MESTRADO EM SAÚDE PÚBLICA

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# Diagnostic accuracy of CDC, IOTF and WHO criteria for obesity classification, in a Portuguese school-aged children population


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| | |
|---|---|
| +LR | Positive likelihood ratio |
| +PV | Positive predictive value |
| -PV | Negative predictive value |
| %BF | Percent body fat |
| AUC | Area under the curve |
| BC | Body composition |
| BF | Body fat |
| BIA | Bioelectrical impedance analysis |
| BMI | Body mass index |
| CDC | Centers for Disease Control and Prevention |
| CI | Confidence interval |
| DXA | Dual-energy x-ray absorptiometry |
| EU | European Union |
| FF-BIA | Foot-to-foot bioelectrical impedance analysis |
| FFM | Fat-free mass |
| FM | Fat mass |
| IMC | Índice de massa corporal |
| IOTF | International Obesity Task Force |
| NYC | New York City |
| OR | Diagnostic odds ratio |
| ROC | Receiver operating charts |
| SD | Standard deviation |
| US | United States |
| VAT | Visceral adipose tissue |
| WHO | World Health Organization |

## RESUMO

**Introdução:**

A Obesidade Infantil é atualmente considerada um problema global de saúde pública, estando a tornar-se uma prioridade de saúde em diversos países. A escolha e adequação dos critérios para a avaliação do crescimento infantil e o ponto de corte ideal de Índice de Massa Corporal (IMC) quer na prática clínica, quer em estudos populacionais, mantêm-se em discussão. Contudo, esta discussão está longe de ser simples, surgindo uma grande diversidade de assuntos que dificultam, ainda mais, a obtenção de uma conclusão. Além disso, muitas vezes os argumentos utilizados são apenas baseados em suposições e em palpites, e goram na tentativa de se revestirem de evidência fiável. Assim, para evitar as consequências altamente preocupantes da má-classificação de crianças, consideramos pesquisar a adequação dos critérios de pontos de corte de IMC através da sua fiabilidade e capacidade de predição de gordura corporal.

O objetivo deste estudo foi avaliar a exatidão de diagnóstico dos pontos de corte de IMC do CDC, IOTF e WHO, na classificação de excesso ponderal e obesidade, comparados com a percentagem de gordura corporal estimada por bioimpedância perna-perna, numa amostra portuguesa de crianças em idade escolar.

**Métodos:**

Uma amostra de 2377 alunos do 1º ciclo (7-10 anos, 47.9% raparigas), inscritos nas 33 escolas públicas de Paços de Ferreira – Portugal, foi examinada durante a primavera de 2007. Peso e altura forma avaliados por um antropometrista treinado, de acordo com o *WHO Training Course on Child Growth Assessment* e a percentagem de gordura corporal (%BF) foi avaliada usando um analisador de composição corporal Tanita BF-666. Cada critério de pontos de corte foi comparado com a %BF, considerada o método de referência, pela análise de sensibilidade, especificidade, valores preditivos positivo (+PV) e negativo (-PV), *likelihood ratio* positivo (+LR) e *odds ratio* de diagnóstico (OR). Foi ainda efectuada uma análise de curvas ROC. As análises estatísticas foram efectuadas nos programas SPSS e R.

**Resultados:**

A sensibilidade mais elevada para a classificação de obesidade foi descoberta usando o critério da WHO (76.4%, 95%CI 72.6-79.9) e a mais baixa usando os pontos de corte do IOTF (44.1%, 95%CI 39.9-48.4). Para a classe de excesso ponderal, a sensibilidade foi superior para os pontos de corte da WHO (91.5%, 95%CI 89.6-93.2), e a mais baixa para o critério da IOTF (78.4%, 95%CI 75.7-80.9). Elevados valores de especificidade foram encontrados para os três critérios, mas o IOTF apresentou o valor mais alto (99.8%, 95%CI

99.6-99.9) para a obesidade, assim como para o excesso ponderal (95.3%, 95%CI 94.1-96.3). Das crianças que foram definidas como obesas pelo IOTF, 98.7% (95%CI: 96.6-99.7) foram correctamente classificados (+PV), comparativamente com 88.2% (WHO) e 93.3% (CDC). Na classe excesso ponderal os +PV foram 79.1% (WHO) e 88.3% (CDC), comparativamente com o IOTF 91.8% (95%CI: 89.8-93.5), de crianças classificadas com excesso de peso de forma correcta. Independentemente da prevalência de obesidade da população (probabilidade pré-teste), o critério da IOTF apresentou a melhor capacidade para classificar os indivíduos como obesos (+LR 273.1, 95%CI 87.8-849.5), assim como com excesso ponderal (+LR 16.7, 95%CI 13.2-21.1).

**Conclusão:**

O critério da WHO parece ser o melhor para detectar obesidade e excesso ponderal em crianças de uma população. Contudo, para confirmação de doença, nomeadamente no contexto clínico, o critério da IOTF parece ser o mais preciso para a determinação de obesidade e de excesso de peso.

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## ABSTRACT


**Background:**

Childhood obesity is currently considered a worldwide public health problem that is becoming a health priority in many countries. The adequacy and selection of criteria for the assessment of growth in children and the optimum body mass index (BMI) cutoff points for obesity definition, both in clinical practice and in population studies are kept under discussion. Although, this discussion is far from being simple and a large span of issues come up and difficult even more the achievement to a conclusion. Moreover, sometimes arguments are only based in suppositions and in well educated guesses and fail to endorse themselves with reliable evidence. Thus, to avoid the consequences of great concern from children misclassification, we consider seeking for the adequacy of BMI cutoff criteria using their feasibility and capacity in predicting body fat (BF).

In this study we aimed to evaluate the diagnostic accuracy of CDC's, IOTF's and WHO's BMI cutoff points in the classification of overweight and obesity, compared to the percentage of BF estimated by leg-to-leg bioelectric impedance, in a Portuguese sample of school-aged children.

**Methods:**

A sample of 2377 elementary students (7-10 years, 47.9% girls), registered in the 33 public schools of Paços de Ferreira – Portugal, were evaluated during the spring of 2007. Weight and height were assessed, by one trained anthropometrist, according to the *WHO Training Course on Child Growth Assessment* and percent body fat (%BF) was measured using a body composition analyzer Tanita BF-666. Each cutoff point criteria was compared with %BF, considered as the gold standard, by the evaluation of sensitivity, specificity, positive (+PV) and negative predictive values (-PV), positive likelihood ratio (+LR) and diagnostic odds ratio (OR). We also made a ROC curve analysis. Statistical analyses were performed by SPSS and R software.

**Results:**

The highest sensitivity for classifying obesity was found using the WHO criterion (76.4%, 95%CI 72.6-79.9) and the lowest using IOTF cutoff points (44.1%, 95%CI 39.9-48.4). For overweight class sensitivity was higher for WHO cutoff points (91.5%, 95%CI 89.6-93.2), and the lower for IOTF criterion (78.4%, 95%CI 75.7-80.9). High specificity values were found for the three criteria but the IOTF showed the highest value (99.8%, 95%CI 99.6-99.9) for obesity, as well as for overweight (95.3%, 95%CI 94.1-96.3). From those children defined as obese by IOTF, 98.7% (95%CI: 96.6-99.7) were correctly classified (+PV), compared to 88.2% (WHO) and 93.3% (CDC). In overweight class +PVs were 79.1% (WHO) and 88.3%

(CDC), compared to IOTF 91.8% (95%CI: 89.8-93.5) of children determined to have overweight correctly classified. Independently of the population obesity prevalence (pretest probability), the IOTF criteria showed the best ability to classify individuals as obese (+LR 273.1, 95%CI 87.8-849.5), or as overweight (+LR 16.7, 95%CI 13.2-21.1).

**Conclusion:**

The WHO criterion seems to be better to detect obesity and overweight in children from a population. Although, to confirm the disease, namely in a clinical context, the IOTF criterion seems to be more accurate to define obesity and overweight.

# INTRODUCTION

## Obesity trends, consequences and costs

Childhood obesity is currently considered a worldwide public health problem that is, indubitably, becoming epidemic in several parts of the world. Studies reported the child overweight and obesity spanning globally in the last decades (1-5) among school-age children, and also in pre-school children (3, 6). Estimations for 2010 were made in school-age children, based on secular trends from 2006 and presuming a linear evolution of prevalence (3). It was estimated that overweight will strike over than 46% of children in the Americas, approximately 41% of children in the Eastern Mediterranean region, and 38% of children in the European region, 27% in the Western Pacific region, and 22% in South East Asia. As regarding to obesity, predictions point to one obese child in each seven in the Americas, and one in every ten children in the Eastern Mediterranean and European regions (3).

Furthermore, the annual increment in childhood obesity prevalence rises every year. In 2006, Jackson-Leach et al. (5) used a linear model to predict the annual increment in prevalence by the year 2010, of children between 5 and 17.9 years of age, in European Union (EU). The model, was conservative to assure a lower margin of error, and gave a lower forecast than would a possibly higher order polynomial model. Even though, the average estimated annual increment in the prevalence of overweight and obesity was estimated to be between 1.5 and 1.9 percentage points by 2010 (5).

In Portugal, prevalence data seems to have a similar progression as in the rest of Europe. Padez et al. (7), reported trends in BMI of Portuguese children, aged 7-9 years old, form 1970 till 2002. This study presented a mean increase in BMI of 2kg/m$^2$, both in girls and boys, in the study period. The velocity of BMI increase was higher in the last period (1992–2002), in consistency with the height velocity that was lower in the second period (1992–2002) than in the first period analyzed (1970–1992). On the other hand, the weight velocity, kept increasing and was higher in the last period (1992–2002) (7). Data from an overview and synthesis of obesity prevalence studies in Portugal, reported a prevalence of overweight in children under the age of 6 years, that reached 13.6% in boys and 20.4% in girls, and obesity varied between 6.5% and 6.9%, respectively, in boys and girls. Children between 6 and 10 years of age had a prevalence of overweight from 14.7 to 30.5% and obesity from 5.3 to 13.2% in boys; in girls, overweight values ranged from 16.5 to 29.1% and obesity from 6.4 to 12.6% (8).

Childhood obesity is not an isolated problem, and its consequences are wider than those related only with obesity prevalence in this specific life span period. The concern with problems in later life is a topic well discussed (2, 9-13). But, the most concerning outcomes are those that occur even during childhood, mainly the obesity-related diseases and obesity emotional consequences and their effect as an economic burden for the health-care system.

The question about if there is a similarity of health risks between adult and childhood obesity has two answers: yes and no. By one hand, obese children already present high hyperinsulinaemia, poor glucose tolerance, type 2 diabetes, hypertension, raised triglycerides, raised total cholesterol, high LDL cholesterol, low HDL cholesterol, early symptoms of hardening of the arteries, nonalcoholic fatty liver disease, sleep apnea, social exclusion and depression (2, 13, 14), as obese adults do. By other hand, due to children's body is still during a growing and developing process, they have a much higher vulnerability to obesity-related diseases (13), and the extent of the latter consequences, due to the earlier development of these diseases, are yet to be evaluated when this generation of obese children pass to adulthood in the present decade (2). Nevertheless, the degree of presence of co-morbidities and disease indicators in populations of obese children is already off some distress. In a study of 2006, Lobstein et al. (14) reported the minimum estimated numbers of children in EU (with 25 countries) with obesity-related disease indicators within the age range 5.0 to 17.9 years. Estimates of obesity-related diseases were: at least 1 obese child in each 5 suffered of raised triglycerides – 21.5% (1.09 million children), raised total cholesterol – 22.1% (1.12 million children), high LDL cholesterol – 18.9% (960 thousands children), low HDL cholesterol – 18.7% (950 thousands children), hypertension – 21.8% (1.11 million children); at least 1 obese child in each 4 suffered of metabolic syndrome – 23.9% (1.21 million children) or hepatic steatosis – 27.9% (1.42 million children); at least 1 obese child in each 4 suffered of hyperinsulinaemia – 33.9% (1.72 million children) (14). These numbers, by themselves already represent a threat to the sustainability of the pediatric health care system. Although, much of the disease burden in the pediatric population may pass unnoticed, first because data presented above are only related to obese children and not from overweight children, that can already suffer of some of the diseases stated before; second, in many circumstances the disease will only be expressed in young adulthood, when the individual experiences a health crisis (14). However, studies confirming the costs of obesity burden in childhood are very recent and a great concern continues with the specific study of costs of premature death promoted by childhood obesity (2). A recent work from Breitfelder and co-workers (15) showed some insights on the costs of childhood obesity. All costs were found to be divided between physician (22%), therapist (29%), hospital (41%) and inpatient rehabilitation costs (8%). Costs in all categories were at least 16% higher for obese children than for all other children, although not statistically significant in all cases, but of economic relevance (15). There were considerable differences in costs per year between

BMI groups: severely underweight (€469) and underweight (€468) children presented similar costs, but were higher than costs with normal weight (€402) children; as BMI increased costs also did, overweight (€468) and obese (€680), being this 1.7 fold than normal children costs. Indirect costs tended also to be higher for obese children (15).

Regarding to the costs and consequences of obesity in adults, there is more evidence available. Some studies reported that for various countries adult obesity accounts for 2 to 7% of a developed country total health care costs (2). Furthermore, and perhaps of higher importance, are the costs of obesity-related diseases, once that obese adults medical expenses are estimated to be 36% higher than those of their nonobese peers, in people younger than sixty-five years old (13).

In Portugal, in 1999, it was estimated the impact of obesity on health care expenditures (16). Total direct health care costs attributable to obesity were €231 million, 3.5% of the total health care expenditures in Portugal in 1996, representing only part of the economic costs that can be attributable to obesity since indirect costs represented almost half of the total costs. The direct health care costs of excess weight (overweight and obesity) represented approximately 3.8% of national out-pocket expenditures in 1995 and 6.9% in 1999 (16), which is a huge burden to family income.

In addition, we should not discard all the intangible costs of adult obesity, i.e. the social and personal costs or losses associated with obesity, as costs spent by families on commercial weight loss programs, costs associated to reduced quality of life of individuals and their lower self-esteem. Although these costs are difficult to access and to define, and might be subject to individual interests and biases of the researcher, they are estimated to be 10 times the direct costs of obesity, and are likely to be true in all of the developed economies (2). As prevalence of childhood obesity rises, there will be found in young adult populations seriously increased rates of heart disease, diabetes, certain cancers, gall bladder disease, osteoarthritis and endocrine disorders (2, 13). The earlier onset of obesity-associated disorders in adulthood will inevitably lead to a longer subsequent lifetime of disability and the expected need for medical treatment may last for their remaining life-times. Hence, more costly referrals into the health care system will occur, creating a significant extra financial burden on national health services, as well as greater losses to society and larger will be the burdens carried by the individuals involved (2, 6, 13, 14, 17).

Studies of some recent cohorts are already warning for the profound implications that higher prevalence of childhood obesity could have in mortality rates within the United States (US) population (17), due to accelerate of complications such as cardiovascular disease, retinopathy and end-stage renal disease, with potential implications for estimates of future life expectancy, and maybe reversing, by the first time, its steady increase in the modern era's, with today's youth on average living less healthy and ultimately shorter lives than their parents did (13, 17).

Furthermore, all the consequences accounted earlier could have an even more disastrous effect if the health services fail to correctly prevent childhood obesity, and treat particularly the heaviest children (2). From this standpoint, the childhood overweight and obesity measurement turns out to be a major discussion point, due to the misclassification of children as overweight or obese, especially when children are under classified.

**BMI criteria for measuring overweight and obesity in children**

Despite all the overwhelming evidence focused till now, some authors underline the need for more research in several areas: collection of national representative and longitudinal data to monitor secular trends and nutritional status (2, 3, 5); the need to agree on evaluation of different countries populations using comparable criteria and standardized methods for assessing children and adolescents nutritional status (2, 5, 13); international collaboration and cooperation to ensure that monitoring can be undertaken in all communities (3); study and clarification of the usefulness of most of the current anthropometric references in predicting long-term health consequences (3).

The methodological problem of inconsistency between criteria of childhood obesity classification is a major obstacle in studying global secular trends for younger age groups (13). The overcome of this challenge may be essential and urgent, by the establishment of consensual criteria for overweight and obesity definition in childhood that would predict morbidity and mortality in adulthood, once discrepancy in criteria may be a main bias in all the field of childhood obesity research, not only in the prevalence assessment (18-20), trends monitor (13) and health system costs burden estimation (15), but also in the study of determinants, consequences and strategies to tackle the epidemic (21, 22), and specially in children's misclassification and its intrinsic consequents in treatment or prevention.

Therefore, it is recently of current discussion, what body mass index (BMI) criteria should be used for assessment of growth in children. The requirement of harmonized and consensual criteria (2, 5, 13), and understanding the adequacy of application of each international criterion at the national level (23), are relevant topics. Although, this discussion is far from being simple and a large span of issues come up and in the most of the times those issues cannot be overlapped, what will difficult even more achieving a conclusion. Furthermore, sometimes arguments are only based in suppositions and in well educated guesses and fail to endorse themselves with reliable evidence.

There are two worldwide used BMI criteria to access children nutritional status, the one developed by Cole et al. (24) and adopted by the International Obesity Task Force (IOTF), and the criteria from World Health Organization (WHO), that is divided in two growth references, one from 0-60 months (25) and other from 5-19 years (26). A third well recognized and used criterion is the 2000 US Centers for Disease Control and Prevention (CDC) Growth Charts for the US (27), this criterion is the one chosen by Portuguese Health Directorate to be used as reference criteria in the children health notebooks, for clinical context utilization.

The main topics of discussion in seeking for the adequacy of cutoff criteria are: a) prevalence of obesity in the original pediatric population and secular trends; b) ethnic background of the original population to achieve a worldwide usage of the criteria; c) infancy feeding practices and the definition of ideal growth pattern; d) methodology for charts development and cutoff points selection; e) feasibility and capacity of BMI in predicting body fat (BF).

a) The prevalence of the phenomenon in the population where the criterion was developed is a very significant condition of the growth charts characteristics. As prevalence become higher and the secular trends in BMI increase, more imprecise will be the assumed “normal” growth definition. The IOTF criterion was designed from six large nationally representative cross sectional surveys on growth from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the US (24), being very difficult, due to that, to characterized the secular trends of BMI for this criteria. Both the CDC and WHO criteria are based on the distribution of representative samples of the US population (26, 27). A recent analysis of birth cohorts reported the extent of the epidemic of obesity in the US (17). The patterns of obesity prevalence over the life course shifted “dramatically” mainly due to increases in obesity among younger individuals in the population (17). Although the CDC recently reported no significant changes in obesity prevalence between 1999–2000, 2001–2002, 2003–2004, 2005–2006 and 2007–2008 for US children except among the very heaviest boys (28, 29), some speculation subsists that long-term trends in obesity may be different for more recent cohorts, mainly due to acceleration of obesity trends, between the transition from adolescence (10–19 years) to young adulthood (20–29 years) (17).

b) Many authors had discussed the feasibility of different criteria to be used worldwide as a reference for children overweight and obesity (14, 21, 22, 24, 30, 31). During many years this discussion was based on the assumption that the best criteria for worldwide comparison should be the one that could represent more extensively all ethnical backgrounds. The CDC criterion, supports that it has a wide racial/ethnic diversity (27), though being suitable to be applied worldwide (32). This assumption is consequentially adopted by the WHO criteria, once it is based on the same surveys used by the CDC to develop their charts (26). Furthermore, the WHO criteria suggests that it fulfills the need for a widely applicable growth reference for older children and adolescents, that countries increasingly recognized for assessing childhood obesity (26). There is no doubt about the multiethnic characteristics of US population, but some restrains should be accounted for trying to use it as multicultural, environmental and geographical reference of growth. Many studies already reported the concern that should be taken with the utilization of the same BMI criteria for different ethnic populations, mainly due to differences in body composition (BC) between races and ethnicities (33-35), but this should also be accounted in a geographic and cultural perspective. A study comparing Asian prepubertal children from New York City (NYC) and Jinan, Shandong, mainland China stated that although no differences were found in mean BMI, Jinan Asians had significantly higher percent body fat (%BF) compared with the NYC Asians ($P$<0.001), being both samples collected from urban settings on two separate continents (34). Therefore, the IOTF criterion seems to be a more suitable one to guarantee the multi-ethnic and -cultural application once its design is based in datasets from 6 worldwide datasets (only the African continent has no representation) (33), including data even from the CDC Growth charts for the US (24). Even though, some authors still demonstrate some skepticism about the usage of international criteria at the national level as definition of overweight and obesity (2, 22, 23), and, it has been suggested that in order to define obesity and its consequences across cultures, there should be developed age-specific BMI criteria and cutoffs for children and adolescents, at the local level (22). We should emphasize that if the rationale of the criterion usage is not the definition of overweight or obesity, but only to assist international comparisons of prevalence's or to establish the progression of prevalence's between countries, in epidemiologic studies, than an international criterion should be used and widely adopted and the IOTF reference seems to be superior for this purpose (5, 23, 36), even if presented along with results using other criteria that the authors choose to report (5), even though the authors acknowledge that the reference data set may not adequately represent non-Western populations (2).

Nevertheless, the issue of National versus International criteria will be further argued in advance.

c) Child feeding practices, mainly during the 1st semester of life will also be determinant to the growth reference definition once different feeding practices will represent different patterns of growth. For some years that exclusive breastfeeding during the 6 months after birth is recommended by the WHO (37) and most pediatric and nutrition societies, because of the unique capabilities of human milk, as the best nutritional basis for growth into a healthier later life, and its possible reducing obesity effect. There are some biological mechanisms that may be related to this effect, owing to the influence of breastfeeding in caloric and protein intake, on insulin secretion, and on the modulation of fat metabolism – fat deposition and adipocyte enlargement (38). Previous studies have found an effect, although small, of breastfeeding on reducing mean BMI in adolescence and adult life (39), as well as many epidemiological studies have found a protective effect of breastfeeding against obesity in latter life, reinforcing the role of breastfeeding as a population strategy of obesity prevention (38), and reduction of child morbidity and mortality (21). So, the definition of a standard of growth as being that of the breast-fed child could launch a bridge between the methods of nutritional assessment and all the guidelines that encourage mothers to breastfeed their children, as the guarantee of optimal nutrition during the infancy.

The WHO growth standards, is being advised to be considered as the children's norm of healthy growth and development (21, 40-42), because they were built based on a sample of healthy breast-feeding infants that onwards received a high-quality complimentary and these standards demonstrate that similar patterns of growth could be found in healthy children from around the world that were engaged in recommended feeding practices and that are raised in healthy environments (21). Nevertheless, this point of view is not consensual between authors, especially when regarding to the recommendation of usage of the same standard for all types of infant feeding (21). If by one hand, WHO standards could be very useful both, as a valuable alternative for countries that have no growth reference and as a good gold standard to analyze and compare growth and development in different populations (42), by other hand, many author still criticize the usage of these reference for monitoring growth of individual children (42), mainly without some previous validation trials (43). Supporting this position some arguments could be declared, but the strongest one is sustained, again, in the great diversity of the human race characteristics, that will certainly induce different growing patterns, because, has show in a recent study, the differences between populations are superior to the differences in feeding practices (42). Therefore it seems more appropriate to use a local reference for individual growth assessment, than to be systematically in contact with probable false problems of over- and under-achievement when using international standards (2, 42). Furthermore, this matter of the virtual over- and under-achievement is a larger problem than it might seems. A conclusion often extracted from the WHO Growth Reference is that children present a high rate of growth, particularly in the first two months. This occurs because in the design there were only used very high achievers (43), i.e. children that achieve higher growth patterns, compared to the rest of the population. This will cause some interpretation problems that could lead to remarkably impaired consequences. If mothers and health professionals, when using the charts to assess the adequacy of exclusive breastfeeding, verify that children have a virtual degree of growth failure, they will certainly take actions like add infant formula to the breastfeeding, or stop the breastfeeding or even both, in attempting to promote higher growth rates as those plotted in the WHO charts (43). By itself, this consequence, is exactly the opposite one off the first purposes of the WHO Growth references – the breastfeeding promotion (25). Nevertheless, de Onis et al. reported latter that growth assessment should not be done by looking at a single measurement point but at the overall trajectory of development to determine whether a child is tracking along the curve or is crossing centiles towards the lower centiles. Before deciding that exclusive breastfeeding is inadequate, most health professionals should make considerations about: baby's birth weight, growth trend, any lactation problems and infections that might explain the apparent growth failure (44).

d) Other issues in the discussion of criteria adequacy are both the methodology used for charts development and the selection of cutoff points, which differ between criteria, and those differences may explain, in part, the enormous variations that occur in the prevalence of overweight and obesity (22). The WHO 5-19 years (26) and the CDC criteria, as said before, were developed based on US population representative samples; the WHO growth standard from 0-60 months (25), sampled only children selected to represent optimal growth (exclusive or predominant breastfeeding for at least 4 months, single birth, non-smoking mother and absence of significant morbidity in the newborn) (20, 22). In contrast, the IOTF criterion was essentially developed to be representative of the whole population, and was based on children from cross-sectional surveys (20, 22). These differences are demonstrative of how greatly the criteria fail, due to be used in differently settings from those they were originally developed for. Although, the inadequate use, becomes clearer when analyzing cutoff points definition methods. The main problem of cutoff points for obesity in childhood is that in their development authors seems to systematically fall in the error of use a random definition. In fact, one could say that most of the times the cutoff point definition is characterized by the total absence of criterion. The CDC and WHO use percentiles, statistically based cutoff points, that were chosen to be different for each criteria (20, 22) to determine overweight and obesity. Furthermore, select the $95^{th}$ percentile to define obesity is to assume that, for the reference population, exactly 5% of children within each age- and sex- group are obese (45). This assumption is not real and can only be taken virtually. When developing the IOTF criteria, Cole et al. had the attention to avoid the arbitrarily selection of cutoffs. In fact, that was even one of the author's critics to the other previous criteria (24). Contrasting with the other criteria, these cutoff points were defined independently of the distribution of the reference population. They were extrapolated at age 18 from the BMI of 25 and 30 $kg/m^2$, assuming the authors that, from those BMI values onwards, children presented inherent health risks (22). However, this different standpoint is also considered to be inadequate. If the percentile method (derived from statistical definitions) incorporates arbitrary assumptions (45), IOTFs method, although not dependent of percentile choosing, also makes a similar assumption (statistical criteria of morbidity and mortality), when presumes that the proportion of children of the reference population with obesity is the same for each age- and sex- group (45). Furthermore, the advocacy of Cole et al. of a relation between their cutoff points with health outcomes is yet to be established (45).

e) Off all the discussion topics, the one that we consider to be the most concluding in seeking for the adequacy of cutoff criteria is the feasibility and capacity of BMI in predicting BF. Therefore this will be the discussion topic in which we will detain ourselves longer.

**BMI as a proxy measure of body fat**

As it is widely recognized, BMI [body mass index = weight (kg) / height $(m)^2$] or, as is former definition, Quetelet Index, developed by Adolphe Quetelet in the 19th century, is no more than a arithmetic association between two dimensions – weight and height[2]. Thus, BMI's inherent mathematical origin does not consider any kind of biological postulation based on physiological or metabolic fundamentals. In children, BMI varies with age and gender. It typically rises during the first months after birth, falls after the first year and rises again around the sixth year of life. Therefore, any given value of BMI has always to be evaluated against age- and gender-specific reference values (2). BMI's main epidemiological statement is the aiming to remove the effect of the height element from the estimation of relative weight (46). However, population based studies in children evidenced that some residual association with height remains in BMI, meaning that taller children have a greater BMI than shorter children when their true relative weights are equal (33). The index weight/height$^3$ adjusts better for height during puberty, although the BMI correlates better of BF mass (33). The WHO have suggested, since a long time, the use of BMI as a method definition for normal weight deviations, based on the principles that BMI is easy to evaluate, is an inexpensive method for large studies (14), has references to match up to (although not widely recognized and consensual), allows a methodological continuation with adult evaluations and has a good correlation with BF (another questionable assumption). Despite its usefulness both in clinical practice and in epidemiological studies – is currently the best available anthropometric estimate of fatness for public health purposes and should be used as the main measure of assessment overweight and obesity in childhood and adolescence for survey purposes (33) – only few health professionals are skilled of identifying and taking in consideration BMI's limitations, and using it properly for assessing the nutritional health status of children (23, 46). This is a problem once it can potentially confound the identification of those individuals at real risk of negative health outcomes associated to misadjusted adiposity. One should not forget that BMI assessment is manifestly dependent of measurement error, which could be resumed into a model of the sum of errors associated with the instrument used, with the child being measured, and with the observer(s) doing the measuring (47). Experienced anthropometrists, should present mean inter-observer differences for height and weight of 0.3 cm and 0.02 kg, respectively, with corresponding standard deviations of 0.2 cm and 0.03 kg (48). Other limitations of BMI as a measure are also well recognized mainly in its relation to BF (33). Due to its incapability of taken in consideration the fatness status of individuals, BMI is not ideal as a direct measure of individual children adiposity (2, 33), because the relationship between BMI and BF, cardiovascular risk factors, and long term health outcomes is noticeably dependent of individual variability (8). For a comparable BMI, older persons have higher BF compared with younger persons, and women have higher BF compared with men (14). Consequently, a phenomenon of underestimation of obesity may occur among these groups (2, 14), and it could also occur in children. Actually, BMI is more suitable to survey weight variations than to estimate BF.

At this point there is a question that comes up from this line of reflection: what are the best definitions of obesity and overweight? Do they mean high body weight for the actual height, i.e. high BMI? In fact, obesity and overweight should be defined as excessive BF or excessive adipose tissue, once it is not only the weight that is associated with all the co-morbid conditions (49). Thus, the ideal definitions of obesity and overweight should be based in two principles: either on their ability to predict adverse future health outcomes or on a close correlation with indicators of future cardiovascular and metabolic disease (33). To our knowledge, there are no published papers defining cutoff points for BMI in children based on current or future health outcomes of excessive BF in children. Nevertheless, some studies had tried to evaluate the relationship between %BF calculated from skinfold measurements and indicators of biomedical status such as blood pressure and blood lipids, and have suggested 30% fat in girls and 20–25% in boys, as the cutoff points for obesity (50, 51).

There are some characteristics related to BC, that simplified is the ratio between fat-free mass (FFM) and fat mass (FM), that will avoid the correct proxy measure of BMI, and that should be prudently taken in account in the interpretation of BMI results. First the variation of FM according to age and gender, in pubertal and prepubertal groups (33), (34). Variations in %BF in growing children, particularly in girls are well recognized to occur, and should promote variations in the BMI cutoff points (52). Second, significant ethnic and racial differences also occur in terms of adiposity (33-35). BMI can be an acceptable proxy measure of excess fatness in diverse ethnicities, especially when ethnic-specific BMI reference points are implemented (35). Third, changes in BC can occur while weight and thus BMI stay unchanged, when muscle mass increases and FM is reduced due to dieting and physical exercise (33). Fourth, as concerned to children and adolescents, and similarly to adults, a variety of cardiovascular and diabetes risk factors, are more closely correlated with intra-abdominal or visceral adipose tissue (VAT) than to total FM (53), and neither BMI nor FM correlate well with VAT or with cardiovascular risk factors (33). Fifth, BMI and FM are strongly correlated, but not strongly enough to make deductions useful at the individual level. Thus BMI is a valuable screening tool to identify children who should have further evaluation and follow-up, and is also appropriated for population surveillance (36), but should not be used as diagnostic test of level of adiposity (33, 54).

**Measuring body fat**

BC analysis is in constant evolution these days, and multiple methods have been developed to assess BF, directly or indirectly. Although the most appropriate methods for access BF are densitometry (hydrostatic weighing or Bod Pod) and dual-energy x-ray absorptiometry (DXA) (55), these methods are confined to few research centers and lack of usefulness in field studies, as well in the clinical practice. For this propose, bioelectrical impedance analysis (BIA) has emerged recently has an alternative, tailored to the requirements of population examinations, particularly suitable for large-scale studies in children, due to its unique characteristics has a BC analysis device: portable, non invasive, cheap, quick, user friendly and reliable (56). BIA assessment of BC was first proposed by Lukaski (57), and the technique is based on the differing electrical conductivities (water content) of various components of the body, determined from body resistance and reactance measurements (57, 58). The introduction of simple foot-to-foot BIA (FF-BIA) devices altered children BC evaluation to an easier procedure that just required that the child step on the scale with the bare foot in the electrode foot plates. BIA had presented good accuracy in the estimation of FFM and FM, even better than anthropometric index (59), and has already been used in studies of BMI validation (60, 61). Some concerns about the validation of FF-BIA devices had been demonstrated before (62). Yet, much more studies have evidenced that FF-BIA is convenient and validated in measuring BC in children (59, 63-65), is a good alternative to DXA for the measurement of FM (63) and, although more suitable for large epidemiological studies (66), if interpreted with caution (65), is not associated with a significant decrement in clinically performance relative to a traditional impedance devices (64) and may be very useful for detection of variations in nutritional status, identifying children at risk of underweight or obesity, that would not be found using anthropometry alone, in field and at clinical settings (67).

To classify children as overweight or obese based on measurements of BF there is, again, the need to choose a criteria with a certain cutoff point. The biological definition of what is or is not normal is very complex. An ideal cutoff point should be the one that establishes a well defined relation between the screening variable and selected health outcomes (68). The problem is that the perfect cutoff point that truly separates disease from non-disease does not exist. Although the main purpose of the cutoff point is to separate clearly “normal” from “non-normal”, some over-position has always to be assumed, and the main rationale of the cutoff point is to diminish the most as possible that over-position. Thus, any cutoff point implies mistakes and so, it involves sensitivity and specificity concepts (68). In this case for BF, the choice of the cutoff point is virtually indivisible from the choice of the gold standard that ideally should be a more direct measure of BF, which is obviously more difficult to obtain, such as DXA (60). Nevertheless, as said before BIA for measure FM is a good alternative to DXA (63). The challenge is though, what cutoff criteria to choose, from the few that are presented in the bibliography. Project Heartbeat in the United States published BF curves plotted with support of an alternative bioimpedance system (RJL Systems) (69). These curves were derived using a sample of children aged 8.5–17.5 years. However, the 85th and 95th centiles from this US data are much higher and this most likely reflects the great prevalence of obesity in the US. McCharty et al. published BF centile curves as an alternative to the use of BMI curves, aiming to reduce misclassification in large-framed and/or muscular children, by BMI (70). The paper states the by assessing the adipose tissue mass, it enhances the capacity of association of excess weight with co-morbidities (70). Nevertheless, these cutoffs share a common problem with the previous that is the lack of clinical correlates on which to base such cutoffs. Therefore, to overcome this problem, Lohman and Going suggested cutoffs based in the higher likeliness of children to have elevated (compared with their peers) cardiovascular risk factors (55). Using the triceps skinfolds approach, the authors recommend that the cutoff points for obesity should be %BF values above 30% for boys and 35% for girls (55). This criterion not only has a great bias dependency, due to the need of highly trained anthropometrists to examine the subjects, as it does not defines a transition group between normal fatness and obesity, very useful for preventive actions.

Every gold standard or cutoff point choice carries with it an unavoidable risk that has to be previously assumed, especially when they are already based in arbitrary principles and lack of correlations with the risk of developing the outcome. However, the choice of the reference system will not influence the identification of genuine risk factors for overweight or obesity, as it is BF (36).

Recently it was suggested that the metabolic syndrome is far more common among children and adolescents than it had been reported previously and that its prevalence increases directly with the degree of obesity, along with the worsening of each element of the syndrome (71). Furthermore, this association is independent of age, sex, and pubertal status, and subjects follow-up suggested that the metabolic syndrome phenotype persists over time and tends to progress clinically (71).

These evidences added to all the issues that have been presented before, underline and reinforce the great importance of being certain about the more appropriate BMI criteria to predict BF in children, and that more specific recommendations should be made on the basis of studies of sensitivity/specificity and differential risk among the various BMI criteria currently available (47).

## OBJECTIVE

In this study we aimed to evaluate the accuracy of CDC's, IOTF's and WHO's BMI cutoff points to define overweight and obesity, applied in a sample of Portuguese school-aged children, using percent BF assessed by foot-to-foot bioelectric impedance analysis as the gold standard.

## PARTICIPANTS AND METHODS

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### Subjects

Participants of this cross-sectional study were resembled from the total population of students of the 33 public elementary schools of the region of Paços de Ferreira – total 55,985 inhabitants in 2007 (72) – during the spring of 2007. All subjects previously took home a letter explaining the nature and procedures of the study, and requesting to their parents/supervisors permission for their child to take part. After receiving parental signed written consent, children were considered to be included in the study. All the concerns with individual privacy were taken, once children were measured individually in an appropriated room. Data was anonymised by individual codification and values measured were not revealed to the children, but only to the parents, by a closed letter. Only individuals between 7 and 10 years were eligible for the study, due to BIA equipment specifications. From the total of 3324 registered children, 3198 were evaluated, but only 2377 children (1239 boys and 1138 girls) matched the criteria of eligibility of the present analysis, representing 95,97% of total registered students (2476) with ages between 7 and 10 years.

### Data Collection

Data on date of birth and gender were collected from the school registries prior to anthropometric evaluation.

One trained anthropometrist performed all the measurements on school premises. All individuals were evaluated in light clothes (t-shirt and underwear), in bare feet and without any kind of ornaments in the hair, wrists or hands. Braiding or other kinds of hairdo were asked to be unmade and glasses were taken off. Children were requested to empty their bladder before the evaluation. Measurements were made in a flat, hard and even surface, and the stadiometer was placed at a right angle between a level floor and against a straight, vertical surface such as a wall or pillar.

All measurements were made according to standard practice described in the *Anthropometric Standardization Reference Manual* (73) and in the *WHO Training Course on Child Growth Assessment* (74). Height was measured to the nearest 0.1cm using a portable stadiometer Seca 214 (Seca, Hamburg, Germany). For height measurements, subjects were standing with the medial borders of their feet at an angle of about 60º and their bodies stretched upward. Their heels, calfs, buttocks, scapulae and posterior aspect of the scull were placed in one vertical plane and with their heads placed in the Frankfort Horizontal Plane. The anthropometrist supported children's head under the chin with the bridge formed between the thumb and the forefinger of the hand contrary to the one that pulls down the headboard. A supporting technician kept children's feet together and ensured that children knees an belly were extended. Body weight and %BF were measured to the nearest 0.1kg and 0.1%, respectively, using a FF-BIA body composition analyzer TANITA BF-666 (TANITA Corporation, Tokyo, Japan). For BIA assessment all procedures followed the technical requirements described elsewhere (58). For weight measurements, subjects kept standing still in the middle of the scale, feet slightly apart (on the marked footprints) and weight evenly distributed by both legs. Age was calculated in months based on the date of the survey relative to date of birth. Body mass index (BMI) was calculated as weight (kg)/height $(m)^2$, and children categorized using mid-year cutoff points (12-month age intervals), i.e., for boys aged 8.0–8.9 years, we used the 8.5-year cutoff point for the 12-month age interval estimates. The %BF was calculated from the built-in prediction equation in the TANITAs analyzer device.

**Criterion-based for definition of BMI cutoff points**

The definitions for BMI cutoff points were distinct by each specific criterion. Although based in different assumptions, all the three BMI classifications aimed to separate underweight, overweight and obesity from those individuals considered eutrophic or normal weight. The CDC criteria used the centile methodology (27). In this case the $5^{th}$, $85^{th}$ and $95^{th}$ centiles were considered the upper limit for underweight and lower limit for overweight and obesity, respectively. IOTF criteria used Cole et al. cutoff points defined by using the LMS method for the calculation of a z-score and afterwards making an adjustment to match the prevalence of each cutoff point to that of the same cutoff point in the age of 18y (24). Therefore, thinness is classified as the equivalent to BMI <18.5 in adults (75) and overweight and obesity to the correspondent BMI ≥25 and ≥30 in adults. WHO based their growth references for school-aged children (26) in the calculation of the standard deviations (SD) from the mean after transformation into z-scores by Cole et al. LMS method (76). The underweight cutoff point was z-score -2SD and overweight and obesity were defined as z-sores +1SD and +2SD respectively. We selected as gold standard, the percentage %BF as determined by McCharty et al. (70). The cutoff points were derived from an analysis in a BF monitor and, using LMS method (76), and seven centile curves were calculated. The upper limit of underfat was defined as the $2^{nd}$ centile and the lower limits of overfat and obesity were defined as $85^{th}$ and $95^{th}$ centile (70).

**Statistical analysis**

Age intervals were defined for a width of 12 months, to calculate the corresponding cutoff points for each criterion.

The agreement between the different BMI criteria was calculated using unweighted and weighted kappa coefficients. Kappa values below 0.40 are indicative of week concordance, between 0.40 and 0.75 concordance is considered good and values higher than 0.75 are assumed to be in excellent concordance. In this study %BF was considered as the gold standard to analyze the performance of each BMI criteria cutoff points.

Assuming %BF from FF-BIA as gold standard, accuracy of diagnosis of each cutoff point were evaluated using sensitivity, specificity, positive predictive value (+PV), negative predictive value (-PV), positive likelihood ratio (+LR), and diagnostic odds ratio (OR). Also, receiver operating charts (ROC) analysis was performed to estimate the cutoff point that maximizes the sensitivity and specificity using CDC and WHO criteria. The IOTF criterion was not analyzed by ROC method, once LMS curves were not plotted and used during its final development.

The level of significance for all analysis was fixed as 0.05. Statistical analyses were performed with SPSS (version 18, Chicago, USA) and R Software.

## RESULTS

The characteristics of participants by sex are presented in table 1. All variables tended to be similar in both boys and girls, except for %BF that was 3.92% higher in girls than in boys (25.0% vs. 21.1%; *p* <0.001).

Table 1. Characteristics of participants by sex

| Variables | Boys (n=1239) | Girls (n=1138) | *p* value |
|---|---|---|---|
| | Mean (SD) | | |
| Age (years) | 8.1 (0.95) | 8.1 (0.94) | 0.974 |
| Height (cm) | 132.4 (7.36) | 132.4 (7.97) | 0.955 |
| Weight (kg) | 32.3 (7.47) | 32.7 (7.67) | 0.248 |
| BMI (kg/m$^2$) | 18.3 (2.89) | 18.5 (2.95) | 0.110 |
| BF (%) | 21.1 (6.33) | 25.0 (6.40) | <0.001 |

BF, body fat; BMI, body mass index; SD, standard deviation.

Prevalence estimations for each BMI cutoff criteria are provided by gender and age in table 2. Boys presented higher prevalence of underweight with IOTF (1.3%), compared with CDC (0.5%) and WHO (0.2%). WHO classification had the higher prevalence for overweight (25.3%) and for obesity (20.5%) compared to the same categories in CDC classification (20.8% and 17.4%, respectively) and IOTF classifications (21.8% and 9.2%, respectively). IOTF also showed higher underweight prevalence (3.2%) in girls compared with CDC (1.4%) and WHO (0.5%). Overweight (29.7%) and obesity (17.3%) prevalence in girls also were higher when using WHO cut off points compared to CDC (22.7% and 16.3% respectively) and IOTF (27.4% and 10.5%, respectively).

IOTF presented lower prevalence values in both categories – overweight (14.9%) and obesity (11.3%) – compared to WHO and compared to CDC – overweight (7.3%) and obesity (8.2%). The CDCs cutoff points as compared to WHO systematically resulted in lower prevalence values for both categories – overweight (7.6%) and obesity (3.1%).

In girls, IOTF criterion showed a systematical tendency to underestimate both cutoff points – overweight (9.1%) and obesity (6.9%) – compared to WHO and also as compared to CDC – overweight (1.2%) and obesity (5.9%). The CDCs cutoff points compared to WHO systematically underestimate both categories – overweight (8.0%) and obesity (1.1%).

Table 2. Prevalence of BMI category for cutoff points criteria, by gender and age

| BMI categories | 7y | 8y | 9y | 10y | Total |
|---|---|---|---|---|---|
| | n (%) | | | | |
| **Boys** | | | | | |
| CDC | | | | | |
| Thinness | 1 (0.3%) | 1 (0.2%) | 2 (0.6%) | 2 (2.0%) | 6 (0.5%) |
| Normal weight | 228 (60.2%) | 251 (62.1%) | 212 (59.6%) | 68 (68.0%) | 759 (61.3%) |
| Overweight | 84 (22.2%) | 80 (19.8%) | 76 (21.3%) | 18 (18.0%) | 258 (20.8%) |
| Obesity | 66 (17.4%) | 72 (17.8%) | 66 (18.5%) | 12 (12.0%) | 216 (17.4%) |
| IOTF | | | | | |
| Thinness | 1 (0.3%) | 2 (0.5%) | 7 (2.0%) | 6 (6.0%) | 16 (1.3%) |
| Normal weight | 262 (69.1%) | 283 (70.0%) | 226 (63.5%) | 68 (68.0%) | 839 (67.7%) |
| Overweight | 82 (21.6%) | 81 (20.0%) | 85 (23.9%) | 22 (22.0%) | 270 (21.8%) |
| Obesity | 34 (9.0%) | 38 (9.4%) | 38 (10.7%) | 4 (4.0%) | 114 (9.2%) |
| WHO | | | | | |
| Thinness | 1 (0.3%) | 0 (0,0%) | 0 (0,0%) | 1 (1,0%) | 2 (0,2%) |
| Normal weight | 206 (54.4%) | 219 (54,2%) | 183 (51,4%) | 61 (61,0%) | 669 (54,0%) |
| Overweight | 97 (25.6%) | 104 (25,7%) | 93 (26,1%) | 20 (20,0%) | 314 (25,3%) |
| Obesity | 75 (19.8%) | 81 (20,0%) | 80 (22,5%) | 18 (18,0%) | 254 (20,5%) |
| **Girls** | | | | | |
| CDC | | | | | |
| Thinness | 1 (0.3%) | 5 (1.5%) | 8 (2.2%) | 2 (2.6%) | 16 (1.4%) |
| Normal weight | 199 (55.7%) | 195 (57.9%) | 229 (62.4%) | 55 (71.4%) | 678 (59.6%) |
| Overweight | 92 (25.8%) | 81 (24.0%) | 71 (19.3%) | 14 (18.2%) | 258 (22.7%) |
| Obesity | 65 (18.2%) | 56 (16.6%) | 59 (16.1%) | 6 (7.8%) | 186 (16.3%) |
| IOTF | | | | | |
| Thinness | 5 (1.4%) | 11 (3.3%) | 17 (4.6%) | 3 (3.9%) | 36 (3.2%) |
| Normal weight | 205 (57.4%) | 193 (57.3%) | 220 (59.9%) | 53 (68.8%) | 671 (59.0%) |
| Overweight | 101 (28.3%) | 98 (29.1%) | 95 (25.9%) | 18 (23.4%) | 312 (27.4%) |
| Obesity | 46 (12.9%) | 35 (10.4%) | 35 (9.5%) | 3 (3.9%) | 119 (10.5%) |
| WHO | | | | | |
| Thinness | 1 (0.3%) | 2 (0.6%) | 3 (0.8%) | 0 (0.0%) | 6 (0.5%) |
| Normal weight | 177 (49.6%) | 169 (50.1%) | 204 (55.6%) | 47 (61.0%) | 597 (52.5%) |
| Overweight | 115 (32.2%) | 102 (30.3%) | 98 (26.7%) | 23 (29.9%) | 338 (29.7%) |
| Obesity | 64 (17.9%) | 64 (19.0%) | 62 (16.9%) | 7 (9.1%) | 197 (17.3%) |

BMI, body mass index; CDC, Centers of Disease Control and Prevention; IOTF, International Obesity Task Force; WHO, World Health Organization; y, years.

The agreement between the different cutoff points is presented in table 3. In boys, a good agreement value was achieved between IOTF and WHO (kappa 0.640; 95% CI 0.586-0.695), and excellent agreements resulted between CDC and the other two criteria for BMI cutoff points, IOTF (kappa 0.769; 95% CI 0.717-0.822) and WHO (kappa 0.864; 95% CI 0.805-0.922).

Female's agreement values compared to boys were generally higher, particularly for comparisons made between IOTF and other criteria. Excellent agreement values in girls were achieved between all criteria for BMI cutoff points. IOTF and WHO presented the lowest agreement (kappa 0.758; 95% CI 0.698-0.818). IOTF compared to CDC showed the higher agreement value (kappa 0.881; 95% CI 0.823-0.939), while CDC compared with WHO (kappa 0.874; 95% CI 0.812-0.935) was very similar.

Table 3. Agreement assessment between each BMI criteria, by gend

| | CDC | IOTF |
|---|---|---|
| Boys | | |
| IOTF | | |
| Percentage of agreement | 83.8% | |
| Kappa unweighted (95% CI) | 0.689 (0.649-0.728) | |
| Kappa weighted (95% CI) | 0.769 (0.717-0.822) | |
| WHO | | |
| Percentage of agreement | 89.1% | 72.8% |
| Kappa unweighted (95% CI) | 0.811 (0.781-0.841) | 0.513 (0.469-0.557) |
| Kappa weighted (95% CI) | 0.864 (0.805-0.922) | 0.640 (0.586-0.695) |
| Girls | | |
| IOTF | | |
| Percentage of agreement | 91.0% | |
| Kappa unweighted (95% CI) | 0.842 (0.813-0.872) | |
| Kappa weighted (95% CI) | 0.881 (0.823-0.939) | |
| WHO | | |
| Percentage of agreement | 90.0% | 81.4% |
| Kappa unweighted (95% CI) | 0.831 (0.801-0.860) | 0.685 (0.646-0.723) |
| Kappa weighted (95% CI) | 0.874 (0.812-0.935) | 0.758 (0.698-0.818) |

BMI, body mass index; CDC, Centers of Disease Control and Prevention; IOTF, International Obesity Task Force; WHO, World Health Organization.

Accuracy and performance analysis of the different BMI cutoff points are shown in table 4. WHO cutoff points presented the higher sensitivity values for overweight (0.915; 95% CI 0.896-0.932) and obesity (0.764; 95% CI 0.726-0.799). Specificity analysis showed higher results for IOTF classification 0.953 (95% CI 0.941-0.963) and 0.998 (95% CI 0.996-0.999), respectively. +PV presented higher results for categories overweight (0.918; 95% CI 0.898-0.935) and obesity (0.987; 95% CI 0.966-0.997), where both endorsed to IOTF cutoff points.

Table 4. Accuracy and performance analysis of cut-off points by each BMI criteria using as gold standard %BF

| BMI cutoff points | Sensitivity (95% CI) | Specificity (95% CI) | + Predictive Value (95% CI) | - Predictive Value (95% CI) | + Likelihood Ratio (95% CI) | Odds Ratio |
|---|---|---|---|---|---|---|
| CDC | | | | | | |
| Overweight | 0.850 (0.827-0.872) | 0.925 (0.910-0.938) | 0.883 (0.862-0.903) | 0.902 (0.886-0.917) | 11.31 (9.40-13.59) | 69.50 |
| Obesity | 0.720 (0.680-0.757) | 0.985 (0.979-0.990) | 0.933 (0.906-0.955) | 0.926 (0.914-0.937) | 49.48 (33.89-72.22) | 173.11 |
| IOTF | | | | | | |
| Overweight | 0.784 (0.757-0.809) | 0.953 (0.941-0.963) | 0.918 (0.898-0.935) | 0.868 (0.851-0.884) | 16.65 (13.15-21.09) | 73.11 |
| Obesity | 0.441 (0.399-0.484) | 0.998 (0.996-0.999) | 0.987 (0.966-0.997) | 0.864 (0.849-0.878) | 273.12 (87.80-849.53) | 484.68 |
| WHO | | | | | | |
| Overweight | 0.915 (0.896-0.932) | 0.838 (0.819-0.857) | 0.791 (0.767-0.815) | 0.936 (0.922-0.949) | 5.66 (5.02-6.38) | 55.81 |
| Obesity | 0.764 (0.726-0.799) | 0.971 (0.963-0.978) | 0.882 (0.851-0.910) | 0.936 (0.925-0.946) | 26.75 (20.43-35.03) | 109.53 |

BMI, body mass index; CDC, Centers of Disease Control and Prevention; IOTF, International Obesity Task Force; WHO, World Health Organization; %BF, percentage body fat.

Diverging from these results, and as somehow expected, -PV higher results were obtained by WHO cutoff points, for overweight (0.936; 95% CI 0.922-0.949) and obesity (0.936; 95% CI 0.925-0.946).

+LR highest values were found for IOTF in both categories, overweight (16.65; 95% CI 13.15-21.09) and obesity (273.12; 95% IC 87.80-849.53).

OR analysis for both categories presented higher values for IOTF cutoff points, overweight (73.11) and obesity (484.68).

ROC was the last performance analysis made. Similar overall accuracy for both CDC and WHO criteria, tested by the area under the ROC curve (AUC), was found for overweight and obesity classification.

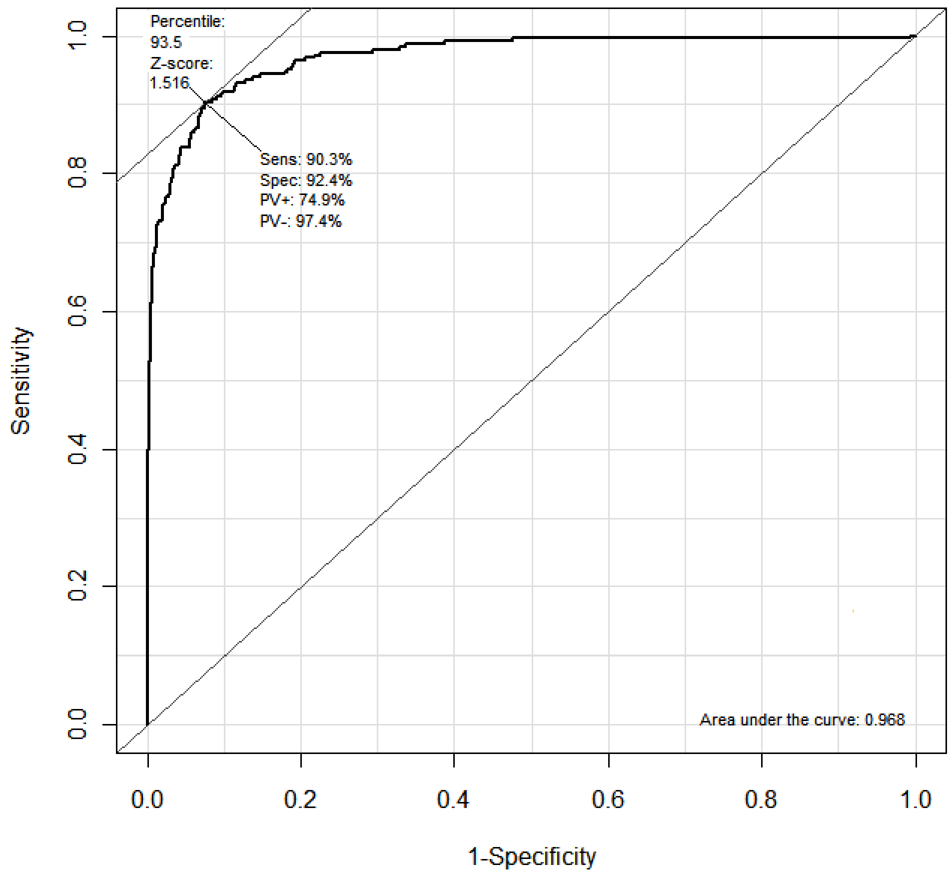


Figure 1. ROC analysis chart for obesity cutoff point in boys, by CDC criterion.

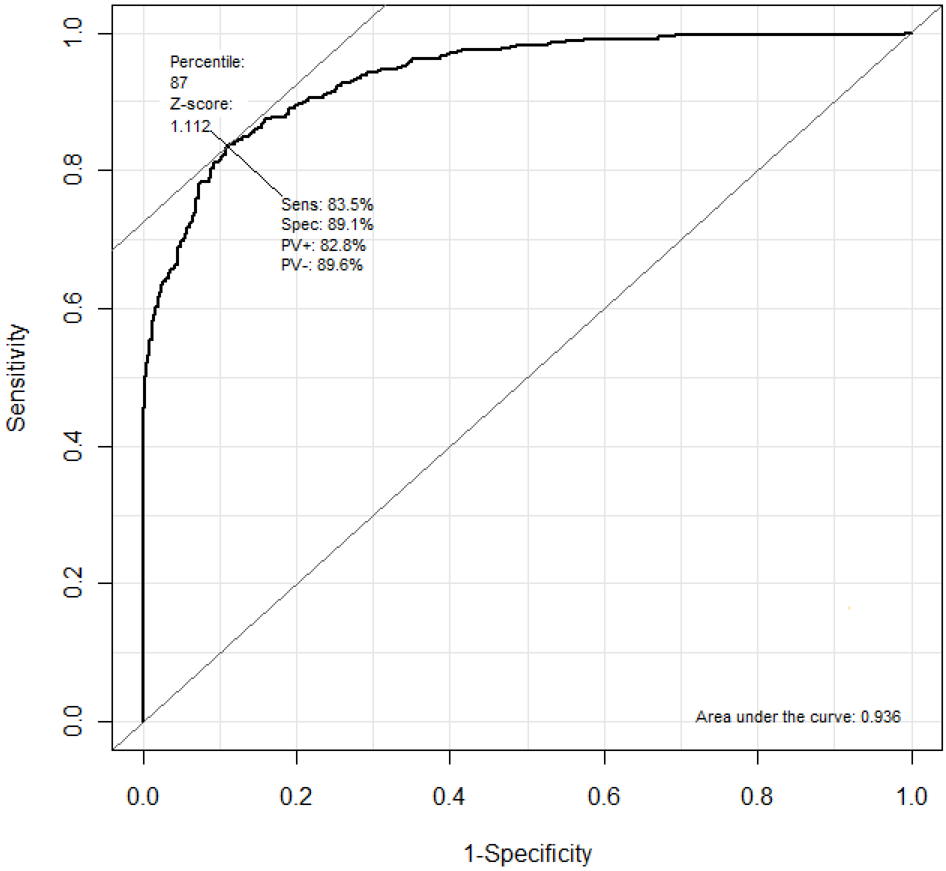


Figure 2. ROC analysis chart for overweight cutoff point in boys, by CDC criterion.

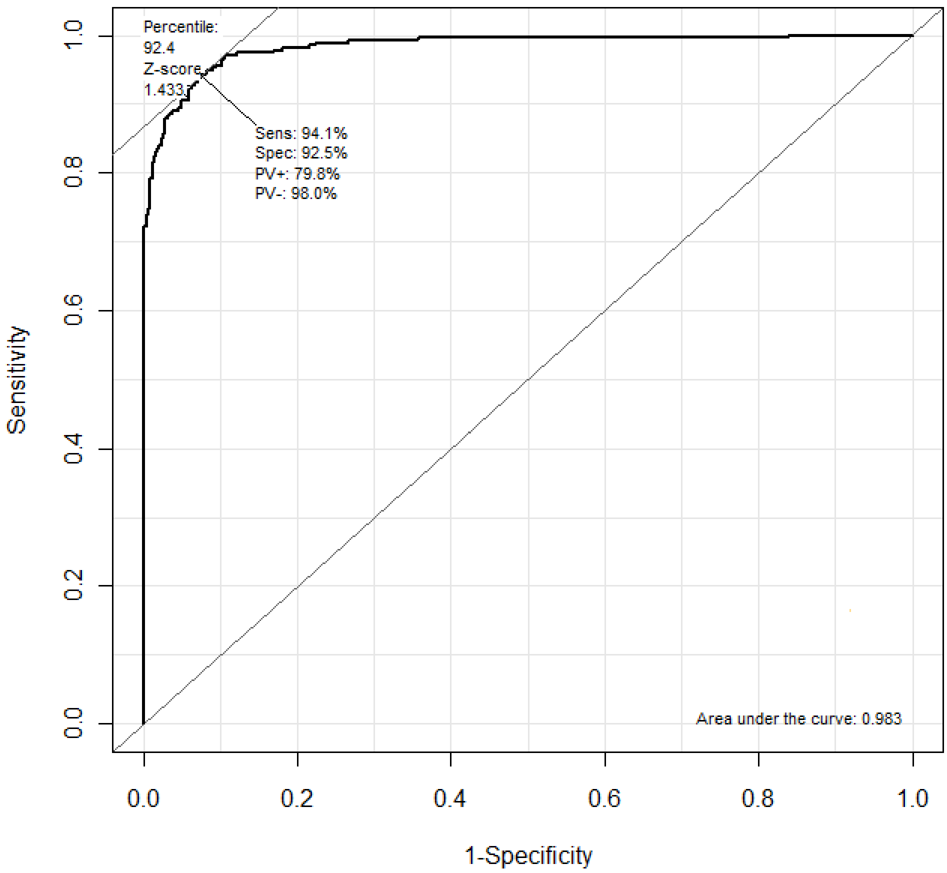


Figure 3. ROC analysis chart for obesity cutoff point in girls, by CDC criterion.

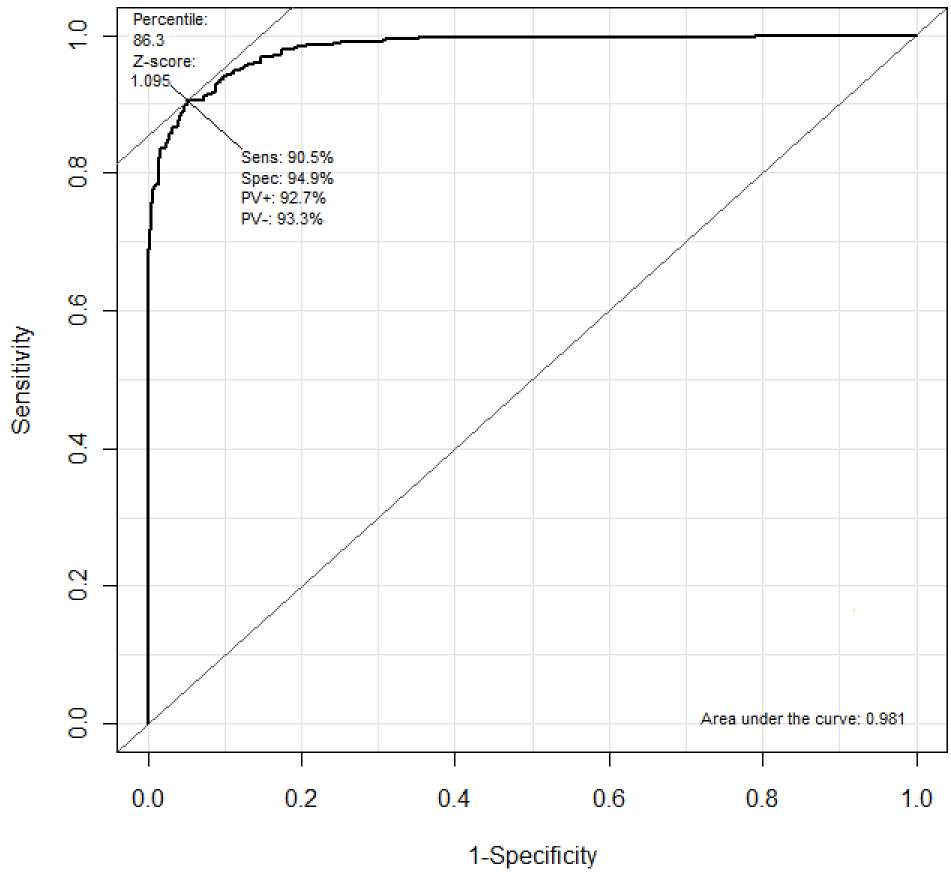


Figure 4. ROC analysis chart for overweight cutoff point in girls, by CDC criterion.

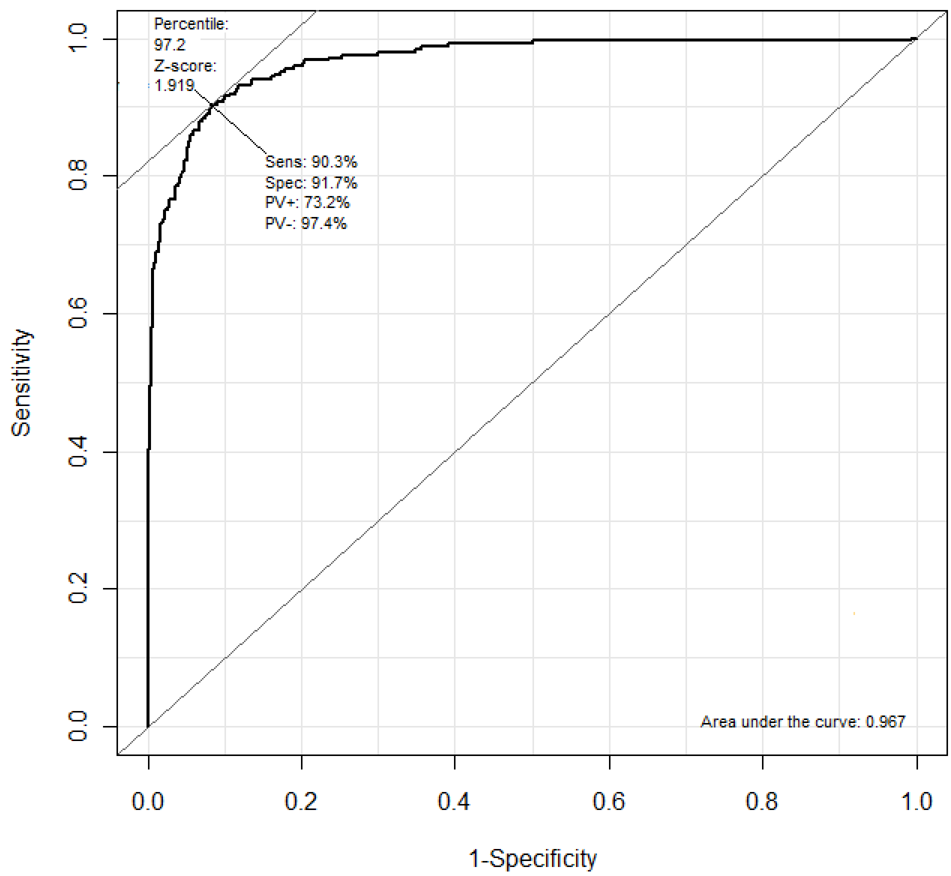


Figure 5. ROC analysis chart for obesity cutoff point in boys, by WHO criterion.

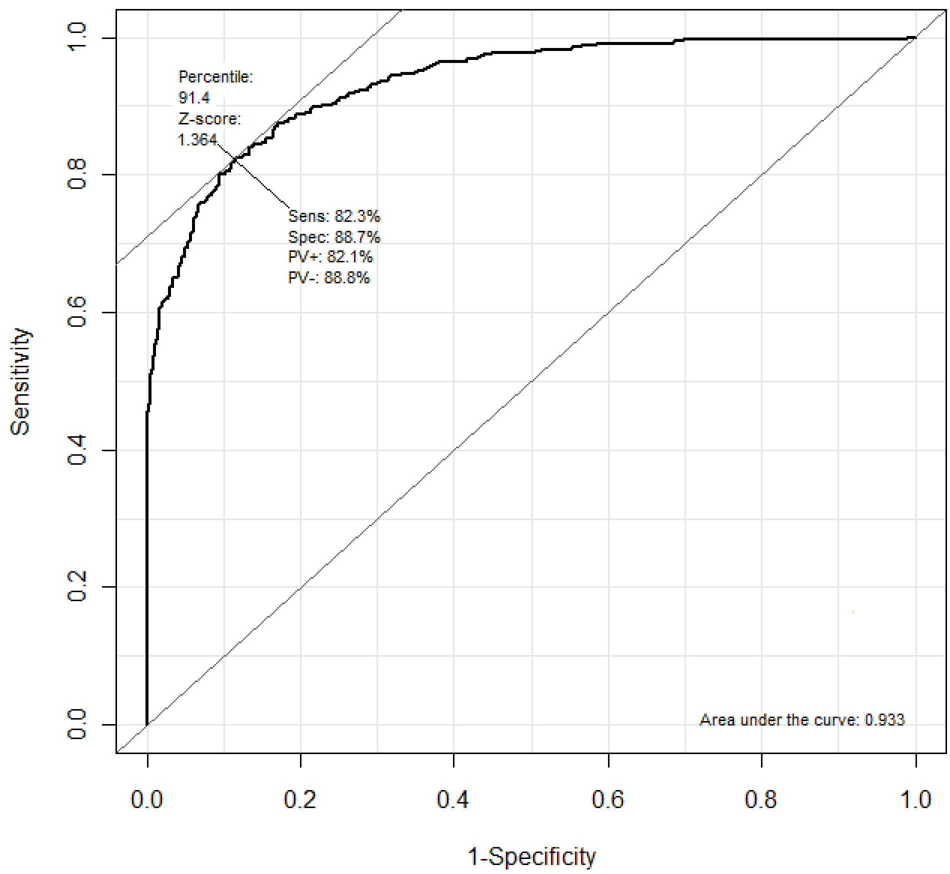


Figure 6. ROC analysis chart for overweight cutoff point in boys, by WHO criterion.

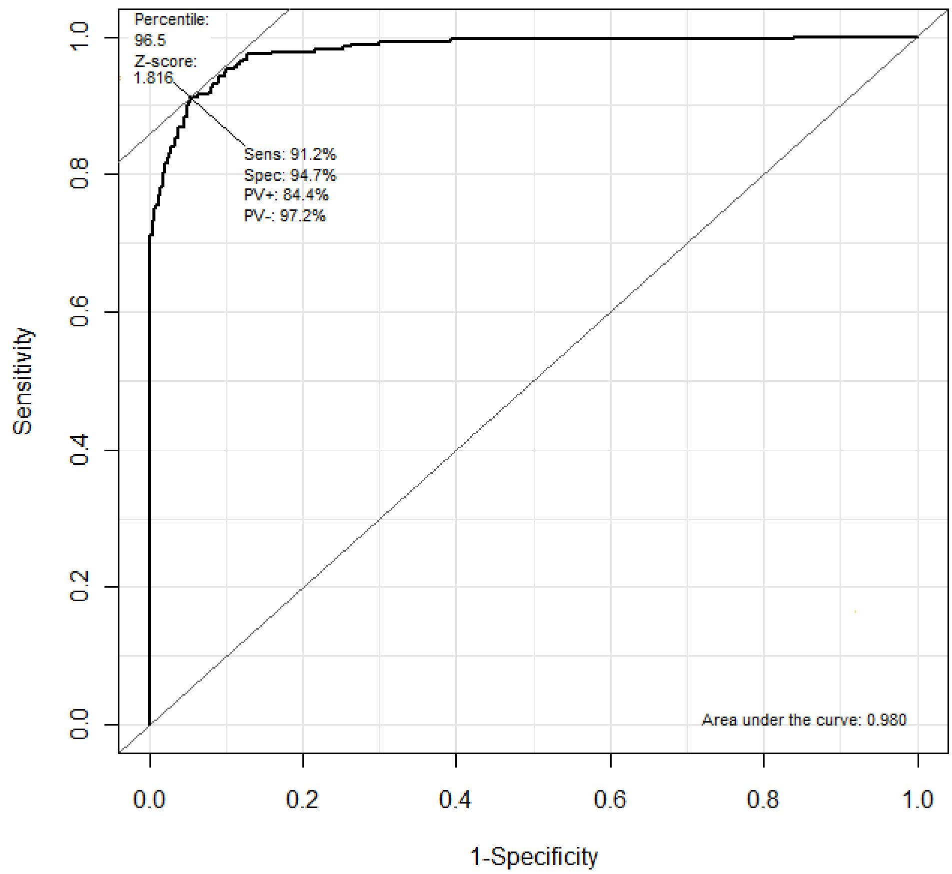


Figure 7. ROC analysis chart for obesity cutoff point in girls, by WHO criterion.

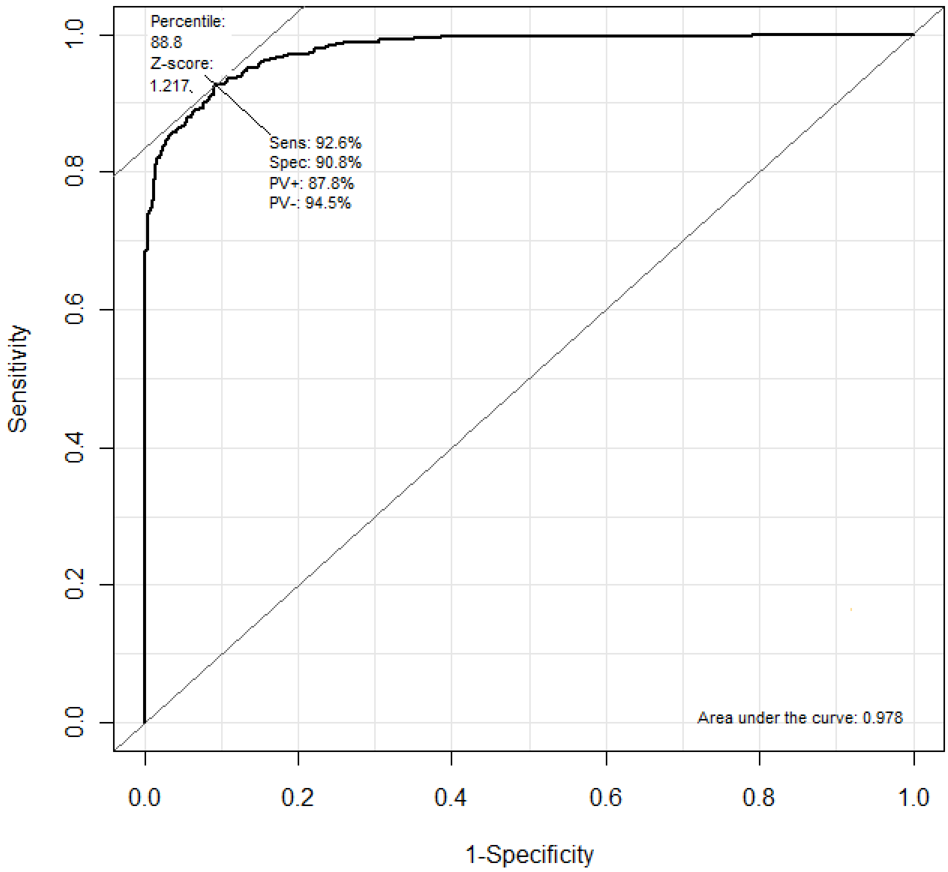


Figure 8. ROC analysis chart for overweight cutoff point in girls, by WHO criterion.

In boys, for obesity category, CDC – figure 1. – showed an area under the curve (AUC) of 0.968, while overweight – figure 2. – has an AUC of 936. In girls CDC criterion for obesity – figure 3. – presented an AUC of 0.983, and within the overweight category – figure 4. – had an AUC of 0.981.

For WHO criterion boys presented an AUC of 0.967 – figure 5. – for obesity and for overweight the AUC – figure 6. – was 0.933. In girls, ROC analysis presented an AUC of 0.980 – figure 7. – for obesity and the overweight category – figure 8. – showed 0.978 for the AUC.

The best cutoff points that maximize sensitivity and specificity for CDC criterion were the $93.5^{th}$ percentile for obesity classification, and the $87^{th}$ percentile for overweight, in boys. In girls, the maximized cutoff points were for obesity the $92.4^{th}$ percentile and for overweight the

86.3$^{th}$ percentile. For WHO criteria the maximization of specificity and sensitivity was achieved, in boys, by the 97.2$^{th}$ percentile for obesity category and for overweight by the 91.4$^{th}$ percentile. In girls, the maximized cutoff points were the 96.5$^{th}$ percentile for obesity classification, and the 88.8$^{th}$ percentile for overweight.

## DISCUSSION

This study draws a line that clearly separates BMI criteria for children, based on the context of their application, whether in screening or in the confirmation of the disease, after a previous test.

The WHO criterion could be preferably used at population level, once it seems to classify better than the other two, groups of individuals as obese or as being overweight. To confirm the disease, namely in a clinical framework, the IOTF criterion appears to be more adequate to define obesity and overweight, in individuals.

A long variety of approaches in comparing BMI international criteria for children, have been reported. Most are based on prevalence differences (18, 22, 45, 77) or in descriptive comparisons (3). Fewer studies attempted an approach based on performance of each criterion against each other, or compared BMI cutoff points with a gold standard method (78, 79). To our knowledge, this is the first study that combines the three most used and recently developed international criteria for BMI classification (24, 26, 27).

Three factors should be taken in account in children's classification of overweight and obesity: an anthropometric indicator, a reference population for comparison, and cut-off points that best identify individuals and populations at risk of overweight/obesity-related morbidity and mortality (80). Regardless all the concerns with characteristics of the development population of each criteria, which should be taken in consideration, our analysis of those three international criteria relied in evidence from the interpretation of accuracy and performance indicators for each one.

We used as gold standard, %BF assessed by FF-BIA analysis. This option could be, somehow, questionable, mainly because BIA had been considered a relatively crude measure of BC (81). Although, studies stating this had strong limitations, whether by a wide age range and/or a small sample size (65, 82, 83). More recently, other authors considered FF-BIA as a feasible measure for use in large-scale epidemiological studies due to both the high correlation and small mean differences against DXA technique, and to FF-BIAs particular advantages in children evaluation, based on its simplicity and its rapid procedure (59, 63-65, 81, 84). Nevertheless, FF-BIA analysis may have some lack in precision to assess small changes in BC, at individual level (66, 84). After determine the feasibility of the method, we had to select the BIA device. Our choice was a TANITA FF-BIA analyzer. The analyzer selection could be a problem, mainly due to putative differences that may occur between BIA devices and successive models (85). Nevertheless, this belief is aimed particularly to DXA and not BIA (85). In fact, TANITAs analyzers are considered to be convenient and validated in assessing BC in children (59, 63, 64, 86).

The next step was the selection of the cutoff point for %BF, to be used as gold standard. As previously said, this selection would always represent a possible bias due to be arguably arbitrary. While many studies use various different but single cutoffs, generally around 30%BF for girls and 20–25%BF for boys, we selected the %BF centile curves published by McCharty et al. (70). Once differences in BC start to occur even in childhood, we reasoned that it would be optimal to select an age-specific criterion of adiposity that reflected these changes in BF, not only by gender, but also by age, over the time. Taylor et al., underlined this considerable variation of %BF values with age in growing children, particularly in girls, and using DXA as the gold standard (87). Their results showed that a single %BF value for classifying children as obese through a wide age spectrum may not be suitable. Although, other authors assume that it would be appropriate if the sample is composed only of prepubertal children (88), they considered that it may generate an underestimation of the excess adiposity in younger girls (87). Lastly, our selected criterion was based in a British 1990 growth reference sample. Owing to the absence of international standards for BIA data, a national criterion was our only option.

%BF was the only variable that presented differences between genders. Girls presented significantly more 4%BF than boys, even with similar weight, height and BMI. These results are analogous to those described previously (34, 87, 89), and may indicate that, despite of the current consensus on BMI as a reasonable indirect measure of adiposity (22, 78, 85, 90, 91), it cannot detect, correctly, the BC disparities between genders and is even considered to perform only moderately well in a whole population (33), mainly at the upper end of the distribution curve. Furthermore, BC varies significantly in children, at any BMI, and is influenced by age, maturity, race, ethnicity, height, BF distribution (87, 90, 91), and also degree of fatness, being better at higher degrees (90). The problem relies in the fact that it is not acknowledged the capacity of BMI percentile changes to replicate those changes in BF in children (92), once only 63% and 69% of the variance in %BF for boys and girls, respectively, can be explained by BMI (91), meaning that it is of more use in epidemiological studies, but relatively poor in predicting BF in any individual child (90).

Other limitation of BMI is that it is not capable of detach BF from fat-free components of body weight, reflecting always both. Mean errors of approximately 21 to 22.5%BF can occur in individuals with average fatness according to age, due to the nonlinearity of the chemical maturation of lean tissue and because maturity proceeds differently by gender (93). In addition, in children aged 11-16 years, increases in overall BMIs come with larger increases in the %BF and simultaneous decreases in FFM, which are related to reduced activity levels (94). Despite our sample assembles much younger children, this is a relevant fact, once it occurs in a period characterized for a rapid growth, with adolescents gaining almost 20% of adulthood height, which is highly related to FFM (95). This reinforces the hypothesis of the error that could be associated to BMI evaluation of differences in BC during childhood, when children could be less active, grow less and slower. Thus, nutritional status accounts for variability in lean tissue properties and the error resulting from this source is of higher magnitude in obese individuals (93).

Prevalence data, showed large differences, not only between criteria, but also within criteria with age variation. Nevertheless, the higher prevalence of underweight was found with IOTF for both genders, and WHO assessed higher prevalence for overweight and obesity, also in both genders. Variation by age within criteria had been reported before (91), and reaffirms the necessity of prudence when comparing BMI of groups that differ by age. Regarding to overweight and obesity, the large differences between methods have also been reported previously (18, 22, 45, 78, 86). Although, our results only showed consistence with that from the US (18) study, that was an overestimation by IOTF of overweight and underestimation of obesity, when compared to CDC. Underestimation of both overweight and obesity by IOTF occurred in comparison with CDC (22, 45, 78). This more conservative observation of the extent of overweight and obesity among pediatric populations have been reported before in comparisons with methods based on percentiles of US reference populations, based on the use of BMI z-scores (2, 45) or even based on centiles charts of UK from The Health Survey for England 2002 (5). Comparisons with ethnic-specific criteria with both CDC and IOTF presented lower estimations of overweight and obesity (35, 86). Disparities between criteria may have arisen because of differences in the data sets used in its development, in smoothing methods, and in approach to setting cutoff points (33, 45). For ages 6–10 y, the IOTF criteria for obesity are generally higher than the CDC or WHO criteria values. These could explain the lower prevalence estimate that was obtained with IOTF (78).

When comparing our results with Portuguese national data differences in prevalence were small. Our sample presented a higher prevalence of overweight and obesity of 1.6% in boys and 4.2% in girls, when comparing to 29.4% in boys and 33.7% in girls, data from Padez et al. (7), using se same criteria (IOTF). This fact rouse up our attention to eventual bias associated with prevalence data, mainly depending on the procedures adopted in data analysis. A common source of bias in the utilization of growth charts is the age interval width selected. Lesser the number of cutoff points used, higher will be the dependence on the assumption of linearity of the points constituting the growth curve. Due to its curvilinear and J-shapped form, it occurs some overestimation of overweight and obesity prevalence in 4-year olds (curves are decreasing), and an underestimation in children aged 6–12 years (curves increasing nonlinearly) (96). In our study we used age intervals of 12 months. Even though we were previously enlightened of the bias tendency of a larger interval, it was mandatory to be done, once our "gold standard" only has intervals of 12 months for its cutoff points. Nevertheless, and owing to the sample age range (7-10 years old), we expect that when occurring a bias, it will be an underestimation of overweight and obesity prevalence, in proximally 2.6% as reported by Kremer et al. (96). Thus, we could assume that our population has really a higher prevalence of obesity than the national prevalence previously reported.

Another concern with prevalence data is that it is constantly changing, thus, survey data collected to develop percentile based cutoffs has a great dependency to the year when the reference was defined. In contrast, the IOTF cutoffs are independent of the level of overweight and obesity in the reference population (5). This may be other explanation for the differences in prevalence observed in our study sample between the IOTF criteria and the other two criteria.

An additional concern with prevalence is the use of the WHO cutoff points in the transition at 5 years between the two WHO standards, 0-60 months (25) and 5-19 years (26). For younger children overweight and obesity are defined with 2SD and 3SD cutoffs (25), but for older ones with 1SD and 2SD cutoffs (26). In the transition of age between 60 and 61 and months the prevalence of overweight and obesity will be dramatically different (20), for the same BMI values.

One should also be aware of the eventuality of adiposity misclassification that rises with the rise of BMI classification. Children in the overweight BMI category should be evaluated for excess adiposity with a lower level of suspicion than the obesity category of BMI, as indicated by expert panels (32, 97), but almost half of children in the overweight BMI category have high adiposity. Analyses of diagnostic patterns propose that pediatricians are capable to identify clinically most children with obese BMI but a less amount of children with overweight, due to the difficulty to judge "The appropriateness of the 26% identification rate between children with a BMI in the $85^{th}$ to 94th percentile range" (98). This fact helps to underline the need for a criterion that allows a more appropriate and valid judgment.

Concerning to underweight, the low number of those cases in our study population was a reason of concern for us in the results extrapolation, being this the reason why this category was no further addressed, during the study.

Kappa coefficient presented the degree of agreement between criteria. Although with less magnitude than the analysis of accuracy and performance compared with the gold standard, agreement analysis is very useful to assess systematic estimation errors between criteria. In boys, best correlations were found between CDC and WHO, but both IOTF and CDC underestimated WHO results. These results could be explained by the fact that CDC and WHO had both similar populations in their criteria development data (US Data from the

National Center for Health Statistics) (26). Although, in girls the results were not similar, once all criteria had higher kappa coefficient and more identical between each other, despite the same systematically tendency to underestimation of IOTF and CDC compared to WHO. When comparing with gold standard, data for both classes demonstrated that an overestimation tendency only occurred in overweight for girls and in both classes for boys, always by WHO criteria. These observations suggest that BMI tends to reflect adiposity differences predominantly at higher BMI percentiles, and changes in BMI percentile in children of lower BMI percentile may occur without appreciable change in adiposity (92). It should also be considered the hypothesis that BMI variation are more suitable to occur due to changes in FFM, than in FM (92), less detectable by BMI. Systematic estimation errors analysis could be of great usefulness in clinical interpretation of BMI data when assessing nutritional status. Serial changes in BMI over time should be clinically monitored for all children aiming to detect significant divergence from the child's BMI trajectory, and substantial deviations may not represent changes in adiposity but rather may have experienced changes in lean mass, particularly if the child falls at the lower BMI percentiles (92).

In boys, when compared with %BF overweight and obesity were systematically underestimated by CDC's (6.9% and 5.1%, respectively) and IOTF (10.7% and 11.4%, respectively) cutoff points. WHO's cutoff points presented a systematically greater tendency to overestimate overweight (10.5%) and obesity (3.9%) while comparing with %BF.

In girls, overweight suffered a systematically underestimation by CDC's (5.1%) and IOTF (5.8%) cutoff points, and a systematically overestimation by WHO's (7.2%) cutoff points, when compared with %BF. In obese category, the comparison against gold standard revealed a systematical greater trend to be underestimated by all BMI cutoff points criteria increasingly, WHO (7.4%), CDC (8.1%) and IOTF (14.0%). Although these tendencies for over- and under-estimations presented by the BMI criteria, the capability of criteria to better classify overweight and obesity, was determined through the diagnostic accuracy analysis.

Sensitivity of BMI represents the probability of a subject to be classified (e.g.) as obese by BMI when the subject is truly obese when evaluated by %BF, or how good the BMI cutoff is at identifying the truly obese. Higher sensitivity values were achieved by WHO for overweight and obesity classes. The sensitivity results are consistent with other studies, 70% for obesity classification with CDC criteria (99), and higher values for CDC when compared to IOTF, also with similar values but somehow higher in IOTF for obesity classification (62.4% in boys and 48.3 in girls), although using skinfold thickness as the gold standard (78). Other studies also reported a poor sensitivity essentially of the IOTF criteria for screening obesity in children, but stratified by gender with large differences, 46% for boys and 72% for girls, and the gold standard of obesity being defined as %BF in the top 5% of the study population (61). Contrarily, Fu et al. reported a sensitivity of 75% for obesity classification with IOTF criteria (86). Consequently, when using BMI for screening or epidemiological surveillance purposes, the WHO criteria could be the one recommended.

Specificity of BMI represents the probability of a subject not to be classified (e.g.) as obese by BMI when the subject is not truly obese when evaluated by %BF, or how good the BMI cutoff is at identifying the non-obese. The higher specificity values for overweight and obesity were presented by IOTF, with values varying between 99.7% and 99.9%, respectively. When comparing only IOTF and CDC criteria for overweight and obesity, results are similar to other studies (78). This results are in line with Reilly et al. that presented a specificity of 99% (61), and with other studies that present similar although slightly lower specificity values for obesity classification with CDC criterion – 95% (99), and with IOTF criteria – 95.8% (86). Due to its elevated specificity value, the IOTF criteria will identify few non-obese children as obese when used clinically, thus being more helpful for true-positive test results. This is particularly needed when false-positive results can harm the patient physically or emotionally, as in the case of obesity. Thus, higher specificity lowers the chance of having false-positive results, which becomes more significant in the highly critical life cycle periods of rapid growth, 1st year of age and puberty, once it allows professionals to avoid incorrect and harmful food restriction, associated with misclassification.

Several studies described that, likewise in our study, current BMI cutoffs when applied to children have generally relatively high specificity, but lower sensitivity in detecting excess adiposity (61, 90, 100, 101), meaning that that non-obese children are unlikely to be wrongly labeled, however obese children may be missed. Specifically they may fail to identify half of the people with excess %BF (101).

+PV values were consistent with specificity results. For both overweight and obesity categories, the higher values were achieved by the IOTF criteria. +PV represents the capacity of a test to identify true positives within all the positives. This is the main objective of diagnostic, regardless of the inherent and particular characteristics of diagnosing “exogenous obesity” which may also be referred to as “simple” or “primary” obesity that is, still by far, the most common diagnosis in the obese child (102).

The OR analysis was used as a large performance indicator for the criteria used in our study population. IOTF criteria had the higher performance for both overweight and obesity categories. These results were distinct from those of Zimmermann et al. (78), that defined the performance of the CDC criteria has being superior and providing more accurate estimates of adiposity. Actually, these were somehow surprising results, but comprehensive, because, for well-known risk factors of childhood overweight, stronger associations in children with higher BMI are observed (103). Thus, due to our large sample and its moderately high values of obese children, it should be expected that the cutoff developed based in the outcome occurrence in adulthood had a better performance.

ROC analysis was used to evaluate together the sensitivity and specificity of BMI cutoffs, thus also as an overall test. The impossibility of carry on an ROC analysis for IOTF criterion turned the interpretation less conclusive. Furthermore, all the results of AUC for CDC and WHO were so similar, that we considered them as being the same for each category by gender, and thus not reaching to any conclusion, except that the accuracy of BMI in predicting adiposity was greater in girls than in boys. Nevertheless, ROC can also analyze the potentially most evenhanded cutoff point in specificity and sensitivity, to define each one of the BMI categories. This analysis revealed that mainly for CDC the reduction of the cutoff point in 1.5 percentile points for boys and 2.6 percentile points for, could probably reduce the number of false-negative results when using this criteria. For WHO, all the maximizations of cutoff points would result in a reduction of the false positive results in both genders and categories.

The best cutoff points that maximize sensitivity and specificity for CDC were the 93.5$^{th}$ percentile for obesity classification, and the 87$^{th}$ percentile for overweight, in boys. In girls, the maximized cutoff points were for obesity the 92.4$^{th}$ percentile and for overweight the 86.3$^{th}$ percentile. For WHO criteria the maximization of specificity and sensitivity was achieved, in boys, by the 97.2$^{th}$ percentile for obesity category and for overweight by the 91.4$^{th}$ percentile. In girls, the maximized cutoff points were the 96.5$^{th}$ percentile for obesity classification, and the 88.8$^{th}$ percentile for overweight.

Nevertheless, we still have to answer the question of what is the ideal cutoff point. Although there is no such concept, we believe that the most similar to the ideal cutoff point is the one that establishes a well defined relation between the screening variable and selected health outcomes. Furthermore, our results are clear in suggesting that as vital as the base of development of each criteria, is the context of application of BMI cutoff points, whether in screening or in a context of confirming disease, at national or international level.

As referred previously, IOTF cutoff points presented a most adequate design, due to be extrapolated from adult cutoff points back into childhood. Even thought, white and Asian adults have disparities in BC expressed in differences of 2–3 BMI points (104), which creates an issue about the universal applicability of adult cutoffs of BMI 25 and 30, and thus, also becomes an issue their use in some child populations for the definition of childhood BMIs that correspond to them (2). Thus, there should not be overlooked that the definition of cutoff points for groups at special risk of health problems due to excess weight, should be adjusted for local factors (2). This adjustment is somehow similar, although by distinct reasons, to other advices made to develop criteria at the national level.

It is well documented that different international criteria may produce a great variety in estimations of weight inadequacy (2, 22, 23, 45), and there have not been made sufficient validation studies to verify criteria adequacy for most countries, although some already concluded that national references could even be most adequate, than IOTF criteria (105). Even more, because of its inherent capability of reporting higher prevalence, WHO criteria is considered by some authors most adequate (106). Nevertheless, these studies did not clarify the question about the correct classification by adiposity level of each criteria, and their capability of reducing the level o uncertainty, reducing though the number of false negative classifications.

In fact, the use of international criteria at the national or local level represents a comparison of a certain growth pattern to the growth pattern of other country or to a combined set of growth patterns form other countries, in a certain moment in time. Therefore, to some extent, makes no sense the recent rush to develop and use of an apparently universal definition of childhood obesity. It may even been considered as premature, not appropriate (23), and with some probable clinically harmful (30). In other hand, expert committees recommend the definition and utilization of BMI cutoff points to define pediatric obesity using national population-specific reference data, which, due to biological differences between populations, provides a safer, practical and evidence-based approach (30). The biological differences are mainly due to ethnic differences in BC and thus to the %BF associated with adverse health consequences (23). Thus, international criteria should preferably be used for inter-countries and time course prevalence comparisons.

As it is being emphasized, the use and interpretation of growth measurements, could be significantly different according to whether they are applied at the individual (for clinical purposes) or in an entire population (for public health purposes). Is also important to clarify that there is a large difference between growth charts, that define a growth pattern, and cutoff points that separate heath from disease.

First of all, we should clarify that the utilization of BMI criteria for clinical proposes in children, is no more than compare one child’s BMI with the growth pattern of a single reference pediatric population, in the Portuguese case, with the growth pattern of another country, once there are no Portuguese growth references. Thus, classifying an individual as overweight or obese requires the first assumption that the individual is comparable to that reference population (2), which most times is not truth. Other questionable fact is related with wrong interpretation of percentile by clinicians (2) that may, sometimes, consider that percentile curves represents an ideal pediatric population when, most of the times and namely in the

Portuguese situation – clinicians use the USA NCHS data – they represent a population with a high prevalence of obesity (17, 28). Nevertheless, the use of centile charts in the clinical follow-up of children is of great usefulness for clinicians, to verify catch-up and leg-down occurrences in growth by the observation of percentile crossing, even without the utilization of cutoff points. Regarding to the use of cutoff points for overweight and obesity assessment at the clinical context, is crucial to pay attention to the seriousness of the problem of misclassification, that in this circumstance will correspond to not receive the appropriate intervention for their nutritional status (107). The misjudgment about the ideal pattern of growth may occur when using the WHO approach. WHO cutoffs were developed based on the concept that, under ideal circumstances, average child growth, is the same everywhere in the world and none of the children in the sample were unhealthy (20). Hence, the edges of the gausian curve would never represent disease our dysfunction (obesity or underweight), but will only characterize much heavier or lighter children than the average, delaying the diagnostic of some children to a later age when the outcomes of overweight and obesity have already been achieved (20). Other clinical concern with BMI utilization is related to the variations of FFM and FM for a certain weight, incapable of being assessed with BMI. Only for higher levels, BMI cutoffs may guarantee a clinical judgment, for levels near the norm misjudgment may occur (2). Changes are also difficult to determine in children followed over time, particularly among children of lower BMI (92). Although, when compared to BMI z-score, BMI is the best measure of change in adiposity, as the within-child variability over time (108). There should not be undermined the fact that z-score values are more difficult to understand and thus to apply, than IOTF BMI cutoff. If BMI is used to identify children at risk, it is in effect being used as a screening test (33), even in a clinical background. Whatever statistical cutoff points are chosen, they are inherently arbitrary and must be followed up by a more detailed evaluation to assess risk (33). But, that does not apply to IOTF criterion, once their cutoff points are based in risk, and not in statistical cutoff points.

As said before, and as supported by the literature, BMI is recognized to be of more use in epidemiological studies and for screening to identify children who should have further evaluation and follow-up, than as a diagnostic test used for predicting FM in any individual child (33, 54, 90). Nevertheless, in our population, and due to its high sensitivity, and thus high capacity to identify overweight and obesity, the WHO criterion should be the one selected as pattern of comparison in the epidemiological field. Reversely, IOTF should be the criterion used in our population, to confirm disease, owing to its high specificity and +LR.

One great obstacle that we found during our literature research was the very inconsistent and incoherent terminology associated to childhood obesity classification. The terms overweight and obesity are often used interchangeably, although not being identical. A common definition is that overweight is an increased weight (not necessarily excess fat) for a certain height, while obesity indicates an excess in FM (22), which is a very unclear definition. The CDC reference documentation recommends that those children with a BMI between the 85$^{th}$ and 95$^{th}$ percentile be classified as "at risk for overweight" and children with a BMI greater than or equal to the 95$^{th}$ percentile be classified as "overweight" (27). Although in the most part of the subsequent papers, children at or above the 95$^{th}$ percentile of the CDC criterion were referred to as "obese" and in others "obesity" refers to US children above the 85$^{th}$ percentile (109). Therefore, the CDC determined that from 2010 onwards the BMI percentile 85th to 95th should be addressed as "overweight'' and the term ''obesity''should be used for a BMI above the 95$^{th}$ percentile (110). The IOTF cutoff points defined by Cole et al. method, assumes "overweight" as BMI ≥25 and "obesity" as BMI ≥30, correspondent to adults (24). As to WHO cutoff were named as "overweight" and "obesity", and were defined as z-sores +1SD and +2SD (26), that are not in agreement with the WHO Child Growth Standards from 0-60 months (25), that use the +1SD, +2SD and +3SD cutoffs to label children as "at risk of overweight", "overweight" and "obese", respectively (111). This is incongruence and even occurring in the same reference criterion but for different age series. One should never forget that overweight and obese children are stigmatized and the implications of negative stereotyping in childhood are carried into adulthood (4, 45). Even though, we consider being more advised to use, for the first cutoff point the term "pre-obesity", for the second the term "obesity" and the term "overweight" for the conjunction of both.

**Study strengths and limitations**

The strengths of our study are firstly, the largely dimensioned sample, which increases the consistency of our results. Furthermore, due to its local representativeness – 96% of total registered students (2476) with ages in the 7-10 years interval – the external validity is assured. However, since the 10 years old children make part of an age set that is in the transition to an upper grade of scholar education this group representativeness could be not guaranteed. This fact could affect the prevalence estimates in this specific group although, it was not expected that influence the general final results.

Moreover, due to the inherent characteristics of some of tests used to assess accuracy (sensitivity, specificity and +LR), that are not dependent on the prevalence of the disease in the study population, these results could be extrapolated four other Portuguese or international populations. As weaknesses we underline, as discussed previously, first the use of a gold standard based in percentile charts for BF, once some caution should be taken comparing individuals across age or sex groups because the reference data are, usually, controlled to give similar results in each group, in all methods based on statistical criteria (45). Other limitation is the adjustment procedure of the measure used to express BC, the %BF. Since %BF is an adjustment of BF using weight, some authors consider this approach unsatisfactory in children (92, 95), stating that BF should be adjusted by height or by other adjustments using height, as the index BF/height$^2$ (92). In this study, we failed to subtract the height effect from BF variable, due to the characteristics of the FF-BIA analyser that only presented values in %BF.

**Final remarks**

It is possible that, in the near future, local and international growth references will coexist and be used to meet specific needs (23). Notice that in this paper is being suggested but not directly underlined till now, that should be developed local population-, ethnic-, age and gender-specific BMI references and cutoffs especially for school-age children but also for adolescents, by collecting national representative in order to define obesity and longitudinal data, to determine its consequences (22, 86, 105, 112). Moreover, pediatric populations differ in FM, FFM and fat distribution (113), and even in their sensitiveness to the metabolic consequences of excessive BF (28), factors that influence largely morbidity and mortality. To overlap this factors and to escape from the common arbitrarily choice of cutoff points, their development should aim the definition of obesity in terms of the degree of adiposity, providing predictive risks of significant metabolic morbidity and disease burden in both the short and long term, throughout the lifecycle (22, 23, 61, 87, 114). Even though, these risk based approaches are quite difficult to determine, thus, alternative approaches can be suggested, like health in childhood estimated using definitions of fit or unfit according to a set of physical fitness criteria, has developed in Taiwan (115).

Furthermore, obese children have a strong tendency to remain in the obese BMI category over time, and when with overweight to progress upwards (81).

Although the choice of which cutoff points to use in the definition of childhood obesity is challenging, when rates of obesity vary so much over time, the urge for national growth references is elevated.

Therefore, for Portuguese children, should be developed national population-specific reference percentile growth charts, and cutoff points for overweight and obesity defined by their association with adverse health outcomes during childhood and beyond.

## CONCLUSIONS

This study is a touchstone in answering to the question of what criteria of BMI classification should be used in school-aged children's nutritional assessment. We established that for different applications, screening and surveillance or in clinical evaluations, despair criteria should be used. Due to great variations in BMI, related to disparities in BC by gender, age, maturity, race, height, and BF distribution, systematic estimation errors analysis could be of great usefulness in clinical interpretation of BMI trajectory, and health professionals should be aware of this potentially confounding effect in the identification of individuals at risk of negative health outcomes.

In Portugal, the WHO criterion seems to be better to detect obesity and overweight in school-aged children from a population. Although, to confirm the disease, namely in a clinical context, the IOTF criterion seems to be more accurate to define obesity and overweight.

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