Caesarean birth and adiposity parameters in 6-to-8 year-old urban Maya children from two cities of Yucatan, Mexico

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ABSTRACT

Objectives: To analyze the association between birth mode and fat mass index (FMI= fat mass [kg]/height $[m]^2$), and z-score values of waist circumference (WCZ) and sum of triceps and subscapular skinfolds (SumSkfZ) in a sample of 256 6 to 8-year-old urban Maya children from the cities of Merida and Motul in Yucatan, Mexico.

Methods: From September 2011 to January 2014, we measured height, weight, waist circumference and skinfolds in children and height and weight in their mothers. Body composition was estimated in both generations through bioelectrical impedance analysis. Data on children's birth mode and birth weight were obtained from birth certificates. A pre-validated questionnaire for mothers was used regarding household living conditions. Multiple regression models were used to analyze the association between birth mode and adiposity parameters adjusting for the effect of place of residence, household crowding index, children's birth weight and maternal fat mass (FM). Separate regression models were run for boys and girls.

Results: Caesarean-born children comprised 43% of the entire sample. Caesarean section (CS) was found to be associated with higher values of body adiposity in girls, but not in boys. Specifically, our models predicted that girls born by CS had an increased value of 0.817 kg/m^2 in FMI and showed higher standard deviations values for WCZ and SumskfZ (0.29 and 0.32 SD, respectively) than girls who were delivered vaginally.

Discussion: Our results support the hypothesis that CS is associated with increased levels of adiposity in childhood, but only in girls.

Key words: caesarean birth, adiposity, children, Mexico, Maya

INTRODUCTION

The purpose of this paper is to test the hypotheses that birth mode impacts later-life body fatness in a sample of indigenous Maya people from Mexico. Hypothesis testing in the fields of human biology and public health often excludes indigenous people and other minority populations. Our goal is to broaden the cross-cultural understanding of birth mode and later life health. The rationale behind this approach is that differences in maternal health status and cross-cultural differences in early feeding patterns and obesogenic environments may generate variation in the relationship between birth mode and later body fatness.

Birth is a significant event in the human life cycle (Trevathan, 1987) and birth mode (either vaginal delivery [VD] or caesarean section [CS]) has been shown to have short- and long-term health implications for the babies and their mothers. Immediately after birth, infants born by CS more frequently show alterations in lung function, thermogenic response, blood pressure and metabolism (Hyde, Mostyn, Modi, & Kemp, 2012). In terms of future health, CS has been reported to be associated with asthma (Thavagnanam, Fleming, Bromley, Shields, & Cardwell, 2008), type-I diabetes (Cardwell et al., 2008) and celiac disease (Decker et al., 2010).

Several studies reported an increased risk of overweight and obesity in individuals who were born by CS compared to those born vaginally (Li, Zhou, & Liu, 2013; Kuhle, Tong, & Woolcott, 2015). The association between CS and offspring obesity has been examined in many studies, including some where systematic reviews and meta-analyses have been conducted. Kuhle et al. (2015) found that CS was associated with an increased risk of overweight (OR = 1.34, 95% CI 1.18-1.51), when overweight was assessed by Body Mass Index (BMI). This study included 24 studies from 15 countries and focused on children and youths between the ages of 2 and 18 years. Li et al. (2013), also conducted a systematic review and meta-analysis and found that the pooled odds ratio for obesity (also assessed by BMI) in adults born by CS was 1.50 (95% CI 1.02-2.20) suggesting that birth mode has long term health implications.

Most studies reported in these reviews used BMI to characterize risk of overweight and obesity in the populations studied. At least two studies have examined the effect of CS on other parameters of adiposity, such as waist circumference and the sum of triceps plus subscapular skinfolds thickness (Huh et al., 2012; Mesquita et al., 2013) and, again, found that infants and young adults born by CS had higher mean values for waist circumference and skinfold thickness compared to individuals born by VD.

The connection between birth by CS and higher risk for obesity seems to be explained by the characteristics of gut bacterial community established in early stages of development (Stinson, Payne, & Keelan, 2018). Studies in both humans and mice show that offspring born by CS are less exposed to maternal bacterial flora in the vagina during birth and this in turn alters the composition of their gut microbiota during the first months of postnatal life. Altered gut microbiota profiles in children and adults born by CS are characterized by an increased capacity of energy harvest and low-grade inflammation, factors potentially related to increased adiposity (Manco, Putignani, & Bottazzo, 2010). Gut microbiota also regulates entero-endocrine cell function influencing the release of several gut hormones that participate in energy store and nutritional balance (Reinhardt, Reigstad, & Backhed, 2009). In summary, these physiological mechanisms could increase the risk for obese phenotypes. In addition, early microbial colonization by CS can shape successional trajectories in microbial communities (Salminen, Gibson, McCartney, & Isolauri, 2004), which, in turns, could generate long-lasting effects on phenotype.

The sex of the offspring seems also to be of importance with female offspring being more affected. However, this evidence was gathered from animal models (Martinez et al., 2017) and more research is needed to ascertain if this also happens in humans.

The human samples included in the above-mentioned studies are, however, all from generally well-off populations that represent the majority ethnic group of their country and none has included indigenous populations. Indigenous populations tend to have different life history trajectories than non-indigenous due to their exposure to historical trauma, i.e. their systematic and historical segregation, abuse, and unequal access to basic health care and education. This is the case with the Maya people of southern Mexico as documented in many socio-cultural studies (Bracamonte, 2007; Farris, 2012). These negative factors are bound to cause a cascade of influences that perpetuate poor health outcomes in the group (Stephens, Nettleton, Porter, Willis, & Clark, 2005) both within a single generation and intergenerationally (Drake & Walker, 2004; Azcorra, Dickinson, Bogin, Rodriguez, & Varela-Silva, 2015; Azcorra, Dickinson, & Datta Banik, 2016).

In particular, poverty and food insecurity may predispose individuals to a greater risk of overweight/obesity (Kaur, Lamb, & Ogden, 2015) and this might even start in the womb. In a study by Singhal and collaborators (2003), poor foetal growth that results in lower birthweight leads to less lean body mass later in life, but it doesn't affect fat mass. This, in turn, may lead to a body composition phenotype that will potentiate the development of cardiovascular diseases. So, it is possible that the impact of delivery mode on phenotype could be exacerbated by the nutritional history of the group.

In fact, indigenous populations are not even regularly included in national health surveys, nor in systematic reviews and meta-analysis (Coimbra et al., 2013). Therefore, despite so many studies in the area, there is a marked gap in the literature regarding birth mode and health outcomes among indigenous groups. Our study aims to start filling this research gap by focusing on the Maya people from Mexico.

The rate of births by CS has increased globally, in particular in low- to middle-income countries including Mexico (Villar et al., 2006; Lumbiganon et al., 2010). According to the 2012 National Survey of Health and Nutrition (ENSANUT as per the Spanish name), in Mexico, the rate of CS was estimated to be 46.9% overall or up to 70% in private hospitals (Heredia-Pi, Servan-Mori, Wirtz, Avila-Burgos, & Lozano, 2014). These figures place Mexico as a country with one of the highest rates of CS in the world. In the southern Mexican state of Yucatan, the rate of CS observed during 2008-2015 ranged from 48% to 53% (SINAC, 2017) and even the rural Maya women experienced high frequencies of birth by CS. In the same context, Mexico and particularly Yucatan, show alarming rates of overnutrition in children and adults (INSP, 2012). In urban contexts, around 40% and 80% of urban Maya children and adults from Yucatan are classified as overweight or obese, respectively (Varela-Silva et al., 2012; Azcorra, Varela-Silva, Rodríguez, Bogin, & Dickinson, 2013; Méndez et al., 2015).

There is one study exploring the association between birth mode and adiposity outcomes in rural Yucatec-Maya children with minimal exposure to the nutritional transition (Veile & Kramer, 2016). Here, the authors found that caesarean-born children showed higher average BMI values than vaginally born children. This association was stronger in the presence of mothers with high BMI. It is important to note, however, that the percentage of overweight among the children was low (5%) and there were no obese children. This means that BMI variations by birth mode, in this sample, occur within a range capped on the right side of the statistical distribution for BMI, and a longer tail on its left side. The mean z-scores for height-for-age (HAZ), an indicator of chronic malnutrition or stunting, were very low. Furthermore, vaginally born children showed significantly lower mean HAZ values (-2.78, SD = 1.06) than caesarean born children (-2.59, SD = 1.07) suggesting that birth mode impacts not only adiposity parameters but also growth in length.

In this study we test the hypothesis that birth by CS is associated with higher body fatness during childhood by using data from a research project that addressed the intergenerational effects and early developmental factors associated with growth and nutritional status in urban Maya families from Yucatan, Mexico. The study of the effect of birth mode on phenotypes provides a useful scenario to analyze the implications of conditions experienced in early stages of development on future health. In this study we aim to analyze the association between birth mode and fat mass index (FMI = fat mass [kg]/height [m]^2), waist circumference and sum of triceps, and subscapular skinfolds in a sample of 256 6- to 8-year old children from the cities of Merida and Motul, in Yucatan, Mexico.

METHODS

Ethical clearance

This research project was reviewed and approved by the Bioethics Committee for the Study of Human Beings of the Center for Research and Advanced Studies of the National Polytechnic Institute (Cinvestav-IPN) of México and the Loughborough University Ethics Advisory Group (R11-P133). Participant mothers signed consent forms and the children gave their verbal assent.

The study location

The cities of Merida and Motul are in the State of Yucatan, Mexico. Merida is the capital city and represents the most important economic center in the Mexican southeast given its importance in terms of services (education, health and commerce) and infrastructure facilities. By 2015, Merida was inhabited by 892,363 people (INEGI, 2016), with a Maya population of around 11% (Lizama Quijano, 2012). The presence of Maya people in Merida corresponds to a process of rural to urban migration that was initiated in the 18th century, during the Spanish Colonial period and the 19th century, after the independence of Mexico, and has intensified since the 1970's. During the last decade, in Merida there have been recorded, on average, 15,000 births per year, of which around 54% have been through CS. The city of Motul, located in the north-central region of the state at approximately 40 km from Merida city, was inhabited in 2015 by 36,097 people; 25% of them were Maya speakers (INEGI, 2016). Nowadays, the economic activities in Motul consist of small-scale livestock production and agriculture, tourism, and *maquiladoras* (manufacturing operations). In Merida, most of the adult population works as employees and wage labourers in small business performing low wage jobs. In Motul, around 550 births have been registered annually during the last ten years, with a CS frequency of around 49%.

Sample

The sample size was calculated considering the statistical power. Setting the significance level at α=0.05, the power at 0.80 with a medium size error of 0.15 and eight independent variables in a multiple regression model, we found that a sample of 107 children and their mothers was required. The final sample consisted of 177 mother-child dyads from Merida and 79 dyads from Motul (49.6% girls of both cities). In both cities participants were recruited through primary schools attended by children. In Merida, participants were recruited in 47 schools from low-income neighbourhoods, with a high concentration of Maya speakers, located in several areas of the city. To allow for maximum socioeconomic variability in the sample, we selected no more than ten children from each school. In schools where more than ten children met the inclusion criteria, ten were randomly selected. In the case of Motul, mother-child dyads were recruited in all public primary schools of the city (n = 12). The inclusion of participants was based on the following criteria: 1) that children were between 6.0 to 8.9 years of age, 2) the presence of the child's biological mother and 3) that each member of the dyad have paternal and maternal Maya surnames.

Data collection

From September 2011 to January 2014 we measured height, weight, waist circumference and triceps and subscapular skinfolds in children and height and weight in their mothers. Children were measured in schools during mornings, two hours after breakfast and before any intense physical activity. Mothers were measured during a home visit. Participants were measured by trained research personnel following standardized procedures (Lohman, Roche, & Martorell, 1998). Body composition was assessed in children and mothers using a bioelectrical impedance analyzer (Bodystat 1500 MDD). In children, body fat mass (FM) was estimated using the equation developed by Ramírez et al. (2012) that was based on a sample of Mexican school children from different geographical regions and ethnicities within the country, using deuterium oxide dilution technique. Fat-free mass (FFM) was calculated using resistance of the bioelectrical impedance, height, and weight values (Equation 1), and then converted to FM (Equation 2) and fat mass index (FMI) (Equation 3).

Equation 1:

$$FFM\ (kg) = 0.661 \times height\ (cm)^{2} / resistance\ (\Omega) + 0.200 \times weight\ (kg) - 0.320$$

Where Ω = ohms

Equation 2:

$$FM\ (kg) = weight\ (kg) - FFM\ (kg)$$

Equation 3:

$$FMI\ (kg/m^2) = FM\ (kg) / height\ (m)^2$$

Body FM in mothers was estimated with an equation developed by Macias et al. (2007) based on a sample of 20 to 50-year-old Mexican women from low, middle, and upper income levels. The predictive equation for bioelectrical impedance was developed using air displacement plethysmography as a standard method to measure body composition. Accordingly, FFM was computed using height, weight, resistance and reactance of bioelectrical impedance and age of adult women (Equation 4), and then was converted to FM (Equation 5).

Equation 4:

$$Mothers'\ FFM\ (kg) = 0.7374 \times [height\ (cm)^2 / resistance\ (\Omega)] + 0.1763 \times [weight\ (kg)] - 0.1773 \times [age\ (years)] + 0.1198 \times [reactance\ (\Omega)] - 2.4658$$

Where Ω = ohms

Equation 5:

$$Mothers'\ FM\ (kg) = weight\ (kg) - FFM\ (kg)$$

Body mass index (BMI) was calculated in children and adult women only for descriptive purposes. Percentiles and z-scores by children's age and sex were calculated for height (HAZ), BMI (BMIZ), waist circumference (WCZ) and sum of skinfolds (SumSkFZ) using the growth reference data published by Frisancho (2008). Stunting (low height-for-age) was defined in children and mothers based on a HAZ below the 5th percentile (or a z-score $\leq$-1.650) in the reference data. Values of reference data for BMIZ, WCZ and SumSkfZ above the 85th percentile (or a z-score >+1.036) were used to define BMI-based excess weight (overweight + obesity) in children and also for high body fatness estimated by waist circumference and SumSkf. Excess weight in mothers was defined as a BMI greater than 25 kg/m^2 (WHO, 1995). Growth reference values for FM/FMI are not available for Mexican populations.

During the home visit, a pre-validated questionnaire for mothers was used regarding household living conditions. We recorded data on family size and number of bedrooms to calculate crowding index. Overcrowding in the home has been shown to be the indicator that best expresses the variation in the living conditions in urban Maya families (Azcorra, Datta Banik, & Dickinson, 2016). Data on children's birth mode (VD vs CS) and birth weight data were obtained from birth certificates provided by mothers.

Data analyses

Student's *t*-tests were used to test differences in mean values of children's anthropometric and body composition characteristics and derived variables by sex and birth mode. Chi-square tests were used to compare the proportions of children's nutritional status categories between groups of birth mode. Normality in the distribution of outcome variables was analyzed graphically through probability plots. The association between CS and child's adiposity was analyzed through multiple linear regression models. Outcome variables were FMI (kg/m^2), WCZ and SumSkfZ. Separate regression models were run for boys and girls. Models for FMI were adjusted for place of residence (Merida vs Motul), household crowding index, child's age, birth weight and maternal FM. Models for WCZ and SumSkfZ were adjusted for the same variables, except for child's age since z-scores already take age into account. The exposure factor was CS. Interactions were statistically tested between CS and maternal FM and child's birth weight. Diagnostic tests were applied to determine model validity. Possible departures from the statistical assumptions were explored through diagnostic plots of residuals; all of these supports the appropriateness of the regression models for the data. Data entry and analysis were made with Stata/IC 11.1 for Windows statistical package (StataCorp LP, 2010). The significance level for statistical tests was $\alpha = 0.05$.

RESULTS

Mean age of children and mothers was 7.54 (SD = 0.83) and 32.99 (SD = 5.53) years, respectively. Caesarean-born children comprised 43% of the entire sample.

Anthropometric characteristics and nutritional status of participants

Twelve percent of children met the criteria for stunting and 37%, 32% and 26% exhibited excess values of BMI, WC and SumSkf according to their age and sex, respectively. Girls showed significantly higher values of WCZ and SumSkfZ than boys. Mean birth weight for all children was 3126 g (SD = 502). The mean value of maternal height was 147.80 cm (SD = 4.95) and 73% of mothers were below the 5^{th} percentile (150 cm) of the growth reference, while 86% of mothers had a BMI above 25 kg/m^2 and their average body FM was 26 kg (SD = 7.60). Mothers of boys and girls born by CS were significantly shorter than mothers of children born vaginally.

Caesarean section and children´s adiposity

Girls born by CS showed significantly higher values in SumSkfZ than those vaginally delivered and differences in FMI and WCZ were nearly significant (p = 0.054 and p = 0.065, respectively). Caesarean-born girls showed a significantly higher proportion of exceeded values of SumSkf (above 85^{th} percentile) than those vaginally delivered (Table 1). Boys born by CS and VD were similar in all adiposity parameters and categories of nutritional status.

TABLE 1 HERE

Results of multiple regression models for outcome variables are shown in Table 2. After adjusting for the effect of covariates, CS delivery was associated with higher values in all adiposity parameters in girls. Specifically, regression models showed that girls born by CS had 0.817 kg/m^2 higher FMI and were 0.29 and 0.32 standard deviations higher in waist circumference and sum of skinfolds respectively than girls delivered vaginally. In boys, CS was not statistically associated with adiposity parameters.

TABLE 2 HERE

DISCUSSION

Excess body weight is a widespread condition among children and their mothers in this sample of urban Maya families from Yucatan. Our results support the hypothesis that CS is associated with increased levels of adiposity in childhood, but only in girls.

There are few studies on the relationship between CS and indicators of adiposity. In a study among young adults (23 to 25 years of age) from the 1978/79 Ribeirão Preto Birth Cohort from Brazil, Mesquita and collaborators (2013) reported that individuals born by CS had an increased risk for having higher mean values of waist circumference ($\geq$90 cm for men and $\geq$80 cm for women), WHtR (>0.5), waist-to-hip ratio ($\geq$0.90 for men and $\geq$85 for women) and triceps and subscapular skinfolds ($>90^{th}$ percentile). These results were found after controlling for the effect of individuals' birth weight and sex, maternal age, parity, schooling, smoking during pregnancy and gestational age. Likewise, studying children enrolled in the Project Viva in Massachusetts in the United States at the age of 3 years, Hu and co-workers (2012) found that CS was associated with higher skinfold thicknesses (0.94 mm; 95% CI, 0.36-1.51 mm). In the context of our sample, CS was associated with higher levels of FMI, sum of triceps and subscapular skinfolds and waist circumference, measures for total body fat and estimates of subcutaneous and deep adipose tissues, respectively.

The effect of birth by CS on phenotype has been previously analyzed in the Maya population. Studying a longitudinal sample of 108 children aged 0 to 5 years from an agricultural community from Yucatan, Veile and Kramer (2016) found that birth by CS was a significant predictor of higher z-score values of weight-for-age and BMI-for-age indicators after adjusting for children's sex, age and birthweight and maternal BMI. More pronounced differences in growth trajectories according to birth mode were found in children whose mothers had higher values of BMI and in children with higher birth weights. In our study, there was no association between birth mode and mother's FM and children birth weight and these results might be explained by the fact that mothers from Merida and Motul have on average higher values of BMI than women studied by Veile and Kramer in the rural Yucatan (mean = 29.74 kg/m^2, [SD = 4.73] vs mean = 27.38 kg/m^2 [SD = 3.56], $p<0.001$).

Regression models showed a positive association between CS and adiposity in girls. Birth weight and maternal FM of girls did not differ according to their birth mode, which suggests that association between CS and outcome variables in this sex group is not explained by these factors. None of the studies on the relationship between CS and indicators of adiposity cited above report sex differences in the effect of CS. There is some evidence in non-human animals that CS has a differential effect on phenotype between males and females. Investigating the impact of CS on body weight gain and gut microbiota during early development in mice, Martinez and collaborators (2017) found that CS delivered mice showed higher post-weaning mass gain than VD controls. In both sexes, mice gained 33% more weight at age 15 weeks if they were born by CS, but female mice showed an increased influence with 70% higher weight gain.

Why were CS deliveries positively associated with greater adiposity levels in girls, but not in boys? Studies in humans and mice suggest that differences in endocrine and immune systems between sexes induce different gut microbiota profiles in males and females (Fransen et al., 2017). Studies have demonstrated sexual dimorphism in several aspects of gut microbiota, including their composition (Dominianni et al., 2015; Mueller et al., 2006; Li et al., 2008), their changes in response to factors such as diet (Bolnick et al., 2014; Karunasena, McMahon, Chang, & Brashears, 2014) and their diversity, structure and individual phylotype during the colonization in germ-free mice (Wang et al., 2016). Females have consistently shown lower abundance of Bacteroidetes in their microbiota, a group of bacteria with beneficial effects in metabolism (Dominianni et al., 2015; Mueller et al., 2006). More importantly sex differences in gut microbiota have shown to play a key role in sex-related diseases (Markle et al., 2013; Yurkovetskiy et al., 2013). A recent study with mice found that a transfer of male microbiome to females drove testosterone-dependent attenuation of autoimmune phenotypes and protection from Type I Diabetes (Markle et al., 2013). It has been proposed that gender differences in the immune system select a genus-specific intestinal microbiota composition, which in turn contributes to gender differences in the immune system (Fransen et al., 2017). In the context of our study, it is possible that higher adiposity levels shown by female offspring in response to caesarean delivery is due to the early configuration of a gut microbiota with less beneficial characteristics in terms of metabolism, in comparison to male offspring. In the study of Martinez and collaborators (2017) cited above, the researchers also found that mice delivered by CS showed a lower diversity in their microbiota at weaning and showed no major changes in microbiome maturity during the four weeks after weaning.

The positive association between CS and levels of fatness in girls, but not in boys, has not been reported in other studies with human samples. Unfortunately, at this point we are unable to explain why it is the case in our data. This fact calls for further research to find the effects of CS on body composition of male and female offspring and the mechanisms that could explain the possible differences between sexes.

Consistent with the global tendency, the rate of CS in this sample was high (43%). Several factors have been associated with high rates of CS. It has been showed that the dual burden of malnutrition –the coexistence of short stature and overweight/obesity- exacerbate obstetric complications through influences on maternal phenotype and new-born size (Wells, Wibaek, & Poullas, 2018). Almost 63% of mothers of this sample exhibited short stature and high BMI. Mothers of children born by CS were shorter than mothers of vaginally delivered children and this finding is consistent with several studies that show a negative association between maternal height and incidence of CS (Mahmood, Campbell, & Wilson, 1988; McGuinness & Trivedi, 1999; Prasad & Al-Taher, 2002; Okewole et al., 2011; Stulp, Verhulst, Pollet, Nettle, & Buunk, 2011; Benjamin, Daniel, Kamath, & Ramkumar, 2012). Maternal height has been shown to be positively correlated with pelvic measurements (Mahmood et al., 1988; Adadevoh, Hobbs, & Elkins, 1989) and this in turn may contribute to the increased incidence of CS deliveries due to cephalopelvic disproportion (Benjamin et al., 2012). On the other hand, maternal obesity before and during pregnancy are related to obstetric complications due to increased CS frequency (Weiss et al., 2004) and exposes the foetus to high levels of nutrients, increasing the risk of high birth weights.

Strengths and limitations

In this study we analyzed the effect of births by CS on more direct parameters of adiposity; most of available studies in children use the indirect measure of body mass index as a proxy for overweight/obesity. Body mass index was used in this study only to describe the nutritional status of mothers and their children. Regarding the limitations of this study, we lack information on children's diet and energy expenditure which would better explain variation in child adiposity. The cross-sectional nature of this study is another limitation, further research is needed to investigate the effect of CS on body fat gain during infancy and childhood.

Conclusion

The results of this study show the frequency of CS among the urban Maya population from Merida, Mexico, is high. Our analyses show that CS delivery is associated with higher values of FMI and z-score values of waist circumference and sum of triceps and subscapular skinfolds in children, but only in female offspring and this finding is not explained by differences in birth weight and maternal fat mass. It is possible that higher adiposity levels shown by female offspring in response to caesarean delivery is due to the early configuration of a gut microbiota with less beneficial characteristics in terms of metabolism.

In a broader context, our results contribute to the discussion on the implications of rising caesarean birth rates on short and long-term offspring health outcomes. It is important to recognize that while caesarean deliveries may save a significant number of lives of mothers and babies, particularly in populations with high risk of perinatal morbidity and mortality, they also have some negative consequences on population health and wellbeing, in the short and long term.

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The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

HA formulated the research question and wrote the first draft of the manuscript. HA and LR analyzed the data. BB, FD, SDB and IVS contributed to the creative process of this paper by providing scientific content and intellectual additions on the subsequent drafts of the manuscript.

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TABLE 1 Descriptive statistics of anthropometric, body composition characteristics and derived variables of mothers and children according to child birth mode by sex

	Boys					Girls				
	VD (n = 71)		CS (n = 58)			VD (n = 76)		CS (n = 51)		
Variable	Mean	SD	Mean	SD	*P*-value	Mean	SD	Mean	SD	*P*-value
Mothers										
Age (years)	33.17	5.04	32.29	5.28	0.339	32.67	5.74	33.66	6.01	0.354
Height (cm)	148.39	4.58	146.27	4.36	0.019	149.40	4.05	146.53	4.76	<0.001
BMI (kg/m^2)	29.76	4.68	30.21	5.04	0.603	29.97	4.80	29.00	4.47	0.256
FM (kg)	26.57	6.98	25.46	7.14	0.402	26.64	7.94	25.07	7.69	0.268
Children										
Age (years)	7.57	0.83	7.59	0.92	0.888	7.55	0.82	7.44	0.77	0.472
Birth weight (g)	3164	398	3086	467	0.383	3142	403	3056	496	0.354
Height (z-score)	−0.70	0.81	−0.57	0.94	0.427	−0.57	0.93	−0.45	0.83	0.451
BMI (z-score)	0.82	0.99	1.04	1.00	0.243	0.58	0.96	0.91	1.00	0.068
WC (z-Score)	0.51	0.83	0.65	0.82	0.368	0.66	0.77	0.92	0.77	0.065
SumSkf (z-Score)	0.30	0.83	0.43	0.86	0.398	0.54	0.79	0.85	0.80	0.038
FMI (kg/m^2)	5.45	2.02	5.78	2.27	0.375	5.67	2.08	6.42	2.18	0.054
Nutritional status										
Exceeded BMI (≥85th percentile)	38%		41%		$X^2_{(1)} = 0.150$, $P = 0.699$	29%		41%		$X^2_{(1)} = 2.04$, $P = 0.153$
Exceeded WC (≥85th percentile)	31%		28%		$X^2_{(1)} = 0.178$, $P = 0.673$	30%		45%		$X^2_{(1)} = 2.91$, $P = 0.088$
Exceeded SumSkf (≥85th percentile)	21%		22%		$X^2_{(1)} = 0.031$, $P = 0.860$	25%		42%		$X^2_{(1)} = 4.02$, $P = 0.045$

BMI, body mass index; CS, caesarean section; FM, fat mass; FMI, fat mass index; SD, standard deviation; Stunting, low height-for-age; SumSkf, sum of skinfolds (triceps, subscapular and suprailiac); VD, vaginal delivery; WC, waist circumference.

TABLE 2 Regression models relating caesarean section to children's fat mass index, waist circumference and sum of triceps and subscapular skinfolds, by sex

	Boys			Girls		
Variable	B (SE)	95% CI	*P*-value	B (SE)	95% CI	*P*-value
Fat mass index (FMI = kg/m^2)	0.275 (0.331)	−0.38 0.93	0.409	0.817 (0.373)	0.08 1.56	0.031
Waist circumference (z-score)	0.143 (0.141)	−0.14 0.42	0.312	0.295 (0.141)	0.02 0.57	0.038
Sum of skinfolds (z-score)	0.128 (0.144)	−0.16 0.41	0.377	0.324 (0.146)	0.03 0.61	0.028

Models for FMI were adjusted for location (Merida vs Motul), household crowding index, children's age (years) and birth weight (g), and maternal body fat mass (kg); models for waist circumference and sum of skinfolds were adjusted for the same variables except for children's age.
SE, standard error.