Should body mass index be adjusted for relative sitting height in cross-sectional studies of chronic diseases in Japanese-Brazilians?

Deve-se corrigir o valor do Índice de Massa Corporal pelo comprimento relativo do tronco em estudos de prevalência de doenças crônicas em nipo-brasileiros?

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Abstract

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The current article aimed to verify the degree of agreement in classification of nutritional status according to body mass index (BMI) and corrected body mass index (BMIc). Data were used from a cross-sectional study of Japanese-Brazilians. Statistical analysis provided prevalence rates for chronic diseases, kappa statistic, and Pearson's linear correlation coefficient. Some 5.9% of Japanese-Brazilians were discordant according to the BMI and BMIc classifications. The weighted kappa statistic (0.94; p = 0.000) indicated good agreement between the classifications. Similar prevalence rates for chronic diseases were obtained for individuals with excess weight classified by these two indices. Similar Pearson's linear correlation coefficients were obtained for these indices and waist circumference and body fat measurements. The results suggest that BMI correction for relative sitting height is probably unnecessary for these individuals.

Body Mass Index; Anthropometry; Chronic Diseases; Japanese-Brazilians

Introduction

Chronic non-communicable diseases are the principal cause of death in both developed and developing countries. This profile has been partially explained by rapid demographic and socioeconomic transformations [1]. In parallel there has been an increase in the number of individuals with excess weight [2,3].

The prevalence of obesity, in turn, is associated with the urbanization and industrialization process, together with the increased availability of food and the reduction in physical activity in recent decades; it is both an independent risk factor and is associated with a series of other factors, like hypercholesterolemia, arterial hypertension, diabetes mellitus, and insulin resistance [4,5,6,7,8].

Anthropometry has been widely used in epidemiological studies to evaluate body composition, due to its low cost and simplicity, and the principal measurements are weight, height, circumferences, and skinfolds [9].

The so-called "Quetelet" index, or body mass index (BMI), or the ratio between weight (in kg) and height squared (in meters), does not indicate body build but total body mass, but it is related to increased morbidity and mortality for values less than 18.5kg/m² (infectious/parasitic diseases) or greater than 25.0kg/m² (chronic diseases, except cancers), thus justifying its use in the identification of individual nutri-

tional status, with or without the combined use of other anthropometric measures [9,10,11,12].

Android-type or central obesity is characterized by major accumulation of fat in the abdominal region (waist) and is an important risk factor for cardiovascular diseases, type-2 diabetes mellitus, dyslipidemias, hyperinsulinemia, and arterial hypertension [13,14,15,16].

Various studies have confirmed the hypothesis that differences in body build account for the difference between BMI and body fat percentage, comparing different ethnic groups and genders [17,18,19,20]. Possible explanations for the differences are the level of physical activity, relative length of the lower limbs, sitting height, or body build [21,22,23].

BMI is influenced by a series of factors, including the effect of body build, i.e., the variation in height caused by the variation between populations in trunk length or sitting height (SH) and length of lower limbs. To show these differences, Norgan & Jones [24] corrected the BMI for relative sitting height (RSH), using a linear regression model separately for each gender. These authors observed that in the British population, corrected BMI values (BMIc), as compared to unadjusted values, increased $1kg/m^2$ or more in 33% of women and 10% of men and $2kg/m^2$ in 5% of women and 1% of men.

Norgan [22], Gurrici et al. [18], and Deurenberg et al. [19] discuss the relationship between trunk length and BMI. These authors observed that individuals with a slight body build presented a higher percentage of fat and not necessarily a higher skeletal mass.

There is evidence that the relationship between body fat and BMI varies according to ethnic group: Asians have a higher degree of adiposity for a given BMI as compared to Caucasians [23]. Prevalence studies have shown that some ethnic groups have a relatively higher obesity risk than others, thereby predisposing to chronic diseases [17,25,26].

Recent decades have witnessed an increase in the prevalence of diabetes mellitus [27] and dyslipidemias [28] in the Japanese population, with diet and the degree of physical activity considered as risk factors. In this context, excess weight can be an important risk factor for theses diseases, since various studies have shown (for the same period) an increase in the prevalence of overweight in Japanese adults [29,30,31,32]. As compared to Caucasians, Japanese are shorter, stockier, with shorter lower limbs, more muscular, and thus present a higher degree of adiposity.

The high prevalence rates for diabetes mellitus, arterial hypertension, and dyslipidemias in the Japanese-Brazilian population [33] called attention to the need to verify the degree of agreement between nutritional status classifications according to BMI and BMIc among individuals with excess weight.

Material and methods

Study design

This was a cross-sectional study using data from the second phase of the epidemiological study conducted by the Japanese Brazilian Diabetes Study Group.

Study population

Japanese immigration to Brazil will have completed 100 years during the current decade. The immigration began in 1908 and extended until the early 1960s, with a break from 1941 to 1952. This fact allowed the coexistence of different generations and age groups. The world's largest *nikkei* population (Japanese and their descendents) outside of Japan lives in Brazil, with an estimated 70% having settled in the State of São Paulo.

After a demographic survey of this community in 1997, all first and second-generation individuals of both sexes and ≥ 30 years of age were invited to participate in the second phase of the study (n = 1,751), of whom 1,330 agreed and were examined. There were 421 losses (24%); of these, 64.6% were due to refusal, 13.5% to change of address, and 21.9% to death (both from 1993 to 1997 and from 1997 – with the census – and 1999/2000 – data collection). Non-participants showed a higher proportion of men < 60 years of age as compared to participants.

In the current study, for calculating and analyzing BMI, three individuals were excluded (n = 1,327) due to lack of information on anthropometric variables.

Data collection

The data were obtained from previously scheduled household interviews by trained professionals who applied standardized, previously tested questionnaires to obtain information on sociodemographic and cultural aspects, health, physical activity, and eating habits. During the household interviews, the appointment (place and date) was set for individuals to appear for the physical, clinical, and laboratory examination.

During the physical examination, anthropometric measures and blood pressure were

taken by trained professionals. Laboratory exams included fasting blood sugar and blood sugar two hours after ingesting 75g of glucose, total and partial cholesterol, and triglycerides.

Trunk length or sitting height was measured with a vertical ruler measuring up to 1.5 meters and accurate to 1cm. The subject sat erect on a table with hands resting on the thighs, feet hanging freely without touching the floor, and head erect and eyes on the horizon [34]. Relative sitting height (RSH) was obtained by dividing trunk length by height. Weight was measured with a Filizola digital scale weighing up to 200kg and accurate to 100g. Subjects were weighed barefoot, with as little clothing as possible. Height was measured with a manual stadiometer attached to the wall, measuring up to 2m and accurate to 1cm, with the subject standing erect, barefoot, heels together, head erect, eyes on the horizon, on a smooth, flat, rigid surface, with arms hanging at the side [11]. Waist circumference (WC) was measured with a non-extensible tape measure, with subjects standing and the measurement taken at the level of the umbilicus.

BMI was calculated by dividing current weight in kg by height in meters squared. Subjects were classified by BMI [35] as obese (≥ 30kg/m^2), overweight (BMI 25-29.9kg/m^2), normal (BMI 18.5-24.9kg/m^2), and underweight (BMI < 18.5kg/m^2).

BMIc was calculated as the sum of the expected BMI value for individuals with mean RSH value and the residue obtained from the simple linear regression model with observed BMI as the dependent variable and RSH as the independent variable [24].

Reactance and resistance were estimated by the electric bioimpedance test (EBI), with a single frequency (50kHz) using a tetrapolar model EBI 101Q (RJL System, Clinton Township, USA). Subjects were fasting and had rested in a room for 15 to 20 minutes before the test. Subjects were asked to remove any metal objects before the test. The site where the electrodes were attached was disinfected previously with alcohol.

Systolic (SAP) and diastolic arterial pressure (DAP) were measured by trained physicians, using automatic digital sphygmomanometers model HEM712C (Omron, Bannockburn, USA). Subjects rested previously for 10 minutes in a calm environment, sitting with the upper member at the height of the heart. Three measurements were taken, and the final value used was the mean of the last two. Subjects were classified as hypertensive with DAP ≥ 90 or SAP ≥ 140mmHg or in use of anti-hypertensive medication [36].

Oral glucose tolerance test was performed in non-diabetic individuals and those reporting a previous diagnosis of diabetes mellitus, but with capillary glucose less than 200mg/dL. Participants on insulin therapy were excluded from this test. Plasma glucose was taken after fasting for at least ten hours prior to blood sampling, and then two hours after the oral glucose overload (75g). Plasma glucose was determined by the glucose oxydase method. Subjects with fasting plasma glucose (FPG) < 110mg/dL and 2h plasma glucose < 140mg/dL were classified as normal, those with FPG $\geq$ 110 and < 126mg/dL and 2h glucose < 140mg/dL were classified as having abnormal fasting glucose (AFG), those with FPG < 126mg/dL and 2h glucose 140-200mg/dL were classified as having impaired glucose tolerance (IGT), and those with FPG $\geq$ 126mg/dL or plasma glucose 2h after ingesting 75g of glucose $\geq$ 200mg/dL or in use of medication for diabetes were classified as diabetic [37].

Total and partial cholesterol and triglycerides were determined by enzymatic kits and processed in an automatic analyzer. Subjects were classified as presenting dyslipidemias with total cholesterol > 200mg/dL or triglycerides > 150mg/dL or high-density lipoprotein (HDL) < 40mg/dL or low-density lipoprotein (LDL) > 130mg/dL [38]. The Castelli index was calculated as the ratio between total cholesterol total and HDL.

Statistical analysis

Point and interval prevalence was calculated with a 95% confidence interval (95%CI), for glucose intolerance (diabetes mellitus, AFG, and IGT), arterial hypertension, and dyslipidemias for individuals with excess weight according to the BMI and BMIc categories [39,40,41]. Mean Castelli index values for Japanese-Brazilians with overweight or obesity according to the BMI and BMIc categories were estimated by point and interval prevalence with 95%CI.

The degree of agreement between classifications of individuals according to the BMI and BMIc categories was evaluated using the weighted kappa statistic.

Correlations between the BMI and BMIc values and weight circumference, resistance, and reactance were studied to obtain Pearson's linear correlation coefficients (point and interval) [40,41].

Calculations and statistical analyses used STATA (Stata Corporation, College Station, USA) and Epidat 3.0 (http://dxsp.sergas.es/default.asp, Pan-American Health Organization/Xunta de Galícia).

Results

Table 1 shows subjects according to BMI and BMIc values. Only 79 individuals (5.9%) were discordant for classification by these indices. The kappa statistic value (0.94; p = 0.000) indicates good agreement between the classifications, suggesting that BMI correction for relative sitting height is unnecessary.

Among discordant individuals, 88% (n = 42) were classified by BMI as underweight or normal, while according to BMIc they were considered normal or overweight, respectively. The inverse situation was observed in discordant individuals classified by BMI as overweight or obese. Apparently, BMI correction for RSH overestimates the total body mass in leaner individuals and underestimates it for those with some degree of excess weight.

Of all the discordant individuals, 49.4% were males, 50.6% were less than 60 years of age, and only 17.7% were first-generation. The majority of these individuals were in the overweight and normal categories.

According to the current study, the BMIc values as compared to unadjusted BMI increased by 1kg/m^2 or more in only 2.8% of men and 1.5% women and by 2kg/m^2 in 0.3% of both women and men.

Table 2 shows the point and interval prevalence rates for diabetes, arterial hypertension, and dyslipidemias in individuals with overweight or obesity according to BMI and BMIc.

The prevalence rates for these diseases were similar among those considered overweight or obese according to the BMI and BMIc classifications. As already observed, according to the kappa statistic, this situation suggests

Table 1

Distribution of individuals according to body mass index (BMI) and corrected body mass index (BMIc).

BMIc	BMI				Total
	Underweight	Normal	Overweight	Obese	
Underweight	33	5	–	–	38
Normal	7	648	22	–	677
Overweight	–	30	445	6	481
Obese	–	–	9	123	132
Total	40	683	476	129	1,328

Weighted kappa statistic = 0.94; p = 0.000.

Table 2

Point and 95% confidence interval (95%CI) prevalence for diabetes, arterial hypertension, and dyslipidemias among individuals with overweight or obesity according to body mass index (BMI) and corrected body mass index (BMIc).

Diseases	BMI		BMIc	
	Overweight Prevalence (95%CI)	Obesity Prevalence (95%CI)	Overweight Prevalence (95%CI)	Obesity Prevalence (95%CI)
Diabetes	45.3 (40.8-49.9)	60.5 (51.5-68.9)	45.1 (40.6-49.7)	58.3 (49.4-66.8)
AFG	14.3 (11.2-17.7)	11.6 (6.7-18.4)	15.6 (12.5-19.1)	12.9 (7.7-19.8)
IGT	27.5 (23.5-31.7)	22.5 (15.6-30.6)	25.8 (21.9-29.9)	24.2 (17.2-32.5)
Arterial hypertension	44.0 (39.5-48.6)	48.0 (39.2-57.0)	43.6 (39.1-48.2)	47.0 (38.2-55.8)
Hypercholesterolemia	67.9 (63.5-72.1)	65.9 (57.0-74.0)	67.2 (62.8-71.3)	68.9 (60.3-76.7)
Hypertriglyceridemia	77.1 (73.1-80.8)	82.9 (75.3-89.0)	76.3 (72.2-80.0)	84.1 (76.7-89.9)
Elevated LDL-c	53.0 (48.4-57.6)	49.6 (40.7-58.5)	51.8 (47.2-56.3)	52.3 (43.4-61.0)
Decreased HDL-c	14.5 (11.4-17.9)	10.9 (6.1-17.5)	15.2 (12.1-18.7)	9.8 (5.3-16.3)

AFG = abnormal fasting glucose; IGT = impaired glucose tolerance; LDL-c = low-density lipoprotein cholesterol; HDL-c = high-density lipoprotein cholesterol.

that BMI correction for RSH did not alter the findings.

Mean Castelli index values in individuals classified as overweight by BMI and BMIc were, respectively, 4.49 (95%CI: 4.487-4.492) and 4.50 (95%CI: 4.497-4.502). A similar situation was observed in obese individuals [4.35 (95%CI: 4.339-4.360) versus 4.34 (95%CI: 4.49 (95%CI: 4.329-4.350)], also suggesting in relation to this index that BMI correction for RSH did not alter results.

Table 3 shows the values for the Pearson linear correlation coefficient between BMI and BMIc and waist circumference, resistance, and reactance. Similar Pearson linear correlation coefficient values were obtained for BMI and BMIc both for WC and resistance and reactance.

Discussion

The Asian population and especially the Japanese are known to present high prevalence rates for chronic diseases. An important risk factor for such diseases is usually obesity, especially of the android type, characterized by over-accumulation of fat in the abdominal region (waist). The question is that obesity is not present in the Asian population at levels that would explain the high susceptibility to chronic diseases. Japanese are also known to have a different body build from non-Asians. The Japanese have a longer relative sitting height, shorter lower limbs, shorter overall height, and a high degree of adiposity. This situation has led various researchers to propose correcting BMI for RSH. Norgan & Jones [24] performed the correction using a linear regression model for the two sexes separately and observed that in the British population, BMIc values, as compared to unadjusted BMI, increased by 1kg/m² or more in a considerable portion of men and women. In previous studies these authors had already shown that differences of 0.01 in RSH were associated with BMI differences of 0.9kg/m² [21,22].

According to the present study, BMIc values as compared to unadjusted BMI increased by 1kg/m² or more in only 2.8% of men and 1.5% of women and by 2kg/m² in 0.3% of women and men, a situation quite different from that observed in the British population by Norgan & Jones [24]. In addition, in the current study, discordant individuals in the two classifications were mainly in the overweight and normal categories, possibly due to the higher number of individuals in these categories. The values obtained for the Pearson linear correlation coefficients between BMI (with and without correction) and WC, resistance, and reactance were

Table 3

Pearson's linear correlation coefficient for body mass index (BMI) and corrected body mass index (BMIc) and waist circumference, resistance, and reactance.

Variable	BMI		BMIc	
	r	95%CI	r	95%CI
Waist circumference	0.83	0.80;0.86	0.84	0.82;0.87
Resistance	-0.60	-0.63;-0.54	-0.56	-0.60;-0.50
Reactance	-0.26	-0.31;-0.21	-0.26	-0.30;-0.21

similar, indicating that BMI correction for RSH did not alter it relationship to either total body fat or localized abdominal fat.

Electrolytes are known to be excellent conductors of electric current while adipose tissue is a poor conductor due to the small amount of water. Due to the fact that the water content in the free fat mass is large, the latter can be predicted by estimates of total body water.

Reactance, in turn, as the opposition to current flow produced by the cell membrane, is an indicator of body fat, and resistance is the pure opposition to current flow across the body, and is the best predictor of free fat mass and total body water. This information indicated that BMI correction for RSH is volumetric and does not interfere in body fat as observed by reactance values.

In the current study, further evidence that for this population BMI correction for RSH does not aid in the identification of individuals at risk (i.e., with higher total body mass) was the absence of differences in Castelli index values according to the overweight and obesity categories by the two BMI values (adjusted and unadjusted). Individuals with excess weight (BMI ≥ 25kg/m²), as compared to normal individuals, are known to have a two-fold risk of hypertriglyceridemia, hypercholesterolemia, and reduced HDL-cholesterol (Ueshima et al., 1998, *apud* Inoue & Zimmet [42]).

According to Garn et al. [43], BMI has limitations, including the fact that it does not take lower limb length or sitting height into account. In the current study, BMI correction for RSH showed a few discordant individuals, but only 5.9% of the total. Another limitation of BMI is that depending on stature, it does not take the variations in different life cycles into account. In the Japanese-Brazilian population studied here, 42.7% were older than 60, so that stature may have been underestimated [11].

A limitation of the current study was the losses of some 24% (n = 319), relatively more

frequent in males and subjects under 60. We believe that they had little influence on the results, since one can suppose that if all the individuals who did not participate in the study (total losses minus deaths) had been examined and were also discordant for the two classifications, the proportion of discordant individuals would still have been relatively low (approximately 20%).

The results of this study suggest that correction of body mass index for relative sitting height in Japanese-Brazilians does not help identify individuals with higher total body mass and thus with greater risk for chronic diseases.

Resumo

O presente trabalho teve como objetivo verificar o grau de concordância entre as classificações do estado nutricional segundo os valores do índice de massa corporal (IMC) e o IMC corrigido (IMCc). Utilizou-se dados de estudo transversal realizado entre nipo-brasileiros. Na análise estatística dos dados foram obtidas as prevalências de doenças crônicas, a estatística kappa e o coeficiente de correlação linear de Pearson. Observou-se que 5,9% dos nipo-brasileiros foram discordantes quanto às classificações pelo IMC e IMCc. O valor da estatística kappa ponderado (0,94; p = 0,000) indicou boa concordância entre as classificações. Prevalências semelhantes de doenças crônicas foram obtidas para os indivíduos com excesso de peso classificados segundo estes dois índices. Valores semelhantes para os coeficientes de correlação linear de Pearson foram obtidos entre esses índices e as medidas de circunferência de cintura e as medidas de gordura corporal. Estes resultados sugerem que, provavelmente, a correção do IMC pelo comprimento relativo do tronco seja desnecessária para esses indivíduos.

Índice de Massa Corporal; Antropometria; Doenças Crônicas; Nipo-brasileiros

Contributors

A. B. Ribeiro was in charge of planning and elaborating the manuscript, data analysis, and drafting of the manuscript. S. G. A. Gimeno contributed to the planning and elaboration of the manuscript, data analysis, revision, and drafting of the manuscript. S. Andreoni participated in the data analysis. S. R. G. Ferreira participated in the planning and revision of the manuscript.

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