Childhood obesity classification systems and cardiometabolic risk factors: a comparison of the Italian, World Health Organization and International Obesity Task Force references

Giuliana Valerio, Antonio Balsamo, Marco Giorgio Baroni, Claudia Brufani, Claudia Forzio, Graziano Grugni, Maria Rosaria Licenziati, Claudio Maffeis, Emanuele Miraglia Del Giudice, Anita Morandi, Lucia Pacifico, Alessandro Sartorio, Melania Manco and on the behalf of the Childhood Obesity Group of the Italian Society of Pediatric Endocrinology and Diabetology

Abstract

Background: Body Mass Index Italian reference data are available for clinical and/or epidemiological use, but no study compared the ability of this system to classify overweight and obesity and detect subjects with clustered cardiometabolic risk factors with international standards. Therefore our aim was to assess 1) the agreement among the Italian Society for Pediatric Endocrinology and Diabetology (ISPED), the World Health Organisation (WHO) and the International Obesity Task Force (IOTF) Body Mass Index cut-offs in estimating overweight or obesity in children and adolescents; 2) the ability of each above-mentioned set of cut-points to detect subjects with cardiometabolic risk factors.

Methods: Data of 6070 Italian subjects aged 5–17 years were collected. Prevalence of normal-weight, overweight and obesity was determined using three classification systems: ISPED, WHO and IOTF. High blood pressure, hypertriglyceridemia, low high density lipoprotein-cholesterol and impaired fasting glucose were considered as cardiometabolic risk factors.

Results: ISPED and IOTF classified more subjects as normal-weight or overweight and less subjects as obese as compared to WHO (p <0.0001) in the whole sample and in groups divided by gender and age. The strength of agreement between the three methods compared to each other was excellent for overweight (including obesity) definition (k > 0.900), while it differed for obesity definition, ranging from the highest agreement between ISPED and IOTF (k 0.875) to the lowest between ISPED and WHO (k 0.664). WHO had the highest sensitivity, while ISPED and IOTF systems had the highest specificity, in identifying obese subjects with clustered cardiometabolic risk factors. Analogous results were found in subjects stratified by gender or age.

Conclusions: ISPED and IOTF systems performed similarly in assessing overweight and obesity, and were more specific in identifying obese children/adolescents with clustered cardiometabolic risk factors; on the contrary, the WHO system was more sensitive. Given the seriousness of the obesity epidemic, we wonder whether the WHO system should be preferable to the national standards for clinical practice and/or obesity screening.

Keywords: Adolescents, Body mass index, Cardiometabolic risk factors, Children, Classification, Cut-offs, Obesity, Overweight
Background
The use of body mass index (BMI) to define overweight (OW) or obesity (OB) in children and adolescents is well established for both clinical and public health applications [1]. At present, the most widely used international growth charts in Europe [2, 3] are those proposed by the World Health Organization (WHO) in 2007 [4] and by the International Obesity Task Force (IOTF) in 2000 [5], updated in 2012 [6]. The WHO system uses arbitrarily chosen cut-points of BMI percentiles and, with regard to subjects from 5 to 17 years, is based on data issued before the obesity epidemic from the National Center for Health Statistics charts (NHES II and III and NHANES I) (1971–1974). Differently, the IOTF system uses smooth sex-specific BMI curves, constructed to match the values of 25 kg/m² (OW) and 30 kg/m² (OB) at 18 years, thus providing age and gender BMI cut-offs for OW and OB, and is based on large data sets from six countries or regions covering different races/ethnicities. Practically, the IOTF approach is founded on the idea that the BMI-based definitions of OW and OB at 18 years of age, which are considered to be associated with health consequences in adults, can be tracked back to younger ages.

National BMI reference data are available in many countries and their adoption is recommended for clinical and national epidemiological use [7]. In order to supply pediatricians with national based growth charts, reference values have been recently developed in Italy on data collected among school-children between 1990 and 2004. The first Italian reference charts for children aged 6 to 20 years were published by Cacciari et al. on behalf of the Italian Society for Pediatric Endocrinology and Diabetology (ISPED) in 2002 [8]. Successively these references were extended to preschool age [9], obtaining charts that apply to the Italian population from 2 to 20 year of age. Obviously, these references can over- or under-estimate the prevalence of OW and/or OB with respect to an hypothetical ideal gold-standard for the assessment of body fat, which indeed is lacking. It is more realistically worth for users of national standards to compare them with the international BMI systems conventionally accepted as reference, in order to be aware of their potential for misclassification.

To our knowledge, no previous study has compared the Italian approach to WHO or IOTF reference systems. Therefore the aim of this study was 1) to assess the agreement between the Italian system and the two most frequently employed international systems, the WHO and the IOTF, in classifying paediatric OW or OB, and 2) to evaluate the potential differences among the Italian and the international systems as regards the ability to detect subjects with clustered cardiometabolic risk factors (CMRFs).

Methods
This study derives from a retrospective cross-sectional survey endorsed by the Childhood Obesity Group of ISPED designed to investigate the prevalence of the major CMRFs in outpatient children followed in specialist centers for the care of OW and OB in Italy. Seventeen obesity services (seven in northern, five in central and five in southern Italy) located in hospital or university hospital settings participated to the study, providing medical records of 6070 children and adolescents aged 5–17 years (3009 males, 3061 females) from 2003 to 2013. They were geographically distributed across the northern (n = 1304, 21.5%), central (n = 2454, 40.4%), and southern (n = 2312, 38.1%) Italian regions. The selection of centers was based on the following criteria: 1) specialized centers for the care of pediatric OW/OB; 2) availability of anthropometric data and CMRFs analyzed with standard methods; 3) centralized procedure for biochemical analysis in each center. The inclusion criteria for subjects were: European ancestry, age (5–17 years), and having complete data set. The exclusion criteria were: secondary OB, chronic diseases, malformations and chronic use of drugs leading to metabolic disturbances (such as steroids). The majority of OW or OB children were referred by their family pediatricians.

To extend the range of body size, data about normal-weight (NW) children and adolescents (n = 1146) were derived from the following databases: 1) 508 subjects randomly selected from the registry database (Verona) [10]; 2) 272 children participating in a study on the risk of complex diseases in the Italian population (Rome, Bambino Gesù Children’s Hospital) [11]; 3) 157 healthy students selected from four schools to participate in a pilot study aimed at preventing CVD in childhood (Rome, La Sapienza) [12]; 4) 259 healthy outpatients evaluated for pre-operative assessment before minor surgery interventions (Santobono Pausilipon n = 52, and Santa Maria delle Grazie Pozzuoli Hospitals, n = 157) [13].

The study was approved by the Ethics Committee of the Second University in Naples, Italy (reference number 834/2016) and conformed to the guidelines of the European Convention of Human Rights and Biomedicine for Research in Children. The directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of personal data was complied with for data storage and handling in order to ensure patient data protection and confidentiality.

Anthropometric and clinical assessment
Body weight was determined to the nearest 0.1 kg on accurate and properly calibrated standard beam scales, in minimal underclothes and no shoes. Height was measured to the nearest 0.5 cm on standardized, wall-mounted height boards according to standardized procedures [14]. The BMI was calculated as weight divided by
pressure values was used for analysis. Without overlapping and widths that covered at least enough to encircle at least one-half of the upper arm sized protocol [15]. Briefly, the cuffs had bladders long enough to circumscribe at least two-thirds of the upper arm. The average of three blood pressure values was used for analysis.

Biochemical parameters
Fasting venipuncture samples were drawn for triglycerides, high-density lipoprotein–cholesterol and glucose measurements and analyzed with standard techniques. Although analyses were performed in different laboratories, all centres belong to the Italian National Health system and undergo to semi-annual quality controls and inter-lab comparisons, contributing to limit the potential differences among laboratories.

Case definitions
Each subject was classified as NW, OW or OB by comparing his/her BMI with ISPED or WHO percentiles for age and sex. According to the ISPED system, the BMI value ≥ 5th percentile and < 75th was considered as NW, the BMI ≥ 75th and < 95th percentile was considered as OW and the BMI ≥ 95th percentile was considered as OB [8]; according to the WHO system the BMI value ≥ 5th percentile and < 85th was considered as NW, the BMI ≥ 85th and < 97th percentile was considered as OW and the BMI ≥ 97th percentile was considered as OB [4]. As regards the Cole’s approach, each subject was classified as NW, OW or OB when his/her BMI cut points was equal to or greater than the value plotted on the sex related curves crossing a BMI of 18.5, 25 and 30 kg/m² at the age of 18, respectively. Subjects were categorized in two age groups: children (6–9.9 years) and adolescents (10–17.9 years).

The following CMRFs were considered: high blood pressure (systolic and/or diastolic blood pressure ≥ 95th percentile for age, sex and height) [15]; high triglycerides (≥ 100 mg/dL between 0 and 9 years and ≥ 130 mg/dL between 10 and 19 years) [16]; low high-density lipoprotein–cholesterol (< 40 mg/dL) [16].

Statistical analysis
Continuous data are reported as means and standard deviations, with categorical data as counts and percentages. Variables not normally distributed (weight, BMI) were logarithmically transformed; for clarity of interpretation, results are expressed as untransformed values. Intergroup comparisons were made by the Student’s t-test. The prevalence of NW, OW and OB using the different classification systems was determined in the whole group and in each gender and age subgroups. The rate of agreement between the different criteria was measured by kappa (k) statistics that measures the agreement in individual levels by calculating $k = (P_o - P_e)/(1 - P_e)$ where $P_o$ = the observed probability of agreement and $P_e$ = the probability of expected agreement by chance. K statistics was rated as follows: < 0 = less than chance agreement; 0.01–0.20 = slight agreement; 0.21–0.40 = fair agreement; 0.41–0.60 = moderate agreement; 0.61–0.80 = substantial agreement; 0.81–0.99 = almost perfect agreement. To compare the criteria as for the NW, OW and OB prevalence, the paired McNemar test was used.

Logistic regression analysis was used to predict the likelihood of clustered CMRFs in BMI groups defined by classification systems, controlling for gender, age, and centers. Dummy variables were created to compute odds ratios (ORs) for these factors. The NW group was the reference group (OR = 1.00).

Results
The anthropometric characteristics of the study population are presented in Table 1, while the distribution of subjects classified as NW, OW or OB according to the different reference systems is shown in the Fig. 1.

By considering either the whole population or groups stratified by gender and age, ISPED and IOTF classified more subjects as NW or OW and less subjects as OB as compared to WHO (p < 0.0001). When the overweight threshold (including obesity) was used, the strength of agreement between the three methods compared each other was excellent; when the obesity threshold was used, the strength of agreement was quite excellent between ISPED and IOTF (k = 0.873), substantial between ISPED and WHO (k = 0.692), moderate between IOTF and WHO (k = 0.731) (Table 2).

The OR for clustered CMRFs was separately calculated for each of the three reference systems. Compared with NW, OB subjects had higher risk of association with clustered CMRFs than OW subjects, independent of the classification system used (Table 3).
Sensitivity and specificity for predicting clustered CMRFs of categories of OW (including OB) or OB subjects defined by ISPED, WHO, or IOTF are synthetized in Table 4.

As regards the definition of OW (including OB), the three systems performed quite similarly. As regards the definition of OB, WHO had the highest sensitivity in identifying OB subjects with clustered CMRFs, while ISPED and IOTF systems performed similarly with a sensitivity of 86–87%. Analogous results were found in subjects stratified by gender or age.

Discussion

This study compared the ability of a national BMI reference system for estimating OW and OB in children and adolescents with the two most frequently employed international systems, the WHO and IOTF systems, and demonstrated that there was a high agreement between the three classification methods in the estimated proportions of overweight (including obesity) prevalence. With specific regard to the obesity classification, instead, the highest prevalence of children and adolescents classified as OB was achieved using the WHO system, while ISPED and IOTF systems performed similarly with a sensitivity of 86–87%. Analogous results were found in subjects stratified by gender or age.

IOTF or WHO standards are the two international systems employed in Europe to classify OW and OB in children and adolescents [2]. IOTF thresholds tended to estimate a lower prevalence of OB subjects in both genders and different age-groups with respect to WHO. This finding is in agreement with a previous paper [9] comparing ISPED with other BMI systems, as CDC 2000 [23] and UK 90 [24] charts, and confirms that the 95th centile of the Italian BMI charts is higher than that of the other references. The agreement on OW classification was excellent by comparing the three systems each other, while it differed regarding OB classification: it was moderate by comparing ISPED versus WHO, and excellent by comparing ISPED versus IOTF. The almost perfect agreement between ISPED and IOTF in identifying children from 5 to 17 years with OW and OB shows that the thresholds set equal to the 75th or 95th centiles of ISPED charts as proposed by Cacciari et al. [9] match quite well the IOTF thresholds for OW or OB in this age range. Differently from our findings, previous studies comparing the IOTF reference with the BMI 85th and

### Table 1

| Gender | Age          |
|--------|--------------|
| Total  | Males        | Females  | Children | Adolescents |
| Number | 6070         | 3009     | 3061     | 2318        | 3752       |
| Age (years) | 11.8 ± 2.7 | 10.9 ± 2.6 | 10.7 ± 2.8 | 8.1 ± 1.2 | 12.45 ± 1.9 |
| Height (cm) | 145.9 ± 15.0 | 147.5 ± 15.4 | 144.3 ± 14.5 | 132.3 ± 9.7 | 154.3 ± 11.1 |
| Weight (kg) | 58.0 ± 23.0 | 59.7 ± 23.6 | 56.4 ± 22.4 | 41.9 ± 12.9 | 67.9 ± 22.3 |
| Body Mass Index (kg/m²) | 26.4 ± 6.7 | 26.6 ± 6.6 | 26.2 ± 6.8 | 23.6 ± 5.4 | 28.1 ± 6.9 |
| Systolic blood pressure (mmHg) | 110.3 ± 14.5 | 111.4 ± 14.7 | 109.1 ± 14.2 | 103.7 ± 12.5 | 114.3 ± 14.2 |
| Diastolic blood pressure (mmHg) | 66.2 ± 10.7 | 66.4 ± 10.7 | 66.1 ± 10.6 | 63.4 ± 10.0 | 68.0 ± 10.7 |
| Glucose (mg/dL) | 84.4 ± 8.6 | 85.2 ± 8.6 | 83.5 ± 8.5 | 75.2 ± 40.7 | 85.7 ± 46.9 |
| Tryglicerides (mg/dL) | 81.7 ± 44.9 | 80.9 ± 45.6 | 82.42 ± 44.3 | 52.1 ± 12.3 | 49.3 ± 12.6 |
| HDL-Cholesterol (mg/dL) | 50.4 ± 12.6 | 50.3 ± 12.9 | 50.5 ± 12.2 | 83.6 ± 8.1 | 84.8 ± 8.9 |
95th percentiles from several countries, underlined that IOTF tended to underestimate obesity prevalence, while it gave similar estimates for overweight [25–29].

The emergence of the childhood obesity epidemic poses the challenge of assessing the presence of CMRFs already in children [30–32], which may influence the intensity of treatment [33]. Since the variety of statistical definitions of OW and OB obtained by the choice of one system instead of another can have clear implications for health resource planning [34–36] we also assessed the ability of the ISPED system to detect the association with CMRFs, in comparison with the other international systems. Our data show that, independently of the classification system used, OW, and even more consistently OB subjects, had significantly increased risk for the presence of clustered CMRFs with respect to NW subjects.

The strength of our study resides in the very large sample size, which allowed also subgroups stratification, in the measured rather than self-reported anthropometric data, and completeness of all the variables recorded. Our study has also some limitations. Firstly, OW/OB subjects were recruited in pediatric obesity services, and may be not representative of the general population. Limitations may also depend on the multicenter recruitment of our subjects. However, anthropometric and clinical data were collected according to standardized procedures, and inter-laboratory quality controls were regularly performed, as prescribed by Italian-law, so that precision and accuracy of anthropometric, clinical and biochemical analysis is guaranteed. In addition, the association between clustered cardiometabolic risk factors and classification of OW or OB was controlled by age, gender and center in the logistic regression analysis to mitigate effect, if there was any, of lack of centralized dosages. Lastly, the cross sectional design of the study does not allow assessing the ability of the BMI cutoffs to predict cardio-metabolic outcomes in adulthood.

### Conclusions

Our results highlight the differences in the agreement in OW and OB classification as well as and in the diagnostic accuracy of the associated CMRFs that may arise using national or international BMI reference data. These differences are explained by population variations in the pattern of BMI with age and

| Table 2 Agreement (kappa coefficient and Standard Error) between the ISPED, WHO and IOTF references for the classification of participants according to the overweight or obesity thresholds |
|--------------------------------------------------|-------------------|-------------------|
| Overweight | Obesity |
| ISPED vs WHO | 0.906 (0.007) | 0.692 (0.010) |
| ISPED vs IOTF | 0.974 (0.004) | 0.873 (0.006) |
| IOTF vs WHO | 0.925 (0.006) | 0.731 (0.009) |

Standard error in brackets

All kappa coefficients were significant (P < 0.0001)

ISPED: Italian Society for Pediatric Endocrinology and Diabetology, WHO: World Health Organization, IOTF: International Obesity Task Force
gender between nations and/or the time of data collection. The use of the IOTF system matches quite well with the ISPED thresholds based upon 75th and 95th percentiles of BMI at least between the ages of 5–17 years, consequently the international system proposed for inter-countries comparison and the Italian system have similar effects of on OW and OB classification and association with CMRFs. However, considering the seriousness of the obesity epidemic now under way, the results of our study arise an important question about whether the WHO standards, that allow to get the highest sensibility in identifying obese children/adolescents with clustered cardiometabolic risk factors, should be suggested instead of the more specific national standards, for clinical practice and obesity screening in Italy.

### Abbreviations

BMI: Body mass index; BP: Blood pressure; CMRF: Cardiometabolic risk factor; HDL-C: High-density lipoprotein-cholesterol; IFG: Impaired fasting glucose; IOTF: International Obesity Task Force; ISPED: Italian Society for Pediatric Endocrinology and Diabetology; K: Kappa; OB: Obesity; OR: Odds ratio; OW: Overweight; Tg: Triglycerides; WHO: World Health Organization

### Funding

None declared

### Availability of data and material

The datasets analyzed during the current study is available from the corresponding author on reasonable request.

### Authors’ contributions

GV conceived, designed and planned the study, performed statistical analysis and interpretation of the data and wrote the draft; AB, MGB, GG and CM provided data to the study and made their contribution in revising the manuscript; CB, CF, MRL, EMDG, AM, LP, AS took part in designing the study and interpretation of the data and wrote the draft; AB, MGB, GG and CM provided data to the study and gave substantial contributions to planning of the study, and revising the manuscript critically for important intellectual content. All of the authors read and approved the final version of the manuscript.

### Competing interests

The authors declare that they have no competing interests.

### Consent for publication

Not applicable

### Author details

1Department of Movement Sciences and Wellbeing, Parthenope University, Naples, Italy. 2Department of Medical and Surgical Sciences, Pediatric Unit, Azienda Ospedaliero-Universitaria S.Orsola-Malpighi, Bologna, Italy. 3Department of Experimental Medicine, Sapienza University of Roma, Rome.

---

**Table 3** Odds Ratios (95% CI) for the presence of at least one CMRF (among high Tg, low HDL-C and HBP) for each reference system, controlled for age, gender and center.

|        | ISPED     | WHO       | IOTF      |
|--------|-----------|-----------|-----------|
| Normal weight | 1         | 1         | 1         |
| Overweight  | 3.481 (2.730–4.439) | 2.686 (1.959–3.683) | 3.934 (3.059–5.060) |
| Obesity    | 6.198 (4.898–7.843)  | 6.446 (5.009–8.295)  | 6.728 (5.276–8.579)  |

**Table 4** Sensitivity and specificity of ISPED, WHO, and IOTF defined categories of overweight (including obesity) or obesity for predicting clustered CMRFs in the total sample and in groups stratiﬁed by gender and age.

- **Overweight**
  - Total
    - ISPED
      - Sensitivity: 98.4
      - Specificity: 21.6
    - WHO
      - Sensitivity: 98.9
      - Specificity: 19.1
    - IOTF
      - Sensitivity: 98.4
      - Specificity: 21.6
  - Gender
    - Males
      - ISPED
        - Sensitivity: 86.3
        - Specificity: 41.3
      - WHO
        - Sensitivity: 96.0
        - Specificity: 28.0
      - IOTF
        - Sensitivity: 87.2
        - Specificity: 40.1
    - Females
      - ISPED
        - Sensitivity: 85.0
        - Specificity: 41.4
      - WHO
        - Sensitivity: 95.4
        - Specificity: 24.7
      - IOTF
        - Sensitivity: 86.4
        - Specificity: 39.1
  - Age
    - Children
      - ISPED
        - Sensitivity: 87.8
        - Specificity: 41.1
      - WHO
        - Sensitivity: 96.7
        - Specificity: 31.2
      - IOTF
        - Sensitivity: 88.2
        - Specificity: 41.0
    - Adolescents
      - ISPED
        - Sensitivity: 87.7
        - Specificity: 42.6
      - WHO
        - Sensitivity: 97.7
        - Specificity: 27.7
      - IOTF
        - Sensitivity: 93.2
        - Specificity: 36.5

- **Obesity**
  - Total
    - ISPED
      - Sensitivity: 85.7
      - Specificity: 40.4
    - WHO
      - Sensitivity: 95.3
      - Specificity: 28.2
    - IOTF
      - Sensitivity: 84.5
      - Specificity: 42.4
Italy. 1Endocrinology and Diabetes, Department of Medical Sciences, University of Cagliari, Cagliari, Italy. 2Endocrinology and Diabetes Unit, Bambino Gesù Children’s Hospital, Rome, Italy. 3Azienda Unità Sanitaria Locale di Viterbo, Viterbo, Italy. 4Department of Pediatrics, Santa Maria delle Grazie Hospital, Pozzuoli, Naples, Italy. 5Division of Auxology, Italian Auxological Institute, Verbania, Italy. 6Department of Pediatrics, AORN, Santobono-Pausilipon, Naples, Italy. 7Pediatric Diabetes & Metabolic Disorders Unit, Department of Surgical Sciences, Dentistry, Gynecology and Pediatrics, University of Verona, Verona, Italy. 8Department of Woman, Child and General and Specialized Surgery, University of Campania “Luigi Vanvitelli”, Naples, Italy. 9Pediatric Diabetes & Metabolic Disorders Unit, Department of Life & Reproduction Sciences, University Hospital of Verona, Verona, Italy. 10Department of Pediatrics and Child Neuropsychiatry, Sapienza University of Rome, Rome, Italy. 11Division of Auxology, Italian Auxological Institute, Milan, Italy. 12Research Unit for Multifactorial Diseases, Scientific Directorate, Bambino Gesù Children’s Hospital, IRCCS, Rome, Italy.

Received: 19 August 2016 Accepted: 20 January 2017

Published online: 04 February 2017

References

1. Daniels SR. The use of BMI in the clinical setting. Pediatrics. 2009;124 Suppl 1:535–41.
2. Bibiloni Mdel M, Pons A, Tur JA. Prevalence of overweight and obesity in adolescents: a systematic review. ISRN Obes. 2013;27:392747.
3. Rolland-Cacher MF. Childhood obesity: current definitions and recommendations for their use. Int J Pediatr Obes. 2011;6:325–31.
4. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. International child and adolescent overweight guidelines for predicting overweight to cardiovascular risk factors among children and adolescents. Bull WHO. 2007;85:660–7.
5. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes. 2012;7:284–94.
6. Reilly JJ. Assessment of childhood obesity: national reference data or international approach? Obes Res. 2002;10:838–40.
7. Cacciari E, Milani S, Balsamo A, Dammacco F, De Luca F, Chiarelli F, et al. Cross-sectional growth charts for height, weight and BMI (4–20 y). J Endocrinol Invest. 2006;29:581–93.
8. Takemoto K, Deckelbaum RJ, Saito I, Likitmaskul S, Grummer-Strawn LM, Flegal KM, Mei Z, et al. CDC growth charts for the United States: Methods and development. National Center for Health Statistics. Vital Health Stat. 2000;1:1246.
9. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Reference ranges of HOMA-IR in normal-weight and obese young Caucasians. Acta Diabetol. 2016;53:251–60.
10. Serra-Majem L, Ribas-Barba L, Perez-Rodrigo C, Ngo J, Aranceta J. The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. Pediatrics. 1999;103:1175–82.
11. Katzmarzyk PT, Tremblay A, Perusse L, Despres JP, Bouchard C. The utility of the international child and adolescent overweight guidelines for predicting coronary heart disease risk factors. J Clin Epidemiol. 2003;56:456–62.
12. Valero G, Maffess C, Balsamo A, Del Giudice EM, Brufani C, Grunni G, et al. Severe obesity and cardiometabolic risk in children: comparison from two international classification systems. PLoS One. 2013;8:e83793.
13. Janssen I, Katzmarzyk PT, Tremblay A, Perusse L, Despres JP, Bouchard C. Accuracy of simple clinical and epidemiological definitions of childhood obesity: systematic review and evidence appraisal. Obes Rev. 2010;11:645–55.

Submit your next manuscript to BioMed Central and we will help you at every step:

• We accept pre-submission inquiries
• Our selector tool helps you to find the most relevant journal
• We provide round the clock customer support
• Convenient online submission
• Thorough peer review
• Inclusion in PubMed and all major indexing services
• Maximum visibility for your research

Submit your manuscript at www.biomedcentral.com/submit