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review article

Clinical procedures used for analysis of the body composition

Procedimentos clínicos utilizados para análise da composição corporal

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Abstract – According to the requirement for precision, accuracy and validation of information to be treated, clinical procedures can be characterized as an acceptable and accessible option for the analysis of components associated with body composition. The techniques with clinical features more commonly used are bioelectrical impedance and anthropometry by skinfold thickness. However, despite the greater feasibility in the face of laboratory procedures, clinical procedures have limitations and specifications regarding the use of their protocols, which should necessarily be considered when they are used. The purpose of this review is to provide a critical analysis about the use of bioelectrical impedance and anthropometry and explain the importance of carrying out well defined application standards to ensure more appropriate body composition estimation.

Key words: Anthropometry; Bioelectrical impedance analysis; Body fat; Skinfold thickness; Methodology.

Resumo – *De acordo com a exigência quanto à precisão, à exatidão e à validação das informações a serem tratadas, os procedimentos clínicos podem se caracterizar como opção aceitável e acessível para análise dos componentes associados à composição corporal. As técnicas com características clínicas mais comunmente empregadas são a bioimpedância elétrica e a antropometria através das medidas de espessura de dobras cutâneas. Contudo, apesar da maior exequibilidade frente aos procedimentos laboratoriais, os procedimentos clínicos apresentam limitações e especificidades quanto ao uso de seus protocolos que, necessariamente, devem ser consideradas quando de sua utilização. O propósito desta revisão é fornecer uma análise crítica sobre o uso das técnicas de bioimpedância elétrica e antropometria e expor a importância da utilização de protocolos bem definidos para garantir estimativas mais adequadas quanto aos componentes de composição corporal.*

Palavras-chave: *Antropometria; Bioimpedância elétrica; Espessuras de dobras; Gordura corporal; Metodologia.*

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INTRODUCTION

The growing interest in monitoring body composition indicators has been drawing the attention of researchers and professionals from different areas of biological knowledge, which has favored the development of new concepts and technological resources that provide increasingly greater precision and accuracy in the determination and interpretation of their components.

Traditionally, the techniques for measuring body composition can be classified according to the purpose of their application: basic and applied research of experimental and epidemiological nature, disease diagnosis and control, or dietary and physical activity interventions in programs of body weight control. These techniques involve laboratory and clinical procedures[1].

Although being more rigorous and accurate, laboratory procedures are extremely more expensive and have limited application in the daily work of professionals and investigators, due to their measurement protocols that require highly complex routines. On the other hand, clinical procedures are less expensive, less rigorous and provide a more immediate interpretation; therefore, they have a greater practical application. Despite the lower rigorousness, the results obtained with their implementation are highly related to those of laboratory procedures and can generate estimation errors within acceptable limits if certain precautions are taken into account.

In regard to the techniques used in clinical procedures, bioelectrical impedance analysis and anthropometry have been the most commonly employed[2,3]. In this sense, the present review article aimed to compile information available in the literature regarding the use of bioelectrical impedance analysis and anthropometry in the monitoring of indicators associated with body composition.

BIOELECTRICAL IMPEDANCE ANALYSIS

The basic principle of the bioelectrical impedance analysis (BIA) technique for body composition analysis is based on the different levels of electrical conduction of biological tissues exposed to several current frequencies. In this case, the human body can be compared with an electrical circuit composed of a resistance (water and fat-free mass) connected in series with a capacitor (cell membranes and fat). Intra- and extracellular fluids behave as conductors, while cell membranes (formed by a non-conductive lipid bilayer interspersed with two molecular layers of conductive protein material) act as capacitance elements or capacitors. Thus, with information on BIA or some of its parameters, it is possible to estimate the amount of body water and, by assuming constant values, the proportion of fat-free mass and body fat[2].

One of the criticisms to the BIA technique is that its principle considers the human body as a perfect cylindrical conductor, which does not seem to be true. However, several validation studies have been conducted using its procedures, and good correlations were found with reference methods[4,5].

The first attempt to show the relationship between impedance measurements and the amount of body water comes from the beginning of the 1960s[6]. However, it was only in the mid-1980s that the first devices for BIA analysis in the clinical field were conceived[7]. At first, the validation criteria of body composition indicators presented by these devices were body density and the amount of body water, based on bicompartmental models. Nevertheless, more recently, very promising indications of validation have been found among subjects aged between 12 and 90 years using multi-compartmental models[8].

Information relative to resistance and reactance in BIA can be obtained using a device named ohmmeter, preferably with two pairs of transmitter and receiver electrodes (tetrapolar technique). Ohmmeters with only one pair of electrodes (transmitter and receiver – bipolar technique) tend to increase reading errors and, if possible, should be avoided[2].

Measurement Protocol

The measurement protocol of the tetrapolar technique consists of fixing the transmitter electrodes distally on the dorsal surface of hand and foot, on the level of the head of the third metacarpal and third metatarsal bones, respectively. In turn, the receiver electrodes are placed proximally on hand and foot as well, the first in the wrist, on an imaginary level of junction of the two styloid apophyses, and the second on the dorsal region of the tibio-tarsal joint, on an imaginary line of junction of the most prominent part of the two malleoli. By convention, the four electrodes should be placed on the right hand and foot, with the individual lying in the supine position, in order to minimize the effects of gravity on the trend of body water to stagnate in the lower extremities when in bipedal position. This measurement protocol is also named horizontal BIA[2].

The two emitting electrodes apply a low-intensity alternating current (between 500 and 800 mmAmp), using cellular fluids as conductors and cell membranes as capacitors. The current difference caused by impedance is then detected by the two receiver electrodes. The analyzer measures the resistance and the reactance produced by the procedure and estimates impedance values. After conductor length (height) and impedance to this electrical current are determined, conductor volume is calculated. Admitting that fat-free mass contains much of the water and electrolytes found in the organism and is therefore the main responsible for the conduction level of the electrical current, the fat-free mass component is estimated and subsequently, based on body weight, the fat component as well[2].

Types of Ohmmeters

Ohmmeters for the analysis of BIA indicators can emit a single-frequency current (mono-frequency) and currents of different frequencies (multi-frequency). All mono-frequency ohmmeters normally work at a frequency of 50 kHz, with electrodes placed on hand and foot in the tetrapolar technique and on the foot-to-foot or hand-to-hand position in the bipolar technique. Impedance at 50 kHz frequency is directly proportional to total body water and subsequently allows for the estimation of fat-free mass. However, it is not possible to determine nor differentiate intra- and extracellular fractions of the water component[9]. On the other hand, multi-frequency ohmmeters use empirical linear regression models at different frequencies, such as 0, 1, 5, 50, 100, 200 and 500 kHz, to estimate total body water, intra- and extracellular fractions, and, by derivation, fat-free mass[10].

More recently, with the technological advance observed in the manufacturing of the devices employed in BIA, the use of frequencies higher than 500 kHz has been suggested. In some cases, spectral frequencies of up to 1300 kHz are proposed[2]. The advantage of applying electrical currents of higher frequencies resides in the possibility of estimating intra- and extracellular fractions more accurately. However, impedance values found in these cases and thus estimates of total body water are very similar to those produced at 50 kHz[11].

As for the models of ohmmeters used in body composition analysis by tetrapolar BIA, the commercial versions more commonly used are *RJL Bia 101* (RJL Systems, Inc.), *Valhalla 1990B* (Valhalla Scientific, Inc.), *Xitron 4000B* (Xitron Technologies, Inc.), and *Biodynamics 310E* (Biodynamics Inc.). However, it is usual to find alternative devices that are extremely simpler and cheaper and involve the bipolar technique. Two examples of this line of equipment are the commercial versions *Tanita* (Tanita Corporation) and *Omron* (Omron Corporation).

The *Tanita* device consists of a sort of scale that contains in its platform electrodes for transmission and reception of electrical current. Subjects stand on their feet on the platform and remain in this position for a few seconds. Electrical current should pass through lower limbs and the abdominal region, and the device itself provides immediate estimates of the amount of fat in proportion to body weight for the subject. In the option with the *Omron* device, the subject should hold the device with the arms extended in front of the body, forming an angle of 90º with the trunk, with both hands on the electrodes, so that electrical current can pass through upper limbs and the upper trunk region.

Both alternative protocols do not show information on resistance and reactance, probably inducing to estimation biases. Additionally, in the two cases, the individual should remain in the standing position for the performance of measurements, which constitutes an important limitation[2]; therefore, this procedure is called vertical BIA technique. When comparing estimates associated with the amount of fat in proportion to body weight, it is observed that the differences between the two protocols of BIA measurement (horizontal and vertical) are relevant and statistically significant[12].

In general, taking the laboratory procedures as a reference, vertical BIA tends to underestimate fat-free mass values compared with horizontal BIA[12]. Therefore, despite its low cost, easy operation and portability, if that is the case, the vertical BIA technique should be used with caution.

Methodological Aspects

Although providing a relatively easy and rapid measurement, the use of the BIA technique requires the individual to comply with a number of previous procedures, without which the quality of the information obtained will be impaired[2,13]: (a) not having taken diuretic medication in the last 7 days; (b) having fasted for at least 4h; (c) not having taken alcoholic beverages in the last 48h; (d) not having performed intense physical activity in the last 24h; (e) urinating at least 30min before the measurement; and (f) remaining at least 8-10min in absolute rest in supine position before having the measurement taken.

Besides these precautions, the quality of the measurements may be somewhat influenced by the characteristics and calibration of the equipment, body position, hydration level and food intake of the individual, room and skin temperature. Table 1 summarizes the studies available in the literature that analyzed the impact of these factors on the variation in resistance values and consequently in fat-free mass and body fat values.

Significant changes in conductivity of electric current may also occur due to the use of heavy clothing and metal items (earrings, watches, bracelets, rings, etc.)[2]. Near ovulation, women usually show a higher tendency to water retention. Moreover, measures obtained in the first hours after awakening tend to have higher reproducibility due to the small variations in metabolism at rest[13].

As for restrictions to the use of the BIA technique, currently no adverse effects have been observed, although it is important to take into account that BIA can affect the electrical activity of pacemakers and defibrillators, when it should thus be avoided[13]. On the other hand, considering that BIA is related to changes in water distribution, as occurs in some severe conditions, in such cases its theoretical assumptions become invalid[20].

In regard to the equations employed to estimate fat-free mass, the independent variable more frequently used is the impedance index (height/resistance). In this case, by virtue of the biological variations observed in the proportion of body water among individuals of both sexes and of different ages, specific expressions for each sex and age group are designed.

The literature provides a number of equations for this purpose, specifically for youth[21] and adults[8,9]. However, a priori, it is not advisable to use these equations in subjects that may have different biological characteristics

Table 1. Studies that analyzed the impact of different situations on the variation in free-fat mass (FFM) and fat mass (FM) values using the bioelectrical impedance technique.

Experimental situation	Variations in resistance values	Impact on FFM and FM	References
Use of different types of ohmmeters	± 21 ΩW	Changes in FFM and FM values	Kyle et al. [9] Deurenberg et al. [14]
Abduction of extremities from 30º to 90º	↓ 12 ΩW	Reduction of around 1.5% in FM	Kushner et al. [15]
Changing the electrodes from the right to the left side	7-18 ΩW	Changes in FFM and FM values	Kushner et al. [15]
Previous water intake (700 ml)	↑ 9 ΩW	Increase of up to 3% in FM	Kushner et al. [15] Heitmann [16]
Intake of solid food	-4 a 14 ΩW	Reduction of between 8-10% in FM	Kushner et al. [15] Heitmann [16]
Performance of moderate physical exercise	↓ 3%	Normal values after 60 min	Roos et al. [17]
After 60 min in the supine position	↑ 17 ΩW	Increase of around 2% in FM	Roos et al. [17]
Reduction in ambient air temperature from 35º to 14º C	↑	Reduction in FFM and increases in FM	Buono et al. [18]
Increase in ambient air temperature from 15º to 35º C	↓	Increase in FM and reductions in MLG	Buono et al. [18]
Use of oral contraceptive		No significant impact	Machado et al. [19]

to those from which equations were derived. In this case, it is necessary to establish validation indicators before using the equations in specific populations.

Additionally, another important aspect to be noted refers to the equations included in the software that accompanies the different devices. Their manufacturers usually provide only one choice of regression equation in each device. Thus, if the predictive equation that accompanies the equipment in use is not of interest to the professional and of the investigator, we suggest ignoring estimates of fat-free mass and fat obtained and consider only information relative to resistance and/or impedance. Hence, with equations selected by the very professional or investigator, it is possible to estimate fat-free mass and subsequently body fat, using any regression model available in the literature that is deemed appropriate for that specific situation.

ANTHROPOMETRY

The BIA technique provides estimates accurate enough for fat-free mass and body fat components and is therefore the first choice for body composition analysis using clinical procedures. However, due to the cost of the equipment, its relatively sophisticated methodology, and the difficulty in involving subjects in the measurement protocol, its use has been often limited. In this sense, the simplicity of use, innocuousness, the relatively easy interpretation, and the lower cultural restrictions, because it comprises external measurements of body dimensions, led the anthropometric technique to be chosen as the one with the highest applicability and encouraged an increasingly number of professionals to make use of its protocols.

In a body composition analysis involving two compartments (body fat and free-fat mass), the measurement of skinfold thicknesses is the most commonly used anthropometric indicator[3], despite the fact that, in multi-compartmental approaches, information on measurements of bone perimeters and diameters should also be included[22-24]. However, the simpler proposal for the analysis of body composition with the inclusion of anthropometric dimensions is the construction of indices involving measurements corresponding to body weight and height.

These indices are defined by the measurement corresponding to body weight divided by some power of the height measurement (body weight/height^p). The exponential function *p* is established with the purpose of providing maximum correlations between excessive body weight and the occurrence of overweight. The most used *body weight/height* index in the field of body composition is represented by a p value = 2, resulting in the so-called body mass index (BMI), which was originally established as the Quetelet's index (body weight expressed in kg divided by height in m^2).

Although BMI is used in the epidemiological field as an important body composition indicator, its interpretation at the individual level requires some caution. Experimentally, it was observed that, among male adults, BMI = 30 kg/m^2 implies fat percentages of around 30% of body weight at 20 years of age and 40% at 60 years of age. In women aged 20 and 60 years, these values corresponded to 40% and 50%, respectively[25]. In this perspective, it is important to pay attention to the fact that BMI values are actually nothing more but a mathematical adjustment of body weight and height measurements.

In this regard, it should be assumed that a greater accumulation of body fat induces an increase in body weight measurements and, in turn, in BMI values, which justifies the fact that many subjects with body weight above reference values also have excessive body fat. However, excessive body weight may possibly not reflect a greater accumulation of body fat, considering that this higher body weight may be a consequence of high levels of fat-free mass and not of the body fat component. Therefore, it seems to be possible that excessive body fat could induce overweight; however, the opposite may not be true, assuming that an increase in body weight may not necessarily represent an increase in the amount of body fat[26]. In these cases, in order to determine if the individual presents overweight accompanied with excessive fat, or if such overweight is attributable only to a greater development of fat-free mass, it is necessary to make use of other anthropometric procedures that allow to estimate fat and fat-free mass fractions[3].

However, if, on one hand, the association between BMI and body fat indicators was found to be weak among non-obese individuals, on the other, it was observed that BMI is strongly associated with body fat in individuals with considerably higher amount of body fat[26]. In view of that, in the absence of other information related to the amount of body fat, the professional and the investigator shall use BMI as a body composition indicator, despite its methodological and conceptual limitations.

Skinfold thickness

The use of information relative to skinfold thicknesses as a procedure for body composition analysis is grounded on the observation that the greatest proportion of body fat is located in the subcutaneous tissue and, for this reason, the measurements of its thickness is used as an indicator for the amount of body fat located in that region of the body[3]. Through cadaver studies, a close statistical relationship was observed between skinfold thickness measured with a caliper and subcutaneous tissue thickness measured directly by means of an incision made in the same location where the caliper was placed[27,28].

Since the fat located in the subcutaneous tissue is not evenly distributed throughout the body, skinfold thickness should be measured in several regions, in order to obtain a clearer picture of fat disposition. In regard to the strategies of interpretation, skinfold thicknesses can be analyzed in two ways. One of them is considering skinfold measurements of different anatomical regions separately, aiming to provide information on the relative distribution of subcutaneous fat from region to region of the body. The second way is to include them in regression equations, with the purpose of predicting values associated with body density and subsequently with those corresponding to fat in relation to body weight[3].

On the other hand, it should bear in mind that, although being reasonably valid, skinfold measurements are affected by interferences due to the participation of other subcutaneous tissues, resulting thus in approximate values and not in the actual amount of subcutaneous fat[27]. Moreover, when comparing skinfold measurements, it is necessary to consider other important limitations. For example, the compressibility of the subcutaneous tissue and skin thickness[28].

Additionally, the representativeness of the subcutaneous fat content in relation to skinfold measurements shows high variation among individuals and among different anatomical sites from the same individual[28]. Therefore, two similar skinfold measurements, in the same individual, may indicate different subcutaneous fat deposits, according to the anatomical site analyzed.

The level of accuracy and precision of skinfold measurements depends on the type de caliper used, on the extent to which observers are familiar with the measurement techniques and on the perfect identification of the anatomical sites to be measured. As for calipers, several types have been defended and used; however, *Lange* (Beta Technology Incorporated) and *Harpenden* (British Indicators) calipers are those that have exhibited higher accuracy in the measurements observed and higher consistency after repeated measurements[29]. A caliper made in Brazil, the *Cescorf* caliper (Cescorf Equipamentos Ltda.), with mechanics and design very similar to the

Harpenden caliper, has also been recommended. Other options of calipers made in Brazil, *Sanny* (American Medical do Brasil Ltda) and *OpusMax* (Terrazul Tecnologia) calipers, still require further studies before being recommended for routine use.

Despite the quality of the information obtained through the use of the three most recommended calipers (*Lange*, *Harpenden* and *Cescorf*), it is necessary to take into account important differences in the characteristics of each one of them, which leads to systematically different skinfold measurements. The mean spring pressure required for opening caliper jaws at ranges between 2 and 40 mm is 10 g/mm^2, with a maximum variation of 2 g/mm^2 in the three calipers. However, the area of contact with skin surface is 30 mm^2 in the *Lange* caliper (5 x 6 mm), whereas in *Harpenden* and *Cescorf* calipers it reaches 90 mm^2 (6 x 15 mm). Therefore, since the level of compressibility of a caliper depends on the relationship between its area of contact with skin surface and the pressure exerted by its springs[31], a greater area of contact, along with no changes in spring pressure, should lead to higher compressibility among *Harpenden* and *Cescorf* calipers.

Furthermore, the significantly smaller jaws observed in *Lange* calipers should also interfere in the compression of the skinfolds to be measured[30]. Thus, although the three types of calipers may exhibit similar characteristics in terms of spring pressure, the *Lange* caliper shall provide lower dimensions for the same skinfold thickness compared with *Harpenden* and *Cescorf* calipers, due to differences related to design. Experimental evidence reveals that, for the same skinfold thickness, the *Lange* caliper tends to show higher measurements in comparison with the *Harpenden* caliper[29].

The disagreement in the definition of measurement is an additional aspect to be considered when comparing skinfold measurements obtained using the *Lange* caliper with the other two calipers. The *Cescorf* caliper has a measurement definition of 0.1 mm; in the *Harpenden* caliper, it reaches 0.2 mm, with the possibility of reaching 0.1mm through interpolations in the measuring scale; and the *Lange* caliper has a 1.0 mm definition. These differences in measurement definition almost make it impracticable to carry out any attempt to draw a safe and effective comparison between skinfold measurements obtained with the *Lange* caliper and those obtained with *Harpenden* and *Cescorf* calipers.

Another important aspect related to skinfold measurement is the extent to which the observers are familiar with the measurement technique. In this regard, a basic element should be considered: the influence of variations in intra- and inter-observer reproducibility. As for intra-observer measurement reproducibility, it is observed that the magnitude of its indices varies according to observer's experience with the adopted protocol and to the region to be measured. However, the amount of fat accumulated by the subject allows that repeated measurements, performed by the same professional in the same region, agree more closely between smaller dimensions than between larger dimensions. Therefore, the increase in the possibility of occurring intra-observer variations shall be inversely proportional to the increase in the dimensions of the measurements[31].

Regarding the determination of acceptable indices for intra-observer reproducibility, there have been a few attempts of establishing reference models in this field. Therefore, before beginning to use a certain technique of skinfold thickness measurement, it is suggested that each professional or investigator determines his or her own intra-observer reproducibility index, in order to obtain information that is really reliable and useful for future body composition analysis.

When considering inter-observer reproducibility indices, it is noted that, due to the fact that skinfold measurements are carried out on soft tissues, there is the possibility of individual differences among professionals in terms of the exact location and definition of the anatomical sites to be measured. Consequently, these indices can be as twice as high as those for intra-observer reproducibility[31]. Thus, only a strict adherence to the adopted standards and a full mastery of the measurement protocol will make it possible to minimize the possibility of these variations to occur.

When it comes to the protocols of skinfold thickness measurement aiming to analyze body composition, experts in the field developed standard procedures that have been widely accepted by the users of the technique[3]: (a) always perform the measurements on the right side of the body; (b) identify and mark carefully the anatomical site corresponding to the skinfold with a dermatographic pencil; (c) define the deeper subcutaneous cell tissue using the thumb and the index finger of the left hand; (d) pinch the skinfold and place the thumb and the index finger, approximately 8 cm apart from each other, on a line perpendicular to the axis that accompanies the skinfold. The thicker the subcutaneous tissue is, the greater the distance between the thumb and the index finger shall be in order to pinch the skinfold; (e) raise the skinfold around 1 cm above the measurement point; (f) maintain the skinfold raised while taking the measurement; (g) apply the upper edge of the caliper perpendicularly to the skinfold and at nearly 1 cm below the site of repair; (h) release the pressure of the jaws of the caliper slowly; and (i) wait for nearly 2-3 seconds and then release the pressure of the jaws of the caliper so that the reading of the measurement can be obtained.

Some other precautions should be taken in order to improve the quality of the measurements. The performance of a series of three measurements at the same location, alternating one measurement with the other two, is an interesting procedure to minimize measurement errors. In the event of discrepancies higher than 5% between the extreme values of measurements at the same site, a new series of three measurements shall be performed. The intermediate measurement of each site is the value to be adopted for calculation purposes[3].

It is not advisable to take skinfold thickness measurements immediately after intense physical activity. In these cases, the displacement of body fluids towards the skin, in consequence of biological adaptations resulting from the physical effort performed, tends to increase skinfold thicknesses. In addition, measurements should always be taken directly on the skin of the subject when it is dry and free of any product that could cause the sliding of observer's fingers or of the caliper edges[3]. Whenever possible, the use of plastic calipers should be avoided and a minimal definition of 0.1 mm should be obtained, even if it is reached by interpolation of the original measuring scale[32].

As for the location of the anatomic sites for taking skinfold measurements, it varies according to the predictive equation used to estimate the amount of body fat. However, it is important to emphasize the need of complying strictly with the standards proposed by the authors of the selected equation.

Circumference Measurements

This is an alternative anthropometric method of body composition analysis consisting of circumference measurements in specific regions of the body. In principle, circumference measurements have the same advantages than skinfold thickness, related to simplicity, easiness and acceptance; however, they have been proven to be a weak predictive variable of the amount of body fat, due to the fact that they include other tissues and organs besides adipose tissue[24].

The use of circumference measurements in body composition analysis is suggested in two situations. The first one is when an individual has extremely high body fat, which makes skinfold thicknesses to be above the recommended threshold to ensure good quality measurements (> 40 mm); the second one is when the purpose includes gathering information on the pattern of regional body fat distribution[27].

Some concerns regarding the pattern of regional body fat distribution are justified by the close association observed between some health complications caused by cardiometabolic disorders and the greater accumulation of fat in the central region of the body, regardless of age and total body fat[33]. Conceptually, the greater accumulation of fat in the central region of the body, or a centripetal pattern of regional body fat distribution, is characterized by a greater amount of fat in the trunk regions, mainly in the waist, and a relatively lower amount of fat in the extremities. On the other hand, the peripheral pattern of body fat distribution is defined by a greater deposit of fat in the extremities, mainly in hip, buttocks and upper thigh, compared with the trunk.

The ratio between waist and hip circumferences has been frequently used to determine if body fat accumulates predominantly in the central region of the body or in the extremities. As for the interpretation of the values obtained in the waist-to-hip ratio, the literature provides reference indicators that may identify the magnitude of the risk predisposing to the onset and development of cardiometabolic disorders according to age and sex [34]. Another way to predict health-related risks due to a greater accumulation of fat in the central region of the body is to make use of the ratio between waist circumference and height. In this case, waist-to-height ratios higher than 0.50 tend to increase the incidence of cardiometabolic disorders[35].

The main advantage of using the waist-to-height ratio, in comparison with the waist-to-hip ratio, refers to the fact that, in theory, the first shall present higher sensitivity for the analysis of the pattern of fat distribution, considering the probable combined variation of waist and hip circumferences during the process of greater accumulation and reduction of body fat[35]. Additionally, these measurements allow for immediate comparisons of body fat distribution among individuals of different heights.

Predictive equations involving anthropometric measurements

Based on the close statistical relationship between body density measurements and skinfold thickness, which qualifies this anthropometric technique as a good option to develop estimates associated with the amount of body fat, and considering that densitometric procedures are used to validate other techniques, some predictive equations have been proposed, contributing tremendously to enable the application of skinfold measurements in body composition analysis.

When regression equations are used for this purpose, the sum of a set of skinfold thickness measurements is considered to be a good indicator of subcutaneous fat, and the values corresponding to body density of the total body fat. Taking these assumptions into account, the vast number of regression equations available in the literature can be classified into two groups: specific equations and generalized equations.

Specific equations are designed based on information presented by homogeneous groups of individuals in terms of sex, age and body fat levels. Therefore, these equations should be applied in specific segments of the population with similar characteristics. On the other hand, generalized equations are proposed to include individuals with different amounts of body fat and belonging to a broader age range. Thus, there is an attempt to minimize the participation of the degree of adiposity and of the process of organic aging in the statistical relationship between total body fat and subcutaneous fat[36].

At first, it seems clear that specific equations have higher predictive validity when used in individuals belonging to the same segment of the population from which the equation was created; however, the more specific an equation is, the lower its applicability is. Thus, generalized equations conceived based on representative samples of heterogeneous populations in terms of age and adiposity level may increase the range of application.

Prediction errors associated with the use of equations to estimate the amount of body fat are established in mean values around 5%, although biases between 3% and 9% of the actual body fat may be found, depending on the equation used and the amount of body fat for the individual under study[36].

When choosing to use an equation involving skinfold thickness measurements for predicting the amount of body fat, the validation principle of the same equation should be observed in samples of individuals belonging to the population intended to be analyzed. The proposal of equations for this purpose, accompanied by estimation errors of low magnitude, does not necessarily mean that they can be used in all populations. It is thus necessary that they undergo a process of validation to adjust their prediction coefficients and, whenever needed, to establish new specific estimation errors for that population. Therefore, it is important to pay special attention to the validation process of anthropometric equations, with the purpose of establishing more accurate estimates for the amount of body fat[3,36].

In studies that aimed to validate equations based on samples of American, Japanese and European individuals, it was observed that they produce remarkable biases when compared with the use of densitometric procedures in the analysis of the amount of body fat of individuals belonging to segments of the Brazilian population[37]. In this sense, it has been intended to propose equations for the Brazilian population that could provide a better response to this reality[38,39].

Contrary to what has been observed in adults, there are few equation with skinfold measurements proposed with the purpose of estimating body composition parameters in young populations. To some extent, this situation is somewhat incoherent. Considering the difficulties in persuading children and adolescents to cooperate with the protocols of the BIA technique are significantly higher than those observed in adults, it seems that there is a greater need to use predictive equations in this segment of the population.

Among the few specific equations for the youth available in the literature, those suggested by Slaughter et al. received greater acceptance[40]. Their proposal involved the proportion of fat in relation to body weight, obtained by information coming from multi-compartmental analysis as the dependent variable and the sum of triceps and subscapular skinfold thicknesses as the independent variable. The prediction error produced by the equations is estimated to be between 3.6% and 3.9%. The equations were proposed separately for white and black youths, and for those presenting levels of biological maturation corresponding to pre-pubertal, pubertal and post-pubertal stages.

FINAL REMARKS

Depending on the requirement for precision, accuracy, and validation of the information to be treated, clinical procedures can be characterized as an acceptable and accessible option for the analysis of components associated with body composition. In this sense, the techniques with clinical features more commonly used are BIA and anthropometry by skinfold thickness. However, despite the greater feasibility in the face of laboratory procedures, clinical procedures have limitations and specificities regarding the use of their protocols, which should necessarily be considered when they are used.

Although the relative predictive validity of the skinfold thickness technique is similar to that of the BIA technique, if performed under clinically controlled conditions, BIA seems to be more attractive because it does not require specific technical skills from the observer, the method is more comfortable and less invasive for the subject and additionally can be used to analyze the body composition of overweight and/or obese individuals. Despite its lower operational costs in regard to the equipment used, the skinfold thickness technique requires a high degree of training from the observer in order to find the exact location and to perform the correct pinching of the skinfolds, since they are by definition a soft tissue whose anatomical identification is difficult. Moreover, the muscular development and the amount of body fat located specifically in the anatomical region where the skinfold is pinched can change the consistency of the subcutaneous tissue, which boosts the risk of occurring measurement errors.

Many of the equations for body composition analysis involving BIA and skinfold thickness techniques available in the literature are characterized by the use of the classical model of two compartments (fat and free-fat mass). However, when their results are compared with reference methods that are technologically and biologically more advanced and safe, the estimation errors found with these equations can reach values above the expected in the statistical field. In view of that, it is suggested that, when equations are used for this purpose, the investigator should be careful to choose derived equations based on concepts coming from multi-compartmental models, besides using laboratory procedures as a reference method. In this case, unfortunately, up to now, we did not identify equations with such characteristics that were proposed and/or validated for use in the Brazilian population, which severely limits the use of clinical procedures for body composition analysis in our setting.

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