Body mass index as indicative of body fat compared to the skinfolds

Maria Fátima Glaner[1]

ABSTRACT

Background: Body fat is associated with a high incidence of degenerative diseases. Therefore, estimating body fat with the smallest error as possible is primordial. **Objective:** The objective of this study was to verify if the body mass index (BMI) presents consistence in relation to the sum of triceps and calf skinfold (TR + CA) in order to classify girls and boys as above, below and within the recommended standard (reference criterion), considered as adequate for a good health condition. **Methods:** The sample was composed by 694 girls and 716 boys with ages ranging from 10.50 to 17.49 years. The variables were measured and analyzed in relation to the reference criterion presented by the AAHPERD (1988). The data were analyzed by the contingency coefficient and kappa index. **Results and conclusion:** The results indicated that only 48.98% of girls and 57.32% of boys were concomitantly classified by BMI and TR + CA. The kappa index indicated a very weak agreement between the three classification categories of body fat (above, below and within the recommended standard). In conclusion, the BMI does not present consistence in order to classify girls and boys in relation to body fat.

Key words: BMI. Skinfold. Body fat. Reference criterion.

INTRODUCTION

The early development of non-transmissible chronic diseases such as cardiovascular disease, hypertension, high levels of low-density lipoproteins, among others, is significantly associated with high body fat levels[1-4]. On the other hand, extremely low fat levels may be associated to bulimia nervosa[5,6], anorexia[7,8] and calorie-protein undernourishment[9,10].

Therefore, quantifying body fat with the smallest error as possible becomes vital, fact that has led researchers to develop and to validate different techniques to assess it such as: hydrostatic weighting, anthropometry, bioelectric impedance, double-energy x-ray absorptiometry, pletismography, among others.

The anthropometrical technique used is the most employed worldwide for being the cheapest and for presenting satisfactory reliability. This technique makes use of linear measurements, mass, diameters, perimeters and skinfolds. These measurements, alone or combined, are used in order to obtain indexes such as the body mass index (BMI) or the body fat percentage (F%) corrected or not for the respective age.

The BMI has been recommended by WHO[11] as an indicative of body fat for being quickly obtained with no cost at all. However, studies[12-14] have discussed its use with the objective of diagnosing body fat at different age ranges.

On the other hand, the F% obtained from skinfolds measurements has had a wide acceptance among sports researchers. This is due to the fact that F% obtained from the anthropometrical technique is quite well associated and does not differ significantly from the F% obtained from the hydrostatic weighting[15-18], which is considered as validation criterion for other techniques.

After accomplishing the measurements and body fat estimations phase, the following phase or evaluation phase takes place, in other words, performing the analysis of the results obtained.

Two evaluation means are usually used: by referenced norm and by reference criterion. The first one is used when the objective is to verify how a subject is presented when compared to the group that gave origin to the referenced norms. The second one is used when the objective is to verify if the subject reaches a predetermined performance level, for example, if the subject presents an amount of fat suitable with good health or used for the purpose under discussion.

When the objective is to verify the amount of body fat in relation to health, the adequate evaluation mean is the reference criterion, once studies show that people who present body fat within some standards also present lower incidence of non-transmissible chronic diseases when compared to people who present higher amounts of fat in relation to the former ones[1-4].

Different reference criteria may be obtained in the scientific literature in order to evaluate body fat in relation to health. For children and adolescents, the AAHPERD[19] presents reference criteria for the sum of triceps and calf skinfolds (TR + CA) and for BMI.

Knowing the importance of a correct diagnosis with regard to body fat, once the adequate amount of body fat is vital for good health conditions, this study was developed with the objective of verifying if BMI presents consistence in relation to TR +CA in order to classify girls and boys as above, below or within standard (reference criterion) considered as adequate for good health conditions with regard to body fat.

METHODS

Sample

The sample was composed of female and male adolescents from 11 to 17 years of age enrolled in public schools from the cities of Erval Grande – RS (extreme northern region), Chapecó – SC (western region), Concórdia – SC (western region) and Saudades – SC (western region). Taking Chapecó as reference, the distances range from 42 km (Erval Grande) to 95 km (Concórdia).

The urban adolescents live in the city of Chapecó. Three schools were randomly selected as follows: one school in downtown and two others in the outskirts. Two schools in the outskirts were selected, once in this region there are over than twice as many schools as in downtown.

The rural adolescents live in the inland of the other municipal districts. In these municipal districts, the schools were not randomly selected because due to the age range involved in this study (students from the 5th grade on), the school selected was the one placed in downtown. There is only one school in each of these municipal districts that attends children from the 5th grade on.

1. Brasília Catholic University – UCB/DF.

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Correspondence to: Q 201, Lote 6, Bloco B, apto. 803, Águas Claras – 71937-540 – Brasília, DF. E-mail: mfglaner@pos.ucb.br

After this phase, two groups of students from each grade and school were selected. Then the students were invited to participate as volunteers after their parents or responsible signed the free and cleared consent term containing information on the objectives and procedures to be adopted. From the students invited, 98% actually participated in the study. Students who were not present at the collection day and those who did not participate in the Physical Education class due to medical recommendation were excluded from the study. The data collection was performed at the timetable corresponding to this subject. All volunteers presented apparent good health conditions at the collection moment.

The final sample was composed of 694 girls and 716 boys with ages ranging from 10.50 to 17.49 years. This sample was grouped into decimal age, in other words, from 10.50 to 11.49, the age was characterized as 11 years and so on up to the age of 17.

Study variables

The body mass (BM) was obtained with measure unit of 100 g and the stature (ST) with measure unit of 1 mm and the participants were measured as described by Gordon *et al.*[20]. These two variables were measured by the same appraiser, which presented a measurement technical error lower than 0.5% for each variable.

The BMI was obtained through the following equation:

$$BMI = \frac{BM\ (kg)}{ST^2\ (m)}$$

The triceps and calf skinfolds was measured according to standardization of AAHPERD[19], with the aid of a Lange compass with measure unit of 1 mm and resolution of 0.5 mm. These variables were measured by the same appraiser, which presented a measurement technical error lower than 3.5% for each skinfold.

Reference criteria

The reference criteria (RC) suggested by AAHPERD[19] for girls and boys from the respective age ranges in this study are presented in board 1. These RC were adopted by being internationally accepted and based on scientific evidences.

BOARD 1
Reference criteria for the sum of triceps and calf skinfolds TR + CA and body mass index (MBI) established by AAHPERD (1998)

Age (years)	Girls		Boys	
	TR + CA (mm)	BMI (kg/m²)	TR + CA (mm)	BMI (kg/m²)
11	16 – 36	14 – 21	12 – 25	15 – 21
12	16 – 36	15 – 22	12 – 25	15 – 22
13	16 – 36	15 – 23	12 – 25	16 – 23
14	16 – 36	17 – 24	12 – 25	16 – 24
15	16 – 36	17 – 24	12 – 25	17 – 24
16	16 – 36	17 – 24	12 – 25	18 – 24
17	16 – 36	17 – 25	12 – 25	18 – 25

Statistical treatment

The analysis of data was performed through the association degree obtained by the calculation of the contingency coefficient between classifications as below, above and within the reference criterion for TR + CA and BMI. The kappa index was also used in order to verify the agreement proportion between classifications. The software used was the Statistical Package for the Social Sciences (Chicago: USA).

RESULTS

Table 1 presents the sample composition by age range and gender, with the respective average values of body mass and stature.

TABLE 1
Size of the sample (n) by gender and age with the respective average values and standard deviation (±) of body mass (BM) and stature (ST)

Age (years)	Girls (n = 694)			Boys (n = 716)		
	n	BM (kg)	ST (cm)	n	BM (kg)	ST (cm)
11	93	37.2 ± 7.6	145.4 ± 7.3	90	37.6 ± 7.9	144.1 ± 5.9
12	103	42.5 ± 8.9	150.4 ± 7.0	102	40.5 ± 9.3	148.8 ± 7.2
13	117	48.2 ± 9.4	157.3 ± 6.5	114	44.6 ± 10.3	155.4 ± 8.6
14	124	50.1 ± 8.9	158.2 ± 5.8	115	51.8 ± 12.5	162.6 ± 8.8
15	103	52.2 ± 7.1	160.0 ± 6.1	103	55.2 ± 9.4	167.3 ± 7.8
16	78	55.4 ± 8.1	161.1 ± 5.8	101	56.9 ± 8.2	169.3 ± 6.7
17	76	55.5 ± 7.7	161.8 ± 5.1	91	63.0 ± 11.6	172.6 ± 6.5

The crossed tabulation of results is presented in a 3X3 contingency Table (table 2). The data indicate that only 48.98% of girls and 57.32% of boys were concomitantly classified by both procedures (hachured values). It is worth emphasizing that as the TR + CA indicates that 320 (46.12%) girls and 207 (28.87%) boys presented fat above recommended values, the BMI classifies them within ideal standard.

The contingency coefficient between data presented in table 2 was of 0.45 for girls and 0.39 for boys, indicating a moderate association degree between the three classification categories of BMI and TR + CA. The kappa index was of 0.13 and 0.15 for girls and boys, respectively, emphasizing a weak agreement between the three categories.

TABLE 2
3X3 contingency Table used in the estimation of the BMI consistence. Frequency and percentile (%) of girls and boys classified according to the three categories of TR + CA and BMI

Body fat levels	BMI below RC	BMI – ideal standard	BMI above RC	Total
		Girls		
TR + CA below RC	6 (0.86%)	1 (0.14%)		7 (1.01%)
TR + CA ideal standard	33 (4.76%)	262 (37.75%)		295 (42.61%)
TR + CA above RC		320 (46.12%)	72 (10.37%)	392 (56.49%)
Total	39 (5.62%)	583 (84.01%)	72 (10.37%)	694 (100%)
		Boys		
TR + CA below RC	14 (1.95%)	23 (3.21%)		37 (5.17%)
TR + CA ideal standard	67 (9.34%)	346 (48.40%)	1 (0.14%)	414 (57.82%)
TR + CA above RC	8 (1.12%)	207 (28.87%)	50 (6.97%)	265 (37.01%)
Total	89 (12.41%)	576 (80.48%)	51 (7.11%)	716 (100%)

BMI = body mass index; RC = reference criterion; TR + CA = sum of triceps and calf skinfolds.

DISCUSSION

The kappa indexes and contingency coefficients obtained between data presented in table 2 for girls and boys show consistence from weak to moderate, respectively, of the BMI as indicative of body fat. In order for the BMI to present satisfactory consistence, the contingency coefficient should be, according to Safrit[21], of at least 0.80. The unsatisfactory consistence of BMI may be visualized in table 2, where only 48.98% of girls and 57.32% of boys were classified correctly or concomitantly by both procedures. These results also indicate that the BMI is a better indicative of body fat for girls than for boys, while in the study of Carrasco *et al.*[22], it was evidenced that the BMI is more suitable to discriminate body fat in women than in men.

In addition to results obtained in this study, other studies[12-14,22-24], in relation to the BMI limitation, show that this parameter is not suitable to check if girls and boys present adequate body fat in relation to good health conditions. This occurs because subjects may present BMI within ideal standard and body fat above the

ideal values or even present BMI below the recommended values and body fat within ideal values. This lack of agreement between BMI and body fat may be explained not only by the fragility of this index but also by the fact that the body fat is associated to the physical activity or physical fitness levels.

In another study, Khongsdier[24] related the self-reported morbidity with body composition estimated through anthropometry and verified that subjects with BMI lower than 18 kg/m^2 and higher than 23 kg/m^2 were not significantly different from those considered as with normal BMI (18 to 23 kg/m^2) with regard to the risk of acquiring diseases.

In this context, the BMI adoption may lead to imprecise evaluations and hence the possible physical activity prescription or intervention programs will not be correct either. Thus, when only BMI is used, the diagnosis could be mistaken, what is reinforced by results of this study that showed that only 10.37% of girls and 6.97% of boys presented BMI above the recommended values. TR + CA indicated that 56.48% of girls and 36.70% of boys presented body fat above recommended values for good health conditions, what is corroborated by findings of Chiara *et al.*[25]. Other studies also indicated a higher prevalence among overweighed or obese people[26,27].

Concomitantly to the search for the best technique to verify body fat levels in relation to good health standards, there is a need that programs proposed by the government or other social entities are implemented in order to reduce overweight and obesity in all age ranges. It seems that the information broadcasted in relation to what obese people should do or not have not given the expected results. It also seems that education could be the best strategy. However, one believes that the teaching institutions have not given the importance the subjects deserves, once it has been evidenced that around 66% of girls and 37% of boys at school age present body fat above recommended values, whereas only 3% of the sample presented body fat below minimum standards.

Considering the high number of girls and boys with body fat above ideal standards or reference criterion, the development of possible strategies in order to reduce this high-risk behavior is encouraged. Otherwise, it will lead to high social costs in a near future, according to study of Lessa *et al.*[28].

A body fat diagnosis the more precise as possible is vital in childhood and adolescence, once overweighed children or adolescents generally become obese adults[29,30], and the latency period of non-transmissible chronic diseases associated to high amounts of body fat starts at the phase of life. The importance of this quantification is reinforced by Chor *et al.*[31], who evidenced that cardiovascular diseases are the main cause of death among the Brazilian adult population (40-49 years). This results in the loss of many productive years of life, suggesting that the load of risky factors (use of tobacco, obesity, arterial hypertension, diabetes, sedentary, stress, among others) contribute to several death causes[32].

It is worth emphasizing that this study presents the use of an indirect technique to estimate body fat as main limitation. The fact of not using a technique considered as gold standard may decrease the validity of results. However, a recent study[33] demonstrated the validity of the anthropometrical technique in age ranges similar to this study. Furthermore, the skinfolds measurements were considered as satisfactory when the measurement technical error in each skinfold was lower than 5%, and the error presented for skinfolds in this study was lower than 3.5%.

Considering the limitation of this study, it is worth emphasizing the absence of studies conducted in Brazil with this type of designing, involving rural samples and the reference criteria proposed by AAHPERD[19], which are extensively used in this country in order to compare and/or analyze the physical fitness variables associated to health, among them the body fat.

CONCLUSIONS

In function of the established objective, one concludes that the BMI presents no consistence to classify girls and boys aged from 10.5 to 17.49 years with regard to body fat as below, above and within the reference criterion for good health conditions, once only 48.99% of girls and 56.93% of boys were correctly classified.

The performance of new studies with similar design as this one is suggested; however, with the involvement of adults and older adults in order to verify if the findings will be similar to these.

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REFERENCES

1. Gaziano JM. When should heart disease prevention begin? N Engl J Med 1998; 338:1690-2.
2. Eckel RH. Obesity and heart disease: a statement for healthcare professionals from the nutrition committee, American Heart Association. Circulation 1997; 96:3248-50.
3. Rippe JM, McInnis KJ, Melanson KJ. Physician involvement in the management of obesity as a primary medical condition. Obes Res 2001;9:S302-11.
4. Campbell I. The obesity epidemic: can we turn the tide? Heart 2003;89:ii22-4.
5. Gendall KA, Bulik CM, Sullivan PF, Joyce PR, McIntosh VV, Carter FA. Body weight in bulimia nervosa. Eat Weight Disord 1999;4:157-64.
6. Jackson TD, Grilo CM, Masheb RM. Teasing history and eating disorder features: an age – and body mass index – matched comparison of bulimia nervosa and binge-eating disorder. Compr Psychiatry 2002;43:108-13.
7. Kerruish KP, O'Connor J, Humphries IR, Kohn MR, Clarke SD, Briody JN, et al. Body composition in adolescents with anorexia nervosa. Am J Clin Nutr 2002; 75:31-7.
8. Probst M, Goris M, Vandereycken W, van Coppenolle H. Body composition of anorexia nervosa patients assessed by underwater weighing and skinfold-thickness measurements before and after weight gain. Am J Clin Nutr 2001;73:190-7.
9. Esteban Perez M, Fernandez-Ballart J, Salas-Salvado J. The nutritional status of the older population as a function of the institutionalization regimen. Nutr Hosp 2000;15:105-13.
10. Marcondes E. Normas para o diagnóstico e a classificação dos distúrbios do crescimento e da nutrição – última versão. Clin Pediátrica 1982;4:307-26.
11. OMS (Organização Mundial de Saúde). Necessidades de energia e de proteínas. Série de informes técnicos. Ginebra: Suiza, 1985;724.
12. Ricardo DR, Araújo CGS. Índice de massa corporal: um questionamento baseado em evidências. Arq Bras Cardiol 2002;79:61-9.
13. Taylor RW, Falorni A, Jones IE, Goulding A. Identifying adolescents with high percentage body fat: a comparison of BMI cutoffs using age and stage of pubertal development compared with BMI cutoffs using age alone. Eur J Clin Nutr 2003;57:764-9.
14. Frankenfield DC, Rowe WA, Cooney RN, Smith SJ, Becker D. Limits of body mass index to detect obesity and predict body composition. Nutrition 2001;17: 26-30.
15. Sloan AW. Estimation of body fat in young men. J Appl Physiol 1967;23:311-5.
16. Jackson AS, Pollock ML, Ward A. Generalized equations for predicting body density of women. Med Sci Sports Exerc 1980;12:175-82.
17. Thorland WG, Johnson GO, Tharp GD, Housh TJ, Cisar CJ. Estimation of body density in adolescent athletes. Hum Biol 1984;56:439-48.
18 Glaner MF, Rodriguez Añez CR. Validação de equações para estimar a densidade corporal e/ou percentual de gordura para militares masculinos. Trein Desportivo 1999;4:29-36.
19. AAHPERD (American Alliance for Health, Physical Education, Recreation and Dance). Physical best. Reston, VA: American Alliance for Health, Physical Education, Recreation and Dance, 1988.
20. Gordon CC, Chumlea WC, Roche AF. Stature, recumbent length, and weight. In: Lohman TG, Roche AF, Martorell R, editors. Anthropometric standardization reference manual. Abridged edition. Champaign: Human Kinetics Books, 1991:cap. 1.

21. Safrit MJ. Introduction to measurement in physical education and exercise science. St. Louis: Mosby, 1986.
22. Carrasco FN, Reyes ES, Rimler OS, Rios FC. Exactitud del índice de masa corporal en la predicción de la adiposidad medida por impedanciometría bioeléctrica. Arch Lationam Nutr 2004;54:208-86.
23. Graves MM, Adams TM. Differences in disease risk stratification based on BMI versus percent body fat values. Med Sci Sports Exerc 2004;36(Sup 5):S75.
24. Khongsdier R. BMI and morbidity in relation to body composition: a cross-sectional study of a rural community in North-East India. Br J Nutr 2005;93:101-7.
25. Chiara V, Sichieri R, Martins PD. Sensibilidade e especificidade de classificação de sobrepeso em adolescentes, Rio de Janeiro. Rev Saúde Pública 2003;37: 226-31.
26. Pimenta APA, Palma A. Perfil epidemiológico da obesidade em crianças: relação entre televisão, atividade física e obesidade. Rev Bras Ciên e Mov 2001;9:19-24.
27. Batista Filho M, Rissin A. A transição nutricional no Brasil: tendências regionais e temporais. Cad Saúde Pública 2003;19(Sup1):S181-91.
28. Lessa I, Mendonça GAS, Teixeira MTB. Doenças crônicas não-transmissíveis no Brasil: dos fatores de risco ao impacto social. Bol Oficina Sanit Panam 1996; 120:369-413.
29. Rolland-Cachera MF, Deheeger M, Guilloud-Bataille M, Avons P, Sempre M. Tracking the development of adiposity from one month of age to adulthood. Ann Hum Biol 1987;14:219-29.
30. Bouchard C. A epidemia de obesidade. In: Bouchard C, editor. Atividade física e obesidade. Barueri: Manole, 2003:cap 1.
31. Chor D, Fonseca MJM, Andrade CR. Doenças cardiovasculares: comentários sobre a mortalidade precoce no Brasil. Arq Bras Cardiol 1995;64:15-9.
32. Lessa I. Tendência dos anos produtivos de vida perdidos por mortalidade precoce por doença arterial coronariana. Arq Bras Cardiol 2002;79:611-6.
33. Brown DD, McKenzie JE, Cullen RW, Lagally KM, Dennis KK. A comparison of body composition techniques to determine body fat percentages in high school wrestlers. Med Sci Sports Exerc 2004;36(Sup 5):S73.