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The Scope of Body Mass Index (BMI) and other body component measurements

Most significant features of the different body component measurement methods

Abstract

This paper presents and compare the scopes of the body component measurement methods and techniques currently in use. Next to the best known and widespread Adolphe Quetelet's Body Mass Index, 'New Body Mass Index' created by Prof. Trfethen. Moreover, it presents and compares the bioelectrical impedance analysis and the Electrical Impedance Myographs methods, too. This article aims to go through one by one the body component measurement methods, and to compare the most important feature of them, for a better understanding of their usability.

Keywords: body mass index, professional sports, body component measurements, skinfold, new body mass index, bioelectrical impedance analysis

Introduction

The perfect body is the subject of inquiry of the civilization from ages. In the last century beside the representatives of different arts the scientists also set up standards of the human body. Body mass index has been used for several 100 years; BMI divides a person's weight by the height squared. This formula has never been corrected or changed during its use. Would it be perfect for all earthlings, all age groups, all physical activities - especially for all sports practitioners? Some scientists say that the BMI leads to confusion and misinformation – especially in the fields of professional sports (URL5).

In the early nineteenth century the insurance companies gained a significant increase in the fields of life-insurances in the United States of America. They had to set up some kind of universal system based on human body ratio, indicating the level of health; and offering an easy access. The emphasized feature of the measurement process was 'universal' - all people, all age groups and both sexes - should be measured with the same method (ALMIDA, 1913).

Before that time there was no measurement of this type, so it had to be invented, developed. *'Superficially, it might seem simplest and most informative to express the weight of the individual as a percentage of the average weight of persons of the same height, age and sex in the population to which he belongs. That was the reasoning that led to publication of 'standard height-weight' tables by the life insurance industry, beginning with the Medico-Actuarial Mortality Investigations of 1912'* (Keys, 1972)

Background

To fulfil the most important viewpoint, i.e. the universal application, the measurement had to be based on some anthropometric features. This discipline is *'the study of the measurement of the human body in terms of the dimensions of bone, muscle, and adipose (fat) tissue. Measures of subcutaneous adipose tissue are important because individuals with large values are reported to be at increased risks for hypertension, adult-onset diabetes mellitus, cardiovascular disease, gallstones, arthritis, and other disease, and forms of cancer'* (URL2)

However, in that time already existed some anthropometric measurement for example the skinfold-measurement, which is a method for determining body fat composition. (Ojo, 2017) According to the medical dictionary the definition of the skinfold measurement is: *'A skinfold caliper is used to assess the skinfold thickness, so that a prediction of the total amount of body fat can be made. This method is based on the hypothesis that the body fat is equally distributed over the body and that the thickness of the skinfold is a measure for subcutaneous fat'* (URL3 'Skinfold-measurement')

Finally, the Body Mass Index (BMI) became a worldwide recognized and supported measurement method. It is not an exact physical method, but a theoretical indicator, which is derived from a mathematical formula. Body Mass Index defined as *'the weight in kilograms divided by the square of the height in meters.'* (Rolland-Cachera, 2014, 117.) The insurance companies have selected the fastest solution, which can be used without any additional investment or

special knowledge. And thanks to this method - which later got the name Body Mass Index - the employees could use a simple formula, from behind a desk.

This calculation was the fastest and the cheapest, so the most economical. And these were the most important aspects for the insurance companies at that times. The inventor of this formula was Adolphe Quetelet, under the premise that ‘the transverse growth of man is less than the vertical’, derived the function most used today to characterize relative body weight, that is, the ratio of weight (kg) to height (m) squared (Blackburn, 2014). *‘Adolphe Quetelet at age 23, the remarkable Belgian mathematician went to study in Paris under Poisson, Laplace and Fourier and returned to found the Royal Astronomical Observatory, then to develop and promote the sciences of statistics and of anthropometry. All was part of his grand scheme to measure and characterize ‘l’homme moyen’—average man—by the mean values of measured variables having a normal distribution!’* (Faerstein – Winkelstein, 2012, 762–763.) In other words, Quetelet has coined the average of the average mass.

The Imperfection of Quetelet’s formula

From the past century, experts from different disciplines have criticized the Quetelet’s formula with different reasons. The most outstanding reason was the high-level of inaccuracy at body fat ration. However, the Body Mass Index does not measure body fat directly, researches have shown, that Body Mass Index correlates with direct measures of body fat: *‘Regression of F/H^2 on W/H^2 (Quetelet’s index) gave a correlation coefficient of 0.955 for women and 0.943 for men. The deviation of the body fat estimated from Quetelet’s formula from the ‘true’ value was not much greater than that when density, water or potassium were used as a basis for estimating body fat. It is concluded that Quetelet’s formula is both a convenient and reliable indicator of obesity’* (Garrow – Webster, 1985, 147-153.)

Alternative Solutions

The newest critics is Professor Trefethen, mathematician at Oxford University. According Trefethen the Quetelet’s formula is inaccurate and misleads the user, as the formula leads to confusion and misinformation. *‘The height term, he says, divides the weight by too much when people are short, and by too little when they are tall. The result is that short people being told they are thin-*

ner than they really are, while tall people are made to think that they are fatter than they are. ' (Trefethen, 2013) Therefore Prof. Trefethen has created a 'New Body Mass Index' (URL2). This formula is based on the original one, the ration of height derived the weight square, but Professor says there is missing an important third factor, which would represent the third dimension where the human body exists. *'The oddity is the appearance of that exponent 2, though our world is three-dimensional. You might think that the exponent should simply be 3, but that doesn't match the data at all. It has been known for a long time that people don't scale in a perfectly linear fashion as they grow. I propose that a better approximation to the actual sizes and shapes of healthy bodies might be given by an exponent of 2.5.'* (Trefethen, 2013, 42.) The new body weight formula is as follows: the weight multiplied by 1.3 and divided by the square of the height. This correction will result in a more realistic index for millions of people. *'If the new numbers gave a more accurate indication of actual health issues, this could be a significant change for the better.'* (Trefethen, 2013) This theory is so new that there are simply not enough collected data to compare on a bigger pattern to verification.

And this is the point where the power of Body Mass Index's long data record history shows itself, not to mention the wilderness of the pattern. The new theories have no real chance to compete with its proved way. As we could learnt from above examples, the mathematical formula of the Body Mass Index is serving as an average and approximate determination. This is a guidance for organizations just like insurance companies. However, there are some organizations with huge staff, still not accepted Quetelet formula. For example, the Army of the United States of America uses a variation of the skinfold methods: measuring the neck circumference the waist circumference and the hip circumference and different skinfold sizes. And the person's weight, age and gender are also taken into account (Army Regulation, 40-501.). Several armies use this method, because its needs more detailed data for determination of the body fat ratio.

The most criticized part of the Body Mass Index is its inappropriate correlation to the body fat ratio. As Garrow and Webster proved: the correlation coefficient is 0.955 for women and 0.943 for men (Garrow – Webster, 1985, 147-153.) These correlations are good enough, but there exist more punctual, and more effective body fat measure methods. These measurement techniques mostly fulfill all the requirements in the field of accuracy. So, it could be used by numerous types of scientists, researchers and professional sport experts, too (URL6).

The punctuality of the measurement depends on the elaboration and exactness of the data survey. In case of a mathematical formula - like the BMI formula -

is not provided a high level of preciseness. In addition, the body fat ratio has only secondary and derived connection with this formula. Nevertheless, worthy to note that Quetelet's purpose was to find the formula for an average man's measurement, and he doubtlessly did it (URL4).

To reach a more precise measurement method in the case of the body fat, a more exact measurement technique is required. The following techniques are all based on exactness and fullness, so the results are more precise. All of them are time-consuming, and to complete these measures needs special knowledge and measurement tools. But the results are useful for those professionals, in whose worlds the details have got a high level of importance, where the numbers behind the point play a role.

One of the best-known body fat measure methods is DEXA, which '*stands for 'Dual-Energy X-ray Absorptiometry,' because it uses the absorption properties of your body to figure out which bits are fat and which are muscles. This is also how x-rays work in general. Your bones are much dense than everything else in your body, so when someone shines x-rays at you, your bones deflect the rays more. Fat and muscle also reflect radiation differently from each other (and from bone), so we can also use x-rays to determine where you have fat versus muscle.*' (Chlodosh, 2013)

The other available option is: '*computer tomography or magnetic resonance imaging (MRI) give accurate values of body fat, but are inappropriate for routine clinical practice because of the lack of available retrospective data, high cost and technical difficulties.*' (Chlodosh, 2013). In the everyday life these methodologies cannot be used in an effective way (URL7). But the sport industry developers invented a functional tool for the precise measure of body fat and other body components.

The new era of the measurement

The first newly developed body component measure tools are based on the bio-electrical impedance analysis (BIA). It is a widely used method for estimating body composition. BIA measures the opposition of body tissues to the flow of a small (less than 1 mA) alternating current. Impedance is a function of two components (vectors): the resistance of the tissues themselves, and the additional opposition (reactance) due to the capacitance of membranes, tissue interfaces, and nonionic tissues. The measured resistance is approximately equivalent to that of muscle tissue. Impedance measures vary with the frequency of the current used (typically 50 kHz, when a single frequency is used). '*Applications of*

BIA increasingly use multifrequency measurements, or a frequency spectrum, to evaluate differences in body composition caused by clinical and nutritional status. ' (URL1)

The second type of body component measure tools is Bioimpedance Spectroscopy (BIS). BIS is similar to BIA in that both methods measure the body's response to small electrical currents. BIS and BIA devices look similar but use different technology. *'BIS uses a much larger number of electrical currents than BIA, in addition to high and low frequencies, to mathematically predict your amount of body fluid BIS also analyzes the information differently, and some researchers believe that BIS is more accurate than BIA.'* (URL1) So Bioimpedance Spectroscopy is a more exact generation of this totally new measurement method.

The third member of this type of measure method is Electrical Impedance Myographs. *'However, while BIA and BIS send currents through your whole body, EIM sends currents through smaller regions of your body. Recently, this technology has been used in inexpensive devices that are available to consumers. These devices are placed on different parts of the body to estimate the body fat of those specific areas. Because this device is placed directly on specific body regions, it has some similarities to skinfold calipers, although the technologies are very different.'* (URL1)

The EIM is the newest technology so there is no information about precision of this method available. But no question that the body parts measure will be the next step on the path of development. In addition, these measurements use electronic data survey. It means that anytime can have access to these big databases, which lead to a better methodology development. Because these developments are based on a high-precise survey and are not just theoretical formulas.

Conclusion

To sum up: the body component measurement went through a huge development in the last century. In the beginning the Quetelet's mathematical formula (divides a person's weight by their height squared) the Body Mass Index (BMI) was the solution. This was not a real exact measure, it was an estimated derivation from the formula. Over the past decades, the needs arose, to get a more punctual result. The focus increasingly moved from all body components to body fat. So, the new measurement methods also changed to fulfil the requirements.

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Online links in this article

- URL1: *NIH National Institutes of Health Technology Assessment Conference Statement. Bioelectrical Impedance Analysis in Body Composition Measurement*. <https://consensus.nih.gov/1994/1994bioelectricimpedancebodyta01.pdf>
- URL2: *NHES National Health and Nutrition Examination Survey III; Body Measurements (Anthropometry)*. <https://wwwn.cdc.gov/nchs/data/nhanes3/manuals/anthro.pdf>.
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