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Body mass index and childhood obesity classification systems: A comparison of the French, International Obesity Task Force (IOTF) and World Health Organization (WHO) references

Indice de masse corporelle (IMC) et systèmes de classification de l'obésité infantile : une comparaison des références françaises, IOTF et OMS

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Abstract

Aim. – This study aims to compare three body mass index (BMI)-based classification systems of childhood obesity: the French, the International Obesity Task Force (IOTF) and the World Health Organization (WHO) references.

Methods. – The study involved 1382 schoolchildren, recruited from the Lille Academic District in France in May 2009 aged 8.4 ± 1.7 years (4.0–12.0 years). Their mean height and body mass were 131.5 ± 10.9 cm and 30.7 ± 9.2 kg, respectively, resulting in a BMI of 17.4 ± 3.2 kg/m^2. The weight status was defined according to the three systems considered in this study. The agreement between these references was tested using the Cohen's kappa coefficient.

Results. – The prevalence of overweight was higher with the WHO references (20.0%) in comparison with the French references (13.8%; $P < 0.0001$) and the IOTF (16.2%; $P \leq 0.01$). A similar result was found with obesity (WHO: 11.6% vs. IOTF: 6.7%; or French references: 6.7%; $P < 0.0001$). Agreement between the three references ranged from "moderate" to "perfect" ($0.43 \leq \kappa \leq 1.00$; $P < 0.0001$). Kappa coefficients were higher when the three references were used to classify children as obese ($0.63 \leq \kappa \leq 1.00$; $P < 0.0001$) as compared to classification in the overweight (obesity excluded) category ($0.43 \leq \kappa \leq 0.94$; $P < 0.0001$). When sex and age categories (4–6 years vs. 7–12 years) were considered to define the overweight status, the lowest kappa coefficient was found between the French and WHO references in boys aged 7–12 years ($\kappa = 0.28$; $P < 0.0001$), and the highest one in girls aged 7–12 years between the French references and IOTF ($\kappa = 0.97$; $P < 0.0001$). As for obesity, agreement between the three references ranged from 0.60 to 1.00 ($P < 0.0001$), with the lowest values obtained in the comparison of the WHO references against French references or IOTF among boys aged 7–12 years ($\kappa = 0.60$; $P < 0.0001$).

Conclusion. – Overall, the WHO references yield an overestimation in overweight and/or obesity within this sample of schoolchildren as compared to the French references and the IOTF. The magnitude of agreement coefficients between the three references depends on of both sex and age categories. The French references seem to be in rather close agreement with the IOTF in defining overweight, especially in 7–12-year-old children.

Keywords: Classification systems; Childhood obesity; WHO; IOTF; French references

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Résumé

Objectif. – L'objectif de cette étude est de comparer trois systèmes de classification du poids de l'enfant basés sur l'indice de masse corporelle (IMC) : le système français, celui du Groupe de travail international sur l'obésité (International Obesity Task Force, IOTF) et celui de l'Organisation mondiale de la santé (OMS).

Méthodes. – L'étude a recruté 1382 enfants dans l'académie de Lille en mai 2009, âgés de 4 à 12 ans (moyenne = 8,4 ± 1,7 ans). Les enfants mesuraient en moyenne 131,5 ± 10,9 cm avec un poids moyen de 30,7 ± 9,2 kg, correspondant à un IMC moyen de 17,4 ± 3,2 kg/m^2. Le statut pondéral a été déterminé selon les trois systèmes de classification étudiés et leurs concordances ont été calculées avec le coefficient kappa de Cohen.

Résultats. – Les critères de l'OMS donnaient une estimation de la prévalence du surpoids (20,0 %) supérieure à celle donnée par les critères français (13,8 %, $p < 0{,}0001$) et par ceux de l'IOTF (16,2 %, $p \leq 0{,}01$). Des résultats similaires ont été trouvés concernant la prévalence de l'obésité (OMS : 11,6 %, IOTF : 6,7 %, $p < 0{,}0001$, système français : 6,7 %, $p < 0{,}0001$). La concordance entre les trois systèmes allait de « modérée » à « parfaite » ($0{,}43 \leq \kappa \leq 1{,}00$, $p < 0{,}0001$). Les coefficients de kappa étaient plus élevés lorsqu'il s'agissait de la catégorie obésité ($0{,}63 \leq \kappa \leq 1{,}00$; $p < 0{,}0001$) que pour la catégorie surpoids – obésité exclue ($0{,}43 \leq \kappa \leq 0{,}94$; $p < 0{,}0001$). Quand le sexe et l'âge (4–6 ans vs. 7–12 ans) ont été pris en compte pour déterminer le surpoids, le plus petit coefficient kappa a été obtenu entre le système français et celui de l'OMS chez les garçons âgés de 7–12 ans ($\kappa = 0{,}28$, $p < 0{,}0001$), et le plus grand entre le système français et l'IOTF chez les filles âgés de 7–12 ans ($\kappa = 0{,}97$, $p < 0{,}0001$). En ce qui concerne l'obésité, la concordance entre les trois systèmes de classification allait de 0,60 à 1,00 ($p < 0{,}0001$), avec les plus petites valeurs obtenues entre l'OMS et le système français, et l'OMS et l'IOTF pour les garçons âgés de 7–12 ans ($\kappa = 0{,}60$, $p < 0{,}0001$ dans les deux cas).

Conclusion. – Globalement, la classification de l'OMS a conduit à une surestimation de la prévalence du surpoids et/ou de l'obésité dans cet échantillon d'écoliers par rapport aux estimations données par les systèmes de classification français et de l'IOTF. Le degré de concordance entre ces trois systèmes était fonction du sexe et de l'âge des enfants. Le système de classification français semble donner des résultats très concordants avec ceux de l'IOTF en ce qui concerne le surpoids, particulièrement chez les enfants de 7 à 12 ans.

Mots clés : Systèmes de classification ; Obésité ; Enfants ; OMS

1. Introduction

The World Health Organization (WHO) defines obesity as an excess in fat mass great enough to increase the risk of morbidity, altered physical, psychological, or social well-being and/or mortality [1]. A more clinically oriented definition describes obesity as an inflammation of body fat mass affecting health. As such, obesity can be interpreted as a failure of the body systems using external and/or internal input to regulate energy reserves [2,3].

Nowadays, childhood or pediatric obesity is an important public health issue worldwide, especially in developed countries [4]. It is a challenging problem because as soon as it appears, it becomes to control. Consequently, there exists a general consensus that public health policies should focus on preventive strategies starting at early ages [5,6]. To be effective, these preventive strategies require to define reliable tools to determine such parameters as the cutoff value or weight category to be considered for early diagnosis. Body mass index (BMI) is the most widely used tool for this purpose. However, BMI is affected by the dynamics of growth and therefore cannot be used for in children as it is for adults. BMI changes considerably with age [7]. Growth curves giving BMI distribution as a function of age and sex have then been elaborated so as to ensure more adapted application of this tool in the pediatric population [1,3,6,8–21]. The curves currently available were developed in response to the need for appropriate evaluation of body weight status and obesity in children on a national level (e.g. France, Germany, Great Britain, India, China) and/or internationally (e.g. WHO, International Obesity Task force, IOTF). In France, growth curves were first elaborated in 1982 using the data from a longitudinal study conducted from 1953 to 1979 in children born in 1953 and 1954; with a subsequent revision in 1991. This revision did not provide a distinction between obesity and overweight. To solve this problem, a new reference – developed by associating the French method with Cole et al.'s definition – was elaborated in 2010 within the framework of the National Nutrition and Health Program (PNNS) [9,18,19]. Using this new reference, obesity has been defined as a BMI situated above the percentile curve passing through 30 kg/m^2 at 18 years, i.e. the cutoff value for adult obesity [9,12,19].

For the IOTF reference, Cole et al. [9] developed specific percentile cutoff levels for BMI by age and sex in children. This approach is based on the fact that the BMI cutoffs defining overweight and obesity in children as a function of age and sex must be on the BMI percentile curves that pass, at age 18 years, through the values 25 kg/m^2 and 30 kg/m^2 for overweight and obesity respectively [9]. Users can however apply the BMI *Z*-scores corresponding to these values. Cole et al. recommend, as do several international organizations, that researchers and/or clinicians use specific LMS values, when available, for their study population [9]. Otherwise, the LMS values of the international population used in the initial study by Cole et al. (Brazil, Great Britain, Hong Kong, Singapore, United States, The Netherlands) can be used [9].

The WHO Growth References 2007 [22] are the latest BMI percentile curves by age and sex developed by the WHO. They combine two systems, resulting from collaboration between the WHO and the National Center for Health Statistics (NCHS): the

NCHS/WHO International Growth Reference [23] and the WHO Child Growth Standards [24]. Considered, the NCHS/WHO International Growth References [23] cannot be used to determine overweight status before the age of 9 years. In addition, there are no curves beyond the 5th and 95th percentiles [22]. The WHO Child Growth Standards [24] were established by the WHO in 2006. They provide references for the body corpulence distribution as a function of age in children under 5 years, but are based on cross-sectional data that tend to underestimate overweight and obesity and overestimate insufficient weight. Combining these two references, the WHO Growth References 2007 broaden the NCHS/WHO International Growth References to include 5-year-olds. They thus provide an appropriate reference for an age range from 5 to 19 years, and with values from the 1st to the 99th percentiles established with the recommended LMS method [25]. Furthermore, integrating longitudinal data enables the WHO Growth References 2007 to link the BMI percentile curves by age from young childhood (<5 years) to adolescence (19 years). The overweight cutoff level defined by the WHO Growth References 2007 uses the percentile curve that passes through BMI = 25 kg/m^2 in adults [1] (+1 SD which is equivalent to 25.4 kg/m^2 in boys, and to 25 kg/m^2 in girls at 19 years respectively). The obesity threshold is defined by the percentile curve that passes through BMI = 30 kg/m^2 in adults [1] (+2 SD which is equivalent to 29.7 kg/m^2 at 19 years for both sexes) [22].

Nevertheless, although the IOTF and WHO definitions of overweight and obesity are recognized as ''international references'', there is some divergence in the methods used to elaborate these tools and also some discrepancy in the results they produce [6,10,11,17]. Indeed, the BMI cutoffs, or ''risk thresholds'', used to determine that an individual child is in the ''obesity'' or ''overweight'' category vary from one system to another [16,18,26], and often lead to different prevalence figures [6]. For example, a Canadian study reported that 37% of boys aged 2–5 years were in the overweight/obese category using the WHO definition, but that the same figure was only 19% when using the IOTF system [8]. A French study conducted a similar exercise in infants and found that in the 1–6 month age range (both sexes), the French reference values were lower than the WHO reference values [11]: the differences were probably partially related to the specificities of the populations studied. Data were too scarce for French school-age children (>5 years).

The present study was conducted to evaluate the potential differences between three classification systems for BMI – the French, IOTF and WHO systems – in order to define overweight and obesity in a population of schoolchildren.

2. Material and methods

2.1. Design and study population

This study was performed with a sample of schoolchildren recruited from the Lille Academic District (*Agglomération Maubeuge-Val-de-Sambre*) in May 2009. The children and their parents volunteered to participate in this study. Approximately 3000 children were invited to participate in the study. They were enrolled in 50 classes in 29 schools, including 10 kindergartens and 19 primary-elementary schools. As shown in Fig. 1, among the 3000 eligible children, 1814 agreed to participate in the study. Among these 1814 children, 413 were not evaluated for various reasons (e.g. absent at the time of the evaluations), giving a cohort of 1401 individuals. At final analysis, the study cohort included 1382 individuals aged 4–12 years.

Before participation, the children and their parents were informed about the study. The parents or legal guardians gave

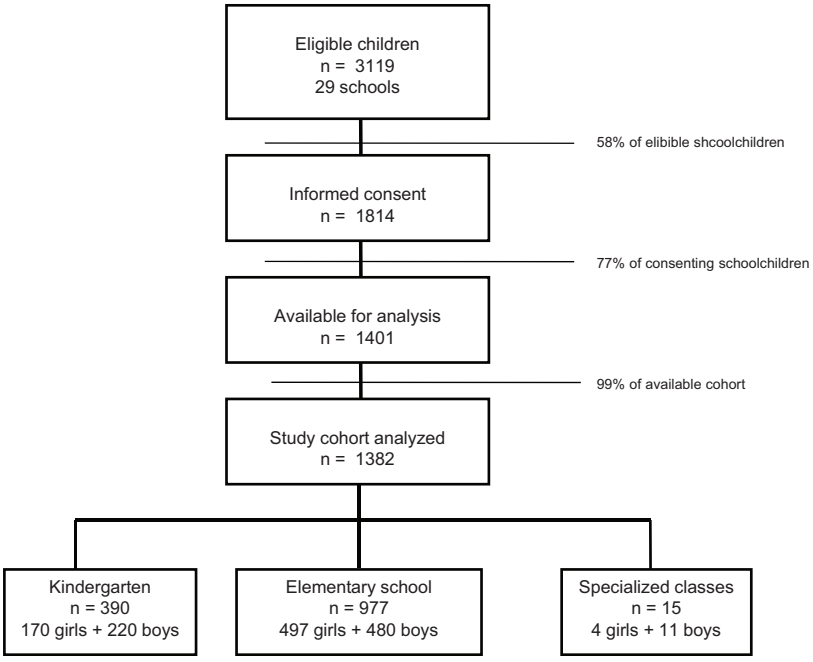

Fig. 1. Schoolchildren recruitment flowchart. Nord-Pas-de-Calais Region, France, 2009.

their written informed consent. This study was approved by the local research ethics committee (Comité de Protection des Personnes de Lille).

2.2. Anthropometric measures

Standing height was measured to the nearest 0.1 cm using a stadiometer (SECA 214, Hamburg, Germany). Weight was measured without shoes to the nearest 0.1 kg using an impedancemeter (TANITA BC-240 MA, Tokyo, Japan). BMI was calculated [weight (kg)/height squared (m^2)] and used to determine the child's weight status according to the different classification systems under study: French, IOTF, and WHO.

2.3. Classification systems and cutoff values

The three classification systems under study are all based on the LMS method [9,25]. This method consists in grouping together data from three specific curves as a function of age: the M (mu) curves correspond to the median BMI; the S (sigma) curves correspond to the coefficient of variation; and the L curves (lambda) correspond to the dissymmetry [25]. Each percentile value of the BMI curve corresponds to one or more standard deviations from the median curve (50th percentile), commonly called the *Z*-score. *Z*-scores are calculated using the formula: $Z = [(\mathrm{BMI}/M)^L - 1]/[L \times S]$.

2.3.1. French references

The BMI *Z*-scores and the corresponding percentiles were calculated using the French LMS values provided by Dr. Marie-Françoise Rolland-Cachera [27] and the free access Growth software developed by Dr. Tim Cole.

The children were classed in their weight status according to the recommendations of the French health authorities (HAS, Haute Autorité de la Santé) [18] :

- obesity: BMI $\geq$ the value obtained by projecting the obesity cutoff level (BMI = 30 kg/m^2) by taking into account the child's age and sex as defined by the IOFT [9];
- overweight: BMI $\geq$ 97th percentile;
- normal corpulence: BMI between the 3rd and 97th percentile.

2.3.2. IOTF references

The BMI values in the study sample were introduced into the free access software developed by Dr. Tim Cole – LMS Growth software (http://www.healthforallchildren.com). *Z*-scores were calculated using the formula associating the international LMS parameters by age as defined by the considered international population (Brazil, Great Britain, Hong Kong, Singapore, United States, The Netherlands) [9]. Each child's weight status was determined according to the cutoff values associated with the percentile curves:

- obesity: percentile curve passing through BMI = 30 kg/m^2 at age 18;
- overweight: percentile curve passing though BMI = 25 kg/m^2 at age 18;
- "normal" weight: percentile curve passing through BMI = 18.5 kg/m^2 at age 18.

2.3.3. WHO References

AnthroPlus (http://www.who.int/growthref/tools/en/) is a free-access software published by the WHO. AntrhoPlus was used to calculate the BMI *Z*-scores of the study sample and determine the weight status of each child according to the following cutoffs defined by the WHO in 2007 [22]:

- for children aged < 5 years:
  - obesity: BMI *Z*-score > 3,
  - overweight: $2 <$ BMI *Z*-score ≤ 3,
  - "normal" weight $-3 <$ BMI *Z*-score ≤ 2;
- for children aged ≥ 5 years:
  - obesity: BMI *Z*-score > 2,
  - overweight: BMI *Z*-score ≤ 2,
  - "normal" weight $-2 <$ BMI *Z*-score ≤ 1.

2.4. Statistical analysis

General characteristics of the schoolchildren are reported as mean $\pm$ SD (range) or as percentage. The adiposity rebound was considered to occur at 6 years [28,29] to distinguish two age groups (4–6 years vs. 7–12 years) for age group comparisons. A Kolmogorov-Smimov test (completed by a Lilliefors test) was used to determine distribution normality (i.e. age, height, body mass, BMI) [30]. As none of the distributions followed a normal law, a log transformation was performed before examining differences by sex using Student's independent *t*-test. The BMI *Z*-scores were compared with Student's *t*-test for pairs. Frequencies of obesity and of overweight were determined for the study population using the cutoffs of the three classification systems. The values obtained for the three systems were compared using the McNemar test for paired proportions. The kappa coefficient (κ) was used to assess the degree of agreement of the three classification systems: French, IOTF, WHO. The systems were considered to be in: disagreement to weak agreement ($\kappa = 0.00$–0.40); moderate to strong agreement ($\kappa = 0.41$–0.80); nearly perfect agreement ($\kappa = 0.81$–1.00); perfect agreement ($\kappa = 1.00$) [21].

The level of significance was set at $P < 0.05$ for all comparisons. SPSS Statistics 17.0 was used for the statistical analysis.

3. Results

3.1. Characteristics of the study population

As shown in Fig. 1 and Table 1, the study population included 671 girls and 711 boys, mean age 8.4 $\pm$ 1.7 years. This sample had 209 children aged 4–6 years and 1173 children age 7–12 years. There was no significant difference between boys and girls regarding height (131.4 $\pm$ 10.6 cm vs. 131.7 $\pm$ 11.3 cm; $P = 0.64$), body mass (30.4 $\pm$ 9.0 kg vs. 31.1 $\pm$ 9.4 kg; $P = 0.17$) or BMI (17.3 $\pm$ 3.3 kg/m^2 vs. 17.6 $\pm$ 3.0 kg/m^2; $P = 0.09$). Thus the distribution by weight

Table 1
Anthropometry, weight status and proportion of obese and/or overweight children. Nord-Pas-de-Calais Region, France, 2009.

	Age (year)	Height (cm)	Body mass (kg)	BMI (kg/m^2)	BMI Z-score			Overweight (%)			Obese (%)		
					Fr	IOTF	WHO	Fr	IOTF	WHO	Fr	IOTF	WHO
Girls	8.4 ± 1.7	131.7 ± 11.3	31.1 ± 9.4	17.6 ± 3.0	0.94 ± 1.49	0.59 ± 1.07[e]	0.55 ± 1.13[a,f]	15.4	17.0	20.9[c]	7.3	7.3	10.6[d,i]
(n = 671)	(4.0; 12.0)	(97.0; 170.0)	(14.0; 96.0)	(10.7; 33.2)	(−4.45; 6.67)	(−4.53; 3.76)	(−4.19; 4.02)						
Boys	8.4 ± 1.7	131.4 ± 10.6	30.4 ± 9.0	17.3 ± 3.3	0.64 ± 1.53	0.45 ± 1.11[e]	0.51 ± 1.26[a,f]	12.4	15.5	19.3[b]	6.2	6.2	12.5[a,f]
(n = 711)	(4.0; 12.0)	(103.0; 163.0)	(15.0−78.0)	(12.6; 54.7)	(−2.68; 8.78)	(−2.46; 4.53)	(−2.68; 8.78)						
Total	8.4 ± 1.7	131.5 ± 10.9	30.7 ± 9.2	17.4 ± 3.2	0.79 ± 1.52	0.52 ± 1.09[e]	0.53 ± 1.20[a]	13.8	16.2	20.0[b,g]	6.7	6.7	11.6[a,h]
(n = 1382)	(4.0; 12.0)	(97.0; 170.0)	(14.0; 96.0)	(10.7; 54.7)	(−4.53; 8.78)	(−4.53; 4.53)	(−4.19; 5.28)						

Fr: French references; IOTF: International Obesity Task Force; WHO: World Health Organization.
[a] Significant differences between the French and WHO references; $P < 0.0001$.
[b] Significant differences between the French and WHO references; $P < 0.001$.
[c] Significant differences between the French and WHO references; $P < 0.01$.
[d] Significant differences between the French and WHO references; $P < 0.05$.
[e] Significant differences between the French and IOTF references; $P < 0.0001$.
[f] Significant differences between the WHO and IOTF references; $P < 0.0001$.
[g] Significant differences between the WHO and IOTF references; $P \leq 0.01$.
[h] Significant differences between the WHO and IOTF references; $P < 0.001$.
[i] Significant differences between the WHO and IOTF references; $P < 0.05$.

status was not a function of sex ($P = 0.17$). Nevertheless, the BMI Z-score determined using the French references was significantly different from the BMI Z-score determined using the IOTF and WHO references (Table 1).

3.2. Prevalence of overweight by classification system

Prevalence of obesity and of overweight in the study population is presented by sex in Table 1 and in Fig. 2.

3.2.1. Prevalence of overweight

There was a significant difference between the French and the WHO references for the proportion of overweight girls (15.4% vs. 20.9%; $P = 0.01$). Similarly there was a difference in the proportion of overweight boys determined using the French references (12.4%) and the WHO references (19.3%) ($P = 0.02$). There was no significant difference in prevalence of overweight children between the French references and the IOTF references for boys (12.4% vs. 15.5%) and for girls (15.4% vs. 17.0%).

The proportion of overweight girls aged 7–12 years was 17.2, 18.1 and 21.5% according to the French, IOTF and WHO references respectively (Fig. 2A). In boys in this same age range, the corresponding proportions were 14.2, 17.1 and 20.1% respectively (Fig. 2B). In both sexes, these proportions were lower than in children aged 4–6 years (Fig. 2). Differences between the two age groups in the prevalence of overweight were greater with the French references than with the two other classification systems ($P < 0.01$): 11.6 percentage points less in 4–6-year-old boys compared with their 7–12-year-old counterparts (Fig. 2B) and up to 13 percentage points in girls (Fig. 2A).

3.2.2. Prevalence of obesity

Regarding children placed in the ''obesity'' category by the French and IOTF references, prevalence was comparable in girls and boys (7.3% in girls and 6.5% in boys) and in the overall population (6.7%). These levels were significantly different from those obtained with the WHO references in girls (10.6%; $P = 0.04$), in boys (12.5%; $P = 0.0001$) and in the overall study population (11.6%; $P < 0.0001$). As shown in Fig. 2, the difference was mainly due to the greater difference between the WHO proportions between the age groups for the ''obesity'' category (up to 8.6 percentage points difference for boys 4–6 years vs. 7–12 years).

3.3. Agreement between the classification systems for excess weight

The kappa coefficients between the French, IOTF and WHO reference systems are presented in Tables 2A and 2B for the categories overweight and obesity.

3.3.1. Agreement for overweight

Regarding the definition of overweight, there was a ''moderate'' agreement between the French and WHO reference systems ($\kappa = 0.44$; 95%CI [0.38–0.50]; $P < 0.0001$). There was a ''nearly perfect'' agreement between the French and IOTF references ($\kappa = 0.91$; 95%CI [0.88–0.94]; $P < 0.0001$) for overweight. This agreement was even stronger for girls (Table 2A). Nevertheless, in this same category, the agreement between the French and IOTF references was ''moderate to strong'' before the age of 7 years (girls: $\kappa = 0.97$; 95%CI [0.95–0.99]; boys: $\kappa = 0.89$; 95%CI [0.83–0.94]; $P < 0.0001$). Compared with the WHO references, the French references were in ''disagreement'' or ''moderate agreement'' for both sexes before the age of 7 years, and also in boys after 7 years. For girls after 7 years, the agreement was considered ''moderate to strong'' (Table 2B).

3.3.2. Agreement for obesity

Among children placed in the ''obesity'' category, the agreement was ''moderate to strong'' ($\kappa = 0.71$; 95%CI [0.65–0.78]; $P < 0.0001$) between the French and WHO references.

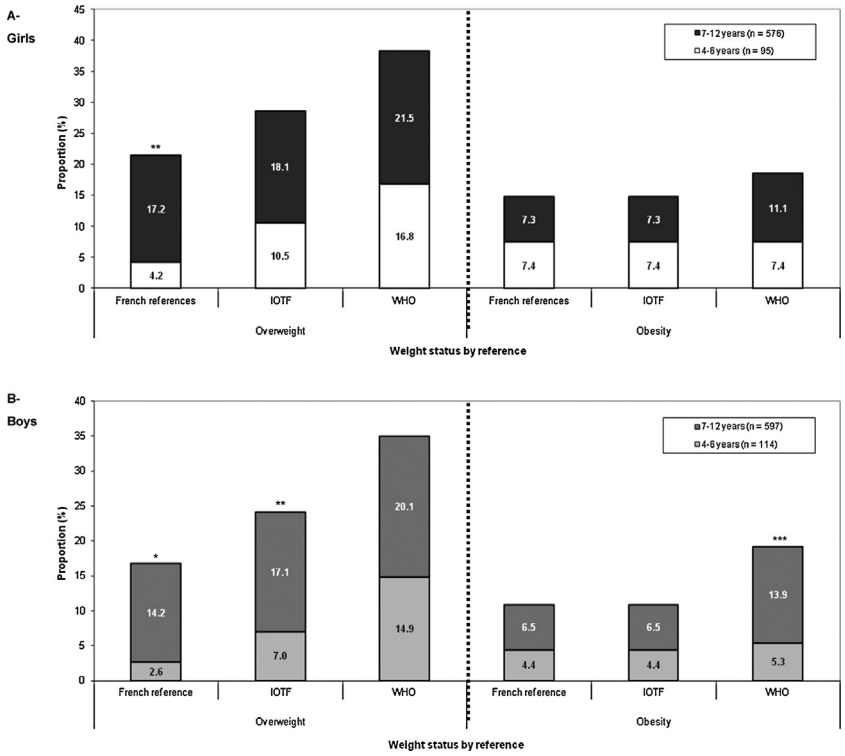

Fig. 2. Classification system, weight status and proportion of overweight and obese children by age and sex. Nord-Pas-de-Calais Region, France, 2009. A. Girls. B. Boys. *** denotes a significant difference between age groups (4–6 years vs. 7–12 years), $P < 0.05$; ** denotes a significant difference between age groups (4–6 years vs. 7–12 years), $P < 0.01$; * denotes a significant difference between age groups (4–6 years vs. 7–12 years), $P < 0.001$.

The agreement was ''perfect'' between the French and IOTF references ($\kappa = 1.00$; $P < 0.0001$). The kappa test also found a ''perfect'' agreement on obesity for all age groups (4–6 years vs. 7–10 years) between the French and IOTF references, both in girls and in boys ($\kappa = 1.00$; $P < 0.0001$) (Table 2B). The same observation was made between the French and WHO references for girls under 7 years. There was ''nearly perfect'' agreement before 7 years between the French and WHO references for boys ($\kappa = 0.91$; 95%CI [0.72–1.09]; $P < 0.0001$) and ''moderate to strong'' agreement after 7 years (girls $\kappa = 0.77$; 95%CI [0.68–0.86]; boys $\kappa = 0.60$; 95%CI [0.50–0.71]; $P < 0.0001$) (Table 2B).

The detailed analysis of the degree of agreement (κ) highlighted the differences in the classification systems (Fig. 3). The WHO system placed 20.0% of the children in the overweight category. Among these 20.0%, the French and IOTF references placed 11.1% (Fig. 3A) and 8.7% (Fig. 3B) respectively in the ''normal'' category. Similarly, among the 16.2% of children in the overweight category using the IOTF references, the French references identified 2.4% as having a ''normal'' weight (Fig. 3 C). For the ''obesity'' category, the WHO system gave the figure of 11.6% (Fig. 3D); among these 11.6%, the French and IOTF references identified 4.8% as belonging to the ''overweight'' category (Fig. 3D).

Table 2A
Agreement (κ) (kappa coefficient and 95% confidence interval) between the French, IOTF and WHO references for the classification of children according to the weight status. Nord-Pas-de-Calais Region, France, 2009.

	Overweight			Obesity		
	Girls	Boys	Total	Girls	Boys	Total
Fr vs. WHO	0.60[a] [0.52; 0.67]	0.27[a] [0.19; 0.36]	0.44[a] [0.37; 0.50]	0.79[a] [0.72; 0.879]	0.63[a] [0.54; 0.73]	0.71[a] [0.65; 0.78]
Fr vs. IOTF	0.94[a] [0.91; 0.98]	0.87[a] [0.82; 0.92]	0.91[a] [0.88; 0.94]	1.00[a]	1.00[a]	1.00[a]
IOTF vs. WHO	0.66[a] [0.69; 0.73]	0.43[a] [0.34; 0.51]	0.55[a] [0.488; 0.60]	0.80[a] [0.72; 0.88]	0.63[a] [0.54; 0.73]	0.71[a] [0.65; 0.78]

Fr: French references; WHO: World Health Organization; IOTF: International Obesity Task Force.
[a] Kappa coefficient significant ($P < 0.0001$).

Table 2B
Agreement (κ) (kappa coefficient and 95% confidence interval) between the French, IOTF and WHO references for the classification of children according to the weight status. North Region, France, 2009.

	Overweight				Obesity			
	Girls [4–6 years]	Girls [7–12 years]	Boys [4–6 years]	Boys [7–12 years]	Girls [4–6 years]	Girls [7–12 years]	Boys [4–6 years]	Boys [7–12 years]
Fr vs. WHO	0.36[a] [0.10; 0.62]	0.62[a] [0.54; 0.70]	0.16[b] [0.0; 0.38]	0.28[a] [0.19; 0.37]	1.00[a]	0.77[a] [0.68; 0.86]	0.91[a] [0.72; 1.00]	0.60[a] [0.50; 0.71]
Fr vs. IOTF	0.54[a] [0.23; 0.86]	0.97[a] [0.95; 1.00]	0.53[a] [0.17; 0.88]	0.89[a] [0.83; 0.94]	1.00[a]	1.00[a]	1.00[a]	1.00[a]
IOTF vs. WHO	0.74[a] [0.54; 0.93]	0.65[a] [0.57; 0.73]	0.51[a] [0.28; 0.77]	0.41[a] [0.32; 0.50]	1.00[a]	0.77[a] [0.68; 0.86]	0.91[a] [0.72; 1.00]	0.60[a] [0.50; 0.71]

Fr: French references; WHO: World Health Organization; IOTF: International Obesity Task Force.
[a] Kappa coefficient significant ($P < 0.0001$).
[b] Kappa coefficient significant ($P \leq 0.01$).

4. Discussion

The purpose of this study was to investigate the agreement between the French, IOTF and WHO systems for defining overweight and obesity in school-age children. Contrasting results were obtained concerning the proportions of children placed in the ''obesity'' and/or ''overweight'' categories by the three systems. There was some convergence between the French and IOTF references, but the WHO references were significantly different, placing higher proportions of children in excess weight categories. For example, for the overweight category, the proportion generated by the WHO definition was 6.2 points higher than that produced by the French system, that was itself 3.8 points higher than the IOTF system. The upward shift produced by the WHO system was seen in both sexes, especially for the overweight category in the 4–6-year-olds and for the obesity category in the over 7-year-olds. The kappa coefficient showed that agreement was ''moderate'' between the WHO references and the two other references, while the agreement between the French and IOTF references was nearly ''perfect''.

In international literature, the perfect agreement observed between the French and IOTF systems is generally not the rule for comparisons between a national and an international system

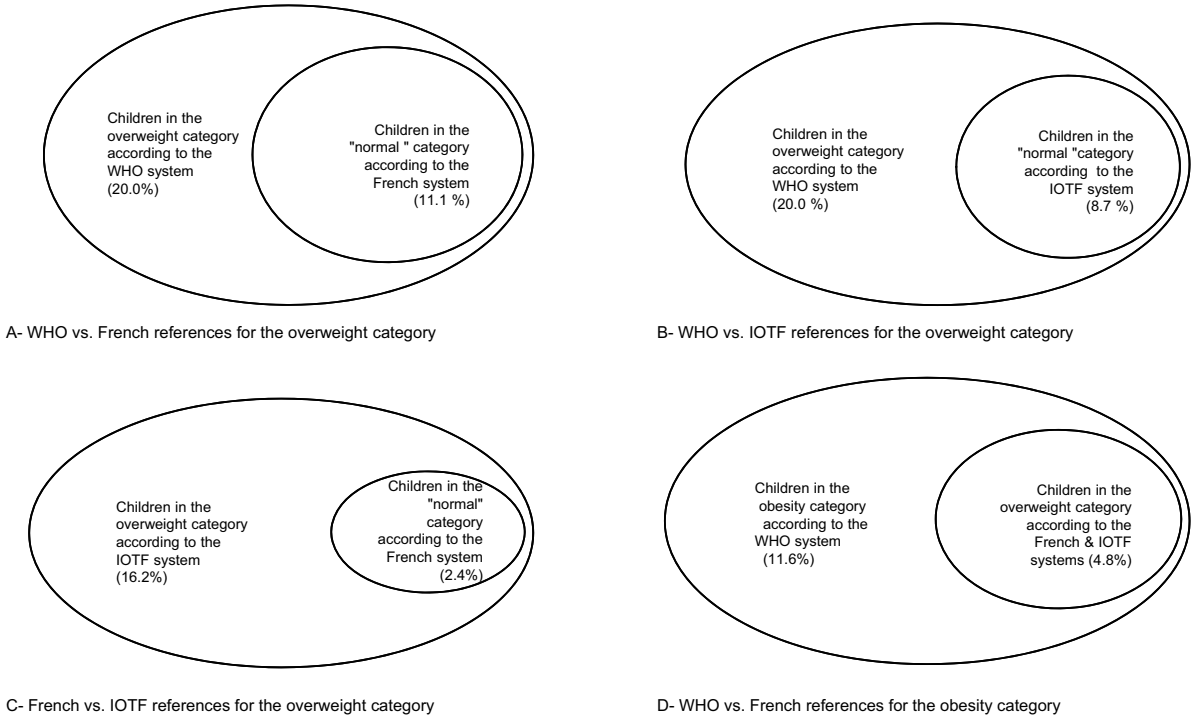

Fig. 3. Analysis of disagreement between the different reference systems as a function of specific weight categories. A. WHO vs. French references for the overweight category. B. WHO vs. IOTF references for the overweight category. C. French vs. IOTF references for the overweight category. D. WHO vs. French references for the obesity category.

for determining obesity prevalence [8,11,17,20,21,31,32]. One of the rare exceptions concerns the data reported by Shields and Tremblay [8] who also found similar obesity prevalence values using two systems, the WHO system and the Centers for Disease Control and Prevention (CDC) system. In our study, this agreement might be related to the fact that the definition of obesity is the same in the French system and in the IOTF system: the percentile curve that passes through BMI = 30 kg/m^2 at 18 years. There are nevertheless differences between the French and IOTF systems concerning the definition of overweight, particularly in the 4–6 years age range. It is also noteworthy that the higher proportions of obesity found with the WHO references were mainly found in children older than 7 years.

As was also noted by Shields and Tremblay [8], the proportions of children placed in the ''overweight'' and ''obesity'' categories in our study were lower with the IOTF system than with the WHO system. The results of their Canadian study [8] were also similar to ours concerning the comparison between overweight prevalence in girls and boys by age. Shields and Tremblay [8] reported that the difference between the IOTF and WHO systems was more pronounced in 6–11-year-old boys. This age group is very close to the age range of the very large majority of the children in our population (5–12 years). This very difference between boys and girls was observed when comparing the French references to the WHO references and the IOTF references. The difference was again more pronounced between the French and WHO references. The WHO references often give higher prevalence figures than national references or other international references. This observation has already been made in studies conducted in India [32], Italy [31] and Great Britain [33]. There are however other studies that give somewhat different results. The study by Rosario et al. in Germany [20] found that the national references gave higher prevalence results than the WHO system. The lack of coherence among these reports highlights the difficulty of comparing epidemiological phenomena on an international level [26]. These difficulties arise in part from the diversity of the methods used to elaborate classification systems.

The literature shows that in the population of European children aged 5–9 years, 22% are overweight and 6% are obese. In France, the prevalence of overweight increased from 10% in 1992 to 16% in 2000 [34]. In recent years, the obesity and overweight percentages have remained rather stable, oscillating around 10–12% for overweight and 3–5% for obesity [35]. This stability was underscored by the national Direction for research, evaluation, studies and statistics (DREES) in its 2011 report on the health status of the French population [36]. In this report, it is noted that, better than stability, there is a slight decline in obesity in 5–6-year-olds [36]. In Northern France, in 2000, 10.2% of boys aged 5–12 years and 18.6% of girls in the same age range were overweight; the obesity figures were 1.3% for boys and 4.4% for girls [37]. The latest data provided by the International Association for the Study of Obesity (IASO) in 2011 for France (using the IOTF references) stated that the prevalence of obesity in boys aged 7–11 years was 2.5% and that the prevalence of overweight in this same age range for boys was 14% (obesity included). In girls in the same age range, the obesity prevalence was 4% and the overweight prevalence (obesity included) 19%. This same institution reported that in 2012 for the WHO region Europe 22.1% of boys were overweight (obesity included) and 5.3% were obese; 20.% of girls were overweight (obesity included) and 4.4% were obese [38]. The results of the present study are in general closer to the European data than the French data. Indeed, recent prevalence figures in France are below those found in the present study. Northern France is known to be one of the French regions with a characteristically high prevalence or frequency of obesity [39,40]. Comparing the results of the study by Jackson-Leach and Lobstein in 2000 [37] with those of the present study suggests that there would be a greater percentage of obese children in Maubeuge (1.3% of obese boys in Northern France vs. 6.2% in Maubeuge). The prevalence figures, by age and sex, are also higher in our study sample than in the European data. The European figures give 2.5% of boys aged 7–11 years as obese [38] vs. 6.5% of boys aged 7–12 years in the present study.

Beyond the differences in the proportion of overweight/obese children, it is important to examine the dynamics of the curves under study. Several observations can be made, especially according to age. It is noteworthy for example that the agreement for placing girls aged 4–6 years in the ''obesity'' category was perfect between the three reference systems. For girls aged 7–12 years, the agreement was moderate between the French and WHO systems and between the IOTF and WHO systems – the agreement between the French and IOTF systems remaining prefect for the reasons linked to the methodology used to construct the new cutoff levels for the French system as mentioned above. The quality of the classifications produced by the reference systems studied should also be examined. A detailed analysis of the results shows that the three systems operate differently. Thus, by placing in the overweight category children who were considered by the French and IOTF systems to have ''normal'' weight, the WHO system displayed dissimilar behavior. The importance of this dissimilarity is particularly patent when considering the impact of the final results on public health policy. If public health authorities were to rely on results issuing from the WHO system, actions targeting children who in reality have ''normal'' weight or are simply ''overweight'' would be relatively overemphasized. Conversely, if national authorities were to consider results issuing from the French references, there would be a tendency to underemphasize such actions. The IOTF references provide a way to limit the impact of these differences. In general, and considering the results of our study, this international system would be the most appropriate for investigating childhood overweight/obesity prevalence. This proposition to use the IOTF references preferentially is also based on the ambiguity of the cutoff levels by age applied in the WHO system, the other international system examined in the present study. Indeed, it is remarkable to note that for children aged over 5 years, the obesity cutoff for the WHO system is +2 SD but that this same

cutoff places children aged less than 5 years in the overweight category. This type of inconsistency is critical when considering widespread application of the WHO reference system.

5. Conclusion

The findings produced by this study lead to the conclusion that the methods used to identify infantile obesity based on BMI as elaborated in the French, IOTF and WHO reference systems produce, in their present state of development, results that are generally different concerning the estimation of the prevalence of obesity and/or overweight in children aged 5–12 years in France. The differences are more pronounced for boys than for girls. Nevertheless, there is perfect agreement between the French and IOTF classification systems for placing children in the obese category. For this body corpulence category, the differences between these two systems and the WHO system can be as high as two-fold. For the other weight categories studied (respectively ''overweight [obesity included]'' and ''overweight''), agreement in classification runs from strong to nearly perfect between the French system and the IOTF system. The IOTF system is the closest to the two other systems, with, in general, an intermediary degree of agreement. The French system nevertheless remains closer to the IOTF system than to the WHO system.

The way children are placed in specific weight categories by the three systems provides insight into their distributional behavior. It can be noted that among the 11.6% of children placed in the obesity category by the WHO system, only 6.7% were placed in this same category by the French and IOTF systems that considered the remaining 4.8% to be overweight. This difference in distributional behavior shows how important it is to choose the appropriate reference system, adapted both for international studies and for clinical applications.

To sum up, the IOTF system appears to be best adapted for population studies; it is the closest to the two other systems. We can thus propose to use the IOTF system conjointly with national references for childhood obesity studies in order to facilitate comparisons with international data while taking into account local specificities.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.respe.2014.11.003.

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