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Birth weight, current body mass index, and insulin sensitivity and secretion in young adults in two Latin American populations

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KEYWORDS
Insulin sensitivity;
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Birth weight;
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Abstract *Background and aims:* Although studies have shown association of birth weight (BW) and adult body mass index (BMI) with insulin sensitivity in adults, there is limited evidence that BW is associated with insulin secretion. We assessed the associations between BW and current BMI with insulin sensitivity and secretion in young Latin American adults.
Methods and results: Two birth cohorts, one from Ribeirao Preto, Brazil, based on 1984 participants aged 23–25 years, and another from Limache, Chile, based on 965 participants aged 22–28 years were studied. Weight and height at birth, and current fasting plasma glucose and insulin levels were measured. Insulin sensitivity (HOMA%S) and secretion (HOMA%β) were estimated using the Homeostatic Model Assessment (HOMA2). Multiple linear regression analyses were carried out to test the associations between BW and adult BMI z-scores on log HOMA%S and log HOMA%β. BW z-score was associated with HOMA%S in the two populations and HOMA%β in Ribeirao Preto when adult BMI z-score was included in the model. BW z-score was associated with decreasing insulin secretion even without adjusting for adult BMI, but only in Ribeirao Preto. BMI z-score was associated with low HOMA%S and high HOMA%β. No interactions between BW and BMI z-scores on insulin sensitivity were shown.
Conclusions: This study supports the finding that BW may affect insulin sensitivity and secretion in young adults. The effect size of BW on insulin status is small in comparison to current BMI.

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Introduction

Several studies have reported a negative association between birth weight (BW) and glucose intolerance or insulin resistance in adults [1–3]. Studies have also shown that such an association is amplified by later catch up of body mass index (BMI) [4–6]. There is also a well known positive association between BMI and glucose intolerance or insulin resistance [6,7]. It has been noted that, among those who had low BW, high risk of insulin resistance has been observed only in those who experienced catch up growth [8,9]. However, some studies have reported that current adult BMI is associated with insulin resistance regardless of BW and postnatal growth [10,11]. Studies have also assessed the effect of these factors on insulin secretion but results are not consistent [1,5,12,13].

There has been some controversy too as to whether the association between birth weight and insulin resistance is linear [1,2], as it was the case in a Pima Indian population [14].

There is limited information as to whether there is an association between prenatal growth and sensitivity/resistance to insulin in young adults, as the majority of the studies have looked at this association in the over 50 year olds [1,15]. However, it would be important to establish whether the association has already been established in childhood [2,6,16] or young adulthood as some have suggested [4,5]. Studies performed in children and young adults have used Homeostasis Model Assessment (HOMA) to estimate insulin resistance because diabetes prevalence is low at these ages[17]. The use of an updated computer HOMA2 model which estimates insulin sensitivity (HOMA%S), the opposite of insulin resistance, and insulin secretion (HOMA%β) has been recommended recently [18].

In this study we assessed the association between BW and current BMI with HOMA%S and HOMA%β using data from two cohort studies in which insulin status was assessed when the participants were in their mid twenties in Ribeirao Preto, Southeast Brazil, and Limache, Chile.

Methods

Study subjects

Ribeirao Preto is a wealthy urban area of Brazil. As many as 9067 newborn babies corresponding to 98% of the total births in the city were evaluated soon after delivery from June 1, 1978 to May 31, 1979. In the follow-up survey, twin deliveries (146) and babies whose mothers did not live in this city at the time of delivery (2094) were excluded from the study. Of the 6827 singletons, 343 had died by 20 years of age. One in 3 of the remaining 6484 individuals were selected for evaluation at age 23–25 years. Losses (705) occurred because of refusal to participate, imprisonment, death after 20 years of age, and failure to attend for interview. Losses were replaced using the same sampling frame[19,20]. After exclusion of cases with missing values, 1984 subjects were included in the analysis.

The Chilean study was carried out in Limache, a semi rural area. The sampling frame was 3096 singleton live-births occurring in Limache between 1974 and 1978, as recorded in the local hospital register of births. From the entire sampling frame, 995 individuals were randomly selected for the study and their measurements at birth collected. 21.6% individuals who emigrated from the city, refused to participate in the study, were serving a custodial sentence or had a mental disability were replaced, using the same sampling frame. These subjects were contacted and studied from 2001 to 2003 when aged 22–28 years. 30 subjects with missing data on variables of interest to this study were excluded from the analysis, thus leaving 965 participants for the analysis.

Data collection

In both cities information on neonatal variables was collected using the same questionnaire. In Ribeirao Preto, trained nutritionists, physiotherapists, doctors and nurses measured weight and length at birth. In Limache, these measurements were taken by trained university nurses and extracted from the maternity records. Measurements were taken following the established Chilean National Health Service norms, which have remained unchanged throughout the study. In both settings newborns were weighed without clothes immediately after birth, in scales calibrated periodically with an accuracy of 10 g. Height was measured in barefoot subjects to the last complete millimeter and weight was measured using beam weighing scales which were calibrated periodically. Subjects were wearing underwear only. BMI was estimated as the ratio of body weight to height squared and expressed as kg/m^2.

A doctor or nursing technician collected a blood sample after a fast of at least 12 h. In both Ribeirao Preto and Limache an enzymatic colorimetric method (GOD/PAP, Human diagnostic, Germany) with a coefficient of variation of 4.2% was used to record blood glucose levels. Insulin was determined by radioimmunoassay (Insulin kit, DPC, Los Angeles, USA) with a coefficient of variation of 7.9%.

Fasting plasma insulin and fasting plasma glucose data were used to estimate insulin resistance using the original Homeostatic Model Assessment (HOMA1-insulin resistance = fasting plasma glucose × fasting plasma insulin/22.5), and to estimate insulin sensitivity (HOMA%S, the opposite of insulin resistance) and insulin secretor activity as β-cell function (HOMA%β) using the HOMA computer model as an approximated linear solution (HOMA2 model, available from http://www.dtu.ox.ac.uk/index.php?maindoc=/homa/). This model takes into account variations in hepatic and peripheral glucose resistance, increases in the insulin secretion curve for plasma glucose concentrations above 10 mmol/L (180 mg/dL) and the contribution of circulating proinsulin[18].

The Chilean project was approved by the Ethics Committee of the Faculty of Medicine, University of Chile, and the Brazilian study by the University of Sao Paulo in Brazil. Participants were asked to sign a consent form after reading or listening to explanatory notes about the study. All participants signed a consent form.

Statistical analyses

HOMA2%S and HOMA2%β were log transformed before regression analysis as they were not normally distributed

and were standardized separately by country. BW and BMI z-scores (standard deviation scores) were used as continuous variables in the analysis. Sex and gestational age adjusted BW z-scores were derived separately for each location using the Canadian reference[21]. Adult BMI z-score was calculated subtracting the subject's BMI from the average BMI of each location and then divided by the BMI standard deviation of each location.

The analyses were carried out independently for each city because insulin levels were substantially higher in Limache than in Ribeirao Preto. Models were not stratified by sex because interactions involving gender were non-significant in either study.

Four multiple linear regression analyses were carried out to disentangle the effect of early and adult life factors on insulin sensitivity and secretion, following the recommendation of Lucas and colleagues [22]. The early model included BW z-score only while the late model included adult BMI z-score only. The combined model included both BW and adult BMI z-scores. The fourth model assessed an interaction between BW and adult BMI z-scores on the outcomes of interest. A squared power term for BW z-score was also included in some models to test for possible non-linear effects. All models were repeated with adjustment for gender, age (years), full time education ($\leq$8, 9–11 and $\geq$12 years), smoking status (current smokers were those who smoked at least 1 cigarette a day in the last month), alcohol consumption (excessive if ethyl alcohol >31 g/day), preterm birth (gestational age <37 weeks based on the last normal menstrual period as informed by the mother), and maternal years of full time education at the time of the child's birth ($\leq$8, 9–11 and $\geq$12 years). Residual analysis indicated that the models fitted the data well.

Models excluding preterm births (n = 135 in RP and n = 110 in Chile) were also estimated.

Results

The Limache sample had higher BMI, especially in women, higher plasma glucose and insulin, and lower HOMA%S and higher HOMA%β than the Ribeirao Preto sample. The insulin levels were substantially higher in the Limache sample. In Ribeirao Preto, males showed higher BMI, plasma glucose and insulin, and lower HOMA%S and HOMA%β than females. In Limache, males had higher plasma glucose levels and lower insulin secretion than women (Table 1).

In the unadjusted model, BW z-score was not associated with HOMA%S in either of the two cities (Tables 2 and 3). BMI z-score was associated with decreased insulin sensitivity in the two studies. In the combined model, which included BW and BMI z-scores as independent variables, a positive association emerged between BW z-score and HOMA%S. Effect sizes were higher for BMI z-score (−0.47 for Ribeirao Preto and −0.49 for Limache) than for BW z-score (0.07 for both places). Thus, for each standard deviation increase in BW there is a decrease of −0.47 standard deviations in log HOMA%S in Ribeirao Preto and −0.49 in Limache. No interaction between BW and BMI z-scores on insulin sensitivity was detected. Adjustment did not change estimates appreciably (Tables 2 and 3).

As in the HOMA%S analysis, BW z-score was associated with HOMA%β in the combined analysis in the Brazilian

Table 1 Birth weight, gestational age, adult body mass index (BMI), fasting plasma glucose and insulin concentrations, insulin resistance and sensitivity, and measure of β-cell function, of young adults by gender, Ribeirao Preto, Brazil, 2002/04, and Limache, Chile, 2001/03.

	Ribeirao Preto, Brazil [a]		Limache, Chile	
	Men	Women	Men	Women
N	967	1017	422	543
Birth weight (kg)	3.4 (2.5; 4.2)[e]	3.2 (2.4; 4.0)	3.2 (2.4; 4.0)[f]	3.2 (2.3; 4.0)
Birth weight z-score	−0.22 (−1.83; 1.38)[f]	−0.31 (−1.90; 1.39)	−0.35 (−1.76; 1,37)[f]	−0.35 (−1.73; 1,41)
Gestational age	39 (36; 41)[d]	39 (36; 42)	39 (35; 42)[f]	39 (35; 42)
Adult body mass index (kg/m^2)	24.4 (19.0; 33.5)[e]	22.5 (17.9; 34.4)	24.8 (20.5; 31.9)[f]	25.1 (19.8; 35.8)
Adult body mass index z-score	0.02 (−1.09; 1.90)[e]	−0.37 (−1.32; −2.09)	−0.23 (−1.19; 1.36)[d]	−0.15 (−1.34; 2.26)
Plasma glucose (mg/dl)	86.0 (72.0; 100.0)[e]	80.0 (69.0; 94.0)	87.8 (73.8; 101.7)[e]	83.7 (69.8; 98.8)
Plasma insulin (mU/l)	6.0 (1.0; 20.0)[d]	5.1 (0.9; 17.4)	10.0 (6.6; 22.0)[f]	10.2 (6.1; 22.3)
HOMA1-IR[b]	1.3 (0.2; 4.4)[e]	1.1 (0.2; 3.7)	2.2 (1.3; 4.9)[f]	2.1 (1.2; 5.0)
HOMA2-IR[c]	0.8 (0.1; 2.5)[d]	0.7 (0.1; 2.2)	1.3 (0.8; 2.8)[f]	1.3 (0.8; 2.7)
HOMA2-%β[c]	87.4 (30.8; 194.6)[d]	92.4 (33.3; 193.5)	123.5 (82.1; 201.1)[e]	134.5 (90.4; 229.1)
HOMA2-%S[c]	131.5 (40.0; 750.9)[e]	151.7 (45.7; 782.0)	78.8 (35.9; 118.7)[f]	77.6 (36.7; 128.8)

Values are median (p5; p95).

[a] All differences comparing genders between settings were statistically significant ($p < 0.001$), except that mean birth weight was not different comparing women from Ribeirao Preto, Brazil with Limache, Chile ($p = 0.077$) and birth weight z-score was not different comparing men and women from Ribeirao Preto, Brazil with Limache, Chile ($P > 0.10$).

[b] HOMA1-IR = Fasting plasma glucose (mmol/l) × Fasting plasma insulin (mU/l)/22,5.

[c] Calculated using the HOMA (Homeostasis Model Assessment) computer model available from http://www.dtu.ox.ac.uk/index.php?maindoc=/homa/.

[d] $P < 0.01$ men compared to women in each setting.

[e] $P < 0.001$ men compared to women in each setting.

[f] not significant.

Table 2 Multiple linear regression models for insulin sensitivity (log HOMA2-%S) of young adults by birth weight (BW) and body mass index (BMI) z-scores. Ribeirao Preto, Brazil, 2002/04.

Models	Not adjusted		Adjusted [a]	
	Standardized coefficient (95% CI)	*P* value	Standardized coefficient (95% CI)	*P* value
Early model[b]				
Birth weight z-score	0.03 (−0.01; 0.08)	0.125	0.04 (−0.01; 0.09)	0.05
Late model[c]				
Adult BMI z-score	−0.47 (−0.51; −0.43)	<0.001	−0.48 (−0.52; −0.44)	<0.001
Combined model[d]				
Birth weight z-score	0.07 (0.03; 0.11)	0.001	0.08 (0.05; 0.12)	<0.001
Adult BMI z-score	−0.48 (−0.52; −0.44)	<0.001	−0.49 (−0.53; −0.45)	<0.001
Interaction model[e]				
Birth weight z-score	0.07 (0.03; 0.11)	0.001	0.08 (0.04; 0.12)	0.809
Adult BMI z-score	−0.47 (−0.51; −0.43)	<0.001	−0.48 (−0.52; −0.44)	<0.001
Interaction term	0.02 (−0.02; 0.06)	0.342	0.02 (−0.02; 0.06)	0.272

[a] Adjusted for gender, age, schooling, smoking habit, alcohol consumption, preterm birth and maternal schooling at the time of the child's birth.
[b] Early model: included BW z-score only.
[c] Late model: included adult BMI z-score only.
[d] Combined model: adjusted for BW and adult BMI z-scores.
[e] Interaction model: interaction term between BW and adult BMI z-scores added to the combined model.

sample, but not in the Chilean sample (Tables 4 and 5). In the Brazilian sample, BW z-score was associated with decreased insulin secretion in the early adjusted model even without adjustment for BMI z-score. The size effect for BMI in Brazil (z-score = 0.41) was slightly stronger than in Chile (SDS = 0.33) in the adjusted models, while BW z-score in Brazil was −0.08 in the adjusted analysis. No interaction between BW and BMI z-scores on insulin secretion was detected (Tables 4 and 5).

A squared term for BW z-score was not significant in any of the analyses (data not shown).

Analysis excluding preterm deliveries was carried out and showed similar results (data available on request from the authors).

Table 3 Multiple linear regression models for insulin sensitivity (log HOMA2-%S) of young adults by birth weight (BW) and body mass index (BMI) z-scores. Limache, Chile, 2001/03.

Models	Not adjusted		Adjusted [a]	
	Standardized coefficient (95% CI)	*P* value	Standardized coefficient (95% CI)	*P* value
Early model[b]				
Birth weight z-score	0.04 (−0.02; 0.11)	0.181	0.04 (−0.02; 0.10)	0.228
Late model[c]				
Adult BMI z-score	−0.49 (−0.55; −0.44)	< 0.001	−0.50 (−0.57; −0.44)	< 0.001
Combined model[d]				
Birth weight z-score	0.07 (0.01; 0.12)	0.014	0.06 (0.01; 0.12)	0.033
Adult BMI z-score	−0.50 (−0.56; −0.45)	< 0.001	−0.51 (−0.56; −0.45)	<0.001
Interaction model[e]				
Birth weight z-score	0.07 (0.01; 0.12)	0.015	0.06 (0.01; 0.12)	0.035
Adult BMI z-score	−0.50 (−0.56; −0.44)	<0.001	−0.51 (−0.57; −0.45)	<0.001
Interaction term	−0.01 (−0.06; 0.06)	0.919	−0.01 (−0.06; 0.06)	0.976

[a] Adjusted for gender, age, schooling, smoking habit, alcohol consumption, preterm birth and maternal schooling at the time of the child's birth.
[b] Early model: included BW z-score only.
[c] Late model: included adult BMI z-score only.
[d] Combined model: adjusted for BW and adult BMI z-scores.
[e] Interaction model: interaction term between BW and adult BMI z-scores added to the combined model.

Table 4 Multiple linear regression models for insulin secretion (log HOMA2-%β) of young adults by birth weight (BW) and body mass index (BMI) z-scores. Ribeirao Preto, Brazil, 2002/04.

Models	Not adjusted		Adjusted[a]	
	Standardized coefficient (95% CI)	*P* value	Standardized coefficient (95% CI)	*P* value
Early model[b]				
Birth weight z-score	−0.04 (−0.08; 0.01)	0.089	−0.05 (−0.09; −0.01)	0.042
Late model[c]				
Adult BMI z-score	0.38 (0.34; 0.42)	<0.001	0.41 (0.37; 0.45)	<0.001
Combined model[d]				
Birth weight z-score	−0.07 (−0.11; −0.03)	0.002	−0.08 (−0.12; −0.04)	< 0.001
Adult BMI z-score	0.39 (0.34; 0.43)	<0.001	0.41 (0.37; 0.45)	<0.001
Interaction model[e]				
Birth weight z-score	−0.07 (−0.11; −0.02)	0.002	−0.08 (−0.12; −0.04)	< 0.001
Adult BMI z-score	0.38 (0.34; 0.42)	<0.001	0.41 (0.37; 0.45)	<0.001
Interaction term	−0.01 (−0.05; 0.03)	0.609	−0.02 (−0.05; 0.02)	0.406

[a] Adjusted for gender, age, schooling, smoking habit, alcohol consumption, preterm birth and maternal schooling at the time of the child's birth.
[b] Early model: included BW z-score only.
[c] Late model: included adult BMI z-score only.
[d] Combined model: adjusted for BW and adult BMI z-scores.
[e] Interaction model: interaction term between BW and adult BMI z-scores added to the combined model.

Discussion

The main findings of this study were that in the combined analysis BMI and BW z-scores were independently associated with HOMA%S in the two populations, and HOMA%β in Ribeirao Preto only. Current BMI z-score was associated with HOMA%S and HOMA%β, in each model, in the two populations. The effect sizes of the associations were stronger for current BMI z-score than BW z-score in the two cohorts. BW z-score was associated with HOMA%S in both studies and HOMA%β in Ribeirao Preto when BMI z-score was included in the model. Furthermore, in the adjusted model

Table 5 Multiple linear regression models for insulin secretion (log HOMA2-%β) of young adults by birth weight (BW) z-score and body mass index (BMI). Limache, Chile, 2001/03.

Models	Not adjusted		Adjusted [a]	
	Standardized coefficient (95% CI)	*P* value	Standardized coefficient (95% CI)	*P* value
Early model[b]				
Birth weight z-score	0.03 (−0.03; 0.09)	0.341	0.03 (−0.03; 0.09)	0.366
Late model[c]				
Adult BMI z-score	0.34 (0.28; 0.40)	<0.001	0.33 (0.27; 0.39)	<0.001
Combined model[d]				
Birth weight z-score	0.01 (−0.05; 0.07)	0.667	0.02 (−0.04; 0.08)	0.608
Adult BMI z-score	0.34 (0.28; 0.40)	<0.001	0.33 (0.27; 0.39)	<0.001
Interaction model[e]				
Birth weight z-score	0.01 (−0.05; 0.07)	0.827	0.01 (−0.05; 0.07)	0.767
Adult BMI z-score	0.33 (0.26; 0.39)	<0.001	0.31 (0.25; 0.37)	<0.001
Interaction term	−0.05 (−0.11; 0.01)	0.117	−0.06 (−0.12; 0.01)	0.087

[a] Adjusted for gender, age, schooling, smoking habit, alcohol consumption, preterm birth and maternal schooling at the time of the child's birth.
[b] Early model: included BW z-score only.
[c] Late model: included adult BMI z-score only.
[d] Combined model: adjusted for BW and adult BMI z-scores.
[e] Interaction model: interaction term between BW and adult BMI z-scores added to the combined model.

BW z-score was associated with HOMA%β in Ribeirao Preto only, even without adjustment for BMI z-score.

Interpretation of the findings

Lower HOMA%S and higher HOMA%β was observed in Limache than in Ribeirao Preto, consistent with a previous report[23]. These differences may be due in part to differences in the prevalence of overweight and obesity which were higher in Limache than in Ribeirao Preto (34.3% were overweight in Limache compared to 23.9% in Ribeirao Preto, and 15.5% were obese in Limache versus 12.0% in Ribeirao Preto), differences in total caloric intake (2963 kcal/day in Limache and 2121 kcal/day in Ribeirao Preto), physical inactivity (38.3% in Limache and 33.2% in Ribeirao Preto) and smoking (56.4% in Limache and 17.2% in Ribeirao Preto) [24].

Our study confirms that BMI is a powerful determinant of HOMA%S and HOMA%β, as others have shown [4,7,10]. Our study demonstrates that the association of BMI z-score with low HOMA%S and high HOMA%β may correspond to an increase of HOMA%β which compensates for the low HOMA% S. Previous studies have reported that the effect of BMI on insulin resistance is more consistent and of higher effect size than BW [10,14], as also shown in our study. Results from a study using an animal model have shown that decreased fetal size is associated with beta-cell hyperfunction in early life, which is consistent with our findings [13]. It is expected that as these cohorts become older, the compensatory increase in HOMA%β will probably decrease [13]. Thus low HOMA%β could be an early warning of diabetes mellitus in a not too distant future in our population of young adults. It is expected that in Limache the burden of diabetes will be higher than in Ribeirao Preto, as HOMA%S is low and HOMA%β is high in Limache [25].

Some of our results support the fetal origin hypothesis of insulin sensitivity/resistance, as some other studies have previously shown [7,22]. Perhaps the most interesting finding of our study was to demonstrate that the effect of BW cannot be considered without reference to current BMI. In the model which included only BW z-score there was no association between this variable, and HOMA%S and HOMA% β, except in the adjusted model for insulin secretion in Ribeirao Preto. The findings in the Limache study are less consistent: an association between BW z-score was found for HOMA%S but not for HOMA%β, but only when BMI z-score was included in the analysis.

There is some evidence that weight gain in postnatal life is associated with insulin resistance [4,6,7]. The role of weight gain on insulin status was not evident in our study because the coefficients of BMI z-score in relation to insulin status were very similar in the late model (without BW z-score) and the combined model (with BW z-score).

Effects sizes of BMI on insulin sensitivity were high (−0.48 SDS in RP and −0.50 in Limache), in agreement with previous findings[26]. Although there were important differences in risk factors for diabetes between the two settings, estimates suggest that effect sizes of BMI on HOMA%S were the same in Limache and Ribeirao Preto. Although most studies have shown an effect of BW on HOMA%S, this observation is not unanimous[27]. Gupta et al. found higher insulin resistance among Indian low BW children [28] whereas in the UK no association was observed in children[10,11]. Evidence that BW affects HOMA%β is inconclusive[12]. There are reports that low BW was associated with elevated HOMA%β [5], whereas others did not found an association[1,2,26]. In our study BW z-score was associated with HOMA%β before and after adjustment for current BMI z-score, but only in Ribeirao Preto. There was no suggestion of a non-linear association between BW and either insulin resistance or secretion in our study, as has been previously suggested [14,29].

Strengths and weaknesses

The strengths of this study are that it is based on two large randomly selected populations, with a high participation rate, in two countries of intermediate industrial development. Our analysis contrasts two populations facing nutritional transition with different characteristics regarding obesity, smoking, physical activity and caloric intake. Inspite of these marked contrasts in life style between Ribeirao Preto and Limache, the results were consistent regarding the associations with insulin status. The updated version of the HOMA model used had the advantage that it has been shown to be highly correlated with the euglycaemic clamp [18]. Simultaneous evaluation of HOMA%S and HOMA%β was performed, leading to a better understanding of the effects of BW and BMI z-scores on these phenomena in young subjects [18]. We used the sequence of regression models proposed by Lucas et al. [22] to test the fetal origins of adult diseases to provide an overall picture of the relative effect of BW and BMI z-scores on insulin status.

The weaknesses of our study are the length of time between the initial and second assessment (birth and young adult age), which limited our ability to apply several conditional weight gain periods to our analysis. A sobering aspect of our study was the high infant mortality in the two populations (infant mortality was 35.8 per 1000 livebirths in the Ribeirao Preto birth cohort [30] and 57.6 per 1000 livebirths in Chile in 1975 [31]) which contributed to the attrition rate in the study of Ribeirao Preto and decreased the sampling frame of the Limache study. Although some differences between those traced and lost to follow up were statistically significant absolute differences were small (data not shown).

In conclusion, our study confirms the powerful effect of BMI on HOMA%S and HOMA%β in the two populations. It provided support to the programming hypothesis, as BW was associated with insulin sensitivity in the two populations when BMI was included in the model, and with insulin secretion in Ribeirao Preto before and after adjustment for BMI. However, the effect size of BW on HOMA%S is markedly smaller than that of BMI.

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