

Original Article

Risk factors during the prenatal period and the first year of life associated with overweight in 7-year-old low-income Chilean children

Israel Rios-Castillo, Sheila Cerezo, Camila Corvalán, Mario Martínez and Juliana Kain

Institute of Nutrition and Food Technology (INTA), University of Chile, Santiago, Chile

Abstract

The objective of this study was to identify in low-income Chilean children with normal birthweight which factors occurring during the prenatal period and the first year are associated with overweight (OW)/obesity at 7 years. The sample included 652 7-year-olds from a larger cohort study. We collected anthropometric data at 0, 12 and 84 months, maternal pre-pregnancy and pregnancy characteristics, early feeding practices, number of siblings, birth order, breastfeeding, and timing of solid introduction information. We determined the residuals for z-scores for body mass index (BMI) (BAZ), weight/age and height/age^{0–12 months}, run univariate analysis (X^2 or *t*-test) and multivariate logistic analyses (stepwise approach); $P < 0.05$ was considered significant. We evaluated the goodness of fit of the model using the Hosmer–Lemeshow test and checked for overdispersion using the Pearson's X^2 . The odds of children being OW at 7 years increased if their mothers were OW before pregnancy, if born with a higher BAZ (increase of 18–74% per each additional unit of BAZ) and if their BAZ growth during the first year was higher (62–239% per each unit over the predicted BAZ increase). Higher birth order was protective (6–68% less risk for 2nd birth compared with 1st and 10–73% less for ≥ 3 rd child). All other variables, including gender, were non-significant ($P > 0.1$). In low-income Chilean children with normal birth, four factors during the prenatal period and the first year were associated with OW at 7 years: pre-pregnancy BMI, BMI at birth, BMI gain between 0 and 12 months, and birth order.

Keywords: childhood obesity, prenatal, birthweight, birth order, weight gain.

Correspondence: Professor Juliana Kain, INTA, University of Chile, El Líbano 5524, Macul, Santiago 11, Chile. E-mail: jkain@inta.uchile.cl

Introduction

Childhood obesity is considered a serious public health problem in developed as well as in developing nations (Lobstein *et al.* 2004). Despite efforts being made to tackle this condition, few initiatives have been effective in the long run. In addition, it has not been well established at what ages preventive strate-

gies are more effective (Dubois & Girard 2006); however, there is ample evidence that the increased prevalence of obesity occurs very early in life (Deckelbaum & Williams 2001).

In Chile, according to the National Association of School Assistance and Scholarships (JUNAEB), in charge of collecting anthropometric data on approximately 70% of children in first grade, obesity has

nearly tripled over the last 25 years from 7% in 1987 to 23.1% in 2010 (<http://www.junaeb.cl>). In the cohort study, in which this paper is based on, we have shown that the prevalence of obesity increases with age. In boys, this prevalence is 10.3%, 16.3% and 18.6% at 2, 3 and 5 years, while in girls, these figures are 10.3%, 12.5% and 12.6%, respectively (Kain *et al.* 2009a). Although some small-scale interventions have been effective in reducing obesity (Kain *et al.* 2009b), the experience accumulated from these studies has not translated into effective initiatives that have impacted obesity rates. On the contrary, childhood obesity has been rising continuously irrespective of preventive interventions (Burrows 2000). Because in this country, 87% of pregnant women as well as their offspring have regular health check-ups at public health centres until 5 years of age (Chilean Ministry of Health, available at <http://www.deis.cl>), it is important to determine at the earliest possible, which potential risk factors are associated with later overweight (OW) because of its association to chronic diseases at a young age (Lobstein *et al.* 2004).

We were interested in the identification of these factors in children who were born with normal birthweight since 85% of babies in Chile are born with a birthweight between 2500 and 4000 g, while 5% are born with a birthweight <2500 g and 10% >4000 g (Chilean Institute of Statistics, available at <http://www.ine.cl>). Because it has been shown that growth, especially the first year of life, is associated with either a low or a high birthweight (Stettler *et al.* 2002; Jones-Smith *et al.* 2007), we aimed at eliminating this potential risk factor from the study.

Therefore, the main objective of this study was to identify in low-income Chilean children born with normal birthweight, which factors occurring during

the prenatal period and the first year of life are associated with being OW or obese at age 7.

Methods and procedures

Subjects

The sample included in this study originates from a retrospective and prospective cohort study that began in 2006, with 1196 low-income Chilean preschool children selected at 3–4 years of age from 54 public kindergartens located in Santiago and that belong to the National Association of Kindergartens. Children who attend these kindergartens belong to low-income families; those whose mothers work full time and/or whose mother is head of household are given priority (<http://www.junji.gob.cl>).

The children are presently 9 years of age and will be followed until adolescence with funding provided by Chilean National Research Council (CONICYT). For this study, we restricted the sample to those born between 2500 and 4000 g (as explained earlier, infants with either low or high birthweight may exhibit altered growth patterns during the first year of life), had anthropometric data at 0, 12 and 84 months, and complete information regarding demographic characteristics, pregnancy and feeding practices during the first year of life.

Figure 1 shows the flow of participants according to the inclusion criteria described earlier. The final sample size included 652 7-year-old children.

This study was approved by the Ethics Committee for Human Studies of the Institute of Nutrition and Food Technology, University of Chile. In addition, a signed informed consent was obtained from one of the parents of every child.

Key messages

- Low-income children born with normal weight from a post-transitional country like Chile, four factors during the prenatal period and the first year of life were associated with OW at 7 years of age.
- The four factors are pre-pregnancy BMI category, BMI at birth, BMI gain between 0 and 12 months, and birth order.
- Identifying these risk factors at the health check-ups and applying preventive measures early on, especially regarding excessive weight gain after birth, could contribute to halt the continuing rise of obesity among Chilean children.

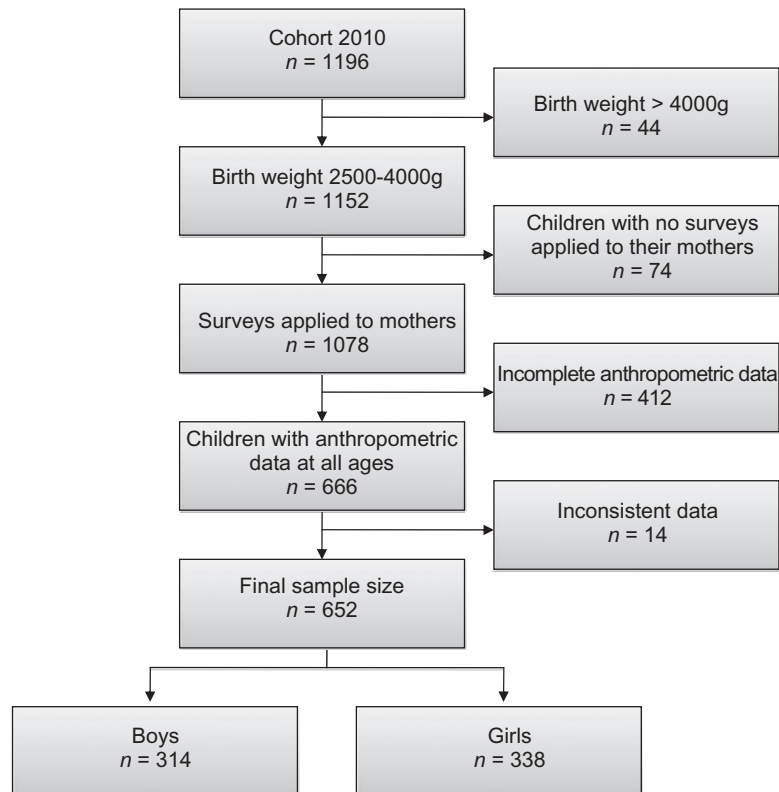


Fig. 1. Flow of participants in the study.

Variables

The information on demographic characteristics, pre-natal aspects and feeding practices during the first year of life was obtained from a survey applied directly to the mothers in 2007, when the children were 4 years of age. Variables considered in this study were: pre-pregnancy weight and height, gestational weight gain (GWG), early feeding practices, smoking during pregnancy, gestational diabetes, other health conditions during pregnancy (hypertension, infections of the urinary tract, cholestasis, respiratory illnesses, risk of preterm delivery), number of siblings, birth order, duration of exclusive and non-exclusive breastfeeding, smoking and timing of introduction of solids, beverages, candy, and snacks (see variables).

Pre-pregnancy nutritional status was classified based on body mass index (BMI) (kg m^{-2}) according to World Health Organisation (WHO) standards (WHO 2000), that is, normal weight (BMI 20–25) and OW (BMI > 25) (none of the women had low

weight). GWG was divided into three categories (low, adequate and high) according to the increase recommended according to pre-pregnancy nutritional status. (Institute of Medicine 2009).

Weight and height measurements of the children at birth and 12 months were obtained retrospectively from health records. Birthweight and birth length are determined at maternity hospitals immediately after delivery by trained personnel under standard procedure. After birth, weight and height are assessed by nurses or nutritionists at the health centre. Infant's weight is obtained using a paediatric balance beam scale with a precision of 10 g; recumbent length is obtained with 0.1 cm accuracy. At 84 months of age, weight and height were collected using standardised procedures by two trained registered dietitians of our team. Weight was measured with a Tanita BC 418 bioimpedance (Tanita Corporation, Tokyo, Japan) and height with SECA stadiometer model 222 (SECA Corporation, Hanover, MD, USA) to the nearest 0.1 cm. Intraobserver and interobserver reliability on

weight and height measurements were confirmed (intraclass correlation ≥ 0.75). We calculated z-scores for BMI (BAZ), height/age (HAZ) and weight/age (WAZ) at birth, at 12 and 84 months, using WHO (2007) references and the residuals for BAZ (ResBAZ), HAZ (ResHAZ) and WAZ (ResWAZ) between 0 and 12 months (this is explained in data analysis). Nutritional status at age 7 was categorised in two groups: normal weight or BAZ $\leq +1$, and OW as BAZ $> +1$ (Onis & Lobstein 2010).

Data analysis

In order to verify whether children included ($n = 652$) had similar characteristics to those excluded ($n = 257$), we compared both groups in terms of gender, pre-pregnancy BMI category, weight gain during pregnancy, nutritional status at birth and at 84 months using chi-square (X^2) for categorical variables and *t*-tests for continuous variables. We then compared separately each of the variables considered as a potential risk factor for OW during the prenatal period and the first year of life with bivariate analysis using chi-square test (X^2) for categorical variables and *t*-test for continuous variables ($P < 0.05$ was considered significant). To assess the association between risk factors with OW at age 7, we used logistic regression analysis. For fitting the logistic model, we used the command glm from STATS PACKAGE OF R software version 2.15.1 (available at: <http://www.R-project.org>). In this analysis, we included cases with complete data on all potential risk factors ($n = 652$). The effect on OW because of the increase in both weight and height during the first year of life was determined by the effect of the observed deviation of BAZ from its predicted value at 12 months (ResBAZ_{0-12 months}). We regressed BAZ at 12 months as outcome and BAZ at birth and sex as covariables. We determined for each child the ResBAZ_{0-12 months} with respect to the prediction of this last model. The same procedure was done for WAZ and HAZ so as to obtain ResWAZ_{0-12 months} and ResHAZ_{0-12 months}. We then performed a stepwise selection procedure with forward selection and backward elimination, with a level of significance of 0.05 and 0.1 for entry and exit of variables from the model, respectively. Gender

was included in every step of model building because of its practical importance. We also evaluated all continuous variables for linearity in the logit using fractional polynomials with two terms, each one with two degrees of freedom and with a level of significance of 0.05. Next, all the paired interactions from terms in the previous model were assessed with a level of significance of 0.05 and 0.1 for entry and exit from the model. This step was performed in a similar way as in the previous stepwise step we described. Finally, we evaluated the goodness of fit of the model using the Hosmer–Lemeshow test, and we checked for overdispersion through the Pearson's X^2 . Although forced to be present in the model, gender was not significant.

Results

Table 1 shows the characteristics of included and excluded children. Gender, pre-pregnancy BMI category, GWG and birthweight were similar ($P > 0.05$). No significant differences in birthweight were observed between these two groups with respect to the nutritional status at 84 months ($P = 0.651$) because birthweight > 4000 g was an exclusion criterion.

Table 2 shows the characteristics of potential prenatal risk factors of later obesity between normal-weight and OW children. Most prenatal risk factors were not associated with OW at age 7, except for pre-pregnancy BMI category and GWG. In normal-weight children, 69.1% had mothers with normal weight before pregnancy vs. 51.8% of OW children. In contrast, 30.9% of normal-weight children had mothers who were OW before pregnancy vs. 48.2% of OW children ($P < 0.001$). Also, we observed that GWG is associated with the nutritional status of the children at 7 years ($P = 0.049$).

Table 3 shows the characteristics of potential risk factors for later obesity during the first year of life in normal-weight and OW children at age 7. Differences were observed at birth determined as weight (in grams), BAZ and WAZ ($P < 0.001$). Also, ResBAZ_{0-12 months} and ResWAZ_{0-12 months} ($P < 0.001$) were significantly different, while the ResHAZ_{0-12 months} was not ($P = 0.16$). Although timing of salty snack introduction was significantly different between normal-

Table 1. Characteristics of included vs. excluded participants [mean \pm SD or *n* (%)]

Variables	Included	Excluded		P-value
	<i>N</i> = 652	<i>N</i> = 257		
	<i>n</i> (%) or mean \pm SD	<i>n</i> for each variable	% or mean \pm SD	
Gender		257		0.377 [§]
Male	314 (48.2)	132	51.4	
Female	338 (51.8)	125	48.6	
PP BMI categories		220		0.52 [§]
Normal*	403 (61.8)	141	64.1	
Overweight [†]	249 (38.2)	79	35.9	
GWG [‡]		204		0.995 [§]
Deficient	147 (22.5)	43	21.1	
Adequate	167 (25.6)	55	27.0	
High	338 (51.8)	106	52.0	
Birthweight	3.328 \pm 0.33	257	3.339 \pm 0.345	0.651**
Normal weight at 84 months	3.289 \pm 0.334	151	3.296 \pm 0.354	0.82**
Overweight at 84 months	3.382 \pm 0.328	106	3.401 \pm 0.323	0.605**
Nutritional status at 84 months				0.765 [§]
% Normal weight	376 (57.7)	151	58.8	
% Overweight	276 (42.3)	106	41.2	

PP, pre-pregnancy; BMI, body mass index; GWG, gestational weight gain; SD, standard deviation. *BMI 19–25. [†]BMI > 25. [‡]Recommendation according to PP BMI category. [§]Normal or overweight according to WHO 2007. [¶]Chi-square test (X^2). **Student's *t*-test.

weight and OW children ($P = 0.031$), this occurred at 24.2 months in the OW and 22.3 months in the normal-weight children.

Table 4 summarises the results of the logistic regression model that explains the association of risk factors during the prenatal period and the first year of life with OW at age 7. We observe that gender was not associated with increased odds of OW at age 7 (odds ratio 1.026, 95% confidence interval 0.73–1.44). Significant but negative effects were observed for pre-pregnancy BMI, BAZ at birth and ResBAZ_{0–12 months}. If mothers were OW before becoming pregnant, there is between 38% and 280% increased odds of their children being OW at age 7. Similarly, babies born with more than 1 unit of BAZ have between 18% and 74% increased odds of being OW at age 7. Babies whose growth rate deviates positively 1 unit of BAZ with respect to the predicted growth rate have between 62% and 239% increased odds of being OW at age 7. Higher birth order is protective; the second-born child has between 6% and 236% less odds of being OW at age 7, while the third-born child and higher has between 11% and 267% less (both comparisons are relative to the first-born).

Discussion

The results of this study show that in low-income Chilean children born with normal weight, four variables are associated with OW at age 7: pre-pregnancy BMI category, BMI at birth, BMI gain between 0 and 12 months and birth order. These results are consistent with the growing evidence that anthropometric characteristics of mothers and their offspring during the first year of life are related with OW in mid-childhood (Dubois & Girard 2006; Péneau *et al.* 2010).

The finding that maternal OW significantly increases the risk of childhood obesity has been reported in many studies (Stettler *et al.* 2002; Whitaker 2004; Reilly *et al.* 2005; Kuhle *et al.* 2010). Tabacchi *et al.* (2007) reported that maternal obesity increases the transfer of nutrients through the placenta, which may produce permanent changes in programming appetite and energy metabolism. Also, a family history of OW and obesity is one of the most important factors for OW in childhood because not only genes that confer susceptibility to obesity are inherited but also OW parents probably have a

Table 2. Prenatal characteristics of normal-weight and overweight 7-year-old children

	Nutritional status at age 7				X ²	P
	Normal		Overweight			
	N	%	N	%		
Sample size	376		276			
Variables						
Gender						
Male	179	47.6	135	48.9	0.11	0.74
Female	197	52.4	141	51.1		
PP BMI category						
Normal	260	69.1	143	51.8	20.22	<0.001
Overweight	116	30.9	133	48.2		
GWG*						
Low	89	23.7	58	21	6.03	0.049
Normal	107	28.5	60	21.7		
High	180	47.9	158	57.2		
Gestational Diabetes						
No	353	93.9	261	94.6	0.136	0.712
Yes	23	6.1	15	5.4		
Other conditions during pregnancy						
No	276	73.4	190	68.8	1.619	0.203
Yes	100	26.6	86	31.2		
Number of siblings						
0	115	30.6	99	35.9	2.66	0.446
1	141	37.5	93	33.7		
2	68	18.1	52	18.8		
≥3	52	13.8	32	11.6		
Birth order						
1	152	40.4	126	45.7	1.823	0.402
2	125	33.2	82	29.7		
≥3	99	26.3	68	24.6		
Smoking during pregnancy						
No	317	84.3	235	85.1	0.0484	0.826
Yes	59	15.7	41	14.9		

PP, pre-pregnancy; BMI, body mass index; GWG, gestational weight gain. Values are presented as absolute and relative frequencies. Chi-square test (X²). *Recommendation according to PP BMI category.

distinct pattern of food intake and physical activity related directly to that of their child immediately after birth. In most cases, OW parents may create and maintain an 'obesogenic' environment (Ong *et al.* 2002; Whitaker 2004; Reilly *et al.* 2005; Tabacchi *et al.* 2007; Kuhle *et al.* 2010).

Several studies have shown an association between gestational diabetes and childhood obesity. It has been well established that offspring of diabetic mothers have a higher birthweight and tend to have higher obesity rates. Intrauterine exposure to diabetes per se conveys a high risk for the development of obesity in excess of risk that originates from genetic factors (Pettitt *et al.* 1993; Dabelea *et al.* 2000). Mater-

nal smoking during pregnancy has also been found to be a risk factor for childhood obesity. Von Kries *et al.* (2002) and Toschke *et al.* (2002) showed in 6 years old German children that there is a dose/dependent association between OW and smoking during pregnancy. These authors also found that smoking after pregnancy was not associated with childhood obesity. In our study, we did not find an association between any of these conditions with OW at 7 years. It is important to remember that the sample does not include macrosomic babies that could partly explain the low prevalence of diabetic mothers (4.4%). Even though the proportion of mothers who smoked during pregnancy was significantly higher than that reported by

Table 3. Anthropometric and feeding practices of normal-weight and overweight 7-year-old children during the first year of life [mean \pm SD or n (%)]

	Nutritional status at age 7		Student's <i>t</i> -test or X^2	<i>P</i>
	Normal	Overweight		
Sample size	376 (57.7)	276 (42.3)		
Anthropometric variables				
Birthweight (kg)	3.28 \pm 0.33	3.38 \pm 0.33	3.55	<0.001
BAZ _{0 months}	-0.118 \pm 0.91	0.146 \pm 0.90	3.66	<0.001
BAZ _{12 months}	0.49 \pm 0.84	1.01 \pm 0.98	8.42	<0.001
ResBAZ _{0-12 months}	-0.23 \pm 0.83	0.319 \pm 0.97	7.76	<0.001
HAZ _{0 months}	0.134 \pm 0.84	0.18 \pm 0.87	0.687	0.49
HAZ _{12 months}	-0.37 \pm 0.93	-0.25 \pm 1.07	1.496	0.13
ResHAZ _{0-12 months}	-0.057 \pm 0.88	-0.046 \pm 1.00	1.405	0.16
WAZ _{0 months}	-0.017 \pm 0.71	0.18 \pm 0.70	3.502	<0.001
WAZ _{12 months}	0.145 \pm 0.8	0.66 \pm 0.93	7.752	<0.001
ResWAZ _{0-12 months}	-0.2 \pm 0.77	0.24 \pm 0.89	6.725	<0.001
Breastfeeding				
Yes (ever breastfed)	357 (94.9)	259 (93.8)		
No	19 (5.1)	17 (6.2)		
Duration of exclusive breastfeeding (months)	2.97 \pm 2.45	2.95 \pm 2.54	-0.129	0.898
Duration of total breastfeeding (months)	12.8 \pm 10.4	14.3 \pm 11.1	1.777	0.076
Timing of solid food introduction (months)	6.22 \pm 1.99	6.31 \pm 2.06	0.557	0.577
Timing of beverage introduction of (months)	13.26 \pm 6.87	12.9 \pm 6.99	-0.642	0.52
Timing of candy introduction (months)	17.04 \pm 9.4	15.87 \pm 8.7	-1.619	0.10
Timing of sweet snack introduction (months)	15.13 \pm 9.4	14.3 \pm 8.54	-1.147	0.25
Timing of salty snack introduction (months)	24.2 \pm 11.45	22.3 \pm 10.5	-2.157	0.031

BAZ, z-scores for BMI; HAZ, z-scores for height/age; WAZ, z-scores for weight/age; Res, residual; SD, standard deviation.

Table 4. Association between risk factors during the prenatal period and the first year of life with overweight at age 7

Variable	Categories	OR (CI 95%)
Gender	Male vs. female	1.026 (0.733–1.438)
PP BMI	Overweight vs. normal	1.965 (1.38–2.802)
BAZ 0 months	Δ 1 sd in z-score	1.433 (1.187–1.738)
ResBAZ _{0-12 months}	Δ 1 in z-score Res	1.958 (1.618–2.39)
Birth order	2nd vs. 1st	0.633 (0.423–0.943)
Birth order	\geq 3rd vs. 1st	0.584 (0.375–0.901)

PP BMI, pre-pregnancy body mass index categories; OR, odds ratio; CI, confidence interval; Res, residual; BAZ, z-scores for BMI. Log-likelihood = -399.146, $n = 652$; Hosmer–Lemeshow = 22.636, d.f. = 18, $P = 0.21$.

Toschke *et al.* (2002) in German mothers (15% vs. 6.2%), smoking was not associated with OW in our sample.

The existing evidence regarding the association between breastfeeding and reduced risk of childhood OW has been inconsistent. In this study, there was no

relationship between duration of breastfeeding and OW at age 7, similar to results reported by several authors (Whitaker 2004; Péneau *et al.* 2010). In studies that have found that breastfeeding is a potential protective factor for childhood obesity (Von Kries *et al.* 1999; Reilly *et al.* 2005; Kuhle *et al.* 2010), results indicate that the effect is observed when breastfeeding is exclusive for at least 4 months. In the present study, duration of breastfeeding (not exclusive) lasted more than a year in both groups, which shows that although exclusive breastfeeding was short, mothers continue with this practice much longer. The average duration of exclusive breastfeeding in both normal-weight and OW children was slightly less than 3 months, which coincided with the completion of post-natal leave of Chilean mothers.

It has been shown that early introduction of formula feeding increases the prevalence of childhood obesity (Armstrong & Reilly 2002; Bogen *et al.* 2004). A recent study (Huh *et al.* 2011) found that in

formula-fed infants, the introduction of solid foods before the age of 4 months was associated with increased odds of obesity at age 3. In this study, solids were introduced at around 6 months in both groups of children, as recommended by WHO (2003).

Because the relationship between either low or high birthweight with later obesity (Dabelea *et al.* 2000; Ong *et al.* 2002; Reilly *et al.* 2005; Karaolis-Danckert *et al.* 2008) has been documented extensively, we decided to include in this study only children with normal weight as is the case of 85% of births in the country. Even with this restriction, birthweight was found to be one of the four variables associated with later obesity.

It has been widely documented that there is an association between early weight gain and childhood OW, being accelerated growth between 0 and 2 years, the period in which most studies have shown to be a critical one for later obesity (Stettler *et al.* 2002; Whitaker 2004; Jones-Smith *et al.* 2007; Tabacchi *et al.* 2007). Other authors (Dabelea *et al.* 2000; Stettler *et al.* 2002; Dubois & Girard 2006; Jones-Smith *et al.* 2007) have shown that accelerated growth during the first year is associated with an increased risk of OW in childhood. Recently, Taveras *et al.* (2011) found that if accelerated growth occurs during the first 6 months of life, there is a higher prevalence of obesity in children 5–10 years of age, and Gillman (2008) reports that the first few weeks or months of life are particularly sensitive for the development of obesity. Baird *et al.* (2005) published a systematic review of 10 studies that evaluated the relationship between infant weight gain and subsequent obesity. The relative risks of later obesity ranged from 1.17 to 5.70 in children with rapid weight gain during the first year of life. Our results support such evidence.

There are several prenatal and post-natal risk factors that not only are associated with OW in childhood but can influence the rate of weight gain during the first years of life and in turn body composition. Karaolis-Danckert *et al.* (2008) report that among rapid growers between 0 and 2 years who have been bottle-fed early on, were exposed to tobacco in utero, had an OW mother and were a first-born child gained significantly more %body fat between 2 and 6 years than rapid growers who did not have these factors.

GWG has been found to be associated with childhood obesity even in women with normal pre-pregnancy weight (Di Tullio 2003). A recent review article by Adamo *et al.* (2012) addressing the interplay between maternal obesity, GWG and lifestyle behaviours that can perpetuate the intergenerational cycle of obesity show that although in most studies GWG has been found to be associated with infant adiposity, separating the environmental from the genetic contributions in producing excessive GWG has been very difficult. Because the recommendation of GWG is related to pre-pregnancy BMI, guidelines recommend a much smaller weight increase for OW and obese women compared with that of normal-weight women. In a study including US women (Weisman *et al.* 2010), 40% of normal-weight women exceeded the recommended GWG compared with 65% of the OW ones. That study showed that OW women were three times more likely to exceed the recommendation as their normal-weight counterparts. In our study, we found similar results, as 59% of the OW women before pregnancy exceeded the recommended GWG compared with 47.5% of the women with normal weight (not shown). Even though we found an association between GWG and OW in the univariate analysis, in the final regression, this variable lost relevance.

In our study, we observed that the odds of becoming OW in mid-childhood is significantly less for the second-born child, or the third- and later-born children compared with the first-born. This has been found in many studies (Al-Isa & Moussa 1999; Stettler *et al.* 2002; Padez *et al.* 2005; Juresa *et al.* 2012). In some studies, this variable losses importance in the adjusted final models (Stettler *et al.* 2002), while in others, it remains significant (38–40). In Italian OW and obese women, Siervo *et al.* (2011) found that first-borns have an increased BMI, adiposity and metabolic risk. Because of the high prevalence of OW and obesity in the mothers of our study, this might also occur among their first-borns.

The main strength of this study is that the sample originates from a contemporary cohort with homogeneous characteristics in terms of socio-economic status and birthweight. Even though the sample size for the present analysis was small, because of the

restrictions we defined, there were no differences between included vs. excluded participants. There are several limitations that have to be noted. These include the fact weight and height at birth and 12 months were collected at the health clinics under a standardised procedure but less stringent than the one used by our research team. The assessment of within group variability and outliers revealed no significant discontinuity. Also, the maternal data used in the analysis (i.e. pre-pregnancy weight and prenatal variables) are self reported, which might introduce systematic reporting bias; however, mean and prevalence of these variables are consistent with Chilean data (Lopez *et al.* 2003; Lagos *et al.* 2004; Parra *et al.* 2007; Mardones *et al.* 2008).

We were not able to obtain anthropometric data from the fathers; therefore, the presence of OW as a potential risk factor for childhood obesity could not be addressed. Because of the difficulty in obtaining this information, most studies do not include this data (Dabelea *et al.* 2000). With respect to maternal educational level, a potential confounder in the development of childhood obesity, some studies have found no association between this variable and obesity in pre-school and school age probably because participants belonged to the same socio-economic level (Pettitt *et al.* 1993; Lamerz *et al.* 2005); however, other authors have reported that parents' knowledge about feeding practices is critical in preventing rapid weight gain (Lagos *et al.* 2004; Reilly *et al.* 2005). In our study, maternal educational level was homogeneously distributed (98% of the mothers did not have a college education).

In conclusion, in our study, four factors during the prenatal period and the first year of life were associated with OW at 7 years of age in low-income Chilean children with normal birthweight: pre-pregnancy BMI category, BMI at birth, BMI gain between 0 and 12 months, and birth order. This underscores the fact that birthweight, even within normal range, is associated with childhood obesity. Identifying these risk factors at the health check-ups and applying preventive measures early on, especially regarding excessive weight gain after birth, could contribute to halt the continuing rise of obesity among Chilean children.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Contributions

IR and SC analysed and interpreted the data and wrote the initial draft of the manuscript. CC provided guidance throughout the process, MM provided most of the statistical analyses, and JK participated in the interpretation of the data, critically reviewed all sections and wrote the final manuscript. All the authors have read and approved the manuscript.

References

- Adamo K., Ferraro Z. & Brett K. (2012) Can we modify the intrauterine environment to halt the intergenerational cycle of poverty? *International Journal of Environmental Research and Public Health* **9**, 1263–1307.
- Al-Isa A. & Moussa M. (1999) Factors associated with overweight and obesity among Kuwaiti kindergarten children 3–5 years. *Nutrition and Health* **13**, 125–139.
- Armstrong J. & Reilly J.J. (2002) Breastfeeding and lowering the risk of childhood obesity. *Lancet* **359**, 2003–2004.
- Baird J., Fisher D., Lucas P., Kleijnen J., Roberts H. & Law C. (2005) Being big or growing fast: systematic review of size and growth in infancy and later obesity. *BMJ (Clinical Research ed.)* **331**, 929–934.
- Bogen D.L., Hanusa B.H. & Whitaker R.C. (2004) The effect of breast-feeding with and without formula use on the risk of obesity at 4 years of age. *Obesity Research* **12**, 1527–1535.
- Burrows R. (2000) Prevention and treatment of obesity since childhood: strategy to decrease the non transmissible chronic diseases in adult. *Revista Medica de Chile* **128**, 105–110.

- Dabelea D., Hanson R.L., Lindsay R.S., Pettitt D.J., Imperatore G., Gabir M.M. *et al.* (2000) Intrauterine Exposure to diabetes conveys risks for type 2 diabetes and obesity: a study of discordant sibships. *Diabetes* **49**, 2208–2211.
- Deckelbaum R.J. & Williams C.L. (2001) Childhood obesity: the health issue. *Obesity Research* **9** (Suppl. 4), 239S–243S.
- Di Tullio G. (2003) Eating errors in the pathogenesis of childhood obesity. *La Medicina Biológica* **4**, 33–40.
- Dubois L. & Girard M. (2006) Early determinants of overweight at 4.5 years in a population-based longitudinal study. *International Journal of Obesity* **4**, 610–617.
- Gillman M.W. (2008) The first months of life: a critical period for development of obesity. *The American Journal of Clinical Nutrition* **87**, 1587–1589.
- Huh S., Rifas-Shiman S., Taveras E., Oken E. & Gillman M. (2011) Timing of solid food introduction and risk of obesity in preschool-aged children. *Pediatrics* **127**, e544–e551.
- Institute of Medicine (2009) *Weight Gain during Pregnancy: Reexamination of IOM Pregnancy Weight Guidelines*. Available at: <http://www.iom.edu/pregnancyweightgain>
- Jones-Smith J.C., Fernald L.C. & Neufeld L.M. (2007) Birth size and accelerated growth during infancy are associated with increased odds of childhood overweight in Mexican children. *Journal of the American Dietetic Association* **107**, 2061–2069.
- Juresa V., Musil V., Majer M., Ivankovic D. & Petrovic D. (2012) Behavioral patterns of overweight and obese school children. *Collegium Antropologicum* **36** (Suppl. 1), 139–145.
- Kain J., Corvalan C., Lera L., Galvan M. & Uauy R. (2009a) Accelerated growth in early life and obesity in preschool Chilean children. *Obesity* **17**, 1603–1608.
- Kain J., Leyton B., Cerda R., Vio F. & Uauy R. (2009b) Two-year controlled effectiveness trial of a school-based intervention to prevent obesity in Chilean children. *Public Health Nutrition* **12**, 1451–1461.
- Karaolis-Danckert N., Buyken A.E., Kulig M., Kroke A., Forster J., Kamin W. *et al.* (2008) How pre- and postnatal risk factors modify the effect of rapid weight gain in infancy and early childhood on subsequent fat mass development: results from the Multicenter Allergy Study 90. *The American Journal of Clinical Nutrition* **87**, 1356–1364.
- Kuhle S., Allen A.C. & Veugelers P.J. (2010) Perinatal and childhood risk factors for overweight in a provincial sample of Canadian Grade 5 students. *International Journal of Pediatric Obesity* **5**, 88–96.
- Lagos S., Espinoza R. & Orellana J. (2004) Estado nutricional materno inicial y peso promedio de sus recién nacidos a término. *Revista Chilena de Nutricion* **31**, 52–57.
- Lamerz A., Kuepper-Nybelen J., Wehle C., Bruning N., Trost-Brinkhues G., Brenner H. *et al.* (2005) Social class, parental education, and obesity prevalence in a study of six-year-old children in Germany. *International Journal of Obesity (2005)* **29**, 373–380.
- Lobstein T., Baur L. & Uauy R. (2004) IASO International Obesity Task Force Obesity in children and young people: a crisis in public health. *Obesity Reviews* **5** (Suppl. 1), 4–104.
- Lopez I., Sepulveda B.H., Jeria C. & Letelier C. (2003) Niños macrosómicos y de peso normal de un consultorio de atención primaria. Comparación de características propias y maternas 1997–2000. *Revista Chilena de Pediatría* **74**, 287–293.
- Mardones F., Duran E. & Villarroel L. (2008) Maternal anemia in Concepcion province, Chile: association with maternal nutritional status and fetal growth. *Archivos Latinoamericanos de Nutricion* **58**, 132–138.
- Ong K.K., Preece M.A., Emmett P.M., Ahmed M.L. & Dunger D.B. (2002) Size at birth and early childhood growth in relation to maternal smoking, parity and infant breast-feeding: longitudinal birth cohort study and analysis. *Pediatric Research* **52**, 863–867.
- Onis M. & Lobstein T. (2010) Defining obesity risk status in the general childhood population: which cut-offs should we use? *International Journal of Pediatric Obesity* **5**, 458–460.
- Padez C., Mourao I., Moreira P. & Rosado V. (2005) Prevalence and risk factors for overweight and obesity in Portuguese children. *Acta Pediatrica* **94**, 1550–1557.
- Parra C.M., San Martín O.A. & Valdés R.E. (2007) Espectro clínico de la preeclampsia: estudio comparativo de sus diversos grados de severidad. *Revista Chilena de Obstetricia y Ginecología* **72**, 169–175.
- Péneau S., Rouchaud A., Rolland-Cachera M.F., Arnault N., Herberg S. & Castetbon K. (2010) Body size and growth from birth to 2 years and risk of overweight at 7–9 years. *International Journal of Pediatric Obesity* **6**, e162–e169.
- Pettitt D.J., Nelson R.G., Saad M.F., Bennett P.H. & Knowler W.C. (1993) Diabetes and obesity in the offspring of Pima Indian women with diabetes during pregnancy. *Diabetes Care* **16**, 310–314.
- Reilly J.J., Armstrong J., Dorosty A.R., Emmett P.M., Ness A., Rogers I. *et al.* (2005) Early life risk factors for obesity in childhood: cohort study. *BMJ (Clinical Research ed.)* **330**, 1357.
- Siervo M., Stephan B., Colantroni A. & Wells J. (2011) First-borns have a higher metabolic rate and carry a higher metabolic risk in young women attending a weight loss clinic. *Eating and Weight Disorders* **16**, e171–e176.

- Stettler N., Zemel B.S., Kumanyika S. & Stallings V.A. (2002) Infant weight gain and childhood Overweight status in a multicenter cohort study. *Pediatrics* **109**, 194–199.
- Tabacchi G., Giammanco S., La Guardia M. & Giammanco M. (2007) A review of the literature and a new classification of the early determinants of childhood obesity: from pregnancy to the first years of life. *Nutrition* **27**, 587–604.
- Taveras E.M., Rifas-Shiman S.L., Sherry B., Oken E., Haines J., Kleinman K. *et al.* (2011) Crossing growth percentiles in infancy and risk of obesity in childhood. *Archives of Pediatrics & Adolescent Medicine* **165**, 993–998.
- Toschke A.M., Koletzko B., Slikker W. Jr, Hermann M. & von Kries R. (2002) Childhood obesity is associated with maternal smoking in pregnancy. *European Journal of Pediatrics* **161**, 445–448.
- Von Kries R., Koletzko B., Sauerwald T., von Mutius E., Barnert D., Grunert V. *et al.* (1999) Breast feeding and obesity: cross sectional study. *BMJ (Clinical Research ed.)* **319**, 147–150.
- Von Kries R., Toschke A.M., Koletzko B. & Slikker W. (2002) Maternal smoking during pregnancy and childhood obesity. *American Journal of Epidemiology* **156**, 954–961.
- Weisman C., Hillemeier M., Downs D., Chuang C. & Dyer A. (2010) Preconception predictors of weight gain during pregnancy: prospective findings from the Central Pennsylvania Women's Health Study. *Women's Health Issues* **20**, 126–132.
- Whitaker R.C. (2004) Predicting preschooler obesity at birth: the role of maternal obesity in early pregnancy. *Pediatrics* **114**, e29–e36.
- WHO (2000) *Obesity: Preventing and Managing the Global Epidemic: Report of a WHO Consultation*. World Health Organization: Geneva, Switzerland.
- WHO (2003) *Global Strategy for Infant and Young Child Feeding*. Geneva, 2003. Available at: <http://www.who.int/nutrition/publications/infantfeeding/en/index.html>; http://www.who.int/childadolescent-health/NUTRITION/global_strategy.htm
- WHO (2007) *WHO Child Growth Standards*. Geneva; 2007 [updated 2007]. Available at: <http://www.who.int/childgrowth/en/> (Accessed 5 March 2011).