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Review article

"IN VIVO" MODELS AND TECHNIQUES FOR BODY COMPOSITION MEASUREMENT

Elvira BAZE[1*], Alajdin HASANI[2*]

[1] *Ministry of Science Albania,*
[2] *Faculty of Medical Sciences University of Tetovo, Republic of North Macedonia*
[*] *Corresponding author e-mail: elvirabaze74@gmail.com alajdin.hasani@unite.edu.mk*

Abstract

Obesity is a complex disease, caused by genetic, environmental, and individual factors. In many industrialized countries this disease affects up to one third of the adult population with a tendency to spread even to pediatric age: thus, undoubtedly presenting the largest epidemic of this third millennium and at the same time, the most common chronic pathology of the world mainly in the western countries. Therefore, it has prompted various researchers to study the phenomenon of overweight / obesity, as well as to develop sophisticated methods and techniques for measurement the fat % in body composition. Some of the earliest information on the composition of the human body has been based on chemical analysis of specific organs, and occasionally for the whole body. But all these techniques require the realization of measurements in laboratory conditions, making it difficult to use them in other conditions especially in quantitative studies with many subjects. Using anthropometric measurements to assess body composition is a simple and reliable method. Through anthropometry, body size and body proportions can be determined by measuring the length, width, perimeter, and fat of the skin folds. Recent studies show that not only total body fat but also the fat in certain areas and in skeletal muscle can be estimated through anthropometric measurements, which makes anthropometric methods, mainly the skin folds measurement, to be one of the most recommended methods for use in estimating the percentage of fat in body composition, in quantitative studies for determining the prevalence of the phenomenon.

Keywords: adipose tissue, body composition, body composition models, compartment model, air replacement plethysmography, dilution method, bioelectric resistance analysis (BIA), bioelectric resistance spectroscopy, total body electrical conductivity (TOBEC), "Dual-energy", "triple-energy", X-ray Absorptiometry (DXA and TXA), magnetic resonance imaging (MRI), computed tomography (CT), anthropometric measurement, Body Mass Index (BMI), skin folds.

1. Introduction

1.1. Body composition determination models: Many models are used to collect data on the anthropometry of the human body and its composition, including measurements of skin thickness (skin folds), perimeters and lengths of specific body parts, and several weight status indices. These basic anthropometric models have been developed to determine body composition for all age groups[1,2].

1.1.1. 2-C Model with two compartments: Some of the earliest information on the composition of the human body has been based on chemical analysis of specific organs, but occasionally for the whole body. The development and use of the 2-C (two compartments) method of body composition has been used more in recent years because of the link that exists in the assessment of body fat associated with cardiovascular disease. In model 2-C, the body is "divided" into two compartments. One consists of body fat and all the rest is summed up in what is called "lean body mass". Direct measurement of body fat mass has not been easy and remains a

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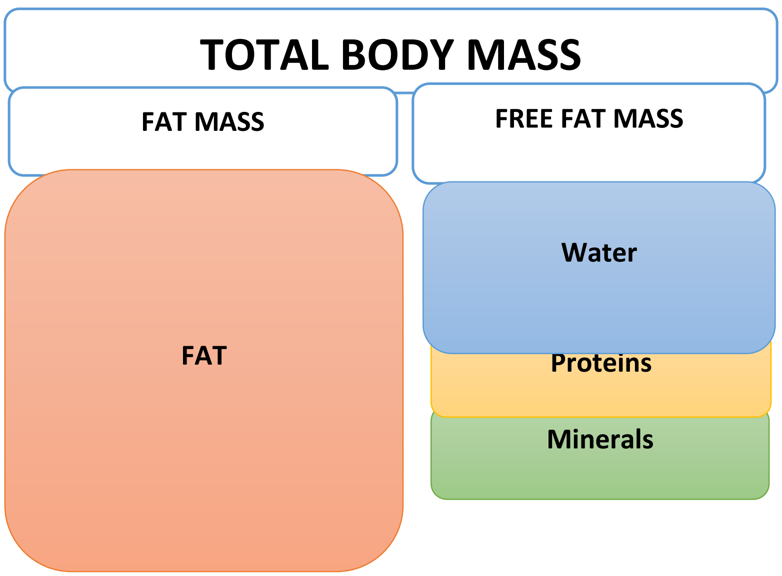
challenge for most body composition measurement techniques. However, if the total lean body mass is determined, it can be indirectly defined as the difference between body weight and body fat mass. The 2-C model, which has been used in body composition research for nearly 50 years, continues to play a vital role, particularly in the evaluation of techniques focused on the assessment of body fat.

The earliest and most widely used methods on the 2-C model are based on measuring total body density. The most common method is hydrodensitometry[3], which from the beginning of its use was developed in universities with a special focus on body fitness, often related to the kinetic measurements of human beings, exercises and sports performance. At the same time the 2K 2-nuclear method was developed, which is based on dilution with radioactive water. This method, referring to the 2-C model, requires more sophisticated technology than hydrodensitometry. For the assessment of body fat with each of these methods, the content of water or potassium in lean body mass should be measured and their concentration should be constant at all ages, 0.732 l / kg for water composition in the body[4] and 68.1 meq / kg for body potassium[5]. Lean body mass density according to model 2-C is estimated to be constant. If young and healthy persons have been the subjects of the study, the use of these three constants was satisfactory, but when the subjects of the study were very young or old persons, different ethnic groups or subjects with different diseases, it was quickly confirmed that these "constants" were the best obtained for average values for the studied populations.



1.1.2. 3-C Model with three compartments: To reduce the limitations that appear in the 2-C model, it is logical to move on to the 3-C model configuration. This requires that measurements by the method of hydrodensitometry, includes the total measurement of water in the body, usually performed by the method of "isotopic dilution". In the 3-C model, lean body mass is divided into two parts: water content and the rest in the solid body (dominated by proteins and minerals). In the 3-C model are used for measurements: 1- water density, 2-fat and 3-solids. The results obtained with this model are more improved than those of the 2-C model for healthy adults and children. However, for patients with a poor protein mass and poor mineral mass in their bones, the values for the density of solid components may be inaccurate, hence the value of the calculated body fat mass may be inaccurate.

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5 FORBES, G. B., J. GALLUP, AND J. HURSH. Estimation of total body fat from potassium-40 content. Science 133: 101–102, 1961.

1.1.3. 4-C Model with four compartments: To extend model 2-C, hydrodensitometry to model 4-C, accurate measurement of protein and mineral compartments is required, following the estimation of the total amount of water in the body. Referring to hydrodensitometry for the 4-C model, the density of proteins in the body and minerals in the bones is estimated at 1.34 and 3.075kg / l (constant) [6].

However, to obtain a measurement of the amount of each compartment, two additional measurements are needed: 1. neutron activation analysis for body proteins and 2. Dual-Energy X-ray Absorptiometry (DXA) for bone minerals. However, these requirements cast doubt on the use of hydrodensitometry in the 4-C model, because if these two additional techniques are necessary, they can be used directly to estimate lean body mass, without the need for measurements via hydrodensitometry.

In the 4-C model, the DXA value for bone minerals is relatively valid, while only eight research centers worldwide have access to direct measurement of body protein mass. It is a more common practice in the 4-C model for protein mass to be assumed to be in proportion to bone mineral mass and depending on age and sex. If one is interested in noticing changes in a short time of fat mass and approximately of mineral mass this is acceptable in model 4-C, as this model does not change significantly for individuals even for long periods of time. It is rare that changes in fat mass cannot be associated with changes in body cell number or protein mass[7,8,9].

A 4-C model has also been developed, which does not require hydrodensitometric measurements. In this model lean body mass is divided into three basic cells or three physiological components: 1. cell body mass, 2. extracellular fluid or water, and 3. extracellular solids. Determined by Moore[10], body cell mass is based on whole-body potassium measurements (consisting of 40K) or by the 42 K plasma tracer dilution method.

1.2. Multi-compartments model

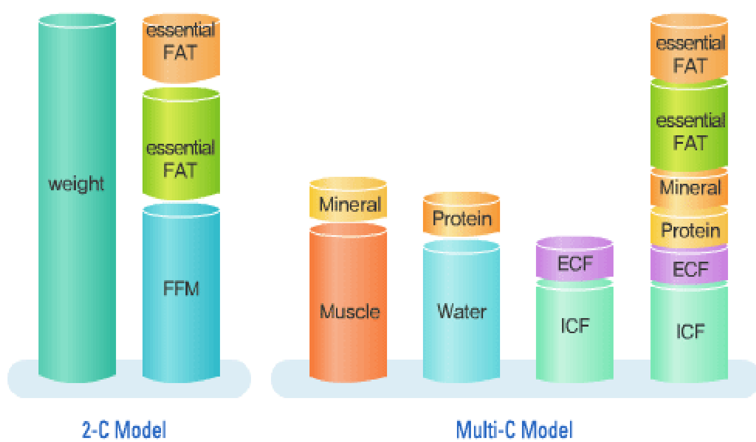

Fig 1.

It is clear that for each recent measurement (model) commented, in case of its use the number of compartments in the body composition models must be increased. Also any additional measurement must be independent of

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[6] SNYDER, W. S., M. J. COOK, E. S. NASSET, L. R. KARHAUSEN, G. P. HOWELLS, AND I. H. TIPTON. Report of the Task Group on Reference Man: ICRP-23. New York: Pergamon, 1984.

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the previous measurement[11,12].
However if the above methods are used at the same time, again we do not get any additional information regarding extracellular water. On the other hand, if these measurements are performed separately, they can obtain a different configuration for the volume of extracellular water, which cannot be obtained by a single technique. If only one method is used then we will have technical or other limitations on the model, related to the method used. Whatever the possibilities, it is good for the methods to be repeated or superimposed to obtain results closer to the real one.
Techniques such as computed tomography (CT) and magnetic resonance imaging (MRI) images provide valuable information about anatomical structure and can be used to monitor specific organs. These last 50 years it has been shown that there is an evolution in the process of transition from model 2C to model 4C of body composition. The five levels of the model are as follows: 1. Elemental, 2. Molecular, 3. Cellular, 4. inner system and 5. body in total. It is interesting to note that the basic 2-C model tends to start at the end of a spectrum (e.g. 40K is termed as an elementary model, while body density is termed as a whole - body model). Each model involves many measurements and tends to shift in the cellular direction or towards the physiological model although generally the relationship between chemical or elemental components (amount of oxygen, carbon, hydrogen, nitrogen, calcium) and molecular structure of tissues (water, proteins, lipids, bone minerals) remain relatively fixed in both healthy and diseased cases. Consistently rebuilding body components from the elementary level is often more reliable and minimizes assumptions about tissue density, dehydration, and / or structure[13].

2. Measurement of body density and volume in the assessment of body composition

2.1. Underwater weight measurement: Due to the early development and widespread use of body density measurement, it has been considered a “gold standard” for body composition measurements, although this is only achieved through the 2-C model. The most common method for determining body density is "underwater weight measurement", which requires the subject to be submerged in water14. The volume of water displaced or the weight of the subject underwater, combined with the laboratory weight of the subject were used to calculate the density of the whole body. However, a problem arises to get an accurate value of body weight[15]. Limitations are related to estimating whole body volume and remaining volume in the lungs[16].
In the classic 2-C model of body composition, body weight can be divided into fat mass and lean body mass. The assumption that fat density is constant is reasonable[17]. However the heterogeneous nature of lean body mass ingredients leads to such a question about the validity of constant density. There are individual variations related to gender and ethnicity[18], such as individual density changes that occur with age, sexual maturity, growth, physical activity, and a considerable number of diseases. In this way the 3-C and 4-C models for underwater weight measurement were developed requiring additional measurements of the main components

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of lean body mass: water, protein and minerals. Types of equations are currently used to measure body fat, along with body composition techniques which require the use of these models. Underwater weight measurement methods have been developed primarily as a way to measure body volume to estimate body fat, expressed as a percentage of body weight (% fat).

Although body weight and volume can be measured without errors, there can still be considerable uncertainty regarding individuals' assessment of % of fat under normal body hydrogen conditions and mineral content. It is estimated that the cumulative errors for body fat (% of fat) is 3-4% of body weight in individuals[19]. However, it has been recommended that without making appropriate corrections for variations in water and mineral fractions of lean body mass, densitometry cannot be used as a criterion or reference method for heterogeneous populations. If someone I was asked to do additional measurements to correct the basic 2-C model of underwater weight it would be contradictory. However, in cases such as pregnancy, where even the slightest radiation against the fetus should be avoided, measuring below I weight should be considered as the proper method.

2.2. Air replacement plethysmography: In recent years, the underwater weight measurement technique has been replaced by the air-replacement plethysmography technique, where the subject is not immersed in water but placed in an isolated room with only oxygen inside[20]. The system consists of two rooms: One is for the subject and the other serves as a volume reference. The room where the subject is located is closed and isolated, the pressure rises slowly and a diaphragm separating the two rooms vibrates to increase the volume.

Fig 2.

An advantage of this technique compared to the results of the underwater weight measurement technique, is that the subject should not be submerged in water, however there are technical limitations that have been identified with this method in relation to volume estimation.

To reduce the technical limitations of this method, frequent measurements should be performed over a short period of time to then calculate an average of the results. Initial studies in adult health have shown a good

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relationship between plethysmography technique and underwater weight measurement method[21]. However, the accuracy of the measurements in the plethysmography method in children has not been fully tested. These instruments are designed for adults and require modifications and improvements to observe young subjects, including infants and children.
Although all technical limitations can be resolved or corrected, doubts remain about the physiological accuracy of using a method to measure lean body mass density among individuals (a common problem with all 2-C models).

2.3. 2H "dilution" technique: The main principle of the 2H "dilution" technique to analyze body composition, is the volume of ingredients, which can be defined as the dose ratio of the tracer administered (taken) orally or intravenously. Usually two fluids are taken (administered) (eg blood, saliva or urine). The sample of one of the fluids is taken before the tracer dose is administered, to determine the natural levels and the second sample is used after some time, when the tracer administered within the subject has penetrated sufficiently.

a. The total amount of water in the body

The 2H “dilution” technique (method) is used to determine the total amount of water in the body, which in healthy adults is in percentages such as ≈73% of lean body mass ≈60% of body weight for non-obese subjects[22]. These fractional constituents are not constant throughout life[23], as well as in diseased body condition[24]. In terms of a normal birth, a baby has the total amount of water in the body ≈80-83% of lean body mass, which then decreases rapidly over the next 3-5 years, and reaches values that has an adult. In clinical conditions, depending on individual hydration reflexes or under the use of certain medications, the body may contain or lose significant amounts of water. Under normal circumstances, the total amount of water in the body tends to self-regulate, while a loss of ≈15% of body water under dehydration conditions can be a serious threat to life. This aspect of body composition is important if it is of interest to monitor body fat mass (where fat is defined as body weight minus lean body mass, and the measurement technique is based on body water parameters). However if the interest is in the cellular mass of the body, e.g. water inside the cell or water in the extracellular space (such as in dehydration or edema) then measurement techniques that respond to the total amount of water are less valuable.

b. Extracellular water

The dilution technique is used to identify the exchange of electrolytes in the body, which are not necessarily the same in all parts of the body[25]. The physiological importance of this exchange of electrolytes at the molecular level, is in the suitability they have to monitor body fluids (inside and outside the cells). To measure the volume of extracellular water, the basic method of dilution technique is the same as that used to measure the total amount of body, except for the tracer added to the water, which in most cases is a non-radioactive Br, used with a commonly obtained plasma sample; after 3-4 hours, although a complete equilibrium is not realized

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after this time[26].

c. Water inside the cell

Intracellular water volume measurements can be obtained using the potassium (potassium) tracer in the dilution technique. This isotope nevertheless survives (circulates in the body) for a short period of time (½ 5 12.4 hours) and is no longer sold in the market. In this way potassium exchange measurements are often not measurable, and therefore rarely used.

3. Bioelectric resistance and the use of methods related to the assessment of body composition

3.1. Bioelectrical Impendence Analysis (BIA): The ability of tissues and moreover of the whole body to conduct electricity has been known for over hundreds of years. Aqueous tissues of the body, in which electrolytes are dissolved, are the best conductors of electricity, while body fat and bones have less conductivity[27]. Although many technical problems have eliminated the applicability of many electrical techniques, methods that use this principle were suggested many years ago[28]. In the 1980s when many commercial instruments were designed for bioelectrical impedance analysis (full resistance) BIA, there was a great interest to carry out the analysis of human body composition through them. At the time it was the most usable method, as the costs were affordable as well as easy to use. Measurements via BIA are performed using 4 electrodes, usually two are connected to the wrist and two to the ankle. For single frequency measurements (usually at 50kHz), a weak current passes to the outside of the electrodes, on which the body's resistance also depends.

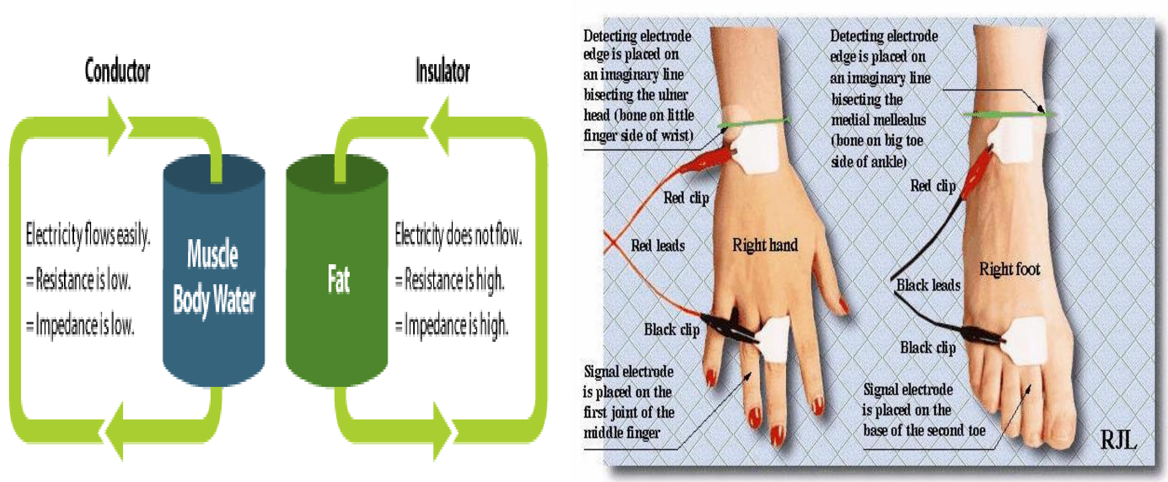

Fig 3.

3.2. Bioelectric Impendence spectroscopy: A complex model has been developed based on the modification of a mixed theory[29], dividing the whole body into serial parts of cylinders, each of which representing body segments[30,31]. For this model measurements for resistance and active resistance are made over a wide number

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of frequencies. A basic instrument for this model, which is commercially available is (Xitron, San Diego, CA)[32] and the technique used is often called bioelectric impendence spectroscopy (BIS). These alternative models of electrical circuits tend to be overly complex, and the individual components do not allow for a simple biological interpretation. Depending on the choice of the single or multi-frequency method the values of resistance obtained are considered as indirect parameters of the body and thus should be alternated with a direct method of estimating body components, such as that of quantifying total water in the body, assessment of potassium, hydrodensitometry. Many equations of frequency- "single" measurement through BIA have been presented in various literatures, which belong to the specific affiliations of the populations studied, especially those which include anthropometric predictions. This leads to the conclusion that the equations tend to be applicable only to the classification of a population and not particularly of the individuals involved in that population[33].

4. Total Body Electrical Conductivity (TOBEC)

An alternative bioelectric method for measuring body composition is Total Body Electrical Conductivity (TOBEC)[34]. This technique is executed, when the body is placed inside a coil, which generates over time an electromagnetic field, the current vortex is inserted into the accompanying tissues of the body. These currents oppose the external direction of the current in the coil, causing turbulence in the external field and then this results in the absorption of a small amount of bodily energy, which is not utilized as heat. The TOBEC instrument is calibrated with a gauge of the total amount of water in the body. Two commercial instruments have been developed (EM-Scan, Springfield, IL) one designed for infants and the other for adults. A list of TOBEC calibration equations has been compiled by Baumgartner[35]. The basic concepts of TOBEC affect the displacement of fluid or electrolytes between intracellular and extracellular components. This technique is used to monitor total water in the body. TOBEC measurements are mainly used to monitor changes in body composition in women during pregnancy or lactation (the period of breastfeeding)[36], in infants [37] and in obese children [38].

5. "Dual-energy" and "triple-energy" ray-X Absorptiometry (DXA and TXA)

The "Dual-energy" and "triple-energy" X-ray (DXA and TXA) techniques are performed primarily to determine bone mineralization, but also provide value-assisted model with three 3-C divisions and four 4-divisions. C (compartments) of determining body composition, by providing information on a specific tissue, of skeletal mass.

Dual- and triple-energy X-ray absorptiometry also provides information about the overall anatomical distribution of bone within the body. Estimates via DXA and TXA for fat percentage determination have also shown that they agree with the values obtained using the model with two 2-C compartments[39]. This indicator

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32 U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES “Bioelectrical Impedance Analysis in Body Composition Measure”, Public Health Service National Institutes of Health Office of Medical Applications of Research Federal Building, Room 618 7550 Wisconsin Avenue MSC 9120 Bethesda, MD 20892-9120, Technology Assessment Conference Statement December 12–14, 1994.

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34 BAUMGARTNER, R. N. Electrical impedance and total body electrical conductivity. In: Human Body Composition, edited by A. F. Roche, S. B. Heymsfield, and T. G. Lohman. Champaign, IL: Human Kinetics, 1996.

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is worth noting that although DXA and TXA provide data on the non-bone mass of the body, the division of tissues in its composition, but through them cannot obtain specific information on the mass of proteins, which is the assessment for connective tissue (ligaments)[40]. Despite these limitations, DXA and TXA technology represent a significant advancement in measurements and techniques for assessing body composition. This procedure, which requires the cooperation of the subject, can be performed within a few minutes and the results can be obtained immediately, and it should be said that further studies are needed to determine the accuracy of these techniques and instruments used to monitor changes in body composition[41].

6. Magnetic Resonance Imaging (MRI) and Computed Tomography (CT)

An important advantage of magnetic resonance imaging (MRI) in contributing to the determination of body composition is the potential of this technique for monitoring changes of adipose tissue under the skin and adipose tissue in organs, separately, information which currently cannot be obtained through any alternative or in vivo technique, except computed tomography. For example, through these techniques can be assessed the relative contribution of all subcutaneous fat components, as well as abdominal adipose tissue, in overall weight loss, through exercise programs, therapies or detoxification[42]. Computed tomography technique uses X-rays that pass-through body, while a set of detectors is positioned on the opposite side of the subject to detect the transmitted radiation. The X-ray source and week detectors placed around the subject as a single unit, giving it a full 360 ° "coverage". Like magnetic resonance imaging, computed tomography provides information and monitors changes in subcutaneous adipose tissue and adipose tissue in organs, in an individual (subject to observation)[43].

7. Anthropometric measurements for the assessment of body composition

Anthropometry is a simple and reliable method, to determine body size and body proportions, by measuring the length, width, perimeter, and fat of the skin (points). Recent studies show that not only total body fat but also fat in certain areas and in skeletal muscle can be estimated through anthropometric measurements. The reliability of anthropometry depends on the standardization of the meter, Caliber and on the capabilities of the anthropometric meter.

More than seven decades ago anthropometry was the only method to determine body size and dimensions. Earlier, in the 1920s, equations for predicting body fat were developed by measuring body length, width, perimeter, and skin fat. The main advantages of this technique are:

- ✓ It is a transferable technique.
- ✓ Easy to use.
- ✓ Not costly.
- ✓ Very useful in study fields,
- ✓ Described as such by many important literatures.

Over the past decades, researchers have stressed the importance of the accuracy of new techniques, such as dual-energy X-ray, absorptiometry (DXA), magnetic resonance imaging (MRI), computed tomography (CT), for measurement of body composition.

However, anthropometry is even more widely used as a method and most recently it has been used to estimate

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the distribution of fat in the body. The development of new methods has not diminished the popularity of anthropometry. In contrast studies have shown that potential new applications have been explored and accuracy in estimates has been increased by applying new techniques as standard[44].

7.1. Body Mass Index (BMI) or Body Mass Index (BMI): Body mass index is obtained from the weight/height2 ratio. The advantage of BMI as an indicator of obesity is the wide availability of data and reference from many countries around the world, as well as opportunities to make predictions about body obesity levels, morbidity, and mortality[45]. High levels of BMI values in childhood are closely related to the risk for overweight and obesity in adulthood. Referring to the World Health Organization (WHO) Classification, BMI levels (or TMT, Body Mass Index), fixing as the upper limit of normal the value of BMI at 24.9%, while three levels of Obesity are defined, respectively:

- Between 25 and 29.9 (level I)
- Between 30 and 39.9 (level II)
- Higher than 40 (level III)

7.2. Measurement of % fat through skin folds: Skin thickness has been accepted as an estimate for body fat because about 40-60% of total body fat is concentrated in the periphery of the body and skin thickness can be measured directly using a caliber. From numerous researchers who have used anthropometric measurements to determine the % of fat in the human body, more than 19 folds have been determined to measure skin thickness. Areas for the triceps are used more often than other areas because it is easy to access, is reproducible, and can measure wider differences in humans. Of the 50 predictive equations most commonly used to measure fat mass and lean body mass, 10 of them are skin measurements that have been used as predictors. The frequencies for each of these 50 equations are:

triceps> subscapular> abdominal and iliac crest> thigh> biceps of pulp> pectoral> umbilicus> thorax.

7.3. Instrument for measuring skin thickness. Caliber: To measure the thickness of the skin in different areas (folds), an instrument called a caliber is used, which is produced in different types (manual or electronic), designed to perform measurements which vary between 60mm to 80mm, but which all are usable for measurements even in obese people. Some calibers have measured up to 40 mm, so they cannot be used on over 40% body fat obese people although they can be many times more reliable than other calibers. Errors that can be made during measurements, both as part of the meter and from the instrument (caliber) used, are considered major issues in skin measurement. Manuals for standardized methods include instrument and subject positioning, a well-handled data collector, and concrete usage practices to ensure consistent results that increase productivity. Special attention in the user manuals is paid to the localization of the location, the "shrink-shrink" condition of the skin, as well as ensuring that the caliber is at 90 degrees, as these are essential for a new productivity and high reliability of the results[46].

7.4. Measurement of% fat through perimeters: For perimeter measurements more than 17 locations have been used, valid for body fat prediction equations in previous decades. Perimeter is measured in the arms, thighs, waist and buttocks, these are more usable than others because this show more differences between people in different parts of the body. Recently, many studies have used perimeter to assess skeletal muscle mass and fat distribution. The productivity and reliability of the method can be increased by paying special attention to the

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[46] WANG J, *aJ*. THORNTON C, KOLESNIK S, & PIERSON RN, JR. *Body Composition Unit, St. Luke's/Roosevelt Hospital, Columbia University, New York, New York 10025, USA*

subject's positioning, using anatomical reference points to locate the measured locations, obtaining accurate readability by using measuring strips directly in contact with the subject's skin without compression his, holding the bar at 90 degrees to the longest axis of the body to measure the perimeter[47].

7.5. Anthropometry of gender, age and ethnicity: A considerable number of references suggest that many anthropometric variables depend on gender, age and ethnicity, as well as on geographical location and the year when the measurement was performed. Anthropometric measurements have been a major component in the seventh survey conducted on national health and nutrition examination since 1960 in the United States[48]. The findings of this survey have been used as international references. The Rosetta Project[49] developed in 1986-1999 is a cross-sectional study using valuable body composition measurement techniques in subjects aged 6-11 years, with different ethnic compositions from New York areas.

Asians, African Americans, and whites, combined by age and body mass index (BMI), show hegemony between the three ethnic groups with gender differences. Women have higher values than men for all 5 locations, which also differ according to ethnicity. At any age, women have higher skin thickness values than men. The highest values are found in middle-aged people. Males exhibit the same pattern as females in abdominal skin thickness versus age, the highest values being found in Middle Ages. In general, males have higher values than females for any type of perimeter at any age. Waist and buttock circumference increases with age, thigh circumference decreases with age, and arm circumference changes slightly with age with respect to both sexes. The same gender differences were observed in children[50].

7.6. Application equations for calculating % fat measured by skin folds: Very early in 1921, the first equation for predicting body fat measured by skin thickness was developed. Since then, many equations have been developed to predict body density to estimate % of fat mass and lean body mass. The triceps and waist circumference have been used for nearly 5 decades to assess nutritional status in hospitalized patients. In about 50 predictive equations (most used for fat and lean body mass), the standard for accepting measurement errors is estimated at 3% to 11%. Many predictive equations have an error of 3-7%[51].

Jackson & Pollock[52] and Lohman[53], (1988) have generalized equations for each gender and Durn and Womersley for gender and age, using the sum of the 4 most used skin-folders in the literature. Body fat measurements taken from underwater weighing and Dual-energy X-ray absorptiometry (DXA), and predicted by three anthropometric models, give the same ranges for % of fat versus age. However the results analyzed by various studies suggest that these underwater weighing models and Dual-energy X-ray absorptiometry (DXA) require further development and correlation with anthropometric measurement models[54].

Equations developed by Lohman (1988) [55]

- 6 to 11 years old: (constant: boys = 3.4, girls = 1.4)% body fat
  = 1.35 (sum of triceps + subscapular points) - 0.012 (sum of triceps + subscapular points) 2 - constant
- 12 to 14 years old: (constant: boys = 4.4, girls 12–13 years old = 2.4)% body fat
  = 1.35 (sum of triceps + subscapular folds) - 0.012 (sum of triceps + subscapular folds) 2 - constant
- 15 to 18 years old: (constant: boys = 5.4, girls 14–15 years old = 3.4)% body fat
  = 1.35 (sum of triceps + subscapular folds) - 0.012 (sum of triceps + subscapular folds) 2 - constant.

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8. Conclusion

Given their epidemic proportions and consequences, it is appropriate to say that overweight and obesity constitute one of the most serious public health problems. This is why it has prompted various researchers to study the phenomenon of overweight/obesity, as well as to develop sophisticated methods and techniques for determining the % of fat in body composition. Some of the earliest information on the composition of the human body has been based on chemical analysis of specific organs, but occasionally for the whole body. The development and use of the two compartments 2-C method of body composition has been used more in recent years because of the connection that exists in the assessment of body fat associated with cardiovascular disease. The most common two- compartments method is hydrodensitometry[56], which from the beginning of its use was developed in universities with a special focus on body fitness. But to reduce the limitations that appear in the 2-C model, it was deemed necessary to configure the model with three compartments 3-C. This requires that measurements by the method of hydrodensitometry, which include the total measurement of water in the body, usually performed by the method of "isotopic dilution". Also, to get more detailed information on body composition the four compartments 4-C model has been developed, which evaluates the density of proteins in the body and minerals in the bones, as well as the multi-partition model.

These models of body composition separation have been the starting point for the development of body composition measurement techniques such as: Underwater weight measurement, air replacement plethysmography, "dilution" method, bioelectric resistance, bioelectric resistance analysis (BIA)), bioelectrical resistance spectroscopy, total body electrical conductivity (TOBEC), "dual-energy" and "triple-energy" X-ray Absorptiometry (DXA and TXA), magnetic resonance imaging (MRI), computed tomography (CT), etc..

But all these techniques require the realization of measurements in laboratory conditions, making it difficult to use them in other conditions and in quantitative studies with many subjects. Using anthropometric measurements to assess body composition is a simple and reliable method. Through anthropometry, body size and body proportions can be determined by measuring the length, width, perimeter, and fat of the skin (points). Recent studies show that not only total body fat but also fat in certain areas and in skeletal muscle can be estimated through anthropometric measurements.

More than seven decades ago anthropometry was the only method to determine body size and dimensions. Earlier, in the 1920s, equations for predicting body fat were developed by measuring body length, width, perimeter, and skin fat. Skin thickness (skin folds method) is accepted as an estimate for body fat because about 40-60% of total body fat is concentrated in the periphery of the body. Skin thickness can be measured directly using a caliber. Especially in children this technique is more applicable, as the concentration of body fat in children is mainly subcutaneous and much less in the organs[57]. Over the past decades, researchers have stressed the importance of the accuracy of new techniques, such as dual-energy X-ray, absorptiometry (DXA), magnetic resonance imaging (MRI), computed tomography (CT), for measurement of body composition, therefore in most cases they are also associated with anthropometric measurements. Anthropometry is even more widely used as a method and most recently it has been used to estimate the distribution of fat in the body. The development of new methods has not diminished the popularity of anthropometry. In contrast studies have shown that potential new applications have been explored and accuracy in estimates has been increased by applying new techniques as standards[58]. The main advantages of this technique are in the ease of transfer of the technique, it is easily usable and inexpensive, and it is very useful in the fields of study, described as such

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