

## Is it time to leave the Body Mass Index (BMI)?

### ¿Es Hora de Abandonar el Índice de Masa Corporal (IMC)?

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**Received:** July 15, 2018

**Accepted:** September 27, 2018

**Keywords:** BMI, Accuracy, Validity, Skewness, Maximum likelihood ratio, ROC.

**Palabras clave:** IMC, Exactitud, Validez, Tasa de Probabilidad Máxima, Distribución anormal

**Cite this as:** Bergonzoli G. Is it time to leave the Body Mass Index (BMI)? IJEPH. 2018; 1(1): e007. Doi: [10.18041/2665-427X/ijeph.1.3877](https://doi.org/10.18041/2665-427X/ijeph.1.3877).

#### Abstract

**Background:** This study was conducted to assess the accuracy when calculating the nutritional status using the new Body Mass Index formula (BMI), taking as Gold Standard the traditional BMI.

**Methods:** The diagnostic accuracy compared the new BMI formula to the traditional BMI. Accuracy analysis included sensitivity, specificity, and predictive values (positive and negative), Youden index, Kappa index, ROC, and maximum likelihood ratio.

**Results:** The new BMI formula yielded good results for all indicators used for measuring the accuracy, in all groups. These results are a good evidence that the new BMI formula could replace the traditional BMI for screening population based nutritional status. However, the new BMI formula detected less subjects in subnormal, normal, and overweight groups; and, more in the obese group. The distribution is biased to the right in both formulas. In overweight and obese groups, the skewness is bigger in the new formula than the original formula; being the skewness 5.91 and 4.81; and 30.9 and 30.3, respectively.

**Conclusion:** Although the results are good evidence that new BMI formula yields similar results to the BMI formula for screening nutritional status at population level, and therefore, could be used interchangeably. Both formulas lack some validity in measuring the obese nutritional status, which do not allow recommending either of these formulas, due to the large dispersion of both formulas.

#### Resumen

**Introducción:** El estudio fue realizado con la finalidad de estimar la exactitud en la medición del estado nutricional de las personas utilizando la nueva fórmula del Índice de Masa Corporal (IMC), teniendo como parámetro de comparación el IMC tradicional.

**Métodos:** El análisis de exactitud fue realizado mediante la estimación de la sensibilidad, especificidad, valor predictivo positivo y negativo, los índices de Youden y Kappa, además de la razón de máxima verosimilitud y la curva ROC.

**Resultados:** Aunque la nueva fórmula IMC arrojó resultados similares a la fórmula tradicional en la mayoría de los indicadores examinados. Ambas fórmulas presentan una distribución muy sesgada a la derecha, siendo mayor en la nueva fórmula comparada con la tradicional. Los resultados fueron mayores en la nueva fórmula, siendo 5.91 y 4.81 en el grupo de sobrepeso, y 30.9 and 30.3, en el grupo obeso.

**Conclusión:** Si bien los resultados encontrados apuntan a que la nueva fórmula se comporta de forma similar a la fórmula original y, por tanto, podrían ser utilizadas en forma intercambiable. Los hallazgos señalan que ambas fórmulas presentan una amplia dispersión hacia la derecha, sesgo que afecta la validez en la medición del sobrepeso y obesidad, resultado que no permite ser recomendadas.

### Key Study Facts

<b>Objective</b>	To assess the accuracy when calculating the nutritional status using the new Body Mass Index formula (BMI), taking as Gold Standard the traditional BMI.
<b>Study design</b>	Cross-sectional
<b>Source of data</b>	Data base from the study developed by the research group CEDETES, of the University of Valle in Cali, Colombia, oriented to measurement risk factors for non-communicable diseases in the municipality of Santiago de Cali in 2013
<b>Population/Sample</b>	6,965 adult records of BMI
<b>Statistical analysis</b>	Accuracy analysis included sensitivity, specificity, and predictive values (positive and negative), Youden index, Kappa index, ROC, and maximum likelihood ratio
<b>Main finding</b>	The new BMI formula yielded good results for all indicators used for measuring the accuracy, in all groups. These results are a good evidence that the new BMI formula could replace the traditional BMI for screening population based nutritional status. However, the new BMI formula detected less subjects in subnormal, normal, and overweight groups; and, more in the obese group.



## Introduction

When, in 1832, the Belgian mathematician, Adolphe Quetelet proposed an instrument to select the fittest men to enter the Belgian imperial army based on his very own principle, according to which: “the transverse growth of a man is less than the vertical,” the intention was not to measure obesity, but to find the men with the physical characteristics most apt to defend the interests of the Belgian empire in the African continent (1).

Shortly before the First World War, actuaries began to notice the links between obesity and life insurance claims, and it was then when the Quetelet Index became a useful tool for estimating life insurance premiums. Later, in 1972, Ancel Keys, an American scientist who studied the effect of diet on health, rescued the index. Then, in 1980, JS Garrow and JD Webster introduced the categories recognized as “obesity” and “overweight” (2,3).

Since 1980, obesity has more than doubled worldwide, and in 2014, more than 1,900 million adults (39%) aged 18 or over were overweight, of which 13% more than 600 million were obese. In that same year, 41 million children under the age of five were overweight or obese, and at least 2.8 million people die each year from overweight or obesity. Economic analysis suggests that each 10% increase in NCDs is associated with a 0.5% decrease in the annual growth of the economy (4).

The 2013 Global Burden of Disease Study, published in May 2014, showed that 37% of men and 38% of women had a body-mass index of 25 kg/m<sup>2</sup> or greater, a rise of 28% in adults and of 47% in children since 1980. An estimated 2.1 billion people are overweight globally. In addition, while some developed countries have seen an apparent slowing of the rise in obesity prevalence since 2006, no country has reported significant decreases for three decades (5).

The World Health Organization (WHO) declared, in 2011, that obesity and overweight derived from the increase in dietary energy consumption had reached epidemic levels. Obesity and overweight are defined as an abnormal or excessive accumulation of fat that can be detrimental to health and are considered precursor conditions for the development of non-communicable diseases, including diabetes, cardiovascular diseases, and cancer (6).

In the United States, in 2008, it was estimated that health costs derived from obesity care amounted to 147 billion dollars; indeed, practically 10% of all medical expenses for that year. The aforementioned figure is much higher than 78,500 million dollars the cost estimated in 1998. This increase in cost can be attributed to the increased prevalence of overweight and obesity (7).

In the United Kingdom, a variation in health expenditure attributable to obesity has been calculated to be between 2.3 and 4.6% of total health expenditure (8). In Canada, a study on the economic cost of 8 diseases associated with obesity estimated the cost at 2 billion Canadian dollars, while another study on the impact of 18 diseases associated with overweight and obesity estimated 6,000 million Canadian dollars (9).

Many health economists are interested in estimating the social costs attributable to overweight and besity, taking into account factors such as early retirement, work efficiency, and the prospects of a healthy life. It is estimated that social costs represent 60% of the total cost of being overweight or obese (10).

In 2014, the McKinsey Institute estimated that the economic burden of being overweight or obese was 2 billion dollars, equaling the expense of smoking and all armed conflicts (11).

Therefore, considering the measurement of overweight and obesity is very important for making informed decisions because of the great impact on health and the economy.

The Body Mass Index (BMI) continues to be the dominant instrument that produces the data, by which the declaration of obesity as a global epidemic is based, and this fact would not be very important if it were not associated with the need to intervene in persons classified as obese or overweight, given the BMI's established relationship with a wide variety of diseases, and the resources required for their care, which for many countries represents a great fiscal effort.

During the last two decades, some scientists have questioned the validity of this instrument to measure the ideal weight of a person to the point that Nick Trefethen (12), a professor of mathematics, said that the body mass index, the standard tool to measure the rate of overweight and obesity, was flawed because it does not take into account the fact that taller people could carry extra natural weight without being obese. He introduced a new formula and insisted that his formula, far from being simply an academic exercise, was an urgent necessity since the results could affect millions of people. The purpose of this study was to measure how accurate the new formula is in measuring the nutritional status of people, compared with the traditional BMI formula.

### What is known

The BMI has been used for classifying nutritional status at population level. World Health Organization (WHO) has supported the use of this instrument. Concerns about BMI validity have arisen lately, due to some detected flaws on the traditional formula.

### What is new

New formula has been proposed to replace the traditional one. However, the accuracy of the new formula has not been tested. This study result contributes with a new piece of knowledge showing that the new formula behave as good as the traditional one, but both have shortcomings when measuring obese people, finding that makes it difficult to recommend them.

### Methods

The present investigation is located within the framework of cross-sectional observational studies, due to the modality of data collection that is subject to a fixed and instantaneous temporality. The source of the data was a base product of the study developed by the research group CEDETES, of the University of Valle in Cali, Colombia, oriented to measurement risk factors for non-

communicable diseases in the municipality of Santiago de Cali in 2013.

For the data collection, a stratified multistage sampling (neighborhoods, blocks, homes) with probability of inclusion of the primary units proportional to the size of the study domain (commune) was designed. The primary sampling unit (first stage) was the neighborhoods, the second the blocks of each stratum, and the tertiary units (third stage) the dwellings occupied by the households of the selected blocks. The sampling terminal unit always corresponds to the observation unit that for this study were the people that make up the family inside the household.

The first stage of the sampling involved the random selection of 1,200 blocks (1,000 principal and 200 replacement if required) distributed in the different neighborhoods of each commune.

In the second stage, 4 households were selected from each block by systematic sampling with random start; so that, there is a total of 4,000 surveys conducted, that are distributed in the 1,000 selected blocks of the 22 communes of the urban area of the municipality of Santiago from Cali Colombia.

A cleaning process to the database provided was carried out prior to the statistical analysis in order to correct errors and discard records that were outside the expected range. The data dictionary, manuals, and protocols for the handling of inconsistencies and missing data were reviewed.

All the records of people over 18 years of age on which there was a registry of weight and height were used. We excluded people with height less than or equal to 1.40 m and weight less than or equal to 40 kg, regardless their age.

It was verified, by means of certain statistical procedures, the detection of violations to statistical assumptions that could cause certain errors or unrealistic results, which would lead to conclusions far from the accumulated body of knowledge.

The statistical analysis for the estimation of the accuracy in the measurement of the nutritional status of the two formulas was made by having as a comparison parameter or "Gold standard" the results obtained from the application of the traditional formula or BMI, which divides the weight in kilograms by the size in meters squared. These measurements were compared with the results obtained from the application of the new formula, which consists of the ratio between the product of the weight in kilograms, multiplied by the constant 1.3, divided by the height in meters, raised to the power 2.5.

Accuracy analysis included sensitivity, specificity, and predictive

values (positive and negative) and was expressed as follows: 100-85% 'very good'; 84-70% 'good'; 69-55% moderate and  $\geq 55\%$  'weak'. Two indexes for interpreting the accuracy of the new BMI formula and the current BMI formula as a gold standard were: You index, which reflects the difference between the rate of true positives and false positives; and the Cohens' Kappa test, a measure of agreement between two raters occurring by chance. The concordance strength for Youden and Kappa values was expressed as follows: 0.81-1.00 "very good", 0.61-0.80 "good"; 0.41-0.60 moderate; and  $\leq 0.40$  "weak". The receiver operation curve (ROC) was also estimated to compare the probability area under the new BMI curves, as the area under the curve reflects the proportion of individuals correctly classified, regardless of the cut-off chosen or the decision rule. The ROC curve has an advantage over the other measures used because it integrates sensitivity and specificity into a single measure. Likelihood ratios are an alternative for assessing the performance of a diagnostic instrument. The likelihood ratio for a particular value of a diagnostic test is defined as the probability of the test result in people with the attribute divided by the probability of the result in people without the attribute. This probability indicates how many times more (or less) likely a test result is to be found in people with the attribute compared with people without it. The main advantage of likelihood ratios is that they go beyond the simple and vague classification of a test result as either normal or abnormal. Finally, the accuracy test measures the ratio between the proportion of true positives and true negatives; it is measured based on its ability to differentiate the subjects with the attribute (13-15).

These indicators were estimated in each of the 4 categories established by the World Health Organization as a reference for the classification of the nutritional status of people, as follows: subnormal weight, those individuals whose BMI is less than 18.5; normal weight for those between 18.5 and 24.9; overweight for those between 25.0 and 29.9, and obesity for those with a BMI equal to or greater than 30.0. The statistical analysis was done using IBM SPSS® Statistics software, version 24.0, and SAS® Statistics software, version 9.4.

## Results

The new formula detected 21 (10.8%) subjects less in the subnormal weight category, 195 (6.8%) less in the normal weight category, 22 (0.84%) less in the overweight category, and 263 (18.3%) more among the obese (Table 1).

The distribution of both formulas in the subnormal and normal groups is skewed to the left while in the overweight and obesity groups they are to the right (Table 2). The bias in the traditional formula is greater where a greater number of extreme values is

**Table 1.** Nutritional Status Distribution Based on Both Formulas.

Nutritional status formula	Subnormal	Normal	Overweight	Obese	Total
BMI	194	2,871	2,613	1,287	6,965
New BMI	173	2,676	2,591	1,523	6,963

**Table 2.** Descriptive Statistics for both Formulas and Groups.

Nutritional status	Subnormal		Normal		Overweight		Obese	
	BMI	New BMI	BMI	New BMI	BMI	New BMI	BMI	New BMI
N	194	173	2,871	2,676	2,613	2,591	1,287	1,523
Mean	17.26	17.27	22.50	22.62	27.10	27.17	33.52	34.00
St Dev	0.8779	0.8675	1.6793	1.6772	1.3960	1.3657	3.9628	4.2040
Skewness	-3.26	-4.52	-3.23	-5.51	5.90	4.81	52.41	49.67

observed, compared with the new formula.

In the groups of subnormal weight, for BMI and New BMI (Figure 1), the result of the Normality test, Kolmogorov-Smirnov (KS) = 0.106, df = 194, p = 0.000; KS = 0.125, df = 173, p = 0.000; respectively. In the normal weight groups, the Normality test, Kolmogorov-Smirnov (KS) = 0.083, df = 2871, p = 0.000; KS = 0.096, df = 2,676, p = 0.000; respectively. In both groups and formulas, the distribution is skewed to the left.

In the overweight groups, for BMI and New BMI (Figure 2), the result of the Normality test, Kolmogorov-Smirnov = 0.071, df = 2613, p = 0.000; KS = 0.081, df = 2591, p = 0.000; respectively. In the obese groups, the Normality test, Kolmogorov-Smirnov (KS) = 0.153, df = 1281, p = 0.000; KS = 0.143, df = 1517, p = 0.000; respectively. In both groups and formulas, the distribution is biased to the right. The traditional formula is much more biased in the overweight group, the skewness was 5.91 and 4.81; and so, it is in the obese group, skewness 30.9 and 30.3, respectively.

The performance of the indicators obtained from the new formula is good, and except for the sensitivity, all the other results can be defined as very good, according to the established criteria (Table 3).

## Discussion

Accuracy and agreement become important when one wants to know if a new method or an instrument result is equivalent to the original; so that, eventually, they can be exchanged either

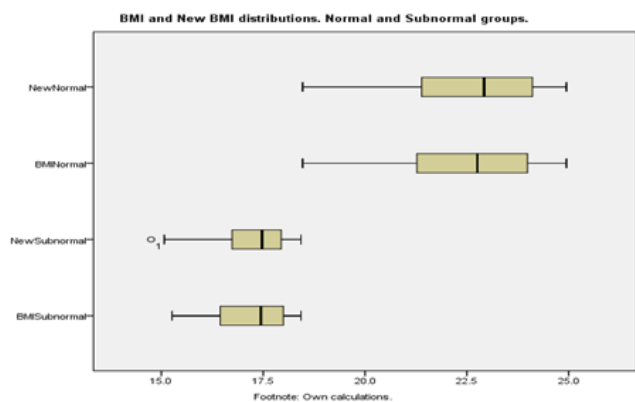
because one of them is simpler, less expensive, and therefore, more cost/effective, or because it is safer for clinical practice or public health screening.

The results of this study show that except for sensitivity the other indicators perform very well, making the two instruments comparable and interchangeable. However, the detection of subjects in the subnormal, normal, and overweight groups is lower in the new formula while it is higher in the obese group; This situation would have important implications for public health since the new formula tends to classify more subjects as obese.

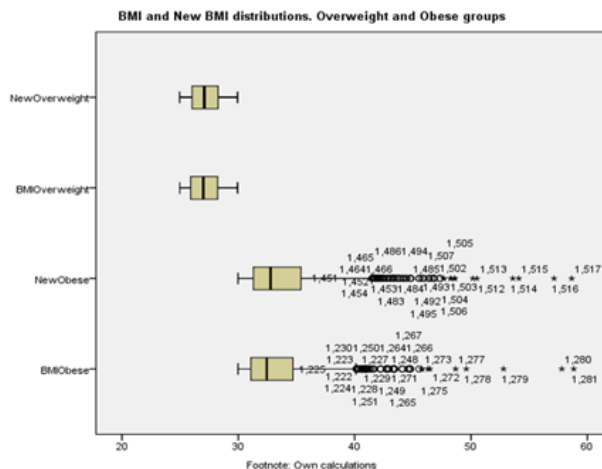
It should be noted, that the distribution of the subjects within each group and for both formulas does not follow a normal distribution. A greater number of extreme values are observed in the obese group using both formulas, making us think that these two formulas are not accuracy in this specific nutritional status.

Although the validity of the traditional formula is highly questioned, and the results obtained with the new formula are similar to those obtained with the traditional formula and therefore, could be interchangeable, the asymmetry to the right observed in both formulas suggests, that none of these formulas is suitable for measuring the obese status, due to their great asymmetry towards the right.

Additionally, studies differ in their assessment of the relationship between BMI and mortality. In particular, BMI in the overweight category (BMI 25- <30 kg/m<sup>2</sup>) is not consistently associated with increased mortality (18, 19). This situation that has led to a



**Figure 1.** Both formulas Subnormal and Normal Groups distribution.



**Figure 2.** Both formulas Overweight and Obese Groups distribution.

**Table 3.** Accuracy indicator results for new formula.

Nutritional status	Indicador								
	Sensibility	Specificity	Predictive value positive	Predictive value negative	Youden index	Kappa	ROC	Accuracy index	Log likelihood ratio
Subnormal	83.1	99.8	92.6	99.5	82.9	87.2	91.4	91.5	7.8 (7.1-8.5)
Normal	90.2	97.9	96.8	93.4	88.1	89.0	94.1	94.1	6.1 (5.8-6.3)
Overweight	88.6	93.7	89.4	93.2	82.3	82.4	91.1	93.3	4.8 (4.6-4.9)
Obese	83.9	99.7	98.9	95.7	83.6	88.5	97.3	91.8	7.6 (7.1-8.2)

debate about the validity of BMI and its established cut-off points for the classification of the nutritional status of people.

One of the limitations of this study is that it does not examine the validity of both formulas, because there is a lot of discussion regarding what BMIs try to measure since they do not take into account muscle mass, bone weight, fat tissue distribution, and other recommended variables for measuring nutritional status.

Challenges in deriving global public health recommendations are unlikely to be resolved by ever-larger datasets without further developments in study data and design. New study designs such as Mendelian randomization (20), new data elements such as weight histories (21), and increased attention to BMI over the life course (22), might improve our understanding of BMI validity in measuring nutritional status at population level.

Finding a valid instrument to measure the nutritional status will continue to be a critical issue because of the implications in terms of health and economical resources for health care. This article contributes with a new piece of knowledge, but the discussion is still open.

Important challenges remain in the effort to translate epidemiological evidence of excess bodyweight and obese information into effective guidelines and public health interventions. The Lancet, via the World Obesity Federation, and other coalitions such as the US National Collaborative on Childhood Obesity Research are championing diverse approaches to this challenge including support for better measurement, systems models, and increased attention to the evaluation of obesity-related policies (23). Substantial research and conceptual questions remain unsolved for these issues.

### Acknowledgement

Thanks to the CEDETES center for facilitating the database for conducting the analysis.

Conflict of interest: No competing interests declared. This comment is solely the responsibility of the author and represents the official views of the Knowledge Production and Management Foundation.

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