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Paper No. : 06 Human Growth Development and Nutrition

Module : 19 Body Composition

Development Team

Principal Investigator	Prof. Anup Kumar Kapoor Department of Anthropology, University of Delhi
Paper Coordinator	Dr. Meenal Dhall Department of Anthropology, University of Delhi
Content Writer	Ms. Shumayla Department of Anthropology, University of Delhi
Content Reviewer	Prof. Satwanti Kapoor Department of Anthropology, University of Delhi

Description of Module	
Subject Name	Anthropology
Paper Name	06 Human Growth Development and Nutrition
Module Name/Title	Body Composition
Module Id	19
Pre-requisites	
Objectives	
Keywords	

Contents of this unit

Learning Objectives:

After the unit student will be able

- To understand the concept of body composition
- To learn the levels of human body composition
- To understand underlying models of body composition

1. Introduction:

Body composition refers to the chemical make-up of the body and is split into two components: Fat Mass which includes adipose tissue and Lean Body Mass or Fat Free Mass which includes bone, muscle, organs, connective tissue. It is the relative percentage of fat, muscle, bone and other tissues in the body. This area of study attempts to partition and quantify body weight and mass into its basic components (Malina, 2004). Two people of equal height and body weight may look completely different from each other because they have a different body composition. Scientists have been studying body composition since the beginning of the 20th century, but research has increased dramatically in the last 25 years as methods for measuring and analyzing the body have grown in accuracy. There is growing evidence that clearly links body composition with health risks and the development of certain diseases. New research indicates that fat loss, not weight loss, can extend human longevity. Adding further to the acceptance of this practice is the importance of body composition in athletic performance and its move from being a laboratory-only procedure to one used in ordinary medical practice and now health clubs or at home. By measuring body composition, a person's health status can be more accurately assessed and the effects of both dietary and physical activity programs better directed.

During fetal development, the inherited genetic information exerts its maximum penetrance on body composition. After birth, nutrition and lifestyle factors will strongly interact with the genome to influence the changes in body composition at different stages of growth.

1.1 Essential fat and Non-essential fat:

Body fat percentage can be calculated as the total mass of fat divided by the total body mass, where body fat can be divided into essential body fat and storage body fat. Essential body fat is necessary for the normal functioning of the body. These include lipids incorporated into brain, nerves, heart, lungs, liver, and mammary glands. Percentage of essential fat is different for male and female. Male have 3% while women can have upto 12% as essential fat. Non-essential or storage fat is the amount of extra fat or the fate reserves stored in the body. The fat cells exist primarily just beneath the skin (subcutaneous) and around major organs (visceral). The amount of storage fat depends on many factors like gender, age, heredity, diet, physical activity etc from person to person.

Body Composition	Components and Function
Intra-cellular Water (ICW)	Body water which exists inside of cell membrane
Extra-cellular Water (ECW)	Body water that exists outside of cell membrane (like blood, interstitial fluid, etc.)
Body Water	The sum of intra-cellular and extra-cellular water
Protein	Main element which composes soft lean mass together with water
Soft Lean Mass (SLM)	skeletal mass which forms the physical strength and internal organs like heart, stomach, etc which keeps the body function
Minerals	Composing bones and electrolytes
Lean Body Mass (LBM)	The amount of body weight which excludes the body fat mass It consists of soft lean mass and minerals.
Body Fat	The amount of body weight which excludes the lean body mass
Weight	The sum of lean body mass and body fat mass Standard weight (kg) : Adult male Height(m)×Height(m) × 22, Female Height(m)×Height(m) × 22

Source: http://www.jawon.com/reng/res/body-composition.html

2. **Levels of Body composition:**

The study of body composition has been historically driven by the availability of methods to measure, or more correctly, estimate it. In other words, the research was to some extent directed by what could be measured rather than what the researchers wanted to measure. Over the past 10 to 15 years, however, significant progress has been made in the development and refinement of techniques to estimate the body composition of the body so that virtually all components of the body can now be measured. This progress has thus been resulted in the modification of the models that provide the framework for studying body composition (Malina, 2004). There are different levels and models to describe body compositions.

Levels ranging from elements to tissues and organs are the building blocks that gave mass, shape and function to all living things. Body composition analysis techniques allow scientists to study how these building blocks function and change with age and metabolic stage. Scientists from different disciplines, as well as healthcare workers, rely on body composition measurements to research for diagnostic purpose.

The central model in body composition research is the five-level model, in which the body mass is considered as the sum of all components at each of the five levels—atomic, molecular, cellular, tissue-organ, and whole body. Certain rules are inherited in the five-level model and, ultimately, all body composition models follow these rules

2.1 Atomic Level

Elements or atoms are the fundamental building blocks of all biological organisms. About 50 of the 106 elements found in nature are also found in the human body, and many of these are required by humans for growth and health maintenance (Heymsfeild et.al, 2005).

Components and Their Relationships

Four elements—O, C, H, and N—account for over 95% of body mass and with an additional seven—Na, K, P, Cl, Ca, Mg, and S—comprise over 99.5% of body mass (Snyder et. al, 1975 and Wang et.al, 1992).

Elements maintain stable or relatively stable associations with other elements and with components at higher levels (Table 2). Several of these associations are (kg/kg): S/N D 0.062; N/protein D 0.16; C/triacylglycerols D

At this level, body mass includes 11 major elements. More than 96% of body mass is accounted for by the four elements: oxygen, carbon, hydrogen and nitrogen. Other key elements include calcium, phosphorus, sulfur, chlorine and magnesium.

Body composition on the atomic level (I) for the 70-kg Reference Man*

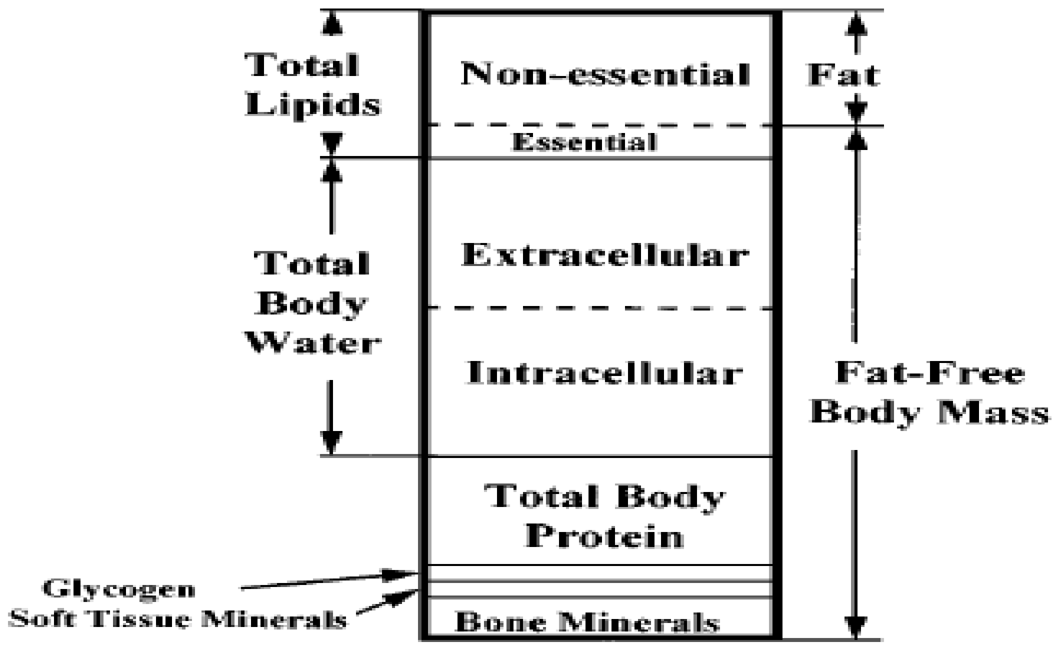
Element	Amount	Percent of body weight
	kg	%
Oxygen	43	61
Carbon	16	23
Hydrogen	7	10
Nitrogen	1.8	2.6
Calcium	1.0	1.4
Phosphorus	0.58	0.83
Sulfer	0.14	0.20
Potassium	0.14	0.20
Sodium	0.1	0.14
Chlorine	0.095	0.14
Magnesium	0.019	0.027
Total	69.874	99.537

Source: Wang, Zi-Mian, R. N. Pierson and Steven B. Heymsfield. "The five-level model: a new approach to organizing body-composition research." ***The American journal of clinical nutrition*** **56.1 (1992): 19-28.**

2.2 Molecular level:

Molecular level body composition components are integral to research in much nutrition areas; including energy, protein, and lipid metabolism, bone mineral homeostasis, and water balance. The many different chemical compounds found in the human body can be classified into five main groups: lipids, water, proteins, carbohydrates (i.e. glycogen), and minerals (Wang et al, 1992)

Lipid includes all biological matter extracted with lipid solvent. This means triglycerides, phospholipids and structural lipids. In contrast, fat refers to the specific family of lipids consisting of triglycerides. Approximately 90% of the total body lipid in healthy adults is triglyceride.



Source: B. Heymsfield, Steven, et al. "Human body composition: advances in models and methods." *Annual review of nutrition* 17.1 (1997): 527-558.

The molecular level provides reference for the development of body composition model that divide body into two or more components.

2.3 Cellular level

Human body can be divided into different components at molecular level, it is the assemblage of these components into cell that creates the living organism. The cellular level of body composition includes the three main components i.e. cells, extracellular fluids and extracellular solids. The cell can be additionally partitioned into two components: body cell mass and fat, of which the former is the metabolically active component. Each of these compartments is now described in additional detail.

Cells: cells are the basic functional unit of life and possess the characteristics like metabolism, growth and reproduction. The cells in human body share many common properties but there are great variations in size, shape, molecular and elemental composition, distribution and metabolism. The interior portion of the cell consists of cytoplasm and a nucleus which contain the genetic material in the form of DNA. Four different categories of cells can be defined on the basis of these differences: connective, muscular, Nervous and epithelial. Further Connective tissues are grouped in three: specialized, dense and loose. Fat cells or adipocytes are loose while bone cells are specialized connective cells. Skeletal, smooth and cardiac cells are in the group of muscle cells. Striated muscle cells account for the large fraction of body and are the foundation of human movement. The cells of the human body consist of fluid and solid components and intracellular fluid and solid as well.

Extracellular Fluid: the fluid outside the cell is known as extracellular fluid. These no metabolizing fluid surrounding cells provides a medium for gas exchange, nutrient transfer and excretory metabolic products. The extracellular fluid is divided into several smaller components such as plasma, transcellular fluid, interstitial fluid, and fluid of bone and dense connective tissue. Plasma is the yellow fluid component of blood in which cells are suspended. About 55% of the whole blood is plasma and about 90% of the plasma is water. The rest consists of dissolved proteins, ions, hormones and other small molecules. About 12 percent of the body weight is accounted for interstitial fluid. While transcellular fluid refers to all body fluid that is formed from the transport activities of cells. Transcellular fluid is constrained within epithelial lined space. Mainly it includes cerebrospinal fluid, bladder urine, joint fluid and ocular. The fluid of bone and dense connective tissue in addition with transcellular fluid is a component of extracellular fluid.

Extracellular solids: like extracellular fluid, extracellular solids are also a no metabolizing part of the human body. It consists mainly of organic and inorganic chemical compounds. Organic extracellular solid mainly includes three types of fibers: collagen, reticular and elastic. Both reticular fibers and collagen are made up of collagen protein and elastic fibers are made up of protein elastin. The inorganic extracellular solids mainly contain phosphorus, calcium and oxygen in bone. Other inorganic components in extracellular solids are magnesium, sodium, citrate and bicarbonate.

2.4 Tissue-organ level:

The human body at cellular level is composed of cells, extracellular fluids and extracellular solids. These three components are further leads to the formation of tissues, organs and systems which is the fourth level of body composition.

Tissues:

Tissues are composed of specialized cells of the same type that are similar in appearance, embryonic origin and function. All the varied tissues of the human body can be categories into four: connective, muscular, epithelial and nervous. Some components of the tissue level are single solid organs like heart, brain, liver and kidney. Thus, the tissue level is also called tissue-organ level.

Body weight at tissue level= connective tissue + muscular tissue + epithelial tissue + nervous tissue Bone is a specialized connective tissue which consists of bone cells bounded by a matrix of fibers and ground substance. Ground substance in bones is calcified and accounts for approx. 65% of the dry bone weight. Another important connective tissue is adipose tissues which are made up of adipocytes with collage nous, fibroblasts, elastic fibers and capillaries. It is located primarily under skin, where it serves as a layer of insulation. It is highly specialized for the storage of fat. It also forms a protective layer around the organs like in case of kidney. Adipose tissues are linked with health conditions like insulin sensitivity, metabolic syndrome and type-2 diabetes. Adipose tissues can be further divided into four types according to their distribution: subcutaneous, visceral, yellow marrow and interstitial.

Organs:

The organ level form by the combination of two or more tissues. Functional units like skin, blood vessels and kidney etc are form by the combination of tissues.

Systems:

More than one organ whose functions are interrelated constitutes a system. Digestive system is an example in which many organs play a role including mouth, esophagus, stomach, intestines, liver and pancreas. Each of the organs has different tissues like stomach contains different kind of tissues (muscular, epithelial, connective and nervous).

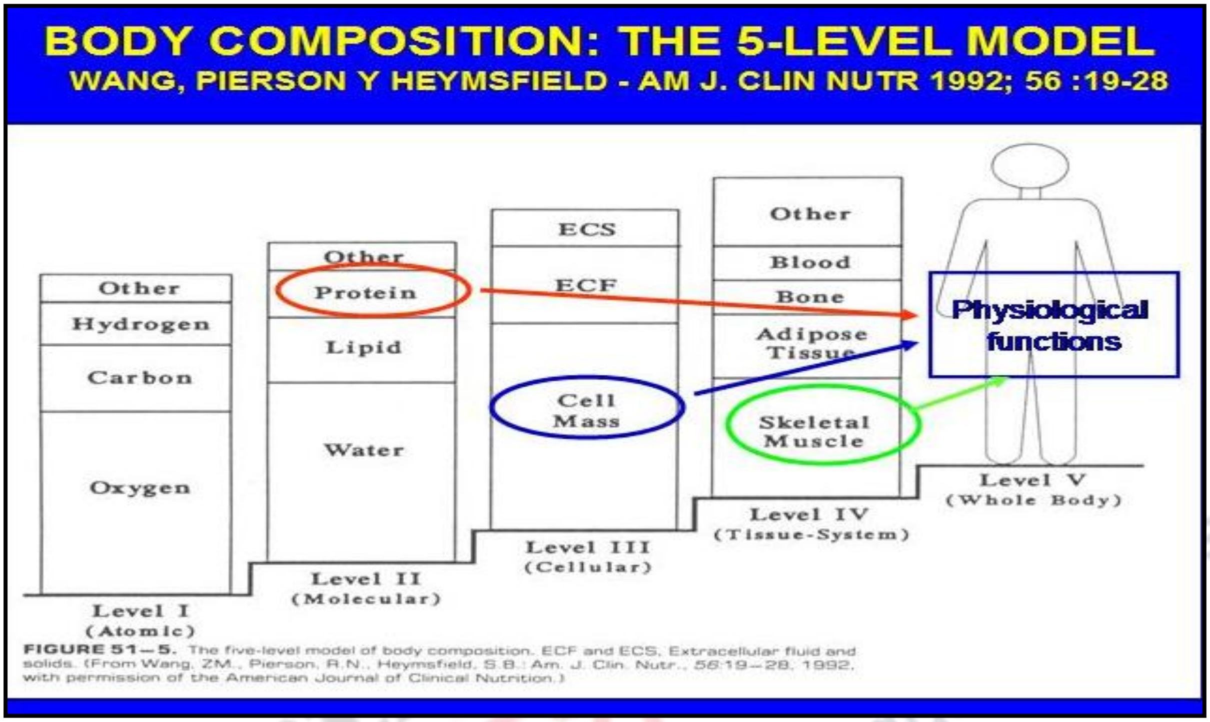
In human body there are nine main systems, hence body weight at system level can be defined as:

Body weight = skin + nervous + circulatory + musculoskeletal + digestive + endocrine + urinary + respiratory + reproductive system.

2.5 Whole-body level:

As clear from the name itself this level consist of regions like appendages, trunk and head, which can be described by anthropometric measures such as length, circumferences and skin folds. These different segments have different forms and compositions that make up the physique of an individual. The whole-body level focuses on physique, form and composition. Body composition refers to relative components of body weight at a given level; body form is mainly concerned with the size and shape of the human body. Size refers to the dimensions, volume and masses of the body. Body shape is described as the relative skeletal dimensions of the body that is generally expressed as the ration of two linear dimensions. For example, relative sitting height or cormic index (sitting height/height) is an index of body shape.

Anthropometry is the basic tool at whole-body level for estimating the size and shape of the body. Anthropometric measurements focus on overall size as well as on specific parts of the body, like waist, length of the arms and legs and hips etc. BMI and skin fold thickness are considered as the most common anthropometric measurements of body composition. These measurements in association with prediction equations can be used to calculate body fat. Major changes in other four level of body composition will manifest on the whole-body level as well. Contrariwise, differences at the whole-body level are related to changes in the other four levels of body composition.



Source: http://www.nutritotal.com.br/icnso/files/525--aulas--Slide7.JPG

1. **Models of Body Composition**:

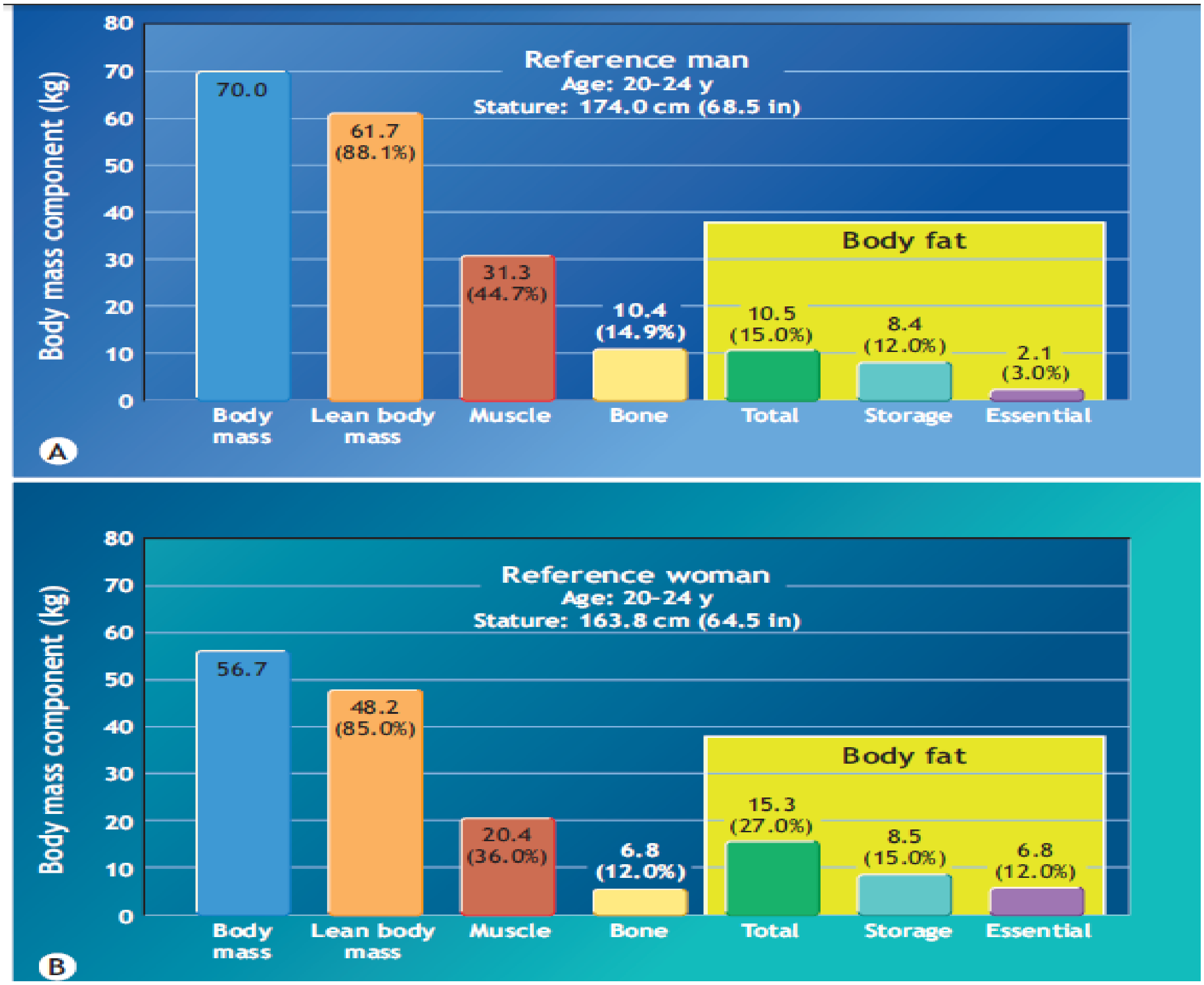
3.1 Two compartmental model:

In basic two compartmental model, the body is divided into two parts; One part consists of body fat, and the other part consist of all the remaining tissues as the fat-free mass (FFM).

It is difficult to measure body fat mass directly and remains a significant challenge for most body composition techniques. Though, if total FFM of the body is determined then one can calculate the body fat indirectly as body fat is the difference between body weight and FFM. The 2C models are body densitometry, ^{40}K measurement, and TBW measurement (Heymsfield *et al.* 1997). Body densitometry measures body density by underwater weighing or air plethysmograhy and then estimates BC assuming of a constant density of FFM and FM (1.1000 kg*$^{L-1}$ and 0.9007 kg*L^{-1}respectively for the "reference man"). Measurement of the natural isotope of potassium ^{40}K by means of γ-counters allows to estimate total body potassium (TBK) because of their constant ratio inside the human body; FFM is then estimated from the potassium content of FFM (68 mEq*kg^{-1} in the reference man). Lastly, measurement of TBW by 2H2O or 3H2O dilution allows to estimate FFM if the hydration of the latter is known (73% in the reference man).

Reference man and reference woman:

Behnke's model for the reference man and woman provide useful information regarding the framework to evaluate a basis that what constitutes "normal" body composition.



3.2 Three compartment model:

For more accuracy the 2C model was expended to the 3-C level with special reference to Under water weighing(UWW) as total body water is one of the measure in this technique. This model assumes the density of water, body solids and fat. But in case of certain disease a patient may be protein depleted or may have less bone mineral mass which make this assumption erroneous. So , the total body fat mass estimation will be inaccurate as the calculated density of the solids was incorrect.(Ellis, 2000)

3.3 Four compartment model

This model is one level extension of 3c model. In this model FFM is divided into three compartments: protein , water and mineral. With the help of these three compartment the forth compartment i.e FFM was calculated. Again in UWW the density of protein and minerall was assumed to be 1.34 and3.075 kg/ltrs respectively. There is a limitation with the 3C model for FFM; the errors in measurement are cumulative and can be transferred directly in mass units of the final estimation of body fat mass.

3.4 Multi compartmental model:

With each additional measurement in the model it may be possible to extend the number of compartments in the body composition model. For instance, a multi component model includes the six-compartment model at the atomic level of body composition. It is the direct analysis of the chemical composition of the body by using in-vivo-neutron activation analysis. Under this analysis, the major elements like hydrogen, oxygen, carbon, calcium, sodium, potassium, chloride and phosphorus are measured. In 1998, Wang and colleagues divided the body weight into water, nitrogen, calcium, potassium, sodium and chloride. Though in-vivo neutron activation analysis provides accurate measures of body composition, it is expensive and mainly used for clinical purposes.

TABLE 1. *Selected equations related to the five-level multicompartment model*

Elemental level

Body Wt = TBO + TBC + TBH + TBN + TBCa + TBP + TBK + TBCl + TBNa + TBMg + . . .

Molecular level

Body Wt = lipid mass (fat) + total body water + total body protein (TBPr) + bone mineral (OM) + soft tissue mineral (STM)

Cellular level

Body Wt = body cell mass (BCM) + extracellular water (ECW) + extracellular solids + fat

Tissue system level

Body Wt = adipose tissue (fat + cells) + skeletal muscle (SM) + bone (mineral + fluid + marrow) + other tissues

Translational equations between cellular, molecular, and elemental levels

TBCa = 0.340 BMC
TBN = 0.161 TBPr
TBC = 0.759 TBLipid + 0.532 TBPr + 0.018 BMC
TBK = 120 BCM
TBCl = 111 ECW
TBLipid = 1.318 TBC − 4.353 TBN − 0.070 TBCa
TBPr = 6.21 TBN
OM = 2.941 TBCa
STM = 2.75 TBK + TBNa + 1.43 TBCl − 0.038 TBCa

Source: Ellis, Kenneth J. "Human body composition: in vivo methods." *Physiological reviews* 80.2 (2000): 649-680.

2. **Body Composition and Sex Differences:**

Sexual dimorphism is common in all animal species. Among humans the difference can be clearly seen. Males are greater in size than the females. During the stages of puberty and adolescence sexual dimorphism in body composition is clearly visible. The difference is characterized by a markedly higher amount of body fat and lower amount of lean body mass among females. Male in comparison to female have higher amount of fat free body mass including bone as well as soft tissue lean body mass, i.e. muscle mass.

Body fat, particularly subcutaneous fat of the lower body represents an important energy store. This fat facilitates the female body to tolerate the energetic cost of pregnancy and lactation. Sexual dimorphism in body size has significant effect on the study of human evolution and development of differences in gender roles among societies too.

3. **Effect of climate on Body composition:**

The influence of climate on body composition, growth and development is well known. The linearity of body tends to be more prevalent in the people living in hot climate, which fits in with the findings that the growth period is prolonged and maturation is delayed in warm regions. The skinfold thicknesses and body fat among American Negroes, American Whites, Sub-Saharan Africans are different. The Eskimos in colder climate tends to be shorter in stature and possess relatively longer trunks and shorter legs. These types of changes in body composition are reflected through the functional changes in body. In the process of adaptation when changes take place in the body, they first reflected in biochemical functioning of the body. Thereafter it leads to physiological changes and finally leads to change body composition internally and morphology externally.

4. **Body composition and Age**:

The process of ageing leads to many changes in body composition even without changing the body weight. With the increase in the age of an individual body fat percent also increase, but body mineral density and lean mass decreases. There is a steady decline of total body water after middle age. The intracellular fluids also showed a decline by this age. The mineral content of bone with age also decreases, even though it is less clear how far this is an inescapable accompaniment of ageing, and the extent to which it reflects a decrease in physical activity. With the age, an increase in the proportion of connective tissue in muscle and other lean tissue is also observed.

It is believed that these changes in body composition are due to energy balance alteration. With growing age the positive energy balance leads to weight gain and vice-versa. However the changes in body composition related with ageing often occur without weight fluctuations also.

5. **The Impact of Exercise on Body Composition:**

Physical activity and training can change the body composition in a characteristic way. The influence of physical activity and exercise on body is governed by the first two laws of thermodynamics. The first law states that energy can neither be destroyed nor be destroyed, but can transfer from one form to another. During exercise, the chemical energy from food intake is converted to mechanical energy of body movement. The amount and proportion of lean body mass under these conditions increases significantly at the expense of fat. The second law states that biological conversion of energy due to entropy is never completely efficient. So, al the energy expanded during exercise does not contribute to the bodily movement. During exercise some of the energy gets converted into muscle work, but most of it gets converted to low grade thermal energy in terms of heat and sweat. Cardiovascular training burns calories, thereby creating a negative energy balance. Weight training increases muscle mass, which maintains a high metabolic rate and helps improve body composition. Muscle mass burn the calories at rest. So combining both elements is a quick way to cut body fat. This applies to growing children, adults as well as to the aged. Novak (1966), explained that trained adolescent boys have a higher lean mass and also slightly increased creatinine excretion than untrained youth.

Summary:

The study of body composition in Human is considered as an important aspect in physiological anthropology. It will gives us some basic concept about how human beings are different from one another. The science of Body composition is an important morpho-physiological aspect in human study and involves the assessment of the amount and proportion of fat, muscle and bone with their chemical composition.

Human body composition can be studied at any level depending upon the models and methods used. It is important to use the model and methods correctly in order to get accurate measures.

Changing in body composition is a continuous process from conception to death. These changes accounts for both genetic as well as environmental factors. In addition to this exercise and other physical activity can bring changes in the body composition of an individual.