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Association between prepregnancy obesity and metabolic risk in Chilean premenopausal women 10 y postpartum

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ABSTRACT

Objectives: One of every four pregnant women in Chile is obese. Gestational obesity is associated with maternal metabolic complications in pregnancy (e.g., gestational diabetes, preeclampsia), but to our knowledge, there is little evidence on relationships with future metabolic risk. The aim of this study was to evaluate the association between prepregnancy obesity (prepregnancy body mass index $\geq$30 kg/m^2) or excessive gestational weight gain (GWG; according to the 2009 recommendations from the Institute of Medicine), and maternal metabolic complications 10 y postpartum in premenopausal Chilean women.

Methods: A prospective study was conducted. In 2006, 1067 Chilean mothers of children born in 2002—participants of the GOCS (Growth and Obesity Cohort Study)—were recruited. Mothers completed a questionnaire concerning sociodemographic, anthropometric, and pregnancy characteristics. Of the sample, 402 women were randomly selected to participate in a study related to the determinants of breast cancer risk in 2012. At follow-up, anthropometry, blood pressure, and fasting labs were measured. Complete data was available for 366 women.

Results: Thirty-two percent of mothers had prepregnancy overweight/obesity and 39.1% had excessive GWG. In adjusted models, prepregnancy obesity was positively associated with increased insulin resistance (odds ratio [OR], 18; 95% confidence interval [CI], 5.2–62.7), metabolic syndrome (OR, 3.3; 95% CI, 1.3–8.3), and hyperglycemia (OR, 3; 95% CI, 1.1–8.6). Prepregnancy overweight/obesity was associated with increased risk for insulin resistance, metabolic syndrome, abdominal obesity, low high-density lipoprotein cholesterol, and hypertriglyceridemia ($P < 0.05$). Excessive GWG was not associated with metabolic risk in the main model but was found to be positively associated in models with correction of weight by possible recall bias.

Conclusions: Gestational obesity was associated with maternal metabolic alterations 10 y postpartum. Prevention strategies for chronic diseases should consider prepregnancy obesity as a modifiable risk factor for future metabolic health.

Introduction

Obesity is considered a worldwide epidemic. Every year, approximately 2.6 million people die as a result of excess weight, which disproportionally affects women [1,2]. In 2010, the Chilean Ministry of Health estimated that 31% of women between the ages of 15 and 44 y were overweight and 20% were obese [3]. Additionally, the prevalence of overweight/-obesity among pregnant women who are beneficiaries of the Chilean public health system reached 59% in 2013, with one of every four women considered obese [4]. Prepregnancy obesity (prepregnancy body mass index [BMI] $\geq$30 kg/m^2) or excessive gestational weight gain (GWG; above recommendations established by the Institute of Medicine [IOM]) [5] are the most important factors in Western societies related to perinatal outcomes as gestational diabetes, preeclampsia, or macrosomia [5–9].

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MLG and CZ designed the research, analyzed the data, and wrote the manuscript. The authors were final reviewers for scientific content and they all read and approved the final manuscript. The authors have no conflicts of interest to declare.

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Prepregnancy obesity and excessive GWG are independently and positively related to maternal retention of weight and fat postpartum and obesity in the short and long terms [10–14]. However, to our knowledge, few studies, all conducted in developed countries, have previously evaluated the relationship between prepregnancy obesity and excessive GWG and future metabolic risk beyond adiposity. One study showed that after 15 y, prepregnancy obesity was related to increased risk for type 2 diabetes, metabolic syndrome (MetS), heart disease, hypertension, and dyslipidemia [15]. This relationship could be explained because among pregnant women who are obese before pregnancy, fat preferentially deposits in central locations, which could be associated with future metabolic complications [16,17]. In relation to excessive GWG, three studies found no association with metabolic risk factors such as insulin resistance (IR), lipids, glucose, and MetS [13,15,18].

Thus, the objective of the present study was to evaluate in a Latin American country that has undergone a very rapid nutrition transition, the association between prepregnancy obesity or/and excessive GWG and maternal metabolic complications (hyperglycemia, dyslipidemia, IR, and MetS), 10 y postpartum in a sample of premenopausal Chilean women from low- and middle-income communities.

Materials and methods

Study design and participants

The present study is a prospective cohort of the mothers of participant children from the GOCS study. The objectives and methods of the GOCS study have been described elsewhere [19,20]. In brief, GOCS was an ambispective cohort started in 2006 of 1196 children born in 2002, who attended public daycare centers (JUNJI) in six neighborhoods in the southeast area of Santiago, Chile. Data on participating children were collected retrospectively from pregnancy to 2006 and then prospectively followed until puberty. The sample is representative of Chilean women living in Santiago who receive public medical care (low- and middle-income individuals, which represent 70% of the Chilean population). In 2012, 483 mothers of GOCS participants were invited to participate in the study DERCAM (Determinants of Breast Cancer) study, which evaluated risk factors for breast cancer. Of the 483 mothers, 402 mothers met inclusion criteria. Exclusion criteria included not having a recent mammogram and having incomplete data. For the present analysis, complete data for 366 women was available (Fig. 1).

Data collection and measurement

Data collection was conducted at two time points, in 2006 and 2012, 10 y postpartum. In 2006, as part of the GOCS study, mothers completed a retrospective survey, reporting sociodemographic characteristics (e.g., education, marital status, occupation) and pregnancy factors (e.g., prepregnancy weight, weight at end of pregnancy, gestational diabetes, preeclampsia, habits as smoking). Gestational age at birth (gestational weeks), birth size (cm), and birth weight (g) were obtained from medical records. In 2012, as part of DERCAM

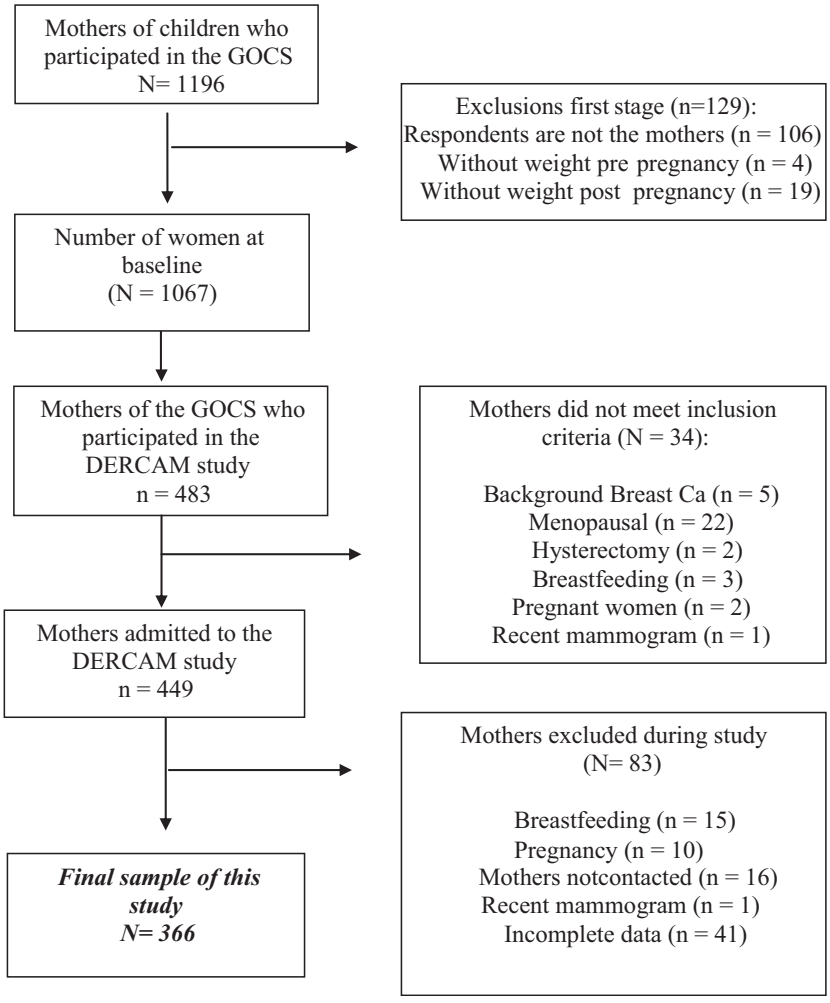

Fig. 1. Diagram of study flow. DERCAM, Determinants of Breast Cancer; GOCS, Growth and Obesity Study.

Table 1
Characterization of the participants of the study at baseline (N = 366), obtained from the participants of the GOCS and DERCAM studies (2006)

Variables	n (%)	Mean (SD)
Sociodemographic characteristics/maternal habits		
Age (y) at delivery		
15–19	48 (13.11)	
20–39	303 (82.79)	
40–44	15 (4.10)	
Education level at delivery		
Secondary/college	253 (69.13)	
Civil status at delivery		
Married/cohabitation	244 (66.85)	
Smoking during pregnancy	58 (15.85)	
Gynecologics–obstetrics		
Parity at delivery		
1	120 (32.79)	
>2	246 (67.21)	
Complications during pregnancy		
Gestational diabetes	20 (5.46)	
Hypertension/preeclampsia	37 (10.11)	
Others: urinary tract infection, lower respiratory tract infection, cholestasis intrahepatic, threatened preterm labor	70 (19.13)	
Maternal anthropometry		
Prepregnancy weight, kg		59.36 (10.96)
Prepregnancy height, cm		157.21 (5.27)
Prepregnancy BMI, kg/m^2*		24.02 (4.29)
Prepregnancy nutritional status		
Underweight	18 (4.92)	
Normal weight	230 (62.84)	
Overweight	86 (23.50)	
Obesity	32 (8.74)	
GWG, kg		
Overall		13.72 (7.92)
Prepregnancy underweight		16.67 (8.59)
Prepregnancy normal weight		13.91 (6.72)
Prepregnancy overweight		13.80 (9.61)
Prepregnancy obesity		10.53 (9.79)
Adherence to IOM 2009 guidelines for GWG†		
Low (under recommendations)		
Overall	111 (30.33)	
Prepregnancy underweight	4 (22.22)	
Prepregnancy normal weight	88 (38.26)	
Prepregnancy overweight	11 (12.79)	
Prepregnancy obesity	8 (25.00)	
Excessive (above recommendations)		
Overall	143 (39.07)	
Prepregnancy underweight	6 (33.33)	
Prepregnancy normal weight	67 (29.13)	
Prepregnancy overweight	46 (56.98)	
Prepregnancy obesity	21 (65.63)	
Newborn characteristics (n = 366)		
Birth weight, g		3349.27 (419.03)
Birth size, cm		49.64 (1.78)
Gestational age at birth, gestational wk		39.08 (1.17)

BMI, body mass index; DERCAM, Determinants of Breast Cancer; GOCS, Growth and Obesity Study; GWG, gestational weight gain; IOM/NRC, Institute of Medicine/National Research Council

* BMI classified according to criteria from the World Health Organization.

† Difference between the weight at delivery and the prepregnancy weight, categorized according to the recommendation of the IOM/NRC [5].

study, a questionnaire about sociodemographic, lifestyle and morbid characteristics, anthropometric measurements, blood pressure, and a fasting blood sample were carried out.

Predictor variable: Prepregnancy obesity and excessive GWG

Prepregnancy obesity was defined as prepregnancy BMI (weight [kg]/height [m]^2) ≥30 kg/m^2 [21]. GWG was calculated as the difference between prepregnancy and the last weight measured before delivery. GWG was classified as inadequate, adequate or excessive according to IOM/National Research Council 2009 recommendations (12.5–18 kg for underweight, 11.5–16 kg for normal weight, 7–11.5 kg for overweight, and 5–9 kg for obesity) [5].

Outcome variable: Metabolic risk 10 y postpartum

Outcome variables were factors associated with metabolic risk: abdominal obesity, hypertension, IR, hyperglycemia, dyslipidemia and MetS. At follow-up, anthropometry and blood pressure were measured and a fasting blood sample was provided. All measurements were conducted by personnel trained at CEDINTA, University of Chile. Weight was measured with a platform scale (SECA, Madison, WI, USA) with an accuracy of 100 g. Women were weighed standing, barefoot, and wearing underwear. Height was measured in duplicate using the measuring rod or stadiometer attached to the SECA scale with a precision 0.5 cm. Waist circumference was evaluated in duplicate using a SECA brand tape measure with a 0.1-cm precision. The midpoint between the last rib and the iliac crest was measured in women standing. Blood pressure was performed in triplicate

Table 2
Association between prepregnancy obesity and obesity/overweight, GWG,* and risk for MetS, 10 y postpartum (N = 366)

Predictor variables	Insulin resistance† (n = 26; 7.10%)	MetS‡ (n = 101; 27.60%)	Components of MetS				
			Abdominal obesity§ (n = 233; 63.66%)	Hyperglycemic‖ (n = 46; 12.57%)	Arterial pressure ≥130/85 mm Hg¶ (n = 55; 15.03%)	HDL <50 mg/dL# (n = 289; 78.96%)	TG ≥150 mg/dL** (n = 86; 23.50%)
Prepregnancy obesity, n (%)††							
Yes	11 (34.38)	20 (62.50)	31 (96.88)	9 (28.13)	11 (34.38)	28 (87.50)	12 (37.50)
No	15 (4.49)	81 (24.25)	202 (60.48)	37 (11.08)	44 (13.17)	261 (78.14)	74 (22.16)
P value‡‡	<0.001	<0.001	<0.001	0.005	0.001	0.215	0.050
Prepregnancy obesity/overweight, n (%)§§							
Yes	15 (12.71)	51 (43.22)	101 (85.59)	22 (18.64)	26 (22.03)	105 (88.98)	40 (33.90)
No	11 (4.44)	50 (20.16)	132 (53.23)	24 (9.68)	29 (11.69)	184 (74.19)	46 (18.55)
P value‡‡	0.004	<0.001	<0.001	0.016	0.010	0.001	0.001
Low gestational weight gain, n (%)‖‖							
Yes	6 (5.41)	27 (24.32)	61 (54.95)	14 (12.61)	17 (15.32)	89 (80.18)	25 (22.52)
No	20 (7.84)	74 (29.02)	172 (67.45)	32 (12.55)	38 (14.90)	200 (78.43)	61 (23.92)
P value‡‡	0.404	0.356	0.022	0.987	0.919	0.706	0.772
Appropriate gestational weight gain, n (%)‖‖							
Yes	6 (5.36)	24 (21.43)	68 (60.71)	12 (10.71)	20 (17.86)	82 (73.21)	19 (16.96)
No	20 (7.87)	77 (30.31)	165 (64.96)	34 (13.39)	35 (13.78)	207 (81.50)	67 (26.38)
P value	0.388	0.080	0.436	0.477	0.314	0.073	0.050
Excessive gestational weight gain, n (%)¶							
Yes	14 (9.79)	50 (34.97)	104 (72.73)	20 (13.99)	18 (12.59)	118 (82.52)	42 (29.37)
No	12 (5.38)	51 (22.87)	129 (57.85)	26 (11.66)	37 (16.59)	171 (76.68)	44 (19.73)
P value‡‡	0.109	0.012	0.004	0.512	0.296	0.181	0.034

AHA/NHLBI, American Heart Association/National Heart Lung and Blood Institute; ATP, Adult Treatment Panel; BMI, body mass index; DBP, diastolic blood pressure; GWG, gestational weight gain; HDL, high-density lipoprotein; HOMA-IR, homeostatic model assessment–insulin resistance; IOM, Institute of Medicine/National Research Council; MetS, metabolic syndrome; SBP, systolic blood pressure; TG, triacylglycerol

* GWG categorized according IOM/NRC [5].

† Insulin resistance defined as HOMA-IR ≥2.5; HOMA-IR calculated according formula proposed by Matthews [22].

‡ Presence of at least three of the five criteria, according to ATP III and AHA/NHLBI [23]: abdominal obesity (waist circumference ≥88 cm), fasting plasma glucose ≥100 mg/dL (or drug treatment for diabetes), blood pressure SBP ≥130/DBP ≥85 mm Hg (or antihypertensive drugs), HDL cholesterol <50 mg/dL (or drug treatment to increase HDL), TG ≥150 mg/dL (or drug treatment for hypertriglyceridemia).

§ Abdominal obesity defined as waist circumference ≥88 cm.

‖ Hyperglycemia defined as fasting plasma glucose >100 mg/dL or reported regularly taking medication to control diabetes.

¶ Having blood pressure SBP ≥130/DBP ≥85 mm Hg (or antihypertensive drugs).

Having HDL cholesterol <50 mg/dL or taking medication to increase HDL cholesterol.

** Having TG ≥150 mg/dL or taking drug treatment for hypertriglyceridemia.

†† Prepregnancy obesity, defined as having BMI ≥30 kg/m^2 before pregnancy.

‡‡ Prepregnancy overweight/obesity, defined as having BMI ≥25 kg/m^2 before pregnancy.

§§ Difference between the weight at delivery and the prepregnancy weight, categorized according to the IOM/NRC recommendation [5] and prepregnancy nutritional status.

‖‖ *P* value calculated with Student's *t* test for continuous variables and χ^2test for categorical variables.

using a digital automatic monitor (Omron 705 IT) on the right arm, with the edge of the sleeve 1 inch above the elbow after a 10-min rest, with no coffee or tobacco consumption 30 min before measurement. The blood sample was drawn after an 8-h fast in the first 5 to 7 d of the menstrual cycle (to prevent hormonal fluctuations). Twelve mL of venous blood were taken from each participant, and centrifuged. Aliquot plasma and serum was transferred to cryotubes and frozen at –80°C. Triacylglycerol (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), total cholesterol (TC), glucose, and insulin were measured. TG and TC were estimated by the colorimetric enzymatic method (HUMAN); HDL-C was isolated by precipitation with phosphotungstic acid and magnesium; glucose by the oxidase method and insulin was determined by radioimmunoassay.

Metabolic risk factors

IR was evaluated using the homeostatic model assessment (HOMA-IR): (fasting insulin [mU/mL] × fasting glucose [mg/dL])/405.

according to formula proposed by Matthews [22]. IR was defined as HOMA-IR ≥2.5.

Hyperglycemia was defined as fasting plasma glucose >100 mg/dL or reported regularly taking medication to control type 2 diabetes.

Dyslipidemia was defined as HDL-C <50 mg/dL, TG ≥150 mg/dL or both, or reported regularly taking medication to control dyslipidemia.

MetS was defined as the presence of at least three of the five criteria, according to National Cholesterol Education Program Adult Treatment Panel III (ATP III) and American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI) [23]:

1. Abdominal obesity (waist circumference ≥88 cm);
2. Fasting plasma glucose ≥100 mg/dL (or drug treatment for diabetes);
3. Systolic blood pressure (SBP) ≥130/diastolic blood pressure (DBP) ≥85 mm Hg (or antihypertensive drugs);
4. HDL-C <50 mg/dL (or drug treatment to increase HDL);
5. TG ≥150 mg/dL (or drug treatment for hypertriglyceridemia).

Statistical analysis

A descriptive analysis of the variables was performed using measures of central tendency (mean or median) and dispersion (SDs, ranges) for quantitative variables and frequency distribution for categorical variables. Differences between groups were tested by Student's *t* test and χ^2. To test the relationship between prepregnancy obesity and excessive GWG and metabolic risk 10 y postpartum (MetS, IR, hyperglycemia, dyslipidemia), we performed logistic regression models crude (model 1) and adjusted by covariates (model 2: adjusted by sociodemographic [maternal age, education and marital status at baseline, smoking during pregnancy]) and gyneco-obstetric characteristics (parity at baseline, maternal height, gestational age, gestational diabetes, hypertension, preeclampsia/eclampsia, and birth weight). Interaction between the two main predictor variables also was tested. Odds ratios (ORs) and 95% confidence intervals (CIs) are reported with $P < 0.05$ considered statistically significant. Stata 12.0 was used for all analyses.

Additionally, we conducted a sensitivity analysis to corroborate associations. Models were repeated eliminating women with extreme GWG and as well as those who reported preeclampsia during pregnancy or gestational

Table 3
Logistic regression models* between prepregnancy obesity and obesity/overweight, gestational weight gain (as categorized according IOM/NRC [5]), and metabolic risk 10 y postpartum

Predictor Variables	Insulin resistance†		MetS‡		Components of MetS‡	
					Abdominal obesity‡	
	Model 1§	Model 2§	Model 1§	Model 2§	Model 1§	Model 2§
Prepregnancy Obesity,‖ OR (95% CI)	11.14 (4.55–27.25)	18.00 (5.16–62.74)	5.20 (2.44–11.11)	3.29 (1.30–8.31)	20.25 (2.73–150.19)	–¶
Prepregnancy overweight/obesity,# OR (95% CI)	3.14 (1.39–7.06)	2.74 (1.01–7.44)	3.01 (1.87–4.86)	2.50 (1.37–4.55)	5.22 (2.95–9.24)	5.51 (2.78–0.94)
Low gestational weight gain,** OR (95% CI)	1.01 (0.31–3.23)	0.77 (0.20–2.92)	1.18 (0.63–2.20)	0.86 (0.39–1.87)	0.79 (0.46–1.34)	0.77 (0.41–1.44)
Appropriate gestational weight gain,** OR (95% CI)	Reference	Reference	Reference	Reference	Reference	Reference
Excessive gestational weight gain,** OR (95% CI)	1.92 (0.71–5.16)	1.69 (0.56–5.08)	1.97 (1.12–3.48)	1.86 (0.94–3.69)	1.72 (1.02–2.93)	1.49 (0.81–2.77)

AHA/NHLBI, American Heart Association/National Heart Lung and Blood Institute; ATP, Adult Treatment Panel; BMI, body mass index; CI, confidence interval; DBP, diastolic blood pressure; GWG, gestational weight gain; HDL, high-density lipoprotein; HOMA-IR, homeostatic model assessment–insulin resistance; IOM, Institute of Medicine/National Research Council; MetS, metabolic syndrome; OR, odds ratio; SBP, systolic blood pressure; TG, triacylglycerol

*Result obtained from logistic regression models, expressed in OR and 95% CI (in parenthesis).

†HOMA-IR ≥2.5; HOMA-IR was calculated according formula propose by Matthews [22].

‡Presence of at least three of the five criteria according to ATP III and AHA/NHLBI [23]: abdominal obesity or waist circumference ≥88 cm, fasting plasma glucose ≥100 mg/dL (or drug treatment for diabetes), SBP ≥130/DBP ≥85 mm Hg (or antihypertensive drugs), HDL cholesterol <50 mg/dL (or drug treatment to increase HDL), TG ≥150 mg/dL (or drug treatment for hypertriglyceridemia).

§Model 1: Crude data, not adjusted for covariates. Model 2: Adjusted by sociodemographic characteristics (maternal age at delivery, maternal education and marital status at baseline, smoking during pregnancy) and gynecologic and obstetrical characteristics (parity at baseline, maternal height, gestational age, birth weight of newborn, and complications during pregnancy [gestational diabetes, hypertension and preeclampsia/eclampsia]).

‖Obesity prepregnancy, defined BMI ≥30 kg/m^2 before pregnancy.

¶Model could not be assessed because it was not possible to separate the effect of prepregnancy obesity on future abdominal obesity (collinearity).

#Women with prepregnancy nutritional status of overweight/obesity (prepregnancy BMI ≥25 kg/m^2).

**Difference between the weight at delivery and the prepregnancy weight was categorized according to the IOM/NRC recommendation [5] and prepregnancy nutritional status.

diabetes. Models were repeated after application of correction factors to self-reported weights (pregnancy and postpartum) by nutritional status categories, suggested by Stommel and Schoenborn to diminish possible recall bias [24].

Ethical considerations

Approval for the GOCS and DERCAM studies were obtained from Ethics Committee at Institute of Nutrition and Food Technology (INTA), University of Chile. All participants signed written consent forms.

Results

The final sample consisted of 366 premenopausal women (Fig. 1). Participants included in this study were similar to those excluded (n = 830) with respect to age at delivery, smoking, GWG, parity, age, and anthropometric and metabolic variables ($P > 0.05$; data not shown). Women who were excluded differed from those included in educational level (elementary education: 39.8 versus 30%), child's birth weight (3412 versus 3349 g) and birth length (50.1 versus 49.6 cm; $P < 0.05$, data not shown).

At baseline (2002, Table 1), the average maternal age at child's birth was 27 y (standard deviation [SD] = 6.5), 31% had some elementary education, 84% did not smoke during pregnancy, parity was 2.2 children (SD = 1.3), and 69% of women experienced no complications during pregnancy.

Prepregnancy overweight/obesity was present in 32% of the sample; average GWG was 13.7 kg (SD = 7.9). Women with prepregnancy obesity gained less GWG compared with those who were normal weight prepregnancy (10.5 versus 13.9 kg; $P < 0.05$; Table 1). More than half (57%) of overweight women and 66% of those who were obese prepregnancy had excessive GWG. Of the 143 pregnant women who showed excessive GWG, 4.2% were underweight, 46.9% normal weight, 34.3% overweight, and 14.7% were obese before pregnancy.

At follow-up (2012), women had increased on average 10 kg in weight (1 kg/y), overweight increased from 27 to 39%, and the prevalence of obesity increased from 10 to 29% (data not shown). Of the women, 7% had IR, 28% MetS, 64% abdominal obesity, 13% hyperglycemia, 15% high blood pressure, 79% low HDL-C, and 23% hypertriglyceridemia.

Bivariate analysis showed that women who were either overweight/obese or obese before pregnancy had higher rates of IR, MetS, abdominal obesity, and hypertriglyceridemia than those who were normal weight ($P < 0.05$). Women with prepregnancy overweight/obese also had significantly higher rates of low HDL-C ($P < 0.05$). On the other hand, women with higher GWG had higher rates of MetS, abdominal obesity, and hypertriglyceridemia ($P < 0.05$; Table 2).

In multiple logistic regression models (Table 3), after adjusting for sociodemographic and obstetric covariates (model 2), prepregnancy obesity was associated with increased odds of IR (OR, 18; 95% CI, 5.2–62.7), MetS (OR, 3.3; 95% CI, 1.3–8.3), and hyperglycemia (OR, 3; 95% CI, 1.1–8.6). No significant association was found between prepregnancy obesity and high blood pressure, low HDL-C, or hypertriglyceridemia ($P > 0.05$). Prepregnancy overweight/obesity was associated with increased risk for IR, MetS, abdominal obesity, low HDL-C, and hypertriglyceridemia ($P < 0.05$). We found no significant associations between prepregnancy overweight/obesity, high blood pressure, and hyperglycemia ($P > 0.05$; Table 3). Excessive GWG was not significantly associated with any of the studied metabolic variables ($P > 0.05$; Table 3). Additionally, interactions between prepregnancy obesity and GWG were not significant in the analysis ($P > 0.05$, data not shown).

Table 3 *(Continued)*

Hyperglycemic‡		AP ≥130/85 mm Hg‡		HDL<50 mm Hg‡		TG ≥150 mg/dL‡	
Model 1§	Model 2 2§	Model 1§	Model 2§	Model 1§	Model 2§	Model 1§	Model 2§
3.14 (1.35–7.29)	3.00 (1.05–8.56)	3.45 (1.56–7.65)	1.71 (0.58–5.03)	1.95 (0.66–5.76)	1.70 (0.46–6.26)	2.10 (0.98–4.51)	1.32 (0.51–3.43)
2.13 (1.14–3.99)	3.91 (0.72–21.30)	2.13 (1.19–3.82)	1.30 (0.62–2.74)	2.80 (1.47–5.34)	3.22 (1.49–6.96)	2.25 (1.37–3.70)	1.99 (1.09–3.63)
1.20 (0.53–2.73)	1.10 (0.41–2.96)	0.83 (0.41–1.69)	0.60 (0.24–1.49)	1.10 (1.03–1.18)	1.17 (0.58–2.38)	1.42 (0.73–2.76)	0.22 (0.01–4.67)
Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
1.35 (0.63–2.90)	1.83 (0.74–4.49)	0.66 (0.33–1.32)	0.67 (0.29–1.55)	1.96 (0.66–5.76)	1.36 (0.68–2.71)	1.72 (1.02–2.93)	1.85 (0.93–3.68)

Sensitivity analysis confirmed our findings when models were reexamined, thus eliminating extreme gains in GWG (Supplement 1), eliminating cases of hypertension, preeclampsia, and gestational diabetes (Supplement 2). When prepregnancy and at-delivery weights were reclassified according to nutritional status categories, excessive GWG was associated with increased risk for IR, MetS, hyperglycemia, and hypertriglyceridemia ($P < 0.05$; Supplement 3).

Discussion

The present study demonstrated that in women from a Latin American country with a rapid nutrition transition, both prepregnancy overweight and obesity were associated with maternal metabolic risk 10 y postpartum. This relationship remained even after adjusting for sociodemographic and gyneco-obstetric characteristics. Rooney et al. also found that pregnant women with prepregnancy obesity had a ninefold greater risk for type 2 diabetes and a fivefold increase in risk for coronary heart disease, hypertension, and dyslipidemia, 15 y postpartum [15]. The present results are consistent with these findings, as they show similar associations in direction and magnitude, despite being from a sample of North American women. Rooney et al. did not evaluate risk for IR or MetS [15].

It is hypothesized that the mechanisms involved in the relationship between prepregnancy obesity and long-term metabolic complications could be postpartum weight retention, postpartum visceral fat, and obesity in the medium and long terms [16,17]. The physiological fat gained during pregnancy is deposited centrally, with preferential selection in central sites among women who are obese before pregnancy [16,17]. In adults, visceral fat is associated with metabolic complications such as IR and type 2 diabetes [25,26]. During pregnancy, visceral fat is associated with impaired glucose tolerance, gestational diabetes, and hypertension or preeclampsia or both [17]. In this study, prepregnancy obesity was a risk factor for IR, MetS, and hyperglycemia, and all women with prepregnancy obesity had abdominal obesity at the end of follow-up. Several researchers suggest that pregnant women who were obese before pregnancy, have higher weight retention postpartum compared with normal or underweight pregnant women, and would be more susceptible to obesity later in life [16,27,28].

Unlike prepregnancy obesity, GWG was not associated with any of the studied metabolic risk variables in the main model but it was significantly associated to IR, MetS, hyperglycemia, and hypertriglyceridemia by analyzing models with corrected weights (model 2, Supplement 3). This could be because the correction slightly increased the sample size of women with excessive GWG, especially in prepregnancy obese women. The relationship between excessive GWG and long-term maternal metabolic risk is not consistent. Most of the studies found positive relationships between excessive GWG and components of MetS as abdominal obesity [13,29] or high blood pressure [18,29] but the relationship with hyperglycemia or hypertriglyceridemia is less clear [13,18]. One explanation for this inconsistency is that the effect of GWG on some metabolic risk factors might need longer follow-up time [13,15]. Excessive GWG is a key factor associated with postpartum weight retention [10,14,30] and failure to lose this weight gained could lead to maintaining and developing maternal obesity, which in turn could have adverse health consequences for women and their offspring, and for their future pregnancies [10].

According to the findings from the present study, prepregnancy obesity may be the most important factor in the development of future metabolic disorders. During pregnancy,

the mother's body is less sensitive to changes in lifestyles due to the short time between the onset of dietary changes and childbirth, and a decreased ability to significantly increase physical activity as gestation advances [31]. Additionally, some authors propose that lifestyle interventions could have minimal effect on maternal metabolism. This is due to the physiological adaptations of pregnancy, where glucose needs to be available for fetal tissues and also as an energy source to lipids [31]. In the early stages of a normal pregnancy, a normal glucose and sensitivity to insulin facilitates cellular anabolism and lipogenesis [5,17,31]. As pregnancy progresses, insulin resistance appears (with associated hyperinsulinemia), which continues progressively until the end of pregnancy when insulin action is 50% to 60% lower, independent of prepregnancy BMI [5,17,31]. In obese pregnant women in late pregnancy, a marked peripheral and hepatic IR occurs. This causes a postprandial state in which an excess of glucose, amino acids, and lipids is in blood circulation [5]. During normal pregnancy, fat oxidation also increases between 50 and 80%, and increases in very-low-density lipoprotein (VLDL), LDL, HDL, and TG [5,17] are observed. In obese pregnant women, VLDL and TG greatly increases and HDL decreases [17]. Additionally, insulin has a decreased ability to suppress lipolysis, which results in yet more free fatty acids in blood plasma [5]. For all these reasons, it is therefore essential to focus on the prevention of prepregnancy obesity through public policies focused on strategies for changes in lifestyles for women of childbearing age.

Strengths and limitations of the study

To our knowledge, this was the first study to evaluate the association between gestational obesity and metabolic risk 10 y postpartum in Latin American women. This was a prospective study, allowing us to evaluate the causal relationship between gestational obesity and future metabolic risk. Because the study sample was randomly selected from the population with a prevalence of prepregnancy overweight/obesity similar to that reported by the National Health Survey 2003 (ENS 2003), it is representative of Chilean premenopausal women. Personnel were trained for standardization of anthropometric and blood pressure measurements and blood sampling, thus reducing possible bias of data.

One of the main limitations of this study is that it relies on self-reported data, specifically pre- and last pregnancy weights. As weight often is under- or overestimated, there is a potential for bias [13,32,33]. However, evidence shows that self-reported weight correlates well with measured weight ($r = 0.86–0.99$), varying between 0.6 g and 2.4 kg [24,33–38]. To reduce this limitation, correction weight factors were applied according to Stommel and Schoenborn [24] and associations remained the same.

Other factors that influence the development of metabolic disorders are unhealthy lifestyles (eating habits and physical activity), which, over time, can lead to health complications [13]. The present sample was representative of low- and middle-income Chilean women, who have been shown to have poor diet quality and high rates of sedentariness [3,39]. Although we did not have information about the presence of preexisting chronic disease, we did have data concerning metabolic complications during pregnancy (e.g., gestational diabetes) and extreme gestational weight gain and sensitivity analysis corroborated the association between prepregnancy obesity and metabolic risk.

Conclusion

Gestational obesity was associated with greater metabolic risk to mothers 10 y postpartum. To our knowledge, this is the first study conducted in a country that has undergone a very rapid nutrition transition and suggests that prevention strategies for chronic diseases should consider early life risk factors, particularly those targeting prepregnancy obesity.

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Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.nut.2017.01.003.

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