recommended the fat-free weight index, fat-free weight/ height, as an indicator of nutritional status.

A limitation of the use of this ratio is that a linear relationship between stature and FFW is assumed. Because this assumption of linearity is considered weak (Slaughter and Christ, 1995), a regression of FFW vs. height has been derived to characterize physique while controlling for differences in stature in athletic and nonathletic populations

(Slaughter and Lohman, 1980; Slaughter *et al.*, 1987). Slaughter and Christ (1995) used this approach to find that participants in some activities have significantly greater than expected FFW (i.e., professional and collegiate football players, judoists, ice hockey players, weightlifters) and other participants (cyclists and long distance runners) have similar or significantly less than expected FFW.

Bolonchuk (2000) employed this approach to examine the influence of dominant somatotypes on FFM independently of stature. Dominant endomorphs and mesomorphs had similar measured and predicted FFM values. In contrast, dominant ectomorphs had significantly less FFM than anticipated.

In the present study, after controlling for the contributions of the other two somatotype components according to sex, partial correlation coefficients showed that endomorphy was positively correlated with BF percentage, FM, FMI, triceps skin fold, subscapular skin fold and supraspinal skin fold in females while in males it was also positively correlated with weight, height, BSA, BF %, FM, FMI and all the skin folds. However, upper arm girth, calf girth, BBH and BBF and were significantly negatively correlated with endomorphy among female subjects. No statistically significant correlation was observed between endomorphy with blood pressure and organ dimensions in both sexes.

Mesomorphy correlated positively with upper arm girth, calf girth, BBH and BBF in both sexes. However, triceps skin fold, suprascapular skin fold, and BF % inversely correlated significantly with mesomorphy among females while, in males, it was BF %, FM, and FMI that significantly correlated negatively with endomorphy. Blood pressure and organ dimensions did not show statistically significant correlation with mesomorphy in both sexes.

Ectomorphy shows more sparing correlation with other variables. It showed a significantly positive relation with BBH and BBF in male subjects only. A statistically significant correlation was also observed between ectomorphy in females with BF %, supraspinal skin fold, upper arm girth, calf girth and BBH while in males, the significant negative correlation was only seen with common bile duct diameter. The result of the negative correlation agrees with the work of Chaplygina *et al.* (2013). Blood pressure and other organ dimensions did not show a significant statistical correlation between the sexes.

From our result, triceps skinfold, subscapular skinfold, medial calf skinfold, and fat mass yielded respectively coefficient of determination (r^2) of 0.527, 0.591, 0.127, and 0.249 accounting for 52.7%, 59.1%, 12.7%, and 24.9% of the variance in fat percentage among female subjects. Height yielded a coefficient of determination of (r^2) of 0.213 accounting for 21.3% of the variance in fat mass among female subjects. In the second step, triceps skinfold, subscapular skinfold and triceps skinfold, medial calf skinfold were used to estimate fat percentage. In the third step, triceps skinfold, subscapular skinfold, and medial calf skinfold were used to estimate percentage skinfold. Triceps skinfold and subscapular skinfold yielded a joint coefficient of multiple regression (R^2) of 0.999 accounting for 99.9% of the variance in fat percentage among female subjects. Triceps skinfold, subscapular skinfold, and medial calf skinfold accounted for the same jointly contributed to the same variance in fat percentage (99.9%) among female subjects. Therefore, to estimate a fat percentage, triceps skinfold, subscapular skinfold, and/or medial calf skinfold are the best estimators to use.

For the male subjects, triceps skin fold, subscapular skin fold, medial calf skin fold, and fat mass yielded coefficient of determination (R^2) of 0.832, 0.652, 0.134, and 0.758

accounting for 83.2%, 65.2%, 13.4%, and 75.8% respectively of the variance in fat percentage among male subjects. When compared to the percent variability's obtained for female subjects, these values are higher, indicating a better goodness of fit of the regression model (hence triceps skin fold, subscapular skin fold, medial calf skin fold, and fat mass are better estimators fat percent in males than in females).

Bruce *et al.* (1980) who used total body potassium and total body water as measurements of FM, reported on multiple regressions of FM on age, height, and weight, which differ from our result shows that all three predictor variables (weight, height, and age) contribute significantly to the determination of both LBM and FM (except age in the calculation of LBM in women). By applying these equations, the size of the two body compartments, LBM and BF, can be calculated with a Standard error of estimate (SEE) below 3 kg.

Durnin *et al.* (1974) have reported that the relation between the log value of the skin fold thickness and body density, measured by underwater weighing, was an almost linear function. They concluded that by using the sum of four skin folds, it was possible to estimate the BF% in a subject with a SEE of 3.5% (2.3 kg BF) for women and 5% (3.7 kg BF) for men.

Hasserger *et al.* (1986) observed that BF% can be calculated from the age and the skinfold value with SEES of 3.2% to 3.8%, and the absolute FM can be calculated from the age and the skin fold value multiplied by the body weight with an SEE of 2.2 kg. When the expression of the skin fold value multiplied by body weight and the absolute FM instead of the relative FAT% were used the correlation increased significantly ($P < 0.01$) from $r = .83$ to $r = .92$ and from $r = .80$ to $r = .94$ in men and women.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

A significant difference in the mean somatotype based on the sex was observed with males being ectomorphic-mesomorph (1.61-4.28-3.04) and females balanced mesomorph (1.75-4.21-1.96). Seven major categories were found irrespective of the sexes: endomorphic-mesomorph, balanced-mesomorph, ectomorphic-mesomorph, mesomorph-ectomorph, mesomorphic-ectomorph, balanced-ectomorph and central. The height, body mass index (BMI), body surface area (BSA), skin folds, bone breadth and body composition variables showed significant sexual dimorphism based on the dominant somatotypes ($p < 0.05$). The BMI, BSA, gall bladder width, common bile duct diameter (CBDD) and body composition variables indicated significant differences according to the age groups in the dominant mesomorphs and ectomorphs ($p < 0.05$). Dominant endomorphy was positively correlated with some skin folds and body composition variables in both sexes. Mesomorphy correlated positively with upper arm girth, calf girth, BBH and BBF in both sexes. Ectomorphy showed more sparing correlation with other variables, i.e., it showed a significant positive correlation with BBH and BBF in male subjects only. No significant correlations were observed in blood pressure and hepatobiliary dimensions with the dominant somatotypes. Tricep skin fold, subscapular skin fold, and medial calf skin fold were the joint best predictors of percent body fat in both sexes ($R^2 = 0.999$).

6.2 Recommendations

- i. The data generated on the somatotype profile of medical students can be used as baseline data in the university in the selection of athletes for sports and by government defense agencies in the survey of young men of military age.
- ii. Normal reference values of the Hepatobiliary parameters of the study population generated taking into cognizance the individual constitution may be used as baseline data in the university as this will contribute to the accuracy of data interpretation.
- iii. Different categories of students with larger sample size and more body organs can be used in order to explore more of the relationship of dominant somatotype with organ dimensions for a more generalised result.
- iv. Further study can be conducted on same population or a different one using a different somatotyping technique.
- v. Further studies should target ethnic groups, other age groups and to explore the relationships between somatotype and susceptibility to disease predisposition.
- vi. Since the empirical formulae derived for BF% may be very population-specific, it must be emphasized that the reported equations only accounts for adult subjects with a relatively normal body constitution. Further investigation is needed to ensure whether the equations also accounts for obese subjects and patients with dehydration, disturbed osmolality, or endocrine disorders.

6.3 Contribution to Knowledge

- i. A baseline somatotype data for the medical students of Ahmadu Bello University, Zaria has being generated. Based on the data, mean somatotype of male and

female subjects were ectomorphic-mesomorph (1.61-4.28-3.04) and balanced mesomorph (1.75-4.21-1.96) respectively.

- ii. A reference value for the normal hepatobiliary dimensions of the study population has being generated: liver length (10-19 cm), caudate lobe length (4-8 cm), caudate lobe APD (1-5 cm), gall bladder length (2-8 cm), gall bladder Width (1-6 cm), and CBDD (0.1-0.7 cm).
- iii. A means of predicting BF % for the study population has been generated. In this context the best models for BF % prediction were:
 - a. $BF \% = 0.052 + (0.956) \times TSF + (0.967) \times SSF + (0.004) \times MSF$ (female),
 - b. $BF \% = 0.052 + (0.956) \times TSF + (0.969) \times SSF$ (female),
 - c. $BF \% = (-3.929) + (0.988) \times SSF + (0.975) \times TSF$ (male),
 - d. $BF \% = (-3.929) + (0.975) \times TSF + (0.988) \times SSF$ (male),
 - e. $BF \% = (-3.957) + (0.972) \times TSF + (0.989) \times SSF + (0.007) \times MSF$ (male).

REFERENCES

- Adamu, A.A., Chaplygina, H.V., Nelasson, N.Y., Kondrashev, A.V., Morosova, A.V., and Volkov, G.V. (2007). Some Ultrasonographic peculiarities in the Anatomy of Abdominal Organ, *Journal of Ultrasound Medicine*, 26(1), S1-S230.
- Ahmed, S.M., Adams, A. and Chowdhury, A.M. (1998). Chronic energy deficiency in women from rural Bangladesh: some socioeconomic determinants. *Journal of Biosocial Science*, 30, 349-358.
- Ajayi, A., Edjomariégwe, O., Abraham, K., and Ibeabuchi, N. M. (2016). Somatotype of Undergraduate Medical Students of the University of Lagos. *Journal of Applied Life Sciences International* 8(1), 1-8
- Akinyinka, O.O., Sanni, K.A. and Falade, A.G. (1999). Arm area measurements as indices of nutritional reserves and body water in African new-borns. *African Journal of Medicine and Medical Sciences*, 28, 5-8.
- Altman, D.G. (1980). Statistics and ethics in medical research: III How large a sample? *British Medical Journal*, 281(1), 1336-8
- Amusa, L.O., Goon, D.T. and Amey, A.K. (2011). Somatotype in 7-13-year-old South African rural school children. *African Journal for Physical, Health Education Recreation and Dance*, September (Supplement 2:2), 30-41.
- Araoye, M.O. (2004). Research Methodology with statistics for health and social sciences, Ilorin: Nathade Publishers.
- Arce, P.L., Flores, A.A., Lelievre, C.S., Marincovic, D.I., Gutierrez, O.B. and de la Rosa, F.B. (2012). Changes of Somatotype in High School Students, V Region, Chile: 1985-2010. *Nutrition Hospital*, 27(1), 270-275.
- Arfai, K., Pitukcheewanont, P.D. Goran, M.I. (2002). Bone, muscle, and fat: sex-related differences in prepubertal children. *Radiology*, 224, 338-344.
- Badenhorst, L., de Ridder, J.H. and Underhay, C. (2003). Somatotype, blood pressure and physical activity among 10- to 15- year old South African boys: the Thusa Bana study. *African Journal of Physical, Health Education, Recreation and Dance*, 9(3), 184-195.
- Battista, R.A., Pivarnik, J.M., Dummer, G.M., Sauer, N. and Malina, R.M. (2007). Comparisons of physical characteristics and performances among female collegiate rowers. *Journal of Sports Science* 25(1), 651-657.
- Bhasin, M.K. and Jain, S. (2007). Biology of the tribal groups of rajasthan, India: Age changes in somatotype. *Anthropologist*, 9(4), 257-265.
- Bhuiyan, A. R., Gustat, J., Srinivasan, S. R., Berenson, G. S. (2003). Differences in body shape representations among young adults from a biracial (Black-White),

- semirural community: the Bogalusa heart study. *American Journal of Epidemiology*, 158(1), 792-797.
- Boileau, R.A., and Lohman, T.G. (1977). The measurement of human physique and its effect on physical performance. *Orthop Clin North American*, 8 (33), 563±581.
- Bolonchuk, W.W., Siders, W.A., Lykken, G.I., Henry, C. and Lukaski, H.C. (2000). Association of Dominant Somatotype of Men with Body Structure, Function during Exercise and Nutritional Assessment. *American Journal of Human Biology*, 12(2), 167-180.
- Bouchard, C. (2000). Familial resemblance for physique heritabilities for somatotype componen. *Annals Human Biology*, 27(1), 467-77.
- Bruce, A., Andersson, M., and Arvidsson, B. (1980). Body composition: Prediction of normal body potassium, body water and body fat in adults on the basis of body height, body weight and age. *Standard Journal of Clinical Laboratory Investigation*, 40, 461-473.
- Bulbulian, R. (1984). The influence of somatotype on anthropometric prediction of body composition in young women. *Medical Science Sport Exercise* 16(1), 389- 397.
- Carter, J. E. L. (1996). Somatotype analysis - review and comments, In *Human Biology- Global Developments*. Pp. 95-103. L.S. Sidhu and S.P. Singh (Eds.). USG Publishers and Distributors, Ludhiana.
- Carter, J. L. E., and Heath, B. H. (2002). Somatotyping development and applications, Cambridge University Press, Cambridge.
- Carter, J.E.L. and Heath, B.H. (1990). Somatotyping: development and applications. New York: Cambridge University Press.
- Carter, J.E.L., Ackland, T.R., Ross, W.D. and Mazza, J.C. (1994). Kinanthropometry in a quatic sports, A study of world-class athletes Champion, IL: Human Kinetics. Pp 165-169.
- Carter, J.L.E., & Heath, B.H. (2003). *Somatotyping development and applications*. Cambridge: University Press, Cambridge.
- Chakrabarty, S., Pal, M., Bharati, S., and Bharati, P. (2008). Body form and nutritional status among adult males of different social groups in Orissa and Bihar states in India. *Journal of Comparative Human Biology*, 59(1), 235-251.
- Chandel, S., and Malik, S.L. (2012). Anthropometric somatotype of kshatriya and kurmi of uttar pradesh: population and gender differences. *Human Biology Review*, 1(1), 1-15.
- Chaplygina, E.V. (2009). Somatotypological laws of anatomical variability of the liver and gallbladder in human youth and the first period of mature age, Volgograd, pp. 46.

- Chaplygina, E.V. and Gubar, A.S. (2014). Connection linear parameters of liver with individual somatotype, *Medical news of north Caucasus*, 9(4), 357-359.
- Chaplygina, E.V. and Kuchieva, M.B. (2012). Regional and constitutional sizes features of the thyroid gland in healthy people of the various somatic types living in the Rostov region, *Medical sciences*, 2(1), 386-388.
- Chaplygina, E.V., Gubar A.S., Ramadan K.V. and Sokolova Y.N. (2014). The variability of the linear parameters of liver, depending from a position of the authority in the abdominal cavity. *Medical sciences*, 2(1), 388-390.
- Chaplygina, E.V., Gubar, A.S., Klimova, S.I. and Litvinova, L.V. (2013). The dependence of the liver volume from somatotype and gender of the patient, *Scientific reviews*, 7(1), 445-450.
- Christian, H., Anders, G., Jytte, J. and Claus, C. (1986). Prediction of body composition by age, height, weight and skinfold thickness in normal adults. *Metabolism: clinical and experimental* 35(12).
- Comas, J. (1960). Biotypology and constitutional types. In *Manual of Physical Anthropology*. (pp.319-366). Illinois: Charles C. Thomas Publisher.
- de Bruin, N.C., van Velthoven, K.A. and de Ridder, M. (1996). Standards for total body fat and fat-free mass in infants. *Archives of Disease in Childhood*, 74, 386-399.
- Delbeke, D. and Martin, W.H. (2005). Update of PET and PET/CT for hepatobiliary and pancreatic malignancies. *HPB (Oxford)*, 7, 166-79.
- Dhingra, B., Sharma, S., Mishra, D., Kumari, R., Pandey, R.M. and Aggarwal, S. (2010). Liver and spleen size by ultrasonography. *Journal of Indian Paediatricians*, 47, 475-476.
- Ding, J., Kritchevsky, S.B., Newman, A.B., Taaffe, D.R., Nicklas, B.J., Visser, M. and Harris, T.B. (2007). For the Health, A. B. C. S., effects of birth cohort and age on body composition in a sample of community-based elderly. *American Journal of Clinical Nutrition* 85(2), 405-410.
- Dupertius, C.W., Pitts, G.C., Osserman, E.F., Welham, W.C. & Behnke, A.R. (1951). Relation of specific gravity to body build in a group of healthy men. *Journal of Applied Physiology* 3(1), 676-680.
- Durnin, J.V.G.A. and Womersley, J. (1974). Body fat assessed from total body density and its estimation from skinfold thickness: Measurements on 481 men and women aged from 16 to 72 years. *British Journal of Nutrition*, 32(1), 77-97.
- Eiben, O.G., Buday, J. and Bosze, P. (2004). The physique of patients with carcinoma of the female genital tract. *European Journal of Gynaecology. Oncology*, 25(1), 683-688.

- Ellis, K.J., Shukla, K.K., Cohn, S.H., Pierson, R.N.Jr. (1974). A predictor for total body potassium in man based on height, weight, sex and age: applications in metabolic disorders. *Journal of Laboratory Clinical Medicine* 83, 716-727.
- Emilia, A. and Silvia, M. (2015). Changes in somatotype characteristics in the middle-aged Bulgarian men. *Nutrition Hospital*, 32(6), 2910-2915.
- Fields, D.A. and Goran, M.I. (2000). Body composition techniques and the four compartment model in children. *Journal of Applied Physiology*, 89, 613–620.
- Fomon, S.J., Haschke, F. and Ziegler, E.E. (1982). Body composition of reference children from birth to age 10 years. *The American Journal of Clinical Nutrition*, 35(5), 1169-1175.
- Furuse, J., Nagase, M., Ishii, H. and Yoshino, M. (2003). Contrast enhancement patterns of hepatic tumours during the vascular phase using coded harmonic imaging and Levovist to differentiate hepatocellular carcinoma from other focal lesions. *British Journal of Radiology*, 76, 385-92.
- Gakhar, I. and Malik, S.L. (2002). Age changes and sex differences in somatotypes among jats of delhi. *Anthropologist*, (Special Issue) 1(1), 115-125.
- Gallagher, D., Ruts, E., Visser, M., Heshka, S., Baumgartner, R. N., Wang, J. and Heymsfield, S. B. (2000). Weight stability masks sarcopenia in elderly men and women. *American Journal Physiological Endocrinology Metabolism* 279(2), E366-375.
- Gaur, R., Talwar, I.D.I. and Negi, V. (2014). Age and Sex Variations in the Somatotypes of Rajput Adolescents of the Kullu District of the Himachal Pradesh Province, North India. *International Journal of Anthropology*, 29(4), 227-244.
- Goon, D.T., Amusa, L.O., Shaw, B.S., Shaw, I. and Akusu, S.W. (2013). Somatotypes of Andibila children aged 7 to 14 years in Oju, Nigeria *African Journal for Physical, Health Education, Recreation and Dance (AJPHERD)* Volume 19(4:2), 1037-1046.
- Goran, M.I., Allison, D.B. and Poehlman, E.T. (1995). Issues relating to normalization of body fat content in men and women. *International Journal of Obesity*, 19, 638-643.
- Goran, M.I., Gower, B.A. and Nagy, T.R. (1998). Developmental changes in energy expenditure and physical activity in children: evidence for a decline in physical activity in girls before puberty. *Pediatrics*, 101, 887-891.
- Gordon, E. (1984). Physique, lipids and kilojoule intake of a group of South African Caucasoids young adults. *Ph.D. thesis*, University of the Witwatersrand, Johannesburg.

- Haronian, F. and Sugarman, A.A. (1965). A comparison of Sheldon and Parnell's methods for quantifying morphological differences. *American journal of physical anthropology*, 23,135-41.
- Harrison, G.A., Weiner, J.S. Tanner, J.M. and Barnicot, N.A. (1977). Human Biology: An introduction to human evolution, variation, growth, and ecology Oxford: Oxford University Press.
- Haschke, F. (1989). Body composition during adolescence. In: 98th Ross Conference on Pediatric Research, Body composition in infants and children'. *Columbus, Ohio: Ross Laboratories*, pp. 76-83.
- Hashimoto, M., Itoh, K., Takeda, K., Shibata, T., Okada, T. and Okuno, Y. (2008).Evaluation of biliary abnormalities with 64-channel multidetector CT. *Radiographics*, 28, 119-34.
- Hattori, K., Tahara, Y. and Moji, K. (2004). Chart analysis of body composition change among pre- and postadolescent Japanese subjects assessed by underwater weighing method. *International Journal of Obesity*, 28, 520-524.
- Heath, B.H. and Carter, J.E.L. (1967).A modified somatotype method, *American Journal of Physical Anthropology*, 27(1), 57-74.
- Hebbelinck, M., Duquet, W., Bornos, J. and Carter, J.E.L. (1995). Stability of somatotypes: A longitudinal study of Belgian children age 6-17 years. *American Journal of Human Biology*, 7(5), 575-588.
- Herrera, H., Rebato, E., Hernandez, R., Hernandez-Valera, Y. and Alfonso-Sanchez, M.A. (2004). Relationship between somatotype and blood pressure in a group of institutionalized Venezuelan elders. *Gerontology*, 50: 223-229.
- Hounsfield, G.N. (1973). Computerized transverse axial scanning (tomography). 1. Description of system. *British Journal of Radiology*, 46, 1016-22.
- Igharo, O.K. and Bakke, M.M.(2013). Investigation of William H. Sheldon's constitutional theory of personality: A case study of the University of the Gambia. *Mediterranean Journal of Social Sciences*, 4(7).
- International Society for the Advancement of Kinanthropometry, (2001).International Standards for Anthropometric Assessment. The University of South Australia Holbrooks Rd, Underdale, SA, Australia.
- Ji, C. and Ohsawa, S. (1996). Changes in somatotype during growth in Chinese youth 7-18 years of Age. *American Journal of Human Biology*, 8(1), 347-359.
- Jonas, E., Hultcrantz, R., Slezak, P., Blomqvist, L., Schnell, P.O., Jacobsson, H. (2001). Dynamic 99Tcm-HIDA SPET: non-invasive measuring of intrahepatic bile flow. Description of the method and a study in primary sclerosing cholangitis. *Nuclear Medicine Communication*, 22, 127-34.

- Jurimae, T., Jurimae, J. and Leppik, A. (1999). A relationship between body bioelectrical resistance and somatotype in pre-adolescent children. *Acta Kinesiology. University Tartuensis*, 4(1), 103-121.
- Kalender, W.A., Seissler, W., Klotz, E. and Vock, P. (1990). Spiral volumetric CT with single-breath-hold technique, continuous transport, and continuous scanner rotation. *Radiology*, 176, 181-3.
- Kalichman, L. and Kobylansky, E. (2006). Sex- and age-related variations of the somatotype in a chuvasha population. *Journal of Comparative Human Biology*, 57(1), 151-162.
- Kalichman, L., Livshits, G., and Kobylansky, E. (2004). Association Between Somatotypes and Blood Pressure in an Adult Chuvasha Population. *Annals Human Biology*, 31(4), 466-476.
- Kalichman, L., Malkin, I. and Kobylansky, E. (2005). Association between physique characteristics and hand skeletal aging status. *American Journal of Physical Anthropology*, 128(1), 889-895.
- Katzmarzyk, P.T., Malina, R.M., Perusse, L., Rice, T., Province, M.A., Rao, D.C. and Bouchard, C. (2000). Familial resemblance for physique: Heritabilities for somatotype components. *Annals of Human Biology*, 27(1), 467-77.
- Kim, Y.K., Kim, C.S., Chung, G.H., Han, Y.M., Lee, S.Y. and Chon, S.B. (2006). Comparison of gadobenate dimeglumine-enhanced dynamic MRI and 16-MDCT for the detection of hepatocellular carcinoma. *American Journal of Roentgenology*, 186, 149-57.
- Kirby, A., Gebiski, V and Keech, A.C. (2002). Determining the sample size in a clinical trial. *Medical Journal Australia*, 177:256-7.
- Koleva, M., Nacheva, A. and Boev, M. (2002). Somatotype and disease prevalence in adults. *Revised Environmental Health*, 17(1), 65-84.
- Koleva, M., Nacheva, A. and Boev, M., (2000). Somatotype, Nutrition, and Obesity. *Revised Environmental Health*, 15(1), 389-98.
- Kotani, K., Tokunaga, K., Fujioka, S., Kobatake, T., Keno, Y., Yoshida, S., Shimomura, I., Tarui, S. and Matsuzawa, Y. (1994). Sexual dimorphism of age-related changes in whole-body fat distribution in the obese. *International Journal of Obesity and Related Metabolic Disorder*, 18 (4), 207-212.
- Kretschner, E. (1921). *Körperbau und Charakter*. Berlin: Springer-Verlag.
- Kyle, U.G., Genton, L., Hans, D., Karsgaard, L., Slosman, D.O., and Pichard, C. (2001). Age related differences in fat-free mass, skeletal muscle, body cell mass and fat mass between 18 and 94 years. *European Journal of Clinical Nutrition*, 55 (8), 663-672.

- Kyle, U.G., Schutz, Y. and Dupertuis, Y.M. (2003). Body composition interpretation. Contributions of the fat-free mass index and the body fat mass index. *Nutrition*, 19, 597-604.
- Liiv, H., Wyon, M., Jurimae, T., Purge, P., Saar, M., Maestu, J. and Jurima, J. (2013). Anthropometry and somatotypes of competitive dance sport participants: a comparison of three different styles. *Homo* 65(2), 155-160.
- Li-Tao, Y., Jian-Fei, Z., Ning, W., Hua, H., Zeng-Xian, L., You-Feng, W. and Huan-Jiu, X. (2015). Study on the adult physique with the Heath-Carter anthropometric somatotype in the Han of Xi'an, China; *Anatomical Science International*.
- Lu, P.W., Cowell, C.T. and Lloyd-Jones, S.A. (1996). Volumetric mineral density in normal subjects, aged 5-27 years. *The Journal of Clinical Endocrinology and Metabolism*, 81, 1586-1590.
- Makgae, P.J., Monyeki, K.D., Brits, S.J., Kemper, H.C.G., and Mashita, J. (2007). Somatotype and blood pressure of rural South African children aged 6–13 years: ellisras longitudinal growth and health study. *Annals of Human Biology*, 34(2), 240-251.
- Malina, R. M., Cumming, S. P., Kontos, A. P., Eisenmann, J. C., Ribeiro, B., and Aroso, J. (2005). Maturity-associated variation in sport-specific skills of youth soccer players aged 13–15 years. *Journal of sports sciences*, 23(5), 515-522.
- Malina, R.M. (1996). Regional body composition: age, sex and ethnic variation. In Roche AF, Heysnfield SB & Lohman TG (eds.). Human body composition. Champaign, IL: *Human Kinetics*.
- Malina, R.M., Bouchard, C. and Bar-Or, O. (2004). *Growth, Maturation and Physical Activity* (2Edition) Champaign, IL: Human Kinetics
- Malina, R.M., Cumming, S.P., Kontos, A.P., Eisenmann, J.C., Ribeiro, B. and Aroso, J. (2005). Maturity-associated variation in sport-specific skills of youth soccer players aged 13–15 years. *Journal of Sports Science* 23(1), 515–522
- Malina, R.M., Katzmarzyk, P.T., Song, T.M.K., Theriault, G. and Bouchard, C. (1997). Somatotype and cardiovascular risk factors in healthy adults. *American Journal of Human Biology*, 9(1), 11-19.
- Malina, R.M., Katzmarzyk, P.T., Song, T.M.K., Theriault, G. and Bouchard, C. (1997). Somatotype and cardiovascular risk factors in healthy adults. *Journal of Human Biology*, 9(1), 11-19.
- Marek, K. and Aneta, K. (2013). Determinants of intra-specific variation in basal metabolic rate. *Journal of Comparative Physiology, B*. 183(1), 27-41.
- Maynard, L.M., Guo., S.S. and Chumlea, W.C. (1998). Total-body and regional bone mineral content and areal bone mineral density in children aged 8–18 y: the Fels longitudinal study. *The American Journal of Clinical Nutrition*, 68, 1111-1117.

- Maynard, L.M., Wisemandle, W. and Roche, A.F. (2001). Childhood body composition in relation to body mass index. *Pediatrics*, 107, 344-350.
- Meunier, P., Aaron, J., Edouard, C., and Vignon, G. (1971). Osteoporosis and the replacement of cell populations of the marrow by adipose tissue. A quantitative study of 84 iliac bone biopsies. *Clinical Orthopaedic and Related Research*, 80, 147-154.
- Monyeki, K.D., de Ridder, J.H. and Pienaar, A.E. (1994). A morphological profile of 7 to 19 year old Northern Sotho boys and girls. In: L.O. Amusa (Ed.), *Proceedings of the 1st African Regional Conference on Physical Education, Recreation and Dance*, (pp. 205-272). Gaborone: AFAHPER-SD.
- Monyeki, K.D., Toriola, A.L., de Ridder, J.H., Kemper, H.C.G., Steyn, N.P., Nthangeni, M.E., Twisk, J.W.R. and Van Lenthe, F.J. (2002). Stability of somatotypes in 4 to 10 year-old rural South African girls. *Annals of Human Biology*, 29(1), 37-49.
- Moore, F.D., Olesen, K.H., McMurrey, J.D., Parker, H.V., Ball, R. and Boyden, C.M. (1963). *The body cell mass and its supporting environment: body composition in health and disease*. Philadelphia: Saunders.
- Morin, S.H., Lim, A.K., Cobbald, J.F. and Taylor-Robinson, S.D. (2007). Use of second generation contrastenhanced Ultrasound in the assessment of focal liver lesions. *World Journal of Gastroenterology*, 13, 596370.
- Mosteller, R.D. (1987). Simplified calculation of body surface area (letter). *New England Journal of Medicine*, 317, 1098.
- Neni, T.R. (2012). Relationship Between Somatotype and Blood Pressure Among 30 -70 Years Old Javanese People in Sleman, Yogyakarta Province, *Journal Kedokteran Yarsi*, 20 (3), 118-127.
- Nguyen, T.V., Maynard, L.M. and Towne, B. (2001). Sex differences in bone mass acquisition during growth: the Fels Longitudinal Study. *Journal of Clinical Densitometry*, 4, 147-157.
- Norgan, N.G. (1990). Body mass index and body energy stores in developing countries. *European Journal of Clinical Nutrition*, 44(1), 79-84.
- Ozener, B. and Duyar, I. (2008). The effect of labour on somatotype of males during the adolescent growth period. *Journal of Comparative Human Biology*, 59(2), 161-172.
- Parizkova, J., Adamec, A., Berdychova, J., Cermak, J., Horn, J. and Teply, Z. (1984). *Growth, Fitness and Nutrition in Pre-School Children*. Prague: Charles University.
- Parker, L., Reilly, J.J., Slater, C., Wells, J.C.K. and Pitsiladis, Y. (2003). Validity of six field and laboratory methods for measurement of body composition in boys. *Obesity Research*, 11, 852-858.

- Parnell, R.W. (1954). Somatotyping by physical anthropometry. *American Journal of Physical Anthropology*, 12(1), 209-239.
- Parnell, R.W. (1958). Behaviour and Physique. London: Edward Arnold Publishers Ltd.
- Pavlovsky, O., and Kobylansky, E. (1997). Population Biology of Human Aging. *Angelo Pontecoroboli Editore*, Publishing House, Firenze, Italy.
- Peeters, M.W., Thomis, M.A., Claessens, A.L., Loos, R.J.F., Maes, H.H.M., Lysens, R. and Beunen, G. (2003). Heritability of somatotype components from early adolescence into young adulthood: a multivariate analysis on a longitudinal twin study. *Annal Human Biology*, 30 (4), 402-418.
- Persson, A., Dahlstrom, N., Smedby, O. and Brismar, T.B. (2005). Volume rendering of three-dimensional drip infusion CT cholangiography in patients with suspected obstructive biliary disease: a retrospective study. *British Journal of Radiology*, 78, 1078-85.
- Pichard, C., Kyle, U.G. and Bracco, D. (2000). Reference values of fat-free and fat masses by bioelectrical impedance analysis in 3393 healthy subjects. *Nutrition*, 16, 245-254.
- Pierce, M.B. and Leon, D.A. (2005). Age at menarche and adult BMI in the Aberdeen children of the 1950s cohort study. *The American Journal of Clinical Nutrition*, 82, 733-739.
- Popescu, A & Sporea, I. (2010). Ultrasound examination of the normal gallbladder and biliary system. *Medical Ultrasonography*, 12(2), 150-152.
- Rabkin, S.W. (2007). Epicardial fat: properties, function and relationship to obesity. *Obesity Revised*, 8 (3), 253–261
- Raguso, C.A., Kyle, U., Kossovsky, M.P., Roynette, C., Paoloni-Giacobino, A., Hans, D., Genton, L., Pichard, C. (2006). A 3-year longitudinal study on body composition changes in the elderly: role of physical exercise. *Clinical Nutrition* 25(4), 573-580.
- Rahmawati, T.N., Hastuti, J. and Ashizawa, K. (2004). Growth and somatotype of urban and rural Javanese children in Yogyakarta and Bantul, *Indonesia. Anthropological Science*, 112(1), 99-108.
- Rajajeyakumar, M. (2015). Impact of somatotype on anthropometric measurements of body fat distribution in young adult population. *Journal of Obesity Weight Loss* S5 (i001).
- Rebato, E., Rosique, J. and Apraiz, A.G. (1996). Somatotypes of 14 to 19 year old urban boys and girls from Bilbao (Basque Country). *Anthropology Anz.*, 54(2), 135-147.
- Reis, V.M., Machado, J.V., Fortes, M.S., Fernandes, P.R., Silva, A.J., Dantas, P.S. and Filho, J.F. (2007). Evidence for higher heritability of somatotype compared to

- body mass index in female twins. *Journal of Physiological Anthropology* 26(1), 9-14.
- Rodriguez, G., Samper, M.P. and Olivares, J.L. (2005). Skin-fold measurements at birth: sex and anthropometric influence. *Archives of Disease in Childhood*, 90, F273–F275.
- Roemmich, J.N. and Rogel, A.D. (1995). Physiology of growth and development. Its relationship to performance in the young athletes. *Clinical Nutrition in Sports and Medicine*, 14(1), 483-502.
- Rolland-Cachera, M. F. (1995). Prediction of adult body composition from infant and child measurements. In P.S. Davis and T.J. Cole (Eds.), *Body composition techniques in health and disease* (pp 100-105). Cambridge: Cambridge University Press.
- Ruff, C. (2002). Variation in body size and shape. *Annual Review Anthropology*, 31(1), 211-232.
- Salusso-Deonier, C. J. (1982). A method for classifying adult female body form variation in relation to the U. S. standard for apparel sizing. *Unpublished doctoral dissertation*, University of Minnesota, Minnesota.
- Schoenau, E., Neu, C.M. and Rauch, F. (2001). The development of bone strength at the proximal radius during childhood and adolescence. *The Journal of Clinical Endocrinology and Metabolism* 6(1), 613-618.
- Schutz, Y., Kyle, U.U.G. and Pichard, C. (2002). Fat-free mass index and fat mass index percentiles in Caucasians aged 18 – 98 years. *International Journal of Obesity*, 26, 953-960.
- Seeman, E. (2001). Sexual dimorphism in skeletal size, density, and strength. *The Journal of Clinical Endocrinology and Metabolism*, 86, 4576-4584.
- Sheldon, W.H., Dupertius, C.W. and McDermott, E. (1954). *Atlas of Men*. New York Harper Bros.
- Sheldon, W.H., Stevens, S.S. and Tucker, W.B. (1940). *The Varieties of Human Physique*. New York Harper Bros.
- Sidebottom, A.C., Brown, J.E. and Jacobs, D.R. (2001). Pregnancy-related changes in body fat. *European Journal of Obstetrics, Gynecology, and Reproductive Biology*, 94, 216-22.
- Singh, A.P. and Singh, S.P. (2006). Somatotopic variations: an analysis of some traditional occupations. *Journal of Human Ecology*, 19(4), 249-251.
- Singh, L.D. (2011). Somatotypes of the affluent and non-affluent meitei boys of manipur, India. *Anthropologist*, 13(1), 9-16.

- Singh, S.P. (2007). Somatotype and disease- a review. *Anthropologist special*, 3(1), 251-256.
- Slaughter, M.H. & Christ, C.B. (1995). The role of body physique assessment in sports science. In: Davies PSW, Cole TJ, editors. *Body composition techniques in health and disease*. Cambridge: Cambridge University Press. pp 166-194.
- Slaughter, M.H. and Lohman, T. G. (1980). An objective method for measurement of musculo-skeletal size to characterize body physique with application to athletic population. *Medical Science Sports Exercise* 12(1), 170-174.
- Slaughter, M.H. and Lohman, T.G. (1976). Relationship of body composition to somatotype. *American Journal of Physical Anthropology* 44(1), 237-244.
- Slawik, M., and Vidal-Puig, A.J. (2006). Lipotoxicity, overnutrition and energy metabolism in aging. *Ageing Research Revised*, 5(2), 144-164.
- Slyper, A.H. (1998). Childhood obesity, adipose tissue distribution, and the pediatric practitioner. *Pediatrics*, 1998; 102: e4.
- Strickland, S.S. and Ulijaszek, S.J. (1994). Body mass index and illness in rural Sarawak. *European Journal of Clinical Nutrition*, 48(3), S98-S108.
- Tanner, J. M. (1952). The physique of students: An experiment at Oxford, *Lancet*, 2, 405-9.
- Tanner, J.M. (1964). The physique of the Olympic athlete. London: George Allen and Unwin
- Tanner, J.M., Israelson, W.J. & Whitehouse, R.H. (1960). Physique and body composition as factors affecting success in different athletic events. *Journal of Sports Medical Physical Fitness* 14(1), 397-411.
- Taylor, R.W., Jones, I.E. and Williams, S.M. (2002). Body fat percentages measured by dual energy x-ray absorptiometry corresponding to recently recommended body mass index cut-offs for overweight and obesity in children and adolescents aged 3–18 y. *The American Journal of Clinical Nutrition*, 76, 1416-1421.
- Toriola, A.L. and Igbokwe, N.U. (1985). Relationship between perceived physique and somatotype characteristics of 10 to 18 years old boys and girls. *Perceptual Motor Skills*, 60, 878.
- Van der Sluis, I.M., de Ridder, M.A. and Boot, A.M. (2002). Reference data for bone density and body composition measured with dual energy x-ray absorptiometry in white children and young adults. *Archives of Disease in Childhood*, 87, 341-347.
- Van, I.T.B., Yang, M.U., Heymsfield, S.B., Funk, R.C. and Boileau, R.A. (1990). Height normalized indices of the body's fat-free mass and fat mass: potentially useful indicators of nutritional status. *American Journal of Clinical Nutrition* 52(1), 953-959.

- Van-Itallie, T.B., Yang, M.U. and Heymsfield, S.B. (1990). Height-normalized indices of the body's fat-free mass and fat mass: potentially useful indicators of nutritional status. *The American Journal of Clinical Nutrition*, 52, 953-959.
- Ventrella, A.R., Semproli, S., Jurimae, J., Toselli, S., Claessens, A.L., Jurimae, T. and Brasili, P. (2008). Somatotype in 6-11-year-old Italian and Estonian schoolchildren. *Homo Journal of Comparative Human Biology*, 59(5), 383-396.
- Vice Chancellor Office, ABU-Zaria Nigeria (2013). The five years of Mahdi administration at Ahmadu Bello University. 1st Ed. Zaria (Nigeria); Ahmadu Bello University Press; 2004. P.74, 89-91, 206, 207.
- Visser, M., Pahor, M. and Tylavsky, F. (2003). One- and two-year change in body composition as measured by DXA in a population-based cohort of older men and women. *Journal of Applied Physiology*, 94, 2368-2374.
- Visser, M., Pahor, M., Tylavsky, F., Kritchevsky, S.B., Cauley, J.A., Newman, A.B., Blunt, B.A. and Harris, T.B. (2003). One- and two-year change in body composition as measured by DXA in a population-based cohort of older men and women. *Journal of Applied Physiology*, 94(6), 2368-2374.
- von Herbay, A., Vogt, C., Willers, R. and Haussinger, D. (2004). Real-time imaging with the sonographic contrast agent Sono Vue: differentiation between benign and malignant hepatic lesions. *Journal of Ultrasound Medicine*, 23, 1557-68.
- Wang, J., Thornton, J.C., Kolesnik, S. and Pierson, R.N. (2000). Anthropometry in body composition. An overview. *Annals New York Academic Science*, 904, 317-326.
- Warntjes, J.B., Dahlqvist, O., Lundberg, P. (2007). Novel method for rapid, simultaneous T1, T2*, and proton density quantification. *Magnetic Resonance Medicine*, 57, 528-37.
- Warntjes, J.B., Leinhard, O.D., West, J. and Lundberg, P. (2008). Rapid magnetic resonance quantification on the brain: Optimization for clinical usage. *Magnetic Resonance Medicine*, 60, 320-9.
- Wells, J.C.K. (2000). A Hattori chart analysis of body mass index in infants and children. *International Journal of Obesity*, 24, 325-329.
- Wells, J.C.K. (2006). The evolution of human fatness and susceptibility to obesity: an ethological approach. *Biological Reviews*, 81(1), 183-205.
- Wells, J.C.K. (2006). The evolution of human fatness and susceptibility to obesity: an ethological approach. *Biological Reviews*, 81, 183-205.
- Wells, J.C.K. and Cole, T.J. (2002). ALSPAC study team. Adjustment of fat-free mass and fat mass for height in children aged 8 years. *International Journal of Obesity*, 26, 947-952.
- Wells, J.C.K., Fuller, N.J., Dewit, O., Fewtrell, M.S., Elia, M. and Cole, T.J. (1999). Four-component model of body composition in children: density and hydration of

- fat-free mass and comparison with simpler models. *American Journal of Clinical Nutrition*, 69, 904-912.
- William, S.R., Goodfellow, J., Davies, B., Bell, W., McDowell, I. and Jones, E. (2000). Somatotype and angio-graphically determined atherosclerotic coronary artery disease in men. *American Journal of Human Biology*, 12, 128-138.
- Williams, S.R.P., Goodfellow, J., Davies, B., Bell, W., McDowell, I. and Jones, E. (2000). . Somatotype and angiographically determined atherosclerotic coronary artery disease in men. *American Journal of Human Biology*, 12(1), 128-138.
- Wilmore, J.H. (1970). Validation of the first and second components of the Heath-Carter modified somatotype method. *American Journal of Physical Anthropology*, 32, 369±372.
- Yang, L.-T., Wang, N., Li, Z.-X., Liu, C., He, X., Zhang, J.-F., . . . Xi, H.-J. (2015). Study on the adult physique with the Heath-Carter anthropometric somatotype in the Han of Xi'an, China. *Anatomical science international*, 91(2), 180-187.
- Zamboni, M., Zoico, E., Scartezzini, T., Mazzali, G., Tosoni, P., Zivelonghi, A. and Bosello, O. (2003). Body composition changes in stable-weight elderly subjects: the effect of sex. *Aging Clinical Experimental Research*, 15(4), 321-327.
- Zmeev, S.A. (2010). Assessment of the relationship in dimensions and shape of the thyroid gland and somatotype, *Volgograd*, pp. 249-252.
- Zorka, D. and Dragan, A. (2013). Somatotype and Cardiometabolic Profile in Norman Weight and Obese Women. IMSCNS. 8th *International Medical Students Congress Novi Sad*, 1(8), 28.

APPENDIX

DEPARTMENT OF HUMAN ANATOMY

FACULTY OF MEDICINE

AHMADU BELLO UNIVERSITY, ZARIA

Dear Mr/Miss,

LETTER OF INTRODUCTION

I am Musa MUSTAPHA, an MSc student in the Department of Human Anatomy of the institution mentioned earlier. I am carrying out a research on the ***"Relationship between Somatotypes and Hepatobiliary Dimensions, Body Composition, and some Anthropometric Variables of Students in Ahmadu Bello University, Zaria"***.

Participation is voluntary and it involves the collection of certain information about your Bio-data, medical history, measurements of some anthropometric parameters and ultrasound of the liver, caudate lobe, gall bladder, and common bile duct.

The information collected from you will be used strictly to achieve the objectives of this study and for scientific publication. I assure you that this study has been reviewed and approved by my supervisors and the University Committee on Research Ethics.

Thank you for your understanding.

Yours sincerely,

Musa MUSTAPHA

APPENDIX I



HEALTH RESEARCH ETHICS COMMITTEE

AHMADU BELLO UNIVERSITY TEACHING HOSPITAL

SHIKA - ZARIA, NIGERIA.

E-mail: abuthshika@yahoo.com

website: www.abuth.org

Chairman of Board: Chief. Shuaib Oyedokun Afolabi Fnil

Chief Medical Director: Prof. Lawal Khalid, MBBS, FMCS, FWACS, FRCS(ED) mni

Chairman, Medical Advisory Committee: Prof. Abdullahi Mohammed, MBBS, FWACP, FICS

Director of Administration: Barr. Ishak Bello, LL.B, BL., LL.M, PGDM, AHAN, FCAI

ABUTH/HREC/TRG /36

Our Ref: _____

Date: 13th Aug, 2015

Your Ref: _____

ABUTH HREC FULL ETHICAL CLEARANCE CERTIFICATE

Relationship between Somatotype and Ultrasonographic Hepatobilliary Dimensions of Healthy Adults of Ahmadu Bello University Zaria, Nigeria.

ABUTH Ethics Committee assigned number: - ABUTHZ/HREC/P15/2015

Name of the principal Investigator: - Dr. Musa Mustapha

Address of the Principal Investigator: - Dept. of Human Anatomy,
ABU Zaria

Date of receipt of valid application: - 20/5/ 2015

Date of meeting when final determination

on ethical approval was made: - 4th & 5th August, 2015

This is to inform you that the research described in the submitted protocol, the consent forms and other participant information materials have been reviewed and *given full approval by the Health Research Ethics Committee.*

Please note: this approval dates from 14th August, 2015 -14th August, 2016

No participant recruitment into this research may be conducted outside these dates.

All informed consent forms in this study must carry the ABUTH HREC number assigned to this research and the duration of ABUTH HREC approval of the study.

This HREC expects that you submit your application as well as an annual report for ethical clearance renewal 3 months prior to expiration of study dates. This is to enable you obtain renewal of your approval and avoid interruption of your research.

If there is delay in starting the research, please inform the ABUTH HREC so that starting dates can be adjusted accordingly.

No changes are permitted in the research without prior approval by ABUTH HREC, except in circumstances outlined in national code for Health Research Ethics: <http://www.nhrec.net>.

ABUTH HREC reserves the right to conduct compliance assessment visits to your research site without prior notification.


Prof. A. I. Mamman MBBS, FMCPath
Chairman, ABUTH HREC

APPENDIX II

CONSENT FORM

1 Consent to participate in research

Relationship between Somatotypes and Hepatobiliary Dimensions, Body Composition, and some Anthropometric Variables of Students in Ahmadu Bello University, Zaria

You are kindly being asked to participate in a research study conducted by Musa Mustapha for a Master of Science degree under the supervision of Dr. A.A. Adamu, and Dr. W.O. Hamman from the Department of Human Anatomy, Faculty of Medicine, Ahmadu Bello University, Zaria.

If you have any questions or concerns about the research, please feel free to contact: Musa Mustapha, Faculty of Medicine, Tel: 08039297156.

2 Purpose of the study

The purpose of this preliminary study is primarily to establish a relationship of Dominant Somatotypes of Medical Students of Ahmadu Bello University Zaria with Hepatobiliary Dimensions, Body Composition, and other Anthropometric Variables.

This study is a partial requirement for the award of the MSc degree in the Department of Human Anatomy in Ahmadu Bello University, Zaria.

3 Procedure

The data collection will involve collecting information with regards to bio data and social and medical history. This can be achieved in less than two minutes.

In the second phase of the study, the anthropometric measurements will be carried out, somatotype and body composition will be computed and finally ultrasound of the Hepatobiliary will be done.

4 Potential risks and discomfort

There is no associated risk of this procedure, and only discomfort will be the time you will sacrifice while the measurement is being taken.

5 Potential benefits to participants

This research may be of potential benefit to the participant and/or society in the following ways;

- i. The participant may have an opportunity to come in contact with the equipment used in the study as well as gaining knowledge about the names and uses of such equipment.
- ii. The research will provide a database of the normal radiologic anatomic size of organs in a representative population.
- iii. Finding from the study will serve as a baseline for clinical decision making, especially in general medicine where body build has been found to have relations with some disease conditions.
- iv. Identification of adult disease risk factors in these age groups may improve prognosis as a result of the institution of early intervention measures which may be useful for insurance and other policy makers.

6 Payment for participation

Incentives and refreshment will be offered to the participant after participation.

7 Confidentiality

Every effort will be made to ensure confidentiality of any identifying information provided by participants in this study. You will be identified in any reports or publications resulting from the study.

8 Participation and Withdrawal

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may exercise the option of removing your data from the study. You may also refuse to answer any questions you do not want to answer and remain in the study. The researcher may withdraw you from this research if circumstances arise that warrant doing so.

9 Rights of research participants

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research. This study has been reviewed and received ethical clearance from Ahmadu Bello University Research Ethics Board. If you have any questions regarding your rights as a research participant, contact Committee on Ethics; Ahmadu Bello University Hospital, Shika-Zaria. Tel;

10 Signature of research participant/legal representative

I have read the information provided for the study titled **“Relationship between Somatotypes and Hepatobiliary Dimensions, Body Composition, and some Anthropometric Variables of Students in Ahmadu Bello University, Zaria”** as

described within. My question has been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Name of Participant

Signature of Participant

Date

11 Signature of witness

Name of Witness

Signature of Witness

Date

PROFORMA FOR THE STUDY

TITLE: Relationship between Somatotypes and Hepatobiliary Dimensions, Body Composition, and some Anthropometric Variables of Students in Ahmadu Bello University, Zaria

BIODATA

1. Research ID:
2. Sex:
3. Age:

SOCIAL HISTORY

1. Do you consume alcoholic beverages? Yes [] No []
2. If yes, what is the quantity and for how long?
.....
3. Do you smoke cigarettes? Yes [] No []
4. If yes, how many sticks per day and for how long?
5. Do you have any history of yellow discoloration of the eye: Yes [] No []
6. If yes, did you seek medical attention?
7. Have you ever been diagnosed with hepatitis? Yes [] No []
8. If yes, are you on treatment? Yes [] No []

ANTHROPOMETRY

1. Weight (Kg).....
2. Height (cm).....
3. Biepicondylar breadth of humerus (cm):
4. Biepicondylar breadth of femur (cm):
5. Upper arm girth (cm):
6. Calf Girth (cm).....
7. Triceps skinfold (mm):
8. Bicep skin fold (mm):
9. Subscapular skinfold (mm):
10. Supraspinale skinfold (mm):.....
11. Medial calf skinfold (mm):.....

PHYSIOLOGICAL PARAMETERS

- Blood pressure
 - ✓ Systolic blood pressure:
 - ✓ Diastolic blood pressure

ULTRASONOGRAPHIC DIMENSION

1. Liver length in the mid-clavicular line (cm).....
2. Caudate lobe cranio-caudal length (cm).....
3. Caudate lobe anterior posterior diameter (cm).....
4. Gall bladder cranio-caudal length (cm):
5. Gall bladder anterior posterior diameter (cm).....
6. Common bile duct size (cm):

Definition of Terms

- i. Dominant somatotype: defined as a somatotype component rating at least 0.5 points higher than either of the other two component ratings.
- ii. Subscapular skinfold: The thickness of a skin fold with subcutaneous fat tissue just below the inferior angle of the scapula.
- iii. Suprailiac skinfold: The thickness of a skin fold with subcutaneous fat tissue above the anterior superior iliac spine.
- iv. Triceps skinfold: The thickness of a skin fold with subcutaneous fat tissue of the arm over the triceps brachii muscle.
- v. Biceps skinfold: The thickness of a skinfold with subcutaneous fat tissue over the biceps brachii muscle.
- vi. Medial calf skinfold: The thickness of a skin fold with subcutaneous fat tissue on the medial side of the leg.
- vii. Calf girth: The horizontal measurement at the greatest circumference of the calf.
- viii. Upper arm girth, contracted: The measurement at the greatest girth of the upper arm taken in contracted biceps brachii muscle.
- ix. Biepicondylar breadth of the humerus: The greatest distance between the medial and lateral epicondyles of the humerus.
- x. Biepicondylar breadth of the femur: The greatest distance between the medial and lateral epicondyles of the femur.
- xi. Balanced ectomorph: endomorphy and mesomorphy do not differ by more than one-half unit (or equal) and ectomorphy is dominant.
- xii. Balanced endomorph: endomorphy is dominant and mesomorphy and ectomorphy are equal (or do not differ by more than one-half unit).

- xiii. Balanced mesomorph: endomorphy and ectomorphy do not differ by more than one-half unit (or equal) and mesomorphy is dominant
- xiv. Central: no component differs by more than one unit from the other two.
- xv. Ectomorphic endomorph: endomorphy is dominant and ectomorphy is greater than mesomorphy.
- xvi. Ectomorphic mesomorph: ectomorphy is greater than endomorphy and mesomorphy is dominant.
- xvii. Endomorph-ectomorph: endomorphy and ectomorphy do not differ by more than one-half unit (or equal) and mesomorphy is lower.
- xviii. Endomorphic ectomorph: endomorphy is greater than mesomorphy and ectomorphy is dominant.
- xix. Endomorphic mesomorph: endomorphy is greater than ectomorphy and mesomorphy is dominant.
- xx. Mesomorph-ectomorph: mesomorphy and ectomorphy do not differ by more than one-half unit (or equal) and endomorphy is smaller.
- xxi. Mesomorph-endomorph: endomorphy and mesomorphy do not differ by more than one half unit (or equal) and ectomorphy is smaller.
- xxii. Mesomorphic ectomorph: mesomorphy is greater than endomorphy and ectomorphy is dominant.
- xxiii. Mesomorphic endomorph: mesomorphy is greater than ectomorphy and endomorphy is dominant.