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ORIGINAL ARTICLE

Receiver operating characteristic (ROC) curves to identify birth weight cutoffs to predict overweight in Mexican school children

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Abstract

Objective: To identify birth weight cutoffs to predict overweight in school children and adolescents from Chilpancingo, Mexico, in 2004.

Methods: Six hundred and sixty-two male and female children between 5 and 13 years old were selected by probability sampling. Birth weight measures were extracted from vaccination cards. The school children's nutritional status was defined using specific body mass index (BMI) cutoffs according to sex and age. Predicting equations were built using linear regression models. Areas under the receiver operating characteristic (ROC) curves were calculated and two-graph (TG) ROC curves were plotted, respectively, to detect global accuracy and to identify birth weight cutoffs corresponding to the intersection of sensitivity and specificity curves.

Results: Overweight prevalence was higher in female (46%) than male school children (38.5%). Among adolescents, overweight prevalence was also higher in females (43.5%) than males (38.9%). BMI average and birth weight deciles showed a linear relation. Areas under ROC curves showed values ≥ 78% in each stratum of sex and age, depicting a difference by sex in adolescents. TG-ROC curves showed that birth weight cutoffs were slightly higher in boys than in girls, and the sensitivity/specificity intersections were ≥ 0.70.

Conclusions: The study results showed that birth weight cutoffs can be used as overweight markers in childhood and adolescence, being useful as a screening strategy to detect risk groups.

J Pediatr (Rio J). 2009;85(1):42-47: Body mass index, birth weight, sensitivity and specificity, cross-sectional studies.

Introduction

The prevalence of obesity has been increasing dramatically in developed as well as developing countries. The relatively recent transition from agrarian to urban economy resulted in the increased consumption of high-energy-density foods and reduced physical activity, which are both considered important risk factors for overweight.[1]

In 2004, Moraes et al.,[2] in a cross-sectional study related to school children in the urban area of Chilpancingo, state capital of Guerrero, Mexico, identified overweight prevalence levels of 37.7% in male and 46.2% in female children. Among adolescents, these levels were 41.0% for boys and 45.6% for girls. In that study, the authors reported the occurrence of a linear gradient for birth weight tertiles in relation to overweight, even after adjusting for potential risk factors such as intake of high-energy-density foods, time spent on sedentary activities, and frequency of physical activities.

In recent years, a new prevention paradigm has highlighted the intra-uterine relevance of environmental factors, which can influence health throughout life.[3,4] Several studies have detected an independent effect of birth weight on the risk of overweight during childhood and adult life,[2,5,6] being

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overweight alone identified as a risk factor for a large spectrum of chronic conditions, including cardiovascular diseases and type 2 diabetes mellitus.[4,7,8] Silveira et al.[9] in a recent review underlined the relevance of developmental origins of health and disease (DOHaD), recognizing different combinations between low birth weight and overweight related to cardiovascular disease in later life, according to living in developing or developed countries.

Some authors have used receiver operating characteristic (ROC) techniques to identify the accuracy of cutoffs for anthropometric measures in predicting adiposity (body fat percentage) in children and adults.[10,11] However, it seems to be unusual the use of those techniques to identify cutoffs for birth weight in predicting overweight in children and adolescents.

Considering the pertinence of setting up health promotion and prevention strategies at an early stage of life, this study aimed to identify cutoffs for birth weight to predict overweight in school children and adolescents who lived in the urban area of Chilpancingo, Guerrero, Mexico, in 2004.

Methods

Data were extracted from the database of a cross-sectional epidemiological study[4] that reported the prevalence of overweight and associated factors in Mexican school children in 2004. The reference population comprised the universe of students enrolled in elementary schools located in the urban area of Chilpancingo, the state capital of Guerrero, Mexico. The study population consisted of 667 male and female school children, between 5 and 13 years old, selected by random sampling. The sample size was estimated taking into account the overweight prevalence as 25% and a maximum error of 3%. From a total of 59 schools, seven schools located in the urban area of Chilpancingo were selected by probability proportional to size sampling, without replacement.[12] The sampling process was developed in three steps: schools, school grade, and students selection. Data collection was carried out between March and May, 2004.

Due to the impossibility to obtain information about the mothers' gestational age on the occasion of the survey, five children with birth weight ≤ 2,500 g were excluded, resulting in a sample of 662 school children available for this study. The study protocol was submitted and approved by the Research Ethics Committee at Universidad Autónoma de Guerrero, Mexico, and data were collected throughout interviews, after permission by the school children's parents or caregivers who signed a free informed consent form.

Body mass index (BMI) measures were obtained as a result of the weight (in kilograms) divided by the square of the height (in meters). Weight and height were measured using electronic scales and wall stadiometers to the nearest 0.1 kg and 0.1 cm, respectively. The classification of the school children's nutritional status was based on Cole et al. recommendations,[13] based on the cutoff of BMI according to sex and age. Participants were classified in two categories: normal and overweight, the latter category including overweight and obese children.

Birth weight information (in grams) was taken from the children's vaccination cards, presented by mothers or caregivers during the interview.

Age was classified in two groups: children (≤ 10 years of age) and adolescents (> 10 years of age), and the school children were also classified by sex as male or female.

In a first step, the relation between birth weight (x), classified in deciles, and the children's average estimated BMI (y) in each decile was examined. Using regression techniques,[14,15] linear regression models were constructed, followed by more complex second and third-order models and, finally, logarithmic models. The choice of the best model was based on R^2 estimates, p values for F distributions in each model, and residual analysis, choosing, whenever possible, models of the lowest order. A significance level $\alpha = 0.05$ was adopted.

ROC curves[16] were constructed to identify the global accuracy (areas under the curves) of birth weight measures to predicting overweight. The areas under the curves were compared according to sex, into age groups, using chi-square statistics. Those areas were estimated by points and 95% confidence intervals (95%CI).

Non-parametrical two-graph (TG) ROC curves[17] were built for children and adolescents according to sex in order to determine birth weight cutoffs (d_0) predicting overweight which corresponded to the intersection between sensitivity and specificity curves (θ_0). θ_0 values correspond to the mean between sensitivity (Se) and specificity (Sp) values: $\theta_0 = (Se+Sp)/2$. Values for d_0 were estimated by points and 95%CI.

Stata software version 8.2[18] was used to run regression analysis, and to calculate and compare the areas under the ROC curves. TG-ROC curves were plotted using Computational Methods for Diagnostic Tests (CMDT) software, version 1.0β.[19]

Results

Table 1 shows overweight prevalence according to age groups and sex. The results depicted increased values for Mexican school children and adolescents, mainly for females in both age groups.

Table 2 presents linear regression equations according to sex and age groups, R^2 estimates, and descriptive p-values corresponding to the hypotheses tests based on F statistics. Positive angular coefficients (β) indicate an ascending linear relation between x and y. Based on regression equations, it was identified that the predicted values of BMI (y) increased

Table 1 - Overweight* prevalence (%) according to age group and sex (Chilpancingo, Guerrero, Mexico, 2004)

Nutritional status	Children (≤ 10 years of age)				Adolescents (> 10 years of age)			
	Male		Female		Male		Female	
	n	%	n	%	n	%	n	%
Normal	123	61.50	108	54.00	80	61.07	74	56.49
Overweight	77	38.50	92	46.00	51	38.93	57	43.51
Total	200	100	200	100	131	100	131	100

* Overweight was classified as proposed by Cole et al.,[13] who defined body mass index cutoffs according to age and sex.

by about 4% for increasing of birth weight decile (x) in crude and stratified analysis.

Table 3 shows the global accuracy of birth weight (areas under the ROC curves) for the whole group of school children and according to sex into each age group. The areas under the curves were estimated by points and 95%CI. The chi-square statistics and respective p-values correspond to the hypotheses tests to compare areas under the curves according to sex into age groups. Related to the global accuracy, the estimated areas reached values of more than 78% (crude and stratified analysis), and narrowed confidence intervals, indicating that birth weight measures reached a good discriminatory power to diagnose overweight. The comparison between areas under the curves showed a statistically significant difference by sex in adolescents ($p < 0.01$).

Figure 1 shows TG-ROC curves according to sex in each age group. We can observe that the cutoffs points for birth weight (d_0) were higher in males than in females, in both age groups, and θ_0 values in each group reached levels ≥ 0.70 for the sensitivity/specificity intersections, also indicating that the estimated cutoffs points for birth weight contributed to identify overweight in the study groups.

Discussion

The results revealed a positive linear relation between birth weight and BMI (kg/m^2) in Mexican school children from Chilpancingo. These findings are similar to those reported by other studies that examined the relation between birth weight and BMI in subsequent stages of the life cycle,[20,21] although some authors have found that linearity tends to be attenuated as age increases.[4,22]

In this study, the authors used the areas under the ROC curves to identify the global accuracy of the birth weight measures to predict overweight in children and adolescents. They concluded that the respective measures performed well, as the areas under the curves reached values close to 100% (maximum performance)[23] in all strata.

ROC curves have been widely used to detect the accuracy of BMI cutoffs to diagnose adiposity in children and adolescents.[10,11,24,25] In those studies, the authors have found that BMI is highly accurate to detect adiposity, using different gold standard methods: X-ray absorptiometry, multisite skinfold thickness and bioelectrical impedance analysis.

On the other hand, in a large part of studies that evidenced a relationship between birth weight and overweight,

Table 2 - Regression models* to predict BMI average related to birth weight deciles according to age group and sex (Chilpancingo, Guerrero, Mexico, 2004)

	n	Regression equations	R_a^2 (%)	p†
Crude analysis	657	y = 15.87 + 0.66x	96.03	< 0.01
Children				
Male	200	y = 15.88 + 0.66x	96.03	< 0.01
Female	196	y = 15.90 + 0.65x	96.20	< 0.01
Adolescents				
Male	131	y = 15.81 + 0.67x	96.43	< 0.01
Female	130	y = 15.84 + 0.66x	95.02	< 0.01

BMI = body mass index.
* Regression models: x = birth weight deciles; y = predicted BMI average.
† Descriptive p value related to F statistic.

Table 3 - Areas under ROC curves to estimate global accuracy of birth weight related to overweight according to age group and sex (Chilpancingo, Guerrero, Mexico, 2004)

	n	Areas under the curves (%)	95%CI	Chi-square (p)*
Crude Analysis	657	82.45	79.18-85.73	
Children				2.31 (0.13)
Male	200	84.52	78.89-90.16	
Female	196	77.74	71.07-84.41	
Adolescents				8.72 (0.00)
Male	131	92.34	87.55-97.13	
Female	130	78.66	70.94-86.37	

95%CI = 95% confidence interval; ROC = receiver operating characteristic.
* Chi-square estimates and p values to compare areas under ROC curves in strata.

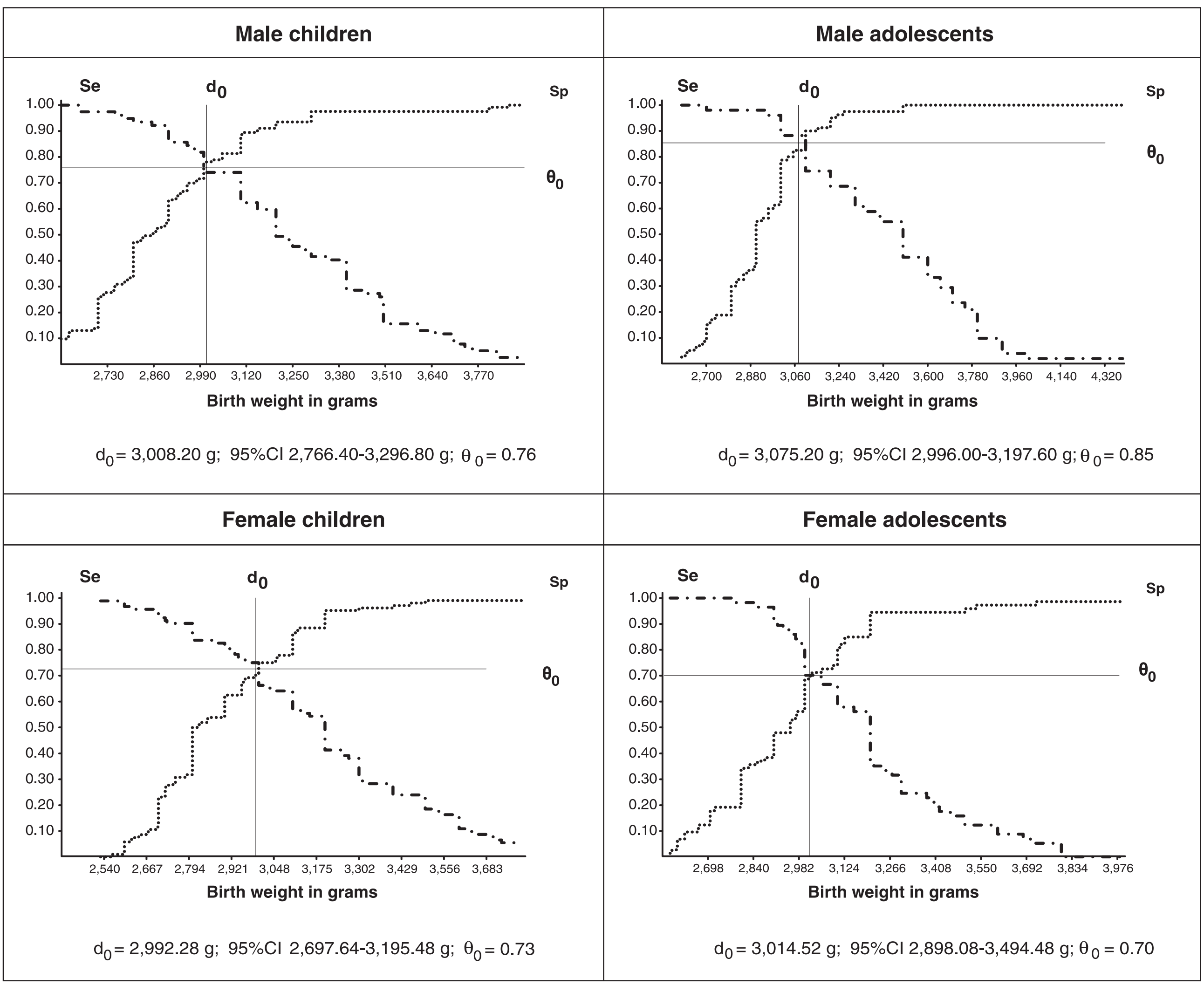

Figure 1 - TG-ROC curves to estimate birth weight cutoff (d_0), sensitivity (Se), specificity (Sp), and intersection (θ_0) related to overweight, according to age group and sex (Chilpancingo, Guerrero, Mexico, 2004)

in subsequent periods of the life cycle, the authors had used different methodologies, such as multivariable techniques to evaluate the magnitude of that association, after adjusting for risk/protective factors.[2,6,26] Moraes et al.,[2] investigating overweight and obesity correlates, detected that birth weight (classified in tertiles) was an independent predictor for overweight and obesity in school children from Chilpancingo. In that study, the authors found that adjusted odds ratios for birth weight measures classified in the third tertile (≥ 3,110 g) reached values of 7.03 (95%CI 3.53-13.99) and 7.91 (95%CI 2.83-22.09), related to overweight and obesity, respectively.

The advantage of the present study was that the use of TG-ROC curves made it possible to define birth weight cutoff points to detect overweight (including 95% confidence intervals) and respective sensitivity/specificity intersections, providing practical and useful information to encourage public health promotion policies. Hence, the use of TG-ROC curves might complement Moraes et al. findings,[2] as the technique permits estimating not only the birth weight cutoff in predicting the outcome but also a convergence point for its sensitivity and specificity which could be applied as a screening strategy in epidemiology.

It could be relevant to highlight that the cutoffs for birth weight in this study suggest high positive predictive values in populations with high overweight prevalence levels, like children from Chilpancingo. However, it cannot be affirmed that those same cutoffs would reach high positive predictive values in populations with low prevalence levels of the outcome under analysis.[17]

Some authors have reported that, in considering the relationship between birth weight and BMI in later stages of the life cycle, the mother's nutritional status before pregnancy could have a positive confounding effect reducing the strength of this association, however without eliminating it.[3,4] The mother's nutritional status before pregnancy was not formally available to be taken into consideration in the present study, and getting the information by interviews might result in the occurrence of recall bias, mainly in cross-sectional designs.

The choice of cutoffs for birth weight measures to predicting future risks for overweight should preferably be based on the evidence coming from longitudinal studies, which are more appropriate to express the natural history of different health outcomes.[11,24] The present study results suggest, however, that the cutoffs found for birth weight measures in Chilpancingo can be used to earlier track newborns for follow-up in order to prevent overweight in subsequent periods, such as late childhood and adolescence.

In this perspective, the results support the recommendation that birth weight cutoffs and the respective sensitivity/specificity based on TG-ROC curves, as those found in the present study, could be appropriate to sustain public policies for health promotion and prevention programs against overweight, in populations with high overweight prevalence levels.

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