Birth weight and obesity in children and adolescents: a systematic review

Abstract

Aim: To verify scientific and epidemiologic evidences of the hypothesis of association between birth weight and overweight/obesity in childhood and adolescence based on a systematic review of the literature. **Method***:* A systematic review was performed in the MedLine/Pubmed, Scielo-Brasil and Lilacs electronic bases. Articles were classified into two categories of analysis based on the Human Development Index of the country where the study was performed: a) birth weight and overweight/obesity in countries with a high Human Development Index; b) birth weight and overweight/obesity in countries with a high, but still ascending Human Development Index, and medium Human Development Index. Downs & Black checklist was adapted and used to evaluate the methodological quality of the fourteen articles chosen. **Results***:* In both categories the association between high birth weight and overweight/obesity was predominant. Additionally, one of the seven articles in the first category found low birth weight as a predictor of body and abdominal fat. In the second category, three articles identified the association between catch-up growth and overweight/obesity and another found low birth weight as a protector for overweight (including obesity). Among the four Brazilian studies found, the association between birth weight and overweight or obesity was not statistically significant in two articles. **Conclusions***:* High birth weight was associated with overweight/obesity in the majority of articles. The association between low birth weight and overweight/obesity needs ongoing investigation.

Key words: Overweight, Obesity, Birth Weight, Literature Review.

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Introduction

As of the 1990's, there have been reports in the literature on the association between low birth weight (LBW), characterized by birth weight below 2500 g, and the presence of overweight or obesity during childhood[1], adolescence[2] and adult life[3,4]. Another study suggested that the amount of fat-free mass during adolescence is lower in newborns with LBW[5].

On the other hand, high birth weight also (HBW), characterized by birth weight equal or over 4000 g, has been associated with the development of excess body weight, during childhood and adolescence[6]. However, results that challenge significant evidence of statistical significance with HBW have also been reported, especially in studies performed in countries in economic ascension[7,8].

Knowing that LBW is more prevalent in impoverished populations and in developing countries[9], while HBW has an increased prevalence in some developed countries like the United States (US) and Canada,[10] and some European countries[11], the socioeconomic level of samples assessed has been appointed as an important confounding variable in the association of birth weight (BW) and obesity. Therefore, this association seems to remain inconsistent in studies performed in children in developing countries[12].

Based on what has been said, it is important to identify in the literature if LBW and HBW have been reported as factors associated with overweight and/or to obesity, so that preventive measures may be planned in mother and infant-juvenile health, focusing on the priorities of each population. In this fashion, the objective of the present study was to verify the level of scientific and epidemiological evidence of the assumption of association between birth weight (BW) and overweight/obesity in childhood and adolescence, based on a systematic review of the literature. The initial questions of the investigation were: Is there an association between BW and overweight/obesity in children and adolescents? Does the association between BW and overweight/obesity in children and adolescents differ according to the human development index of the country in which the study was performed?

Methods

A systematic literature review was performed, trying to find scientific articles describing the association between birth weight and overweight and/or obesity. Articles published as of 1998 were selected. The electronic databases searched were: Scielo-Brasil (*Scientific Electronic Library Online),* Lilacs and Medline/Pubmed by *National Library of Medicine*, in July 2008. The keywords used in the Scielo-Brasil and Lilacs databases were compliant with the definitions in DecS (Health Descriptors) and were: a) birth weight *and* obesity; and low birth weight *and* obesity. In the Medline/Pubmed database keywords defined according to their description on the MeSH (*Medical Subject Headings*) were used, searching: a) *birth weight (or low birth weight) and obesity (or overweight or adiposity)*, and b) *fetal programming and obesity*, and establishing the following inclusion criteria: studies performed in humans of both genders; age group between 6-18 y; and articles published and indexed in the database in the past 10 years. In the latter, articles stored in the *"related articles" links* were also attained. It should be underscored that different keywords were used in each database because of the definitions that each database proposes for keywords. By adopting this procedure, possibly more articles related to the topic of interest were found in each database. Other inclusion criteria were the condition that the variable birth weight was the exposure, and overweight and obesity the outcomes; and those studies considered BMI measurements to quantify fat-free mass or fat mass and anthropometric indexes such as weight-for-height, weight-for-age and related indexes as outcome also be included. As exclusion criteria, the authors defined not to analyze: a) articles with results exclusive

for outcomes in adult or pre-school ages, as these were not age groups of interest; b) review articles, due to the proposal of analyzing only original articles, that is, based on empirical data; and c) clinical trials, because only observational studies were included.

In the search performed on the *Medline/Pubmed* database, a total of 33 articles were found, using the first combination of keywords, 3 of which review articles; and 37 articles using the second combination, 8 of which review articles. In the Scielo-Br database, nine articles were found using the terms birth weight *and* obesity (1 review article) and 1 with the terms low birth weight *and* obesity. In the Lilacs database, 32 studies were found, totaling articles and summaries of post-graduate papers (1 review article). After reading abstracts, 14 articles were selected for analysis. It should be underscored that the reference lists of the articles selected were not consulted.

The methodological quality of each article was assessed based on criteria established by Downs & Black[13], which allow guiding the reader/reviewer as to the limitations of the article assessed, enabling critical reading of the studies published. The original questionnaire had 27 questions, divided in four groups: a) presentation (assessment of items such as clarity to describe objectives, confounding variables, probability values); b) external validation (related to extrapolation of data to the population from which the sample was taken); c) internal validation (analysis of biases, reliability of exposure and outcomes, and use of confounding variables); and d) power of the study. For the present study, questions 8, 13 to 15, 23, 24 and 27 were removed, because they referred to clinical trials. The questions of the scale enabled, objectively, to assess if the article under analysis complied or not with what was being asked. For each question, score zero was given to an article that did not comply with what was being assessed and one (1) if it complied. Only question 5 received score 2 if the question was answered by the article. In this fashion, the maximum score that an article of the present review could reach was 21.

As a synthesis strategy, a script to describe the characteristics of each article was designed, highlighting: authorship, country, year of publication, study design, sample characteristics and size, diagnostic criteria, cut-off points to define overweight and/or obesity, outcome, exposure, main results found, main statistical analyses, and scores on the methodological quality of the studies. Data attained for each article are described in Charts 1 and 2.

As analysis strategy, the fact that the distribution of BW changes according to the socioeconomic level of each nation was taken into account, and the 14 studies were grouped into two categories, according to the classification proposed by the United Nations Development Program (UNDP), based on the Human Development Index (HDI)[14] of the country in which the study was performed: a) BW and overweight/obesity in countries with an HDI above 0.900 (high human development - 7 articles)[5, 6, 15-19], including United Kingdom, Australia, Denmark, Finland, US and Germany; and b) BW and overweight/obesity in countries with an HDI between 0.800 and 0.899 (high but still ascending human development index - six articles) [7, 8, 20-23], including Brazil, Mexico, and the Seychelles Isles and BW and overweight/obesity in countries with an HDI below 0.800 (middle human development index – one article)[24], carried out in China. It should be pointed out that the HDI is calculated based on data of life expectancy at birth, schooling at the elementary, secondary and higher education levels, literacy among adults, and *per capita* Gross Domestic Product in American dollars[14], which explains the methodological approach chosen, as the HDI can be considered as *proxi* of a nation's socioeconomic level. Moreover, the utilization of socioeconomic variables in the articles analyzed was also assessed, as it is an important confounding variable in the relationships with outcomes such as overweight and obesity.

Results

According to what is presented in Charts 1 and 2, 14 articles that met eligibility criteria were identified in the time period studied. Of these, 6 were published as of 2005[6, 17, 20-22, 24], demonstrating that the theme is still current.

Among the 14 articles, the utilization of different diagnosis criteria to assess overweight and obesity (outcome of the present investigation) was perceived, as well as different classifications of birth weight (exposure variable). BMI/Age was the anthropometric index most frequently used (9 articles) to diagnose overweight/obesity, but different criteria and different cut-off points for each criterion were used. The criteria of Cole *et al.* (2000), CDC (2000) and Must *et al.* (1991) were the ones most frequently used. Regarding birth weight, the utilization of z-scores or tertiles and quartiles prevailed, while the categories recommended by the World Health Organization (WHO)[25] were used in a minority of articles (2 in 14) (LBW < 2500 g; Sub-Optimal Birth Weight (SOBW) = 2500 - 2999 g; Optimal Birth Weight (OBW) = 3000 - 3999 g).

The age groups of the samples were very heterogeneous, in that 8 articles assessed children and adolescents, 2 only assessed adolescents (≥ 10 y) and 4 only assessed children (< 10 y).

Regarding collection and use of skin-fold data, since 2006, the WHO[26] has recommended that the same individual be assessed twice and by different evaluators, so as to, by means of inter and intra-evaluator variation, calculate the technical error of measurement (TEM), an important strategy for internal validation of the study. None of the articles published after this date, however, have quoted or published the TEM value.

Below, the results of the studies analyzed are briefly described.

Birth weight and overweight/obesity in countries with a high HDI

In the US, the influence of HBW, of gestational diabetes *mellitus* (GDM) and of mother's BMI on overweight of children and adolescents were observed. Gillmann *et al.*[15] observed that birth weight was associated with overweight in children with ages between 9-14 y, and, those born from mothers with GDM, an association that was also significant. Frisancho[16] did not observe the effect of birth weight on the BMI of children and adolescents, given newborns with high birth weight only became obese adolescents when one of the parents was obese. In Berlin[17], the negative influence of GDM was also observed, given mothers with this condition had children with higher BMI/gestational age at birth, which in turn, was a predictor of overweight at 6-8 y.

In these studies it is possible to verify that the association between BW and BMI of children and adolescents should be controlled by maternal characteristics, especially those related to pregnancy, to avoid for possible confounding effects.

Two studies assessed subjects of the United Kingdom, presenting divergent results. Reilly *et al.*[6] observed that each 100 g increase in birth weight increased the risk of obesity in children at 7 years of age. In addition to birth weight, the catch-up weight growth (compensatory growth and above normal growth standards for weight and/or height) between birth and 2 years and high growth rates in the first year of life were identified as potential risk factors for obesity. In the study of Singhal *et al.*[5], results differed, in that for each standard deviation increase in birth weight there was a 3% increase in the amount of adolescents' fat-free body mass. For fat mass and for BMI, no significant associations with birth weight were observed. Authors adjusted analysis models for socioeconomic variables, height, stages of sexual maturation, and exercise.

In Australian children[18], those born with lower weights and who had higher weights at 7-8 y were observed to have significantly more abdominal fat and a higher percentage of total fat than those born with higher weights. Moreover, it was observed that at each reduction of 1 kg in birth weight, the amount of abdominal fat increased at 7-8

y. Some flaws were identified in the article, such as important confounding variables that were included in other studies but were not included in the article, it is not clear if subjects eligible for the study represent the population of interest (only 24% of the population) and the sample was comprised by subjects who did not belong to the population of interest (29 were volunteer candidates).

In the capital of Finland[19], the association between birth weight/gestational age and overweight of adolescents was observed not to remain after controlling for the other study variables. The article had flaws in the description of characteristics of subjects lost to follow-up and in the validation of the sample studied in regard to the source population (representativeness). Moreover, the fact that authors used the BMI recommended for adults as the cut-off point in the assessment of adolescents (BMI≥25 kg/m^2) draws attention. Such procedure seems wrong and leads to overweight prevalence quite below those expected (in the study, around 4%).

We perceived that among the 7 articles assessed, in 4 (57.2%), there was a significant association between BW and overweight or obesity, in that the score attributed to most of these articles (3) was very near the maximum score they could attain. Among the 4 articles, 3 had associations of HBW with outcomes, and one had results related to association of LBW with high abdominal and body fat deposits. One of the articles also presented association between catch-up weight growth and high growth rate in the first year of life and overweight/obesity. The remaining 3 studies (42.8%), did not identify a significant association of BW with overweight/obesity, in that one of these showed a positive relation between higher birth weights and fat-free mass.

Birth weight and overweight/obesity in countries with high, ascending HDI, and birth weight and overweight/obesity in countries with middle HDI

Four Brazilian studies were assessed, and results differed. Goldani *et al.*[20] observed a positive association between BW and obesity in individuals at 18 y, even after adjusting for socioeconomic and biological variables. However, the article had four flaws, three of which compromised the external validation of the study. In the article of Tomé *et al.*[21], birth weight in the different categories below 3500 g protected for the occurrence of overweight including obesity in school children of Ribeirão Preto (SP) (reference category ≥ 4000g), but also resulted in higher occurrence of low weight (BMI ≤ percentile 5).

In the study of Dutra *et al.*[22] the prevalence ratio for overweight was proportional to the increase of BW, but the association was not statistically significant. The study of Monteiro *et al.*[7], identified an association of catch-up weight growth with overweight and obesity, and the association of catch-up height growth with overweight during adolescence. Birth weight and birth weight / gestational age, however, were not associated with outcomes in multivariate analyses.

In Mexico[23], birth weight above 2890 g was observed to be associated with overweight schoolchildren. In the association with obesity, only BW ≥3110 g had a significant association.

In the Seychelles Isles [8] (Indian Ocean), the positive association between birth weight and overweight and obesity in children was not confirmed in a multivariate analysis. In this case, the faster weight gain in the first year of life (catch-up weight growth), regardless of birth weight, was shown to be significantly associated with the outcome variable.

In China[24], the catch-up weight growth was observed to be more frequent in LBW newborns and with gestational age in the lowest tertile. High birth weight and catch-up weight growth between zero and 3 months of age was associated to overweight (including obesity) of children at seven years of age. The accelerated weight gain up to 3 months of age had a higher effect on BMI at a later age of boys who were born with

Chart 1 *- List of studies on association between birth weight and obesity in children and adolescents, carried out in countries with high HDI and published in the period from 2000 to 2007, according to: authorship / country / year of publication, design of the study, characteristics and size of the sample, reference criterion to diagnose overweight / obesity, outcome and exposure variables, main results / statistical analysis and comments / attributed scores.*

Authors/ Country/Year of publication	Study design	Sample	Diagnosis of overweight/ obesity	Outcome	Exposure	Main results and statistical analysis	Comments / maximum and attained scores
Reilly et al.6/ United Kingdom / 2005	Prospective cohort	909 children at 7 years	BMI ≥ percentile 95 of reference population of the United Kingdom (1990)	Obesity at 7 years	31 variables, among which, BW in 100 g classes	At each 100 g increase in birth weight, the odds ratio of presenting obesity increased in 1.05 (95% CI = 1.03 to 1.07). The catch-up weight growth between 0-2 y and high growth rates in the first year of life were factors independently associated with obesity. / Multivariate logistic regression and CI.	One question did not apply Maximum score: 20 **Attributed score: 19**
Schaefer-Graf et al. 17/ Berlin / 2005	Prospective cohort	324 children at birth and at 2-8 years	BMI ≥ 90 percentile of German reference population (2001)	Obesity at 2-8 years	BMI/ Gestational age	Exposure was the predictor factor for overweight at 6-8 y, even after adjusting for biochemical and mothers' biological variables ($\beta = 0.195$; $p < 0.001$). / Spearman Correlation.	One question did not apply Maximum score: 20 **Attributed score: 18**
Gilmann et al.15/ United States of America / 2003	Cross-sectional nestled cohort	7,981 girls and 6,900 boys 9-14 years	Risk of overweight if p 85th ≤ BMI < p 95th. Overweight if BIM ≥ p 95th of CDC(2000)	Risk of overweight and overweight	Average and standard-deviation de BW and presence of gestational diabetes	Overweight was associate to BW (OR = 1.3; 95% CI = 1.1–1.5) and also in newborns of mothers with gestational diabetes the odds ratio for overweight was significant (OR = 1.4; 95% CI = 1.1–2.0). / Multivariate logistic regression and CI.	Five questions did not apply Maximum score: 16 **Attributed score: 16**
Singhal et al.5/ United Kingdom / 2003	Cross-sectional nestled cohort	86 5-9 year-old children and 78 13- 16 year-old adolescents	Body composition (fat-free and fat mass) by densitometry, electric bioimpedance and skin folds	Fat-free and fat body mass	BW z-scores	BW did not associate neither to BMI ($\beta = 0.7$; $p=0.07$ – adolescents; $\beta=0.4$; $p=0.06$ - children) nor to body fat by any of the equations [(Schaefer et al. (1994): $\beta=0.08$; $p=0.24$ – adolescents; Houtkooper et al. (1989): $\beta=0.04$; $p= 0.52$ - adolescents; Deurenberg et al. (1990): $\beta = 0.05$; $p = 0.30$ – adolescents and $\beta=0.03$; $p=0.26$ - children; and Slaughter et al. (1988): $\beta= 0.05$; $p=0.41$- adolescents and $\beta = 0.04$; $p = 0.21$ – children] and nor by densitometry ($\beta=0.04$; $p= 0.24$ – children). / Multivariate linear regression.	Two questions did not apply to study Maximum score: 19 **Attributed score: 15**

Chart 1 *-continuation*

Garnett et al.18/ Australia / 2001	Prospective cohort	255 children at 6 months and at 7-8 years	Weight assessed by Australian reference -Hamill et al. (1979) and body composition by densitometry	Percentage of body fat and abdominal fat	z-scores of BW and of weight at 7-8 years	BW < 3,000 g and higher weights at 7-8 years determined more abdominal fat (p<0.001) and percentage of total fat (6.53±1.3%), when compared to high weight (BW >4,000 g) (4.14±0.5%) (p <0.001). At each 1 kg reduction in BW, increased the amount of abdominal fat in 0.18 millimeters (β = -0.18; 95% CI = -0.31 to -0.04, p = 0.009). / Student t Test/ Multivariate linear regression.	Three questions did not apply Maximum score: 18 **Attributed score: 15**
Pietiläinen et al.19 /Finland /2001	Retrospective Cohort	2062 boys and 2314 girls (twin), at 16 years	BMI ≥25 kg/m2	Overweight	Percentiles BW/ gestational age	Newborns above percentile 95 of birth weight/ gestational age presented the most elevated odds ratio for overweight at 16 years, but the association was not significant (OR = 2.7; 95% CI = 0.7 – 10.8). / Logistic regression adjusted for biological variables of parents.	Two questions did not apply to study Maximum score: 19 **Attributed score: 17**
Frisancho 16/ United States of America / 2000	Prospective cohort	1993 newborns assessed at 15-17 years, and their parents	BMI and triceps skin fold as continuous variables	BMI Average, standard-deviation and z-scores	BW/ gestational age (SGA, AGA and LGA), BMI of parents, BMI and triceps skin fold of mothers	BMI of adolescents was higher when the BMI of one of the parents was high, regardless of category of birth weight/ gestational age (GA). The same result was observed when comparing skin folds of mothers and their adolescent children. RR for higher BMI in adolescence was proportional to BW/GA (1.9 for small for gestational age (SGA), 2.2 for adequate for gestational age (AGA) and 5.7 for LGA), but higher maternal BMI determined higher incidence of high BMI. For adolescents born LGA and mothers with high BMI, there was the highest incidence of high BMI (13.1%)./ Incidence and RR. BMI of father and of mother were significantly associated with high BMI of adolescents, but not with birth weight. / Linear multiple regression.	One question did not apply to study Maximum score: 20 **Attributed score: 20**

Legend: CDC = Centers for Diseases Control and Prevention; BW = birth weight; OR = odds ratio; CI = Confidence Interval; BMI= Body Mass Index; BW= birth weight; g = grams; OR = odds ratio; CI=confidence interval; SGA= small for gestational age; AGA= adequate for gestational age; LGA= large for gestational age; RR = Relative Risk.

Chart 2 *– Relation of studies on association between birth weight and obesity in children and adolescents, carried out in countries with high, ascending HDI, and middle HDI, published in the period from 2001 to 2008, according to: authorship / country / year of publication, study design, characteristics and size of the sample, reference criterion to diagnose overweight / obesity, outcome and exposure variables, main results/ statistical analyses and comments / attributed scores.*

Authors/ Country/Year of publication	Study design	Sample	Diagnosis of overweight/ obesity	Outcome	Exposure	Main results and statistical analysis	Comments / maximum and attributed score
Hui et al.24 / China / 2008	Prospective cohort (77.5% of electable population)	6075 term born children, assessed at 3 and 12 months and at 7 years	BMI z-scores compared to CDC curves (2000) and overweight and obesity according to Cole et al. BMI (2000)	BMI and overweight z-scores (including obesity) at 7 years	*BW and weight gain z-scores (catch-up)*	Catch-up was more frequent for LBW NB and with GI in the lowest tertile. However, OR for overweight (including obesity) were higher for children with highest BW and who had catch-up in the periods between 0-3 months (OR = 4.97; CI 95% = 3.16 – 7.83 – boys; OR = 3.32; CI 95% = 1.85 – 5.95 – girls) and between 3-12 months of age (OR=5.95; CI 95%=3.66–9.68– boys; OR=5.46; CI 95% =3.03 – 9.82 – girls). / Multivariate logistic regression and CI.	One question did not apply to the study Maximum score: 20 **Attributed score: 19**
Goldani et al.20/ Brazil / 2007	Prospective cohort	1189 boys at birth and at 18 years	BMI as a continuous variable	Mean BMI at 18 years	Perinatal variables, among which, BW (<2500, 2500-2999, 3000-3499, 3500-3999, ≥4000 g)	BW associated linearly and proportionally to BMI at 18 years, in bivariate analysis (BW ≥ 4000g and mean BMI =23.63: β=1.37; 95% CI = 0.22-2.53). After adjusting for socioeconomic and biological factors, the association remained similar (BW ≥ 4000g: β=1.22; 95% CI = 0.01-2.45; p<0.05)/. Linear Regression.	One question did not apply to study Maximum score: 20 **Attributed score: 15**
Goldani et al.20/ Brazil / 2007	Prospective cohort	1189 boys at birth and at 18 years	BMI as a continuous variable	Mean BMI at 18 years	Perinatal variables, among which, BW (<2500, 2500-2999, 3000-3499, 3500-3999, ≥4000 g)	BW associated linearly and proportionally to BMI at 18 years, in bivariate analysis (BW ≥ 4000g and mean BMI =23.63: β=1.37; 95% CI = 0.22-2.53). After adjusting for socioeconomic and biological factors, the association remained similar (BW ≥ 4000g: β=1.22; 95% CI = 0.01-2.45; p<0.05)/. Linear Regression.	One question did not apply to study Maximum score: 20 **Attributed score: 15**
Moraes et al. 23/ México / 2006	Cross-sectional	700 children and adolescents from 5-13 years	Overweight and obesity According to BMI of Cole et al. (2000)	Overweight and obesity	22 variables, among which, BW in tertiles	Schoolchildren with BW ≥ 2890 grams and ≥ 3110 g had a higher odds ratio for overweight and obesity (OR = 2.85; 95% CI = 1.49-5.47 and OR = 7.03; 95% CI = 3.53-13.99, respectively). / Multivariate logistic regression and Confidence Intervals.	Five questions did not apply to study Maximum score: 16 **Attributed score: 16**

Chart 2 *-continuation*

Dutra et al. 22/ Brazil /2006	Cross-sectional	810 adolescents between 10-19 years	BMI ≥ percentile 85 of Must et al. (1991)	Overweight	BW <2500g, between 2500 and 3999 g and >4000g	PR for overweight was proportional to BW, but the differences were not significant (BW <2500g: dummy, between 2500 and 3999 g: RP= 1.74; 95% CI = 0.85-3.58; and >4000g: RP = 2.17; 95% CI = 0.92-5.13; p = 0.06)./ Wald Test and Multivariate Poisson Regression.	Four questions did not apply to study Maximum score: 17 **Attributed score: 17**
Monteiro et al. 7/ Brazil / 2003	Cross-sectional nestled cohort	1014 adolescents from 14-16 years	BMI ≥ percentile 85 (Must et al. 1991) for overweight and overweight + skin folds > percentile 90 (Johnson et al. 1991) for obesity	Overweight and obesity	BW (<2500, 2500–3999 and ≥4000g), BW/ Gestational age, catch-up weight growth and catch-up height growth	PR for outcomes in newborns≥4000g were higher, but the differences were not significant (PR= 2.05; 95% CI=0.83-5.08; p=0.047 for overweight; and PR=2.39; 95% CI=0.51-11.22; p=0.173 for obesity). The same occurred for the association between BW/ Gestational Age and overweight and obesity. There was an association between catch-up weight growth and overweight and obesity, and between catch-up height growth and overweight. / Multivariate Poisson Regression and CI.	Only one inappropriateness was found in the article Maximum score: 21 **Attributed score: 20**
Stettler et al. 8/ Seychelles Isles / 2002	Cross-sectional	5514 children and adolescents from 4-17 years	Overweight and obesity according to BMI of Cole et al. (2000) and Height/ Age z-scores	Overweight and obesity	BW and weight gain rate in the 1st year (catch-up weight growth), in kilogram quartiles	BW was associated with outcomes in univariate analysis (OR=1.47; 95%CI= 1.23–1.76; p<0.001-overweight; OR=1.94; 95%CI=1.43–2.62; p<0.001 - obesity). Catch-up in the 1st year of life was associated with overweight and obesity, regardless of BW (OR=1.46; 95%CI=1.27–1.67; p<0.001-overweight and OR=1.59; 95% CI=1.29–1.97; p<0.001 - obesity). / Multivariate logistic regression and CI.	Four questions did not apply to study Maximum score: 17 **Attributed score: 17**

Legend: BMI = Body Mass Index; BW = birth weight; g = grams; NB = newborn; LBW = low birth weight; GA = gestational age; OR = odds ratio; CI = Confidence Interval; PR = Prevalence Ratio.

lower weights in comparison with girls in the same condition.

Among the 7 articles assessed, in 4 (57.2%) there was a significant association between BW and overweight or obesity, in that the score attributed to these articles was very near to the maximum score they could reach. Among the 4 articles, 3 had association of higher weights with outcomes, and one had results related to the association of LBW with low weight. Moreover, in 3 articles there was association of catch-up growth and high growth rate in the first year of life and overweight/obesity. The remaining 3 studies (42.8%) did not identify significant association of BW with overweight/obesity.

Discussion

Based on the analysis of studies of the present revision, it is possible to observe that birth weight has currently become an important theme to Public Health, due to evidence of a possible association to the phenomenon of obesity in childhood and in adolescence.

In brief, of the 14 articles analyzed, in 5 (35.7%) the authors perceived results pointing out that higher birth weights were associated with higher BMI, percentage of fat or overweight/obesity. Of these studies, 3 were performed in developed countries of North America and Europe, in which an increase in HBW rates is being observed, probably due to the occurrence of mother obesity and gestational diabetes, which were also factors associated with overweight and obesity in children and adolescents. Among the 14 studies, 3 identified association between birth weight and overweight/obesity only in analyses not adjusted for confounding factors, indicating multivariate analyses as essential in the associations for the outcomes overweight and obesity. The association between catch-up growth and overweight/obesity was observed in 4 studies, in that 3 were carried out in countries of ascending and middle HDI. Catch-up growth is characterized as fast growth in weight and/or height, compensatory and above normal growth standards for a specific age, which occurs during rehabilitation, resulting from a nutritional disease or deficiency[25,27]. Given situations of nutritional deficiency are more common in countries of lower human and economic development, there is a probable association between this fact and obesity in childhood in these countries, while in those more developed, the prevailing association is the one between high birth weight and obesity.

Only one article reported positive results for the association between lower birth weights and higher BMI in childhood. According to a review study performed by Barker[28], three main physiological mechanisms are mentioned in the literature as being mediators of the effects of LBW in the later development of obesity and even in other conditions. The first mechanism would be the change in the phenotype expression generated by the insufficient replication of cells, which seems to lead the body to store energy, as an adaptive response. A second mechanism would be the change generated in metabolism through hormone expression, highlighting an association between higher resistance to insulin and LBW. Another hypothesis still, would be that LBW predisposes individuals to be more vulnerable to environmental influences present in posterior phases of the life cycle. Sawaya[29] observed some evidence that recovery of LBW through catch-up growth results in higher reserves of fat mass and lower protein reserves in muscles. Singhal *et al.*[5] also identified that children born with low weight had less fat-free mass during childhood and adolescence. Power *et al.*[30], in turn, observed in children from 7-11 y born with Sub-Optimal Birth Weight, tended toward early sexual maturation when compared to children born with Optimal Birth Weight. Theses pieces of evidence seem to indicate that low birth weight does not influence the occurrence of overweight/obesity directly, but results in adaptation mechanisms of the body, such as catch-up growth and hormone variations, which could predispose individuals to develop overweight/obesity. That

is why the assumption of the association between low birth weight and obesity needs to be better studied, especially assessing the composition of the body in terms of fat-free mass and fat mass.

Still, on low birth weight, the assessment of birth weight by gestational age was identified as an important variable of interest in studies, as it can determine if newborns underwent of intra-uterine growth restriction (IUGR) or if the pre-term newborn had adequate uterine development in relation to gestational age.

In relation to the methodological quality of articles, those with a cross-sectional design had higher scores attributed to them. This may be explained because this kind of study is of easier operation and also by the scale utilized, which was developed specifically for cohort and intervention studies. As a reason for lower scores in cohort studies, susceptibility of sample loss is mentioned and, for this reason, there is a methodological need to compare characteristics of subjects not assessed to those who remain in the study, and stricter in the item external validation.

It is worth pointing out that different reference populations were used to identify the prevalence of overweight and obesity among children and adolescents studied, and there was a significant variability in the classification of birth weight. This difference among methods made it difficult to compare studies, and possibly changed the strength of the association between variables of interest in each study, because different BMI classifications interfere in the prevalence of outcome. Even in a same population, if different criteria for diagnosing overweight and obesity are used, distinct data can be generated[31, 32] and, that is why it should be pointed out that a more extensive review, utilizing articles with the same diagnostic criteria, would lead to more consistent results on the association of interest.

Final Considerations

High birth weight appeared associated with overweight/obesity in most articles that reported association of birth weight with overweight/obesity. The need to develop more studies that assess the association between low birth weight and overweight/obesity should be underscored, given the number of articles that verified association with nutritional status were scarce. In relation to studies by level of development of countries, the authors observed that in those with high HDI, the relationship between high birth weight and overweight/obesity was more evident than in the remaining countries; and in developing countries (high, but ascending HDI and middle HDI) catch-up growth was associated with overweight/obesity.

Therefore, it is suggested that as a preventive measure, due care be taken during the gestational period to avoid the occurrence of obesity and diabetes, because both factors can cause newborns to have high birth weight, which in turn, stands out currently as a variable associated with overweight and obesity in childhood and in adolescence. Another measure would be the prevention of nutritional deficiencies that lead to slow intra-uterine growth and weight loss, which could lead to catch-up growth.

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