UNIT 10  HUMAN BODY COMPOSITION

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Learning Objectives

After going through this unit you will:

- understand about body composition and different factors affecting it;
- know the levels of body composition;
- comprehend the human body composition in relation to anthropometry;
- know the application and anthropometric significance of body composition;
- find out the methodology of human body composition following the standard protocol; and
- get the basic knowledge of human body composition and ethnic specificity and disease association.

10.0  INTRODUCTION

Human body composition and other somatic characteristics are known to be influenced by a variety of environmental agents and the lifestyle of the individual. Human body composition and physique phenotypes are complex multifactorial traits that cannot readily be reduced to simple Mendelian phenotypes and inheritance. These traits have evolved under the interactive influence of dozens of factors from the social, behavioral, physiological, metabolic, cellular and molecular domain (Chatterjee, 2006; 2009).

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10.1 BODY COMPOSITION -

As we all are aware, four main components, water, protein, fat and minerals are used to build the body. There are two models that describe fat theory of body composition:

- one is body with fat component and
- another is fat free component.

Again, fats are mainly of two types: one is stored fat and the other is essential fat. The essential fats are present in the important organs of the body like in bone marrow, heart, lungs, kidney, spleen, central nervous system, lipid rich tissues etc. The stored fat is only present in the adipose tissues of the body, from where energy is depleted in need. Amongst these two fats, essential fat is necessary to live life normally. An interesting finding that in women, essential fat percentage is higher than men due to the hormonal changes that take place throughout the life. Storage fat is also present as internal storage fats in internal organ of the body and also as subcutaneous fat under the skin. Subcutaneous fat works as an insulator of the body and helps in maintaining body temperature. In the life cycle of an individual, the relationship of their subcutaneous fat and internal fat may not be the same. At this point it would interest you to know that there is also a term lean body mass found in body composition; it represents the weight of the muscles, bones, ligaments, internal organ etc. As the name reflects, this lean body mass is totally fat free and have small percentage of essential fats.

**History of Body Composition study in Global Perspectives**

Here we can understand about the different types of body composition in different racial groups, viz., Caucasoid, Negroid and Mongoloid. Body composition depends on various factors like, heredity environment and nutrition. Looking at the world scenario in this aspect, we find that people who live in different continents of different geographical regions and climates exhibit varieties of body composition both among males and females (Haroun et al, 2016). For example, among Caucasoid groups who are mainly distributed in temperate zones, have medium to fat body build, lesser subcutaneous fat, tall stature, straight and narrow nose. Such characteristics are necessary to withstand the cold temperature. The Negroids have medium build, i.e., athletic type of physique, flat noses and variation in stature. The Mongoloids have short stature, medium nose, short stature, lean and medium build. We find some variation in the females of these racial groups. The physiological aspects too slightly differ in these groups. Body composition is sometimes in conformity with the climatic zones where they live (Chatterjee, 2014). Due to these physiological and different body compositions individuals comprising of these groups respond to extreme climatic conditions like cold and heat prevailing in arctic and desert conditions (Bhatt et al, 2014). The role of natural selection and its control on these populations cannot be ruled out. Hence, there is a relationship between, physiology, body composition and ecological conditions. Such factor is evident, at a glance made on the males and females, belonging to different racial and ethnic groups distributed in varieties of eco-niches in the world. North American Indians were particularly inclined to a centripetal distribution of fat (Pandit et al 2010). The trunk and upper body are much higher in Tokelau islander who had migrated to New Zealand than in non-migrants. Asians in U.S have a higher body fat percentage, a prominent abdominal obesity, a higher intraunion cellular lipid and/or a higher liver fat content compared to Caucasians. Prepubertal children in U.S have demonstrated that: 1) sex
differences in body fat distribution are present in prepubertal children but that the specific characteristics for Asians differ from African-Americans and Caucasians, and 2) differences in body fat distribution in Asian children, compared with African Americans and Caucasians, are present but vary by sex (Chatterjee, 2014; Bhatt et al, 2005). This comparison of African American, Asian, and Caucasian prepubertal children advocates phenotypic differences. There exist biological differences in the body composition of Blacks and Whites. Black Americans have a high occurrence of obesity-related diseases than the Whites. In general, Blacks have a greater bone mineral density and body protein content than do Whites, ensuing in a greater fat-free body density. Additionally, there are racial (Misra et al, 2004; Yajnik et al, 2003) differences in the distribution of subcutaneous fat and the length of the limbs relative to the trunk. 52% of Black women are overweight according to the third National Health and Nutrition Examination Survey (NHANES III). Blacks are inclined to have less subcutaneous fat in the extremities than in the trunk relative to the fat deposition patterning of Whites. Whites have larger amounts of subcutaneous fat on the front of their bodies while the Blacks tend to carry relatively more fat on the back and lateral portions of their bodies. (Kapoor et al, 2018)

**History of Body Composition study in Indian Perspectives**

The terms body structure and composition are separated for pedagogical reasons, which otherwise are both closely inter-related (Kshatriya et al, 2016, 2021). This is because the development of the three components in the body, i.e., muscles, bone and fat, is reflected in the physique or physical characteristics, or in other words, the structure of an individual. It is this concept of the human development that is related to our body function. It is said that different types of human body have presumably different advantages in different circumstances and at different times (Tyagi et al, 2005). The process of natural selection may favour first one build and then another. There is evidence for example, that the long, thin build of Nilotic Negro has arisen through the very definite advantage such a build, confers in maintaining physiological function in hot environment. The mean body-weight of populations in hot regions is demonstrably lower (in all continents) than that in temperate and cooler climates (Chatterjee et al, 2014). The ratio of sitting height to total height becomes less, as mean temperature increases geographically, i.e., lower limbs tend to be longer in hotter climates (Chatterjee, 2014). The tendency towards attenuation of limbs in hotter climate is seen also in upper limbs, since the ratio of span to height is greater. The dimensions of the trunk also become less in hotter climates. Further Khonsdier (2007) has shown that the body weight/surface area ratio declines from temperate to hotter climates. However, it should be noted that the correlation between body shape and mean temperature account for about 50 or 60 per cent of the total inter-population variance; clearly other factors, particularly population movements (Ghosh et al, 2020), also influence the variation in physique and body composition (Sarkar et al, 2016). Much of the diversity of human form mirrors not overall differences of body composition, but rather inter-individual differences in the regional distribution of fat, muscle and bone. Inter-individual differences in the regional distribution of body fat are viewed to both the relative proportions of deep and superficial fat, and variations in the distribution of subcutaneous fat over the body surface (Kanrar et al, 2021). A centralized or centripetal pattern of fat deposition can be differentiated from a peripheral accumulation of fat. Alternatively, soft-tissue radiographs suggest that within any given individual
there is a close relationship between the accumulation of fat in the upper and the lower limbs. Some of the inter-individual differences in the patterning of superficial fat have a recognizable relationship to the sex of the individual, chiefly the deposits of fat found in and around the breast of the mature female, which apparently constitute an essential reserve of nutrients.

### 10.2 FACTORS AFFECTING BODY COMPOSITION

Body composition is dependent on many factors like age, sex, genes, hormones and so many more.

Let’s go through them briefly:

*Age:* People have a particular weight gaining and weight loss tendency in their total life span, like during aging weight loss happen due to slower metabolism.

*Sex:* Sex is also a factor in weight deposition in body, like women have more tendency to accumulate fat than men due to pregnancy cycle.

*Genes:* Genes that we have from our heredity play an immense role in our body type that a person can be lean or retain fat and which part of his body it will store.

*Hormones:* These can influence water retention and body composition (WHO, 1995).

### 10.3 LEVELS OF BODY COMPOSITION

Body composition can be assessed by in five levels i.e. Atomic, Molecular, Cellular, Tissue, and Whole Body Level. This is known as Five componential model.

- **a)** Atomic Level – Chemical analysis shows six elements like oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus are major elements of human body. The modern in vivo neutron activation analysis (IVNAA) may be the most accurate method to assess atomic level body composition.

- **b)** Molecular Level – Considering molecular level – water, lipids, fats, proteins, minerals, and carbohydrates are most important molecules for body composition. Water is one of the major component of body composition, and it is of two types, i.e. intra cellular and extra cellular. Lipid is one of the most important molecule for body composition. It is also of two types i.e. Phospholipids or essential lipids and Triglyceride or non-essential lipids. It stores energy in the body. Apart from all these Protein, Minerals, and Carbohydrates are most important molecule for body structure followed by body composition.

- **c)** Cellular Level – The materials of different categories are differentiated by intracellular and extracellular. Different types of cells and cellular materials are responsible for body composition i.e. muscle, adipose tissue, blood, bone, skin, liver, and others.

- **d)** Tissue Level – Tissue are of different types. i.e. muscular tissue, connective tissue, epithelial tissue, nervous tissue, etc. Body weight depends on different types of materials as follows-
10.4 MODELS OF BODY COMPOSITION

a) One Compartment model - The use of models in the assessment of body composition allows for the indirect assessment of compartments in the body. Typically, a compartment is homogenous in composition (for example, fat), however, the simpler the model the greater the assumptions made and the greater the likelihood of error.

b) Two Compartment Model - The basic two-compartment (2C) model is derived from measuring the density of FFM by hydrodensitometry and subtracting FFM from total body weight thereby deriving fat mass (body weight” FFM=fat mass).

c) Three Compartment Model - A three-compartment (3C) model consists of fat, fat-free solids, and water. The water content of FFM is assumed to be between 70% and 76% for most species and results from cross-sectional studies in adult humans show no evidence of differences in the hydration of FFM with age. The fat-free solids component of FFM refers to minerals (including bone) and proteins.

d) Four Compartment Model - A four-compartment (4C) model involves the measurement of body density (for fat), total body water, bone mineral content by DXA, and residual (residual=body weight (fat+water+bone)). This model allows for the assessment of several assumptions that are central to the 2C model. The 4C approach is frequently used as the criterion method against which new body composition methods are compared in both children and adults.

e) Five Compartment Model - At the organizational level, a five-level model was developed where the body can be characterized at five levels. The following are the levels and their constituents: atomic=oxygen, carbon, hydrogen, and other (level 1); molecular=water, lipid, protein, and other (level 2); cellular=cell mass, extracellular fluid, and extracellular solids (level 3); tissue-system level=skeletal muscle, adipose tissue, bone, blood, and other (level 4); whole body (level 5).

Check Your Progress 1

1) What is Body Composition?

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2) What are the factors responsible for body composition?

3) What are the different levels of body composition?

4) What are the componential models of body composition?

10.5 ASSESSMENT OF BODY COMPOSITION

The assessment of body composition and of somatic protein stores involves the measurement of different body compartments (water, fat, bone, muscle, and visceral organs). The fat-free mass (mainly composed of muscle) comprises the majority of the somatic protein mass. Generally, somatic protein stores are preserved at the expense of other body fuel sources, especially fat. However, when catabolic illnesses occur there will be fat-free mass depletion. Therefore, body composition techniques are important tools to diagnose protein depletion and to monitor efficacy of nutritional therapies. Simple anthropometric measures are practically useful whereas bioelectrical impedance analysis and dual-energy x-ray absorptiometry are more applicable for research purposes.

10.5.1 Anthropometric Method

Anthropometry is the means of quantifying variation in body size and shape and universally accepted and applicable in health sciences. Since the last two decades the scientific technique of anthropometry has emerged as an important method for population study in biomedical research. Now a days we have several new techniques available, but anthropometry still is non-invasive and less costly and its availability is abundance to detect the size, composition and proportion of the human body.
Human Body Composition

It is one of the most fundamental practical techniques of human biology, since nearly all biological functions are in some way related to one or other aspect of the physical dimension of the body. Anthropometric techniques include measures of skinfold thickness, circumferences, and other somatic measurements to assess component mass and have been the subject matter of human body composition. Populations can be differentiated on the basis of BMI and body fat percentage relationship and somatotype. It reveals that although studies on relationship of overall adiposity, body fat distribution and body composition have been undertaken by several scholars from India but further work needs to be done considering the vast ethnic heterogeneity of Indian populations (Chatterjee, 2013; Beck, 2002; Vellas, 1999).

Anthropometric measurements with the standard instruments by standard methods maintaining protocol, such as for height, weight, sitting height, circumference measurements and skinfold measurements and the physiological variables readings taken with due precautions and standard procedure is recommended. Some derived variables i.e. BMI, sub-ischial height, arm fat, circumference, fat mass, fat free mass, fat mass index, are also considered (Ghosh and Chatterjee, 2006).

Let us try to understand briefly some of the anthropometric variables:

**Body weight** - Body weight of the individual is directly recorded into Kg. with the help of weighing machine.

**Stature** - It is the distance between vertex to floor using anthropometer.

**Sitting height** - The straight distance from sitting plane to vertex by anthropometer.

**Skin fold thickness** - Skinfold technique is a useful process to determine subcutaneous fat (fat just underneath our skin) from specific area of the body. The skinfold is picked up between thumb and forefinger and the jaws of skinfold calliper is applied exactly at the point marked. It’s very economical and can be done easily in fields. Ideally, the sum of three area’s skinfold is required and then the density of fat in the body can be estimated.

- **Biceps skin fold** - The skin fold is picked up on the front of the arm, directly above the centre of the cubital fossa.
- **Medial calf skin fold** - The skin fold is picked up at the level of the maximal circumference of the calf on the medial border of the leg.

**Circumference**: These are girth measurement taken around specified points. The most commonly used circumferences are:

- **Mid upper arm circumference** - The circumference is taken horizontally at the mid of upper arm using flexible steel tape.

- **Abdominal Circumference** - The subject stands with the arms by the sides and the feet together. The tape is placed around the subject at the level of the greatest anterior extension of the abdomen in a horizontal plane, the measurement should be taken horizontally from the plane through the umbilicus’s centre.

- **Hip Circumference** - The subject should stand erect in anatomical position. The measurer should stand erect at the side of the subject so that the buttock region of the subject could be seen properly.
**Body Composition, Human Physique and Somatotyping**

**Thigh Circumference** - Measurement of the proximal and distal thigh circumferences is done by measuring tape.

**Calf Circumference** - The measurements are taken horizontally around the calf and moved up and down to locate the maximum circumference in a plane perpendicular to the long axis of the calf.

Two adiposity indices, BMI (overall adiposity) and WHR (central adiposity) are used and calculated by the following equation:

- BMI = Weight (kg) / Height (m)².
- WHR = Waist circumference (cm) / Hip circumference (cm).
- WSR = Waist circumference (cm) / Stature (cm).

**Percentage of body fat** - Body fat percentage refers to the percentage of the body fat mass (the weight of the fat) in relation to body weight. Body fat percentage and body fat mass are determined by the following calculations:

\[
\text{Body fat percentage} \% = \left( \frac{\text{Body fat mass} \text{ (Kg)}}{\text{Body weight} \text{ (Kg)}} \right) \times 100
\]

10.5.2 **Bioelectrical Impendence Analysis**

Bioelectrical Impedance Analysis (BIA) describes intracellular and extracellular fluid of the body works as an electoral conductor. This technique is used to detect the total body water except the fat mass; it can be measured by machine. The current flows through the human body in the path of biological tissues with least resistance power, these biological tissues act as the insulators or conductor. The frequency helps in measuring this BIA, in low frequency near about 50 kHz extra cellular water (ECW) can detect and in high frequency near about 500–800 kHz intra cellular water (ICW) can be detected (Lukaski, 1987). TBW and FFM (Schoeller, 2005), are correlated with ECW, this made using this method usually use to estimate TBW and FFM. Body image is now being explored in relation to obesity, eating behaviours, body composition, and physical activity. According to American Council of Exercise (ACE) the cut-offs are as following for healthy body composition (Chatterjee, 2013; Lohman, 1988; Nygard)

<table>
<thead>
<tr>
<th>Type</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Essential Fat</td>
<td>10% to 13%</td>
<td>2% to 5%</td>
</tr>
<tr>
<td>Athletes</td>
<td>14% to 20%</td>
<td>6% to 13%</td>
</tr>
<tr>
<td>Moderate Fitness</td>
<td>21% to 24%</td>
<td>14% to 17%</td>
</tr>
<tr>
<td>Acceptable</td>
<td>25% to 31%</td>
<td>18% to 24%</td>
</tr>
<tr>
<td>Obese</td>
<td>over 32%</td>
<td>over 25%</td>
</tr>
</tbody>
</table>

*Source: ACE quoto by Chatterjee 2013, Lohman 1988*

The above table indicates cut-off of essential fat in both sexes, that athletes have less body fat in body but contain more lean mass for gaining muscle in body. The extremely low body fat in body may harm in athletes also and it may cause
severe illness, in these issue female athletes suffers more. In the obesity management reduction of body weight does not mean drastic reduction of weight; it mean slow reduction of non-essential fat in body and increase of lean mass in body through exercise (Nygaard, 2008).

### 10.5.3 Other Important Methods for Assessing Body Composition

The following methods are invasive and direct method for assessing the body composition. All the following methods needs a lab setup or institutional setup, so it is very difficult use in ideal field situation as non-invasive method.

**DEXA (Dual Energy X-Ray Absorptiometry) Scan** – DEXA scan actually perform in medical practices to check the bone density. It’s actually a dual energy X-ray that absorption detect the density of the bone. Dual energy X-ray absorptiometry (DXA) was developed to measure bone mineral mass, which is calculated from the differential absorption of X rays of two different energies. Because this calculation requires allowance for (and hence quantification of) overlying soft tissue, values of fat and FFM are also calculated for whole body scans, using instrument specific algorithms.

**Hydrostatic Weighing**– This method helps in understanding the weight of body submerged in water.

**Body Density**– Body Density can give the most accurate calculation of body composition. Determining body composition there is a model, Four Compartment Model. In this model the detection of body density is important. Overall density of the body can be proportional to the composed density of each compartment.

**Body Volume Indicator**– The Body Volume Indicator (BVI) is a method that used to measure the body shape of individual. This BVI technique does light scanning to measure the shape of the person. Now 3D technique develops to make this measurement more accurate.

**Corpulence Index (CI) Or Ponderal Index (PI)**– It is a measurement of leanness of a person and this leanness has relation with height. It’s also correlating the BMI and cholesterol percentage of the body, that determines the rate of mortality.

**Densitometry**– This approach distinguishes FM and FFM, assuming specific densities of these two tissues, and therefore requires measurement of total body density (body mass/body volume). While the density of fat is indeed relatively constant, that of FFM varies according to its composition. This variability is partly explained by the process of chemical maturation that occurs before adulthood, but interindividual variability is also significant, even in healthy children.

**Isotope Dilution (Hydrometry)**– Deuterium dilution can be used to measure TBW, allowing estimation of FFM. Samples are generally analysed by isotope ratio mass spectrometry; however, clinical services could be based as substantially cheaper but more labour intensive spectrophotometric technique.

**Computerized Axial Tomography (CAT)**: Computed Tomography (CT) (Computerized Axial Tomography (CAT)) is a radiologic imaging modality that uses computer processing to generate an image (CAT scan) of the tissue density in a "slice" as thin as 1 to 10 mm in thickness through the patient’s body.
These images are spaced at intervals of 0.5 to 1 cm. Cross-sectional anatomy can be reconstructed in several planes without exposing the patient to additional radiation.

- **Magnetic Resonance Imaging (MRI):** MRI is an imaging technique that estimates the volume rather than the mass of adipose tissue. By analysing the absorption and emission of energy in the radio frequency range of the electromagnetic spectrum, the technique produces images based on spatial variations in the phase and frequency of the energy absorbed and emitted. It primarily addresses hydrogen nuclei, located either in water or fat, and uses these data to discern tissue types in “imaging slices” which can then be summed to calculate regional tissue volumes.

**Check Your Progress 2**

5) What are the different methods for assessing body composition?

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**10.6 APPLICATION OF BODY COMPOSITION STUDY**

Nutritional status is measured comparing with the cut-off value recommended by World Health Organization (1995) and classified into three categories: underweight (> 18.50), normal (18.50 – 25.00) and overweight (< 25.00) (Ghosh, 2006; Kwok, 1991).

Nowadays obesity is a global epidemic and associated with other communicable diseases and becomes the cause of mortality and morbidity. Body Mass Index (BMI) is mainly used to detect the obesity level in human, however, BMI cannot differentiate the fat and lean mass in body composition and an increasing number of studies are reporting that the relationship between BMI and %BF is different among different populations.

Furthermore, to evaluate the nutritional and health status of the body is best to perform body composition assessment. To detect obesity, the most useful anthropometric parameters are waist-to-hip ratio (WHR), waist circumference (WC) and waist-to-stature ratio (WSR), these are better than only estimating the BMI. Still in Indonesia, the anthropometric assessments and body composition measurement and their association benefits are very limited. This may happen due to less field base works in this population (Chatterjee, 2013; Leslie, 2006; WHO, 1995). Most of the studies suggested the beneficiary points of prediction the equations from the anthropometric measures and the bioelectrical impedance analysis (BIA) to give elaborated assessment of body composition. Body composition and fat distribution differs with gender, with men having less body fat but a relatively greater central distribution of fat. The differences start early in life and become more apparent in puberty due to changes in sex hormone
levels (Stevens et al., 2010). Relationship between body composition and obesity also varies between race and ethnicity.

10.7 ANTHROPOLOGICAL SIGNIFICANCE OF BODY COMPOSITION STUDY

Health policy of a nation is very much important to avoid the health hazards of the people of the nation. There is correct dosage of medicine for treating an illness, but there is a correct dosage of health consciousness and health perception for promoting health benefits. Contemporary medical technology is developed to a great extent and increase the life expectancy of the people. Now medical technology developed largely and increases the life expectancy of the people by introducing lifesaving drugs and modern gadgets, the problem lies in the child health remain the same. Human Body composition in terms of obesity is well recognized in human variation study. Population specific body composition is now the cutting-edge research in the world. Different anthropometric measurements and other methods are used for assessing the human body composition and ethnic specificity and disease association.

Obesity leads the non-comunicable disease, and anthropometry and body composition is very much ethnic specific in nature. Non-communicable disease like Cardiovascular Disease (CVD), Hypertension, Type 2 Diabetes are very much associated with body composition and ethnic specific in nature.

Check Your Progress 3

6) What are the applications of body composition study?

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7) What is the Anthropological significance of body composition study?

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10.8 SUMMARY

Body composition and growth are key components of health in both individuals and populations. The ongoing epidemic of obesity in children and adults has highlighted the importance of body fat for short term and long term health. However, other components of body composition also influence health outcomes, and its measurement is increasingly considered valuable in clinical practice. Hormone, nutrition, gene and several factors are responsible for body composition. Five level of body composition is very important i.e., atomic, molecular, cellular, tissue and whole-body level. One to five componential model are used to study body composition. Anthropometric, BIA and other methods are also used to assess the body composition. Body composition is very much ethnic specific, and it has a close association with population variation and disease association study.
10.9 REFERENCES


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**10.10 ANSWER TO CHECK YOUR PROGRESS**

1) Body composition has four main components: water, protein, fat and mineral. For details refer to section 10.1

2) Body composition is dependent on factors like age, genes, hormones and others. For details refer to section 10.2

3) Body composition can be assessed at atomic, molecular, cellular, tissue and whole body level. For details refer to section 10.3

4) There are five componential models of body composition. For details refer to section 10.4

5) Body composition can be assessed by various measures. For details refer to section 10.5

6) Body composition holds significance for nutritional status. For details refer to section 10.6

7) The study of body composition is an intrinsic part of Human Growth and Development. For details refer to section 10.7