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Accuracy of alternative indexes for assessing the nutritional status of men and women

Acurácia de índices alternativos para avaliar o estado nutricional de homens e mulheres

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Abstract – A good evaluation of the nutritional status requires knowledge on body composition, casting doubts on the accuracy of some indexes. Therefore, the aim of this study was to analyze the accuracy of the following nutritional status indexes: Body Mass Index (BMI), BMI elevated to 2.5 ($BMI^{2.5}$), Fat Mass Index (FMI) and BMI adjusted for fat mass (BMIfat). Participated of this study 280 subjects (aged 17-48 years), from which the results of BMI, $BMI^{2.5}$, FMI and BMIfat indexes were analyzed, having the Hydrostatic Weighing method as reference. FMI presented the highest concordance value, but classified as discrete (k=0.21). The other indexes presented small concordance with results of the reference method (k<0.20). In conclusion, none of the indexes investigated has good accuracy in assessing the nutritional status of the study group, considering that, although they show results of correlation with the reference method, they do not reach the minimum agreement criterion.

Key words: Anthropometry; Body composition; Hydrostatic weighing; Nutritional evaluation.

Resumo – *Uma boa avaliação do estado nutricional requer o conhecimento da composição corporal, colocando em dúvida a acurácia de alguns índices. Dessa forma, o objetivo deste estudo foi analisar a acurácia dos seguintes índices de avaliação do estado nutricional: Índice de Massa Corporal (IMC), IMC elevado à 2,5 ($IMC^{2,5}$), Índice de Massa Gorda (IMG) e IMC ajustado pela massa gorda (IMCgordura). Participaram do estudo 280 sujeitos (idade entre 17 e 48 anos), dos quais foram analisados os resultados dos índices IMC, $IMC^{2,5}$, IMG e IMCgordura; tendo como método de referência a Pesagem Hidrostática. O IMG apresentou o maior valor de concordância, porém classificado como discreto (k = 0,21). Já os demais índices apresentaram concordância pequena com os resultados do método de referência (k<0,20). Em conclusão, nenhum dos índices investigados apresenta boa acurácia para avaliar o estado nutricional do público em questão, tendo em vista que, apesar de mostrarem resultados de correlação com o método de referência, não atingem o critério mínimo de concordância.*

Palavras-chave: *Antropometria; Avaliação nutricional; Composição corporal; Pesagem Hidrostática.*

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INTRODUCTION

There is a growing need to develop good health indicators, since these indicators are used by agencies responsible for monitoring the health conditions of the population. For the Interagency Health Information Network (RIPSA)[1], morbidity and risk factors for diseases make up an important item on the list of basic health indicators in Brazil.

Nutritional status is one of these indicators, since it is a tool for the establishment of the "overweight prevalence rate", and the drastic change contributes to the increase of morbidity and mortality; in addition, the imbalance tending both to malnutrition and for overweight and obesity can trigger risk factors for a varied number of health problems[2], strongly influencing the physical fitness of affected individuals[3]. According to Anjos[4], a good evaluation of the nutritional status requires knowledge on the energy reserves and the metabolically active mass of individuals to be evaluated, which should be obtained by assessing body composition, casting doubts on some indexes that do not take this into account.

One of the indexes most widely used for assessing nutritional status is the Quetelet equation, or body mass index (BMI), which was named by Keys et al.[5] years after its creation. Adopted by the World Health Organization, BMI is considered the simplest nutritional status indicator, involving conventional anthropometric dimensions such as body weight (BW) and height (HEI), but it has the limitation of not estimating the amount of body fat[6].

Despite the wide use, some authors[4,7] recommend caution, since it is fundamental to emphasize that the fact that BW has good correlation with HEI is not enough to recommend universal use. It is important to correlate BMI values with other body composition measures such as body fat percentage (BF %)[4].

With the premise that BMI represents body dimensions in the wrong way, since people of higher HEI values have larger structural and physiological compartments than those with lower HEI values, Trefethen[8] developed a new BMI, called $BMI^{2.5}$ (BMI elevated to 2.5). The most recent formula was created by the researcher of the University of Oxford (UK) and uses, in addition to the already known BW and HEI, also a numerical correction and the power of 2.5; allowing, according to the researcher, placing people in more appropriate categories to HEI. There are some academic papers demonstrating the strong correlation between traditional BMI and new BMI, but this index still needs to be tested through scientific research in different populations with larger samples and using as a reference a method for assessing the nutritional status with better accuracy.

Another index that promises more reliable results when assessing nutritional status is the Fat Mass Index (FMI) developed by Van Itallie et al.[9]. The equation proposes a better determination of the actual body fat variation. FMI takes into account fat mass (kg) and HEI (m) for determination. FMI classification values are cited by Kelly et al.[10], from a validation study with 1195 adult individuals using DEXA as the reference method. However, it should be noted that one of the limitations of the index is that, for use, fat mass value must be obtained by some other validated method.

Also questioning older indexes and seeking a better accuracy when determining the nutritional profile of an individual, Mialich et al.[11] developed BMI adjusted for fat mass (BMIfat) by means of a study with 200 individuals of both sexes. BMIfat is an equation that takes into account, in addition to the BW and HEI values, fat body mass (FM) of the individual (expressed in%). The nutritional status classification follows the standards cited by Mialich et al.[12]. The new index proposes to characterize specific populations and / or delimitations of cutoff points for classification of normal weight, overweight and obesity.

In view of the above, the aim of the present study was to analyze the accuracy of BMI, $BMI^{2.5}$, FMI and BMIfat, as alternative indexes to evaluate the nutritional status of adults of both sexes using Hydrostatic Weighing (HW) as the reference method.

METHODOLOGICAL PROCEDURES

This is descriptive-quantitative study, with the participation of individuals of both sexes, living in Santa Maria-RS, Brazil, which is part of a macro project approved by the ethics research committee with human beings of the Federal University of Santa Maria (CAEE - 11511112.8.0000.5346). Data come from collections with volunteers from the community in general, carried out over a period of two years by two technically qualified evaluators and in a specialized laboratory. The study included individuals who had data regarding chronological age (years), ethnicity, physical activity level, BW, HEI and BF%.

Thus, the study group consisted of 280 subjects aged 17-48 years, analyzing the results from different indexes for nutritional status evaluation (BMI, $BMI^{2.5}$, FMI and BMIfat) and HW.

BW was determined with a Marte® digital scale (Santa Rita do Sapucaí, Brazil), with resolution of 0.1 kg and capacity of 180 kg, and HEI with Cardiomed® stadiometer (Curitiba, Brazil), with resolution of 0.1 cm (according to procedures of Stewart et al.[13]). BMI was calculated by dividing BW (kg) by squared HEI (m). $BMI^{2.5}$ was determined using variables BW (kg) and HEI (m) in an equation consisting of the multiplication of BW by 1.3 and the division of this result by HEI elevated to the power of 2.5. For the classification of individuals both by BMI and by $BMI^{2.5}$, the WHO reference values were used[6].

For the FMI determination, variables FM (Kg) and HEI (m) were used in an equation in which FM is divided by squared HEI. FM was obtained through a Maltron® bioelectric impedance analyzer (BI) (Rayleigh, United Kingdom), model BF-906. For the classification of the FMI results, the Kelly et al.[10] reference table was used.

Finally, to calculate BMI adjusted for FM or BMIfat, BW (kg) was multiplied by 3, FM (%) (obtained by BI) was multiplied by 4, dividing the value by HEI (cm). The classification criteria are those of Mialich et al.[12].

As the reference method of the present study to evaluate the nutritional status through HW, a tank designed and appropriate for this purpose was used, on which a Filizola® scale (São Paulo, Brazil) was installed, with capacity of 6 kg and resolution of 0.01 kg, to verify the underwater weight (UW). The water temperature was set between 32°C and 36°C. The procedures used to verify underwater weight are those described by Salem[14]. To determine Body Density (BD) through HW, an equation that considers variables BW, UW, water density (WD) and residual volume (RV) (Goldman and Becklake equation[15]) was used. After BD determination, the equations to estimate BF% proposed by Heyward and Stolarczyk[16] were used, which can be visualized in Box 1. BF% was classified according to cutoff points of Lohman[17] (Box 1).

Box 1. Equations for converting BD into BF% according to Heyward and Stolarczyk16 and cutoff points for BF% classification according to Lohman17

Equations for converting BD into BF% for specific populations			
Ethnicity	Age	Sex	Equation to estimate BF%
Black	18 – 32	Male	[(4.37/Dc) – 3.93] x 100
	24 – 79	Female	[(4.85/Dc) – 4.39] x 100
White	20 – 80	Male	[(4.95/Dc) – 4.50] x 100
		Female	[(5.01/Dc) – 4.57] x 100
Cutoff points for BF% classification according to sex			
Classification		Men	Women
Risk associated with malnutrition		≤ 5%	≤ 8%
Below mean		6% - 14%	9% - 22%
Mean		15%	23%
Above mean		16% - 24%	24% - 31%
Risk associated with obesity		≥25%	≥ 32%

For nutritional status classification based on results of the indexes investigated and HW, the authors previously mentioned were used in the first moment[6,10,12,17]. Secondly, in view of the analysis using the Cohen's kappa coefficient[18] to determine the diagnostic consistency from the results obtained, and that such analysis is only possible if the number of categories for comparison is the same, the allocation of proposals for the interpretation of each index into three categories was performed (below reference, normal weight and above reference). Box 2 shows the different indexes and their respective categories of interpretation with corresponding reference, as well as the framing of each of these in the three categories of adequacy proposed in the present study (right column).

It is noteworthy that all data analyses were performed considering the specific characteristics of each subject, such as age, ethnicity, sex, body composition and physical activity level. Information regarding the physical activity level of the study group was obtained through the International Physical Activity Questionnaire - short version (IPAQ).

Box 2. Adequacy of categories for nutritional status classification.

Indexes	BMI and BMI2.5	FMI	BMIfat	BF%	Adequacy of categories
References	WHO[6]	Kelly et al.[10]	Mialich et al.[12]	Lohman[17]	
Categories	Severe low weight	Severe deficit	Nutritional risk for malnutrition	Risk associated to malnutrition	Below reference
	Moderate low weight	Moderate deficit			
	Mild low weight	Mild deficit		Below mean	
	Normal weight	Normal weight	Normal weight	Mean	Normal weight
	Overweight	Excess weight	Obesity	Above mean	Above reference
	Obese class 1	Obese class 1		Risk associated to obesity	
	Obese class 2	Obese class 2			
	Obese class 3	Obese class 3			

Descriptive analysis of data was used, the Kolmogorov-Smirnov test was used for the analysis of normality; the Pearson correlation coefficient was used to define the degree of association among nutritional status evaluation indexes; and the Cohen's kappa coefficient[18] was used for concordance analysis. The kappa coefficient results were interpreted according to the following parameters[19]: <0 as absence of concordance; small concordance from 0.00 to 0.20; discrete concordance from 0.21 to 0.40; regular concordance from 0.41 to 0.60; good concordance from 0.61 to 0.80; very good concordance from 0.81 to 0.92; and excellent concordance from 0.93 to 1.00; being acceptable, at least, regular concordance. GraphPad Prism 5.00.288 statistical program was used for the elaboration of graphs; and for data analysis, the Statistical Package for the Social Sciences (SPSS, 21.0, Inc., Chicago, IL, USA), adopting 5% significance level.

RESULTS

Table 1 shows the general characteristics of the study group, stratified by sex.

Table 1. Characterization of the study group (n = 280).

Groups / Variables	Male (n = 210)		Female (n = 70)	
	Mean	sd	Mean	sd
Age (years)	23.7	5.3	21.9	3.2
Body weight (kg)	78.3	11.1	62.7	11.1
Height (cm)	177.2	6.4	165.2	7.1
BMI (kg /m^2)	24.8	2.9	22.8	3.2
BF% (HW)	17.2	5.6	27	5.4

GM = male group; GF = female group; BMI = body mass index; BF% = body fat percentage; HW = hydrostatic weighing; sd = standard deviation.

All variables presented significant correlation with the results of the reference method, being considered high with FMI and moderated with

BMIfat, when considering the Male Group (GM), according to categories proposed by Mukaka[20]. In the Female Group (GF), a moderate correlation was found between BF% results from HW and FMI, BMIfat and BMI$^{2.5}$ results. The other indexes (BMI$^{2.5}$ and BMI for GM and GF, respectively) presented low correlation (Table 2).

Table 2. Correlation values between nutritional status index and BF% (HW) results. Groups PH

Groups HW / Indexes	Male		Female	
	r	p	r	p
BMI	0.536	0.000	0.597	0.000
BMI$^{2.5}$	0.525	0.000	0.619	0.000
FMI	0.716	0.000	0.628	0.000
BMIfat	0.667	0.000	0.626	0.000

BMI = body mass index; BMI2.5 = new body mass index; FMI = fat mass index; BMIfat = body mass index adjusted for fat mass; HW = hydrostatic weighing; R = Pearson correlation coefficient; P = significance level.

Since the main focus of the present study was to analyze the diagnostic concordance between indexes used to evaluate the nutritional state and the HW results, FMI was the one that presented the highest nutritional status diagnostic concordance result, being considered as discreet concordance. The other indexes presented little concordance with results of the reference method. However, none of the indexes were able to reach the minimum concordance level (≥0.41) (Table 3).

Table 3. Diagnostic concordance of nutritional status between study indexes and the reference method (HW).

Groups HW / Indexes		Male					Female				
		ABR	E	ACR	T (n)	k	ABR	E	ACR	T (n)	k
BMI	ABR	1	0	0	1	0.05	0	0	1	1	0.03
	E	56	6	55	117		13	4	39	56	
	ACR	25	8	58	91		0	1	12	13	
	T (n)	82	14	113	209		13	5	52	70	
BMI$^{2.5}$	ABR	3	0	0	3	0.09	0	0	1	1	0.05
	E	64	10	63	137		13	4	37	54	
	ACR	15	4	51	70		0	1	14	15	
	T (n)	82	14	114	210		13	5	52	70	
FMI	ABR	27	1	11	39	0.21	6	1	11	18	0.08
	E	35	10	59	104		4	2	24	30	
	ACR	0	0	29	29		0	0	3	3	
	T (n)	62	11	99	172		10	3	38	51	
BMIfat	ABR	52	4	34	90	0.19	10	3	19	32	0.09
	E	22	9	60	91		3	2	26	31	
	ACR	0	0	17	17		0	0	6	6	
	T (n)	74	13	111	198		13	5	51	69	

HW = hydrostatic weighing; BMI = body mass index; BMI2.5 = new body mass index; FMI = fat mass index; BMIfat = body mass index adjusted for fat mass; ABR = below reference; E = normal weight; ACR = above reference; K = Kappa index; T = total number of subjects.

DISCUSSION

One of the difficulties found for the discussion of results was the fact that no studies were found in literature proposing to test the diagnostic accuracy of FMI, which is the aim of this study. In the study by Schutz et al.[21] with 5635 European adults (18-98 years) aimed at establishing the distribution of percentiles according to age groups and sex for FMI, it was observed that the majority of individuals of both sexes is classified as eutrophic according to reference values[10]. The same occurred in the present study, also considering similar BF% values among studies, which demonstrates the ability to evaluate the independent index of the investigated group. Researchers claim that FMI may be more effective than BMI because it takes into account body fat mass and has a greater practical value for clinical evaluation. It could be inferred that in a way this argument is true, since FMI presented high correlation with BF% (HW) and the results related to the diagnostic power showed discrete concordance; however, this association of results was evidenced only in GM.

BMIfat also seems to be a good option when evaluating the nutritional status of adult individuals, considering correlation results. Mialich et al.[12] validated this index by performing a study with 501 individuals of both sexes aged 17-38 years. The determination coefficient found was high (R^2> 0.81), in relation to the traditional BMI, considering the satisfactory validation. In the present study, moderate correlation values (between 0.5 and 0.7) and small concordance regarding the diagnosis of nutritional status for both sexes were found, but it should be taken into account that, unlike the study by Mialich et al.[12], which used BMI, HW, a method considered as a reference[22,23]. The same author also points out that BMIfat, developed by Mialich et al.[11], was superior for diagnosing obesity in relation to BMI, even when applied in a new study population.

It is important to emphasize that, although low, $BMI^{2.5}$ presented better concordance value than BMI, casting doubt on the ability of the latter index to classify the adequately evaluated nutritional status. Considering that $BMI^{2.5}$ is still a little known index, without much scientific dissemination, it is difficult to find scientific studies that seek to test its accuracy and applicability. In one of the few studies found in literature, Ribas Junior[24], when correlating BMI and $BMI^{2.5}$ results, presented correlation coefficient values indicative of positive linearity between both equations. In addition, some academic papers have indicated that the new index classifies a greater percentage of individuals as being overweight, a fact that was also observed in the GF of the present study.

When analyzing the concordance among indexes, when the results of nutritional status diagnosis are associated, having HW as reference, it is evident that both $BMI^{2.5}$ and BMI present unsatisfactory results, indicating that they are inadequate for this purpose.

As the index that presented the worst results in the present study, BMI tends to classify a higher percentage of individuals as eutrophic, and in fact a large part of them should be classified as above the reference, that is, overweight or obese. Studies have shown that BMI is not the best option when evaluating certain populations[7,25]; however, some authors indicate that this index shows good practical applicability in epidemiological studies[26] and with groups of individuals presenting some pathology[27].

The difficulty in obtaining a large number of volunteers, especially for the female group, is characterized as a study limitation. It is important to emphasize that when investigating human beings, there is a wide range of variables that need to be controlled and failure to comply with some pre-collection guidelines may result in significant sample loss, such as the change in routine water intake and the use of diuretics, which influence BI results; or the consumption of fermentative foods, which may have an impact on HW results.

CONCLUSIONS

It could be concluded that none of the indexes investigated has adequate accuracy to evaluate the nutritional status of the study population, considering that, although they show significant correlation results with the reference method, they do not reach the minimum concordance criterion. Therefore, such indexes should be used with caution, since they can lead to a wrong determination of the nutritional status, and, consequently, can have direct impact in the planning of a possible program of physical exercises and in the health of individuals.

As a solution, we suggest the use of other strategies to evaluate body composition such as anthropometric equations that use the results of skinfolds, since they are easy to apply and have relatively low cost. In addition, FMI tended to present a good result, being more effective than BMI, which is widely used, casting doubt that such index can be efficient in the evaluation of more specific populations.

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