Assessing fat mass from a body composition perspective: a critical review

Evaluación de la masa grasa desde la perspectiva de la composición corporal: un análisis crítico

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How to cite this article:
Vaquero-Cristóbal, R. (2023). Assessing fat mass from a body composition perspective: a critical review. *Cultura, Ciencia y Deporte, 18*(56), 4-13. https://doi.org/10.12800/ccd.v18i56.2033

Abstract

The estimation of fat mass and fat percentage has been used both in the field of health, due to its relationship with various diseases; and in sport, due to its relationship with sports performance. However, the advantages and disadvantages of the different methods of estimating body composition are rarely taken into consideration when evaluating this parameter, including dual energy X-ray absorptiometry (DEXA or DXA); hydrodensitometry; air displacement plestimography; electrical bioimpedance; anthropometry; 2D/3D/4D scanning and ultrasound, as well as whether they are indirect or dual indirect methods. Nor do most studies and evaluations take into consideration the different models from which body composition can be approached, with methods that use a chemical, molecular, cellular, tissue or segmental approach, the most commonly used being the molecular and tissue models. All this leads to the fact that the different methods can be used to estimate adipose mass, fat mass and lipid mass. Although these concepts have been treated as synonyms, there are differences among them that are addressed in this article, as well as what the different assessment methods estimate: lipid mass or adipose mass. It concludes with the practical implications of all the above for fat mass estimation.

Key words: dual energy X-ray absorptiometry, anthropometry, electrical bioimpedance, DEXA, 2D/3D/4D scanner, hydrodensitometry, adipose mass, lipid mass, fat mass, molecular model, tissue model, air displacement plestimography, ultrasound.

Resumen

La estimación de la masa grasa y el porcentaje graso ha sido utilizada tanto en el ámbito de la salud, por su relación con diversas enfermedades; como del deporte, por su relación con el rendimiento deportivo. No obstante, rara vez se tiene en consideración al evaluar este parámetro las ventajas e inconvenientes que presentan los diferentes métodos de estimación de la composición corporal, encontrándose entre ellos la absorciometría de rayos X de energía dual (DEXA o DXA); hidrodensitometría; plestimografía de desplazamiento de aire; bioimpedancia eléctrica; antropometría; escáner 2D/3D/4D y los ultrasonidos, así como si son métodos indirectos o doble indirectos. Tampoco se tienen en consideración en la mayoría de los trabajos y evaluaciones los diferentes modelos desde los que se puede abordar la composición corporal habiendo métodos que realizan un abordaje químico, molecular, celular, tisular o segmentario, siendo los más habitualmente utilizados los modelos molecular y tisular. Todo esto lleva a que con los diferentes métodos se pueda estimar masa adiposa, masa grasa y masa lipídica. Si bien estos conceptos han sido tratados como sinónimos, existen diferencias entre ellos que son abordadas en el presente artículo, así como también se aborda qué es lo estiman los diferentes métodos de evaluación: masa lipídica o masa adiposa. Se finaliza con las implicaciones prácticas de todo lo anterior en la estimación de la masa grasa.

Palabras clave: absorciometría de rayos X de energía dual, antropometría, bioimpedancia eléctrica, DEXA, escáner 2D/3D/4D, hidrodensitometría, masa adiposa, masa lipídica, masa grasa, modelo molecular, modelo tisular, plestimografía de desplazamiento de aire, ultrasonidos.

Introduction

The estimation of body composition, and more specifically fat mass and fat percentage, is a very useful aspect both in the field of health, due to its relationship with diseases such as obesity, hypertension, diabetes, hypercholesterolemia, sarcopenia, osteopenia, osteoporosis or cancer, among others; and in the field of sport, due to its relationship with sports performance (ben Mansour et al., 2021; Carnero et al., 2015; Pletcher et al., 2022).

This has led to numerous research studies measuring this parameter. However, there is a problem in estimating body composition and that is that the only direct method available is dissection of cadavers, making it impossible to use direct methods in the valuation of *in vivo* subjects (Esparza-Ros et al., 2022; Vaquero-Cristóbal et al., 2020). All other methods are indirect or double indirect, and this has led to the use of different methods in the quest to estimate body composition, each with its advantages and disadvantages (Campa et al., 2021; Esparza-Ros et al., 2022; Kasper et al., 2021; Vaquero-Cristóbal et al., 2020). This is why it is said that these methods are estimates rather than calculations, because in all of them a certain margin of error is introduced.

Methods of estimating body composition

Among the methods for estimating body composition is dual energy X-ray absorptiometry (DEXA or DXA), a device that uses low-exposure X-rays to detect the energy of photons through different regions of the body. Since soft tissues, including fat mass, allow photons to pass through better than denser tissues, such as bone, the differences obtained in the photon beam path are used to estimate body composition (Bazzocchi et al., 2016). DXA was originally developed for the measurement of bone mineral density (BMD), but is now considered the gold standard for the assessment of fat mass, although it has certain limitations that should be taken into account in its use (Kasper et al., 2021). These include the need to train assessors, as body regions have to be adjusted by hand; that it assumes that the amount of fat on bone is the same as the amount of fat on non-bone tissue, leading to speculation as to whether it should be considered the gold standard in estimating fat mass; that the software cannot be updated as the database and the values it reports change; the cost of the instrument; and finally that it is not transportable (Kasper et al., 2021).

Another of the most commonly used techniques is hydrodensitometry. This technique was for many years considered the gold standard for the assessment of body composition (McCrory et al., 1995). Based on Archimedes' principle, this technique measures body volume on the premise that when an object is submerged under water its weight is similar to the weight of the water it displaces (McCrory et al., 1995). Thus, this method analyses the water displaced by the body when it is completely submerged. The advantage of this method lies in its accuracy. However, its use has now been reduced due to the discomfort it generates in the subjects evaluated, the long measurement time required, the cost of the system and its maintenance, the impossibility of transporting it, and the impossibility of knowing the segmented distribution of fat by body zones (Kasper et al., 2021).

Following the same logic, air displacement plestimography emerged. This is an alternative to hydrostatic weighing, in which air displacement is measured to measure body density, applying Poisson's law (Higgins et al., 2001). It analyses the volume of air displaced in a closed chamber in which the subject is seated. Among its main advantages are measurement time and ease of use. Its main limitations are the cost of the system, lack of portability, insufficient sensitivity, the large number of pollutant variables involved, and problems of validity when measuring people with low fat, such as the sports population (Kasper et al., 2021).

Among the field methods for the estimation of body composition is electrical bioimpedance. Bioimpedance is a frequency technique that is classified according to the number of frequencies used for analysis (Moon, 2013). This technique consists of generating a current and measuring the time it takes for the current to cross the body by means of electrodes or metal contacts that send a small voltage. Depending on the resistance to current flow observed in the body, the fat mass and fat-free mass are estimated, as the fat mass presents more resistance to the passage of the current as it contains less water than the fat-free mass. What it really measures are electrical properties (impedance, resistance, reactance and phase angle) (Kasper et al., 2021). This method has been widely used because of the speed of measurement with it, non-invasiveness, portability, that it is a method that is generally not overly expensive, and the ease of measurement compared to other methods (Kasper et al., 2021). However, bioimpedance has some limitations, such as the fact that everything that affects the subject's hydration affects it, and that it is less valid the fewer electrodes it has, so it is no longer an economical method (Koulmann et al., 2000). In addition, previous studies have suggested that it may be a valid method for the assessment of populations globally, but may not be a valid method for the assessment of particular subjects, especially in the sports population (Nickerson et al., 2019).

The other widely used field method has been anthropometry. This technique consists of measuring a series of variables following a specific protocol, the protocol of the International Society for the Advancement of Kinanthropometry being the most widespread throughout the world (Esparza-Ros et al., 2019). Among its advantages are that it is inexpensive, non-invasive, requires minimal equipment, is transportable and provides more than just body composition results (Meyer et al., 2013). Its main disadvantage is the influence of the measurer on the variables taken, so it is important to follow a standardised protocol and the measurer has a low technical error of measurement (Kasper et al., 2021).

In addition, new methods for the assessment of body composition have emerged in recent years. These include ultrasound (Kasper et al., 2021). This method analyses the sound reflex, thereby estimating the different body tissues (Kasper et al., 2021). More specifically, this method measures the thickness of subcutaneous adipose tissue by means of ultrasound imaging through the skin at specific locations (Müller et al., 2013). It is a valid and accurate method (Müller et al., 2013), but is heavily influenced by the measurer, it is an expensive and not very transportable method (Kasper et al., 2021).

Another instrument that has been used in recent years for the assessment of body composition is the 2D/3D/4D scanner. This method has been called a method of digital anthropometry (Heymsfield et al., 2018). This type of device involves the use of visible and infrared light to create an avatar of the human body, in which the subject remains motionless in a certain posture (Eder et al., 2013). These data are used to estimate circumferences, volumes, lengths and areas (Heymsfield et al., 2018). Among its advantages are the speed of the measurement, among its disadvantages are the cost if done with equipment and the lack of studies on this technique. Finally, depending on whether a 2D, 3D or 4D analysis is performed, its validity and reliability could change (Kasper et al., 2021).

Models for approximating body composition

Body composition can be approached on five levels. This is a rarely considered issue but which affects the estimation of body composition from all the tools used. Model 1 proposes a chemical/atomic approach. According to this approach, the human being is composed of oxygen (about 64%), carbon (about 18.5%), hydrogen (about 9.5%), nitrogen (about 3.2%), calcium (about 1.5%), phosphorus (about 1%), or other components (about 2.3%). Model 2 proposes a molecular approach. From this model, the body is divided into lipids (about 15%), proteins (about 18%), carbohydrates (about 1%), minerals (about 6%) and water (about 60%). Model 3 takes a cellular approach by differentiating between fat (about 18%), extracellular solids (about 9%), intracellular solids (about 12%), intracellular fluids (about 34%) and extracellular fluids (about 27%). Model 4 considers the body as the sum of tissues. It differentiates between adipose tissue (about 25%), bone tissue (about 10%), musculoskeletal tissue (about 36%) and residual tissue (about 29%). Lastly, model 5, takes a body segment approach, differentiating between mass of the head, trunk, right upper limb, left upper limb, right lower limb and left lower limb (Campa et al., 2021; Esparza-Ros et al., 2022; Kasper et al., 2021; Mecherques-Carini et al., 2022).

Indirect or double indirect methods?

Composition estimation methods can be indirect or double indirect. Indirect methods are defined as those that directly calculate body density and then use a linear regression equation or algorithm to estimate body composition (Campa et al., 2021; Esparza-Ros et al., 2022; Kasper et al., 2021; Mecherques-Carini et al., 2022; Vaquero-Cristóbal et al., 2020). These include DEXA, hydrodensitometry, air displacement plestimography or anthropometry when estimating adipose mass with Kerr (Campa et al., 2021; Kasper et al., 2021; Mecherques-Carini et al., 2022; Ross & Kerr, 1991).

On the other hand, there are the dual indirect methods. With these methods, two linear regression equations or algorithms are used, one to estimate body density and a second to estimate body composition. Double indirect methods are bioimpedance or anthropometry when the equations are used to estimate lipid mass, among others (Campa et al., 2021; Kasper et al., 2021; Mecherques-Carini et al., 2022).

Lipid mass, fat mass or adipose mass?

One of the main problems in addressing fat mass is that the terms lipid mass, fat mass and adipose mass have been classically confused and used as synonyms when they are not (Holway et al., 2011; Mecherques-Carini et al., 2022). Adipose mass refers to the total mass of the adipose cells (adipocyte), as a whole. But although the adipose cell has a high fat mass content, made up of the triglycerides of which it is composed (90%), there is a 10% content that refers to water and minerals. Therefore, when adipose mass is evaluated, not only fat mass is assessed but also other components in a sufficiently significant percentage that the terms adipose mass and fat mass cannot be applied as synonyms. Similarly, fat mass (triglycerides) in turn consists of lipids (83%) and glycerol (16%). Therefore, when fat mass is estimated, it includes not only lipids but also the glycerol that makes up triglycerides as a whole (Holway et al., 2011; Mecherques-Carini et al., 2022).

Thus, lipid mass is a subcomponent of fat mass, which in turn is a subcomponent of adipose mass; lipid mass being 75% of adipose mass, which explains the differences in the results found in the same subject depending on whether lipid mass or adipose mass is being estimated.

What is the practical implication of the above?

Most body composition estimation methods approach body composition from model 2 (molecular) or model 4 (tissue), being able to distinguish between lipid and adipose mass. More specifically, except for DEXA which analyses adipose mass by the tissue model, the rest of the methods (hydrodensitometry, air displacement plestimography and bioimpedance) analyse lipid mass by the molecular model. Then there is anthropometry, which can estimate both lipid mass (model 2) and adipose mass (model 4) depending on the formula used, although there is only one formula for estimating adipose mass from anthropometry (Ross & Kerr, 1991), so most of the formulae used in anthropometry estimate lipid mass (Holway et al., 2011; Mecherques-Carini et al., 2022).

However, this is classically ignored and the different methods and equations are used interchangeably, without taking into consideration that the reported differences depending on the method or equation could vary by up to 30% (Mecherques-Carini et al., 2022; Schubert et al., 2019; Vaquero-Cristóbal et al., 2020), which could be introducing a large error when comparing populations or measurements made by different methods.

In addition, the cheapest methods are double indirect methods, accumulating the error of two linear regression equations/algorithms.

Therefore, when estimating "fat mass" it is necessary to consider: 1) which method is being used, is it indirect or double indirect?; 2) what are its advantages and disadvantages, is it losing validity because of the way it is applied?; and 3) is this method estimating lipid or adipose mass? In addition, populations should not be compared or evolutions made if the methods, models and equations used cannot be assured to be maintained.

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