THE ROLE OF NUTRITION IN BODY COMPENSATION

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ABSTRACT

Body composition data are used to evaluate nutritional status, growth and development, water homeostasis, and specific disease states. Human body composition is studied at atomic, molecular, cellular, tissue, and whole body levels. The levels are interrelated. A "normal weight" human body consists of approximately 98% oxygen, carbon, hydrogen, nitrogen, and calcium; of 60–70% water, 10–35% fat (depending on gender), 10–15% protein, and 3–5% minerals. The variation in body composition between individuals is large, mainly because of variations in fat mass. Variations in fat-free mass are smaller. Several direct, indirect, and doubly indirect techniques are avail-able to measure body composition, each with its own distinct advantages and disadvantages. The choice of method will be influenced by the availability of instrumentation, invasiveness, and radiation danger to subjects, price, accuracy required, and application objectives .Interpretation and application of data from body composition measurements should be carried out with care and should take into account the limitations of the method used, age, gender, and ethnic group

Introduction

Mankind has long been fascinated with the composition of the human body. Centuries ago, the Greeks dissected human cadavers to obtain an insight into the structure and build of the human body, and drawings from the middle Ages of gross muscle structures grace the walls of many famous art galleries. They are prized not only for their artistic merit, but also for what they reveal of the work of the dissectionist of that era. With progress in the development of analytical chemical methods in the twentieth century, these studies of body composition were applied to body tissues, fetuses, and cadavers of newborns. Scientists such as Mitchell, Widdowson, and Forbes performed the most important work of chemical analyses in adult cadavers during the 1940s and 1950s. Today, neutron activation analysis allows the chemical com-position of the human body to be studied in vivo. These early chemical analyses of the body gave insights into the changes occurring during growth and development. They also form the basis for a number of methods now widely used to assess body composition in vivo.

Today, it is known that many diseases and disorders are related to abnormal body composition or to changes in body composition. The most common of these conditions is obesity, in which the amount of body fat is excessively high, leading to abnormalities in lipid and carbohydrate metabolism, high blood pressure, and adult-onset diabetes. At the other end of the nutritional spectrum, energy and protein mal-nutrition results in a decrease in the amount of fat and protein stores in the body, and many diseases are related to abnormalities in total body water or to the distribution of body water across the intracellular and extracellular spaces.

Because of the high variability between subjects in chemical body composition, mainly due to the high variation in body fat stores, the concept of fat-free

mass (FFM) was introduced at the end of the nineteenth century. If body composition data are expressed as a proportion of the FFM, data become much more consistent between individuals. For example, the fraction of water in the FFM (0.73 0.02) is very consistent across individuals, whereas the between-subject variation is two to three times higher if expressed per kilogram of body weight. This high variability in body components led to the definition of a "reference man," an imaginary person with a given body composition.

In this chapter a (global) description of the com-position of the healthy human body is given and discussed at the following levels:

- Atomic
- Molecular
- Cellular
- Tissue
- Whole body.

Of the many methods available to measure body composition, a few are highlighted and a short description of each is given. For more detailed information, the books by Forbes (1987) and Heymsfield *et al*. (2005) on human body composition are recommended for further reading Five levels of body composition

Human body composition can be studied at the atomic, molecular, cellular, tissue, and whole body level. These five levels are related to each other. For example, information at the atomic level can be used, subject to certain assumptions, to provide information at the whole body level.

Atomic level

Many chemical elements (atoms) are found in the human body, but the six elements oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus are the most abundant and together account for more than 98% of body weight (Table 2.1). Indeed, the 11 most common elements account for 99.5% of the atomic body composition. This information was initially based on chemical analysis of carcasses, but today the information can also be obtained by in vivo neutron activation analysis (IVNAA). The classical chemical cadaver analysis, as carried out mainly in the 1940s.

Table 1.1 Body compositions at the atomic level of a 70 kg reference man

Atomic element	Amount (kg)	Amount (% body weight)
Oxygen	43	61
Carbon	16	23
Hydrogen	7	10
Nitrogen	1.8	2.6
Calcium	1.0	1.4
Phosphorus	0.6	0.8
Total	69.4	98.8

The water content in the body varies with age. In a fetus, the water content slowly decreases from more than 90% after conception to about 80% before delivery at about 7 months of gestation. A newborn has about 70% body water, which is about 82% of the fat-free mass. This value slowly decreases further to 72% of the fat-free mass until the body is chemically mature at age 15–18 years. In general, males have more body water (related to body weight) than females, as their body fat content is lower.

still forms the basis for many in vivo techniques that are used to assess body composition.

Molecular level

The chemical elements in the human body are bound in molecules and, in very global terms, the main compartments are water, lipids, proteins, minerals, and carbohydrates. The total amount of water in the body is high and, depending on the body fat content, can be as high as 60–70% of total body weight. Total body water can be divided into intracellular water and extracellular water, and the ratio of the two is an important health parameter that is disturbed in many diseases (Box 2.1).

Lipids appear in the human body in different forms. Essential structural lipids such as the phospholipids (cell membranes) and sphingomyelin (nervous system) form only a minor part of the total lipids in the body. The nonessential lipids, mostly triglycerides or triacylglycerol (fat), are the most abundant. They are the energy store of the adult human body, insulate against cold, protect vital organs such as the kidneys against mechanical damage, and, to a certain extent, enhance the body's appearance. In a "normal weight" healthy adult, the amount of body fat varies between 10% and 25% in men and between 15% and 35% in Table 2.2 Body composition at the molecular level of a 70 kg reference man women in severe obesity body fat can be as high as 60–70% of body weight.

Component	Amount (kg)	Amount (% body weight)
Water		
Extracellular	18	26
Intracellular	24	34
Lipid		
Essential	1.5	2.1
Nonessential	12	17
Protein	10.1	14.4
Mineral	3.7	5.3
Carbohydrate	0.5	0.6
Total	69.8	99.4

Body protein varies between 10% and 15%. It is higher in males than in females, as males generally have more muscles. There is no protein storage in the body and, generally speaking, loss of protein coincides with a loss of functionality given the high protein content and high protein turnover rates in vital organs.

The amount of minerals in the body varies between 3% and 5%, again dependent on body fat. Calcium and phosphorus are the two main minerals. They are found mainly in bones. Carbohydrates are found in the body as glucose (blood sugar) and glycogen, a polysaccharide in muscle and liver cells that serves as a short-term energy store. The amount of carbohy-drates in the body rarely exceeds 500 g. Table 2.2 gives the body composition of the reference man at a molecular level.

Cellular level

At the cellular level, body composition can be described in terms of body cell mass, extracellular fluids, and extracellular solids. The body cell mass includes the cells with all their contents, such as water, proteins, and minerals. Extracellular fluid contains about 95% water, which is plasma in the intravascular space and interstitial fluid in the extra vascular space. Extracellular solids are mainly proteins (e.g., collagen) and minerals (bone minerals and soluble minerals in the extracellular fluid). Body composition at the cellular level is not easy to measure, owing to its complex nature. As will be discussed later, the 40K method can be used to assess body cell mass and some dilution techniques, for example bromide dilution, can be used to assess extracellular water.

Table 1.2 Body composition at the tissue level of a 70 kg reference man

Tissue/organ	Amount (kg)	Amount (% body weight)
Muscle	28	40
Adipose tissue	15	21.4
Blood	5.5	7.9
Bone	5	7.1
Skin	2.6	3.7
Liver	1.8	2.6
Total	57.9	82.7

Conclusion

Given the importance of body composition to evaluate nutritional status and to gain information on certain disease processes, it can be expected that more easy-to-use methods and instrumentation will be developed and become available in the future. Application and interpretation of data from these methods should be used with an awareness of pos-sible limitations, as mentioned above. There is a growing perception that, because of differences in body build, frame size, and possibly also other variables, there are differences in the relationship between BMI and body fat percentage among ethnic groups. Some Aboriginal and Asian people have a higher fat percentage and therefore greater risk for several chronic diseases at a given BMI than Caucasian populations. Conversely, Africans often have higher bone density than Caucasians. Much more research is needed to define the optimal BMI values that will correlate with optimal health and the lowest risk of disease for different populations.

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