Research Article

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Neonatal anthropometry outcomes comparing two gestational weight gain standards

Abstract

Objectives: The gestational weight gain chart published by Rosso and Mardones (RM) was used by the Ministry of Health in Argentina from the 1990s until 2009, when it was replaced by the Calvo et al. chart (CEA). This study compared the diagnostic capability of the RM and CEA charts for identifying mothers at risk of delivering babies with signs of intrauterine growth impairment (Birth length<50 cm, Birth weight <2500 g, Birth weight <3000 g and Birth weight >4000 g).

Methods: Data from pregnant women and neonates studied in Santiago, Chile (n = 27,600), as well as a sub-sample of 11,465 term healthy singleton cases were utilized. Frequency distributions of women and their 95% confidence intervals were calculated for both charts at the first and third trimester of pregnancy. Sensitivity, specificity, positive and negative predictive values of undesirable outcomes of the RM and CEA charts were compared.

Results: The CEA chart classified as either underweight or obese a smaller number of women than the RM chart. The proportion of neonates with signs of intrauterine growth impairment was similar in both charts, however the number of affected neonates was higher in the women considered to be either underweight or obese by the RM chart. Higher sensitivity values for undesirable outcomes were displayed by the RM chart. The sum of sensitivity and specificity was also higher for the RM chart, meaning a greater diagnostic accuracy; this sum was comparable only for birth weight <2500 g. The RM chart was found to have higher positive and negative predictive values for undesirable outcomes than the CEA chart.

Conclusion: The RM chart has a better diagnostic capability than the CEA chart to identify mothers at risk of delivering babies with signs of intrauterine growth impairment.

Keywords: gestational weight gain, growth charts

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Abbreviations:

RM, Rosso and Mardones; CEA, Calvo et al; BMI, body mass index; BW, birth weight; GA, gestational age

Introduction

Maternal body mass index (BMI) at conception and gestational weight gain significantly influence birth weight (BW).[1] Both, obese and underweight women have a higher probability of delivering babies either large or small for gestational age, respectively. Thus, nutritional counseling before and during pregnancy may have a significant impact on neonatal outcomes.[2] Based on data from a population of Chilean gravidas and using BMI as an indicator of maternal nutritional status, we developed a chart, named Rosso-Mardones (RM), to monitor adequacy of maternal nutritional status throughout pregnancy.[3] This chart was used by the Chilean National Health Systems until 2004, when a study by Atalah et al.[4] proposed a wider "normalcy" area for at term maternal BMI.[4]

Currently, most Latin American countries are using either the original RM chart or the modification of this instrument proposed by Atalah et al.[5] One of the exceptions is Argentina, where in 2009 the Ministry of Health replaced the RM chart by a chart proposed by Calvo et al. (CEA). In the United States and in many countries of the Northern Hemisphere, the U.S. Institute of Medicine (IOM) guidelines have been used since the nineties.[6] Thus, a global consensus on desirable gestational weight gain for a given maternal weight/height in early pregnancy is still lacking.[5]

The RM chart has shown a greater sensitivity to identify women at nutritional risk of delivering babies with signs of fetal growth impairment than both the US IOM recommendations and the Atalah chart.[7] Consequently, a percentage of women misdiagnosed as "normal" failed to receive adequate nutritional counseling regarding their desirable gestational weight gains.

In the present study we compared the diagnostic capability of the RM chart and the maternal weight gains chart used by the Argentinian Ministry of Health (CEA chart)[8–10] for identifying mothers at risk of delivering babies with signs of intrauterine growth impairment.

Material and methods

The study was performed using a data base containing information from deliveries at the maternity unit of Hospital Dr. Sotero del Rio, in the South-East Public Health Service of Santiago, Chile.[11] which serves a mixed population of low-income and middle-income families.[12] Genetic studies have shown that in the Chilean population 44 per cent of the genes are indigenous American, 52 percent European and 4 per cent African.[13] Data analysis contributing to this work comply with the ethical standards of the relevant national guidelines on human experimentation provided by the Chilean National Fund for Research in Science and Technology (FONDECYT) and with the World Medical Association's Declaration of Helsinki. The study was approved by the Institutional Ethics Committee (Project ID 12-331).

The general study group included all individual clinical records with singleton live births during the recruitment period from January 22, 2000, to April 24, 2004. From an initial number of 28,898 cases evaluated, a total sample of 27,600 cases with complete anthropometric and health information was considered. 1,298 cases were excluded due to maternal height ⩽130 cm or ⩾200 cm or lacked the required maternal weight data at recruitment. In addition, a sub-sample of 11 466 healthy pregnancies were selected to ascertain the effect of maternal nutritional status on fetal growth excluding the potential effect of confounding factors. Inclusion criteria for the sub-sample included: maternal age over 18 years old, term deliveries (39–41 weeks of gestation), without medical and obstetrical conditions with known effect on fetal growth, and absence of alcohol or drugs consumption. Term deliveries were defined as those with 39-41 weeks of gestation considering that births before 39 weeks and over 41 weeks of gestational age (GA) are associated with adverse child health outcomes.[14–16] Moreover, births before 39 weeks are associated with chronic diseases in adults.[17] The 39–41 weeks GA category constitutes the ideal and typical duration of pregnancy.[18]

Nutritional classification of the women at the beginning and at the end of pregnancy was performed utilizing both the RM and CEA charts. The BMI cut-off points for the two charts at week 10 are the following: underweight category for the RM chart < 21.15 and for the CEA chart <20.00; normal category for the RM chart 21.15-24.49 and the CEA chart 20.00-27.2; overweight category for the RM chart 24.50-26.73 and the CEA chart 27.30-35.70; obese category for the RM chart > 26.73 and the CEA chart > 35.70. At week 40 are the following: underweight category for the RM chart < 26.55 and for the CEA chart <24.60; normal category for the RM chart 26.55-28.90 and the CEA chart 24.60-32.59; overweight category for the RM chart 28.91-30.03 and the CEA chart 32.60-39.60; obese category for the RM chart > 30.03 and the CEA chart > 39.60.

Considering that those extremes of BW, i.e. <2500 g, <3000 g, and >4000 g, are related to increased mortality and morbidity risks during the first month and first year of life, neonates at risk were defined with those values.[14,19–21] In addition, we utilized BL <50 cm as a proxy for shortness at birth, which has been associated with obesity, high blood pressure, insulin resistance, and lower school achievement scores in Chilean children.[22–25]

Maternal anthropometry was measured with beam scales (Condor®, Santiago, Chile) at prenatal health visits and the maternity unit, following a standard protocol.[11]

Pre-pregnancy weight was reported by patients. The start point of nutritional status classification was 10 weeks of gestation for both gestational weight gain charts. Considering the modest weight change typically observed during the first weeks of pregnancy, chart comparison would not be affected by the use of similar pre-pregnancy weight to estimate its value at the beginning of gestation. Instructions for using the CEA chart have been published in 2009, 2012 and 2013.[9,26,27]

Maternal blood pressure was measured utilizing calibrated sphygmomanometers, after seating and resting for at least 15 min. Blood samples were obtained at first trimester for blood group classification, rhesus status, glycaemia and rapid plasma reagin test for syphilis. A urine sample was also included for urine sediment analysis. A second syphilis test, as well as a glucose tolerance test, were performed at week 28 of gestation. Pre-eclampsia was diagnosed by the presence of hypertension, edema, and proteinuria, confirmed by laboratory analysis of a 24-hour urine collection (more than 300 mg/day). Plasma urea concentration and creatinine clearance were also measured. Appropriate high-risk care was assured for all women with significant pathology.

Gestational age was based on the date of the last menstrual period and confirmed by fetal biometry using trans-vaginal ultrasound (first trimester) or trans-abdominal ultrasound (second trimester), performed by trained personnel. Ultrasound equipment included: Voluson 730 PRO (GE Healthcare, Chalfont St. Giles, UK); Acuson 120XP (Acuson Inc., Mountain view, CA, USA).

Mothers and neonates were evaluated and diagnosed by the attending physicians. After delivery, infants were dried and weighed using an electronic self-calibrating scale Tanita 1583 (Tanita Corporation, Arlington Heights, IL, USA, accurate to 10 g), or Seca 345 (Secacorp, Hamburg, Germany, accurate to 20 g). A custom-made neonatometer was used to measure the crown-heel length to the nearest 1 mm.

Proportions of pregnant women in each nutritional category with 95% confidence intervals (95%CI) were calculated at the beginning and the end of pregnancy for both charts. McNemar's χ^2 test was used to investigate the potential differences in the proportions of the four main target events, BL <50 cm, BW <2500 g, BW <3000 g and BW >4000 g, at each maternal nutritional category of the RM and CEA charts. Sensitivity and specificity values for both charts were obtained using the four target events: BL <50 cm, BW <2500 g and BW <3000 g for underweight women and BW >4000 g for obese women. Positive and negative predictive values (PPV and NPV) were also estimated. A p value < 0.05 was considered statistically significant. All analyses were performed using Phyton 3.0 for Windows.

Results

The total sample and the sub-sample of healthy pregnant women did not differ in mean ± SD values of demographic and anthropometric characteristics (Table 1). Nevertheless, the sub-sample of healthy pregnant women had significantly lower proportions of neonates with signs of intrauterine growth impairment: BW<2500 g, BW <3000 g, and BL <50 cm, than the total sample: 6.50 (95%CI 6.23-6.82) versus 0.61 (95%CI 0.47-0.75); 9.24 (95%CI 8.72-9.78) versus 15.12 (95%CI 14.70-15.55) and 34.11 (95%CI 33.24-34.98) versus 46.91 (95%CI 46.32-47.49). In addition, the sub-sample of healthy pregnant women had a significantly higher proportion of BW >4000 g than the total sample: 11.74 (95%CI 11.15-12.33) versus 9.14 (95%CI 8.80-9.48).

Table 1 Demographic and anthropometric characteristics of women and newborns in the total sample and the subsample of healthy pregnant women from the Sotero del Rio Hospital, Santiago, Chile, 2000–2004

	Total sample (n=27,600)	**Healthy sub-sample (n=11,465)**
Variable	Mean±S.D.	Mean±S.D.
Age (years)	26.2±7.2	26.54±6.21
Maternal height (cm)	156.5±5.9	156.62±5.9
Pregestational weight (kg)	61.1±15.3	60.84±10.7
Parity	1.3±1.2	1.3±1.1
Pregestational BMI	24.9±5.9	24.8±4.16
Gestational weight gain (kg)	12.0±20.7	13.28±5.93
Gestational age at birth (weeks)	38.9±2.2	39.71±0.72
Birth weight (g)	3 317.5±581.9	3 505.56±411.35
Birth length (cm)	49.3±2.9	50.15±1.8

The number of women classified as underweight and obese in the sub-sample of 11,465 healthy pregnant cases was higher for the RM chart than the CEA chart. The number of women included in the normal and overweight categories, both at the beginning and the end of pregnancy, was higher for the CEA chart than for the RM chart (Table 2).

Table 2 Frequency distribution (%) and confidence intervals (CI) of pregnant women as diagnosed by the RM chart and the CEA chart at the beginning of pregnancy and the end of pregnancy in the subsample of healthy pregnant women from the Sotero del Rio Hospital, Santiago, Chile, 2000–2004 (3, 8)

	RM at 10 weeks			**CEA at 10 weeks**		
Category	n	%	CI	n	%	95%CI
Underweight	2,052	17.9	17.2-18.6	1,030	8.98	8.46-9.51
Normal	4,159	36.28	35.4-37.16	7,754	67.63	66.78-68.49
Overweight	2,185	19.06	18.34-19.78	2,455	21.41	20.66-22.16
Obese	3,069	26.77	25.96-27.58	226	1.97	1.72-2.23
Total	11,465	100		11,465	100	
	RM at 40 weeks			**CEA at 40 weeks**		
Category	n	%	CI	n	%	95%CI
Underweight	2,028	17.69	16.99-18.39	698	6.09	5.65-6.53
Normal	2,617	22.83	22.06-23.59	7,945	69.3	68.45-70.14
Overweight	1,298	11.32	10.74-11.9	2,547	22.22	21.45-22.98
Obese	5,522	48.16	47.25-49.08	275	2.4	2.12-2.68
Total	11,465	100		11,465	100	

Percentages of neonates with BL <50 cm, BW <2500, BW <3000 g and BW >4000 g observed in each maternal nutrition category were similar for the RM and the CEA charts, both at the beginning and the end of pregnancy in the total sample of 27,600 women. None of the differences observed between the proportions were statistically significant (Table 3). However, the absolute numbers of newborns with signs of intrauterine growth impairment were higher in women categorized as underweight or obese by the RM chart than those classified by the CEA chart.

Table 3 Frequencies, % (n), of newborns with birth weight (BW) <2500 g and <3000 g, birth length (BL) <50 cm, and BW >4000 g, at each total category of maternal nutritional status (n, %, 95%CI) as diagnosed by the RM chart and the CEA chart in the total sample at the beginning (10 weeks) and the end (40 weeks) of pregnancy from the Sotero del Rio Hospital, Santiago, Chile, 2000–2004 (n = 27,600)

10 weeks								
Category	**Chart**	**BW <2500 g**	**BW <3000 g**	**BL <50 cm**	**BW ≥4000 g**	**Total in each nutritional status**		
						n	**(%)**	**95%CI**
Underweight	RM	6.67(268)	18.63(748)	50.83(2 041)	4.66(187)	4,015	14.55	14.13-14.96
	CEA	6.69(115)	18.28(310)	50.06(849)	4.78(81)	1,696	6.14	5.86-6.43
Normal	RM	6.50(636)	16.74(1 638)	48.49(4 746)	6.91(676)	9,787	35.46	34.9-36.02
	CEA	6.43(1 154)	16.07(2 886)	48.05(8 630)	7.58(1 362)	17,960	65.07	64.51-65.63
Overweight	RM	6.13(304)	14.23(705)	45.9(2 275)	9.93(492)	4,956	17.96	17.5-18.41
	CEA	6.18(369)	11.37(679)	41.92(2 504)	13.83(826)	5,973	21.64	21.16-22.13
Obese	RM	6.71(593)	12.25(1 083)	43.93(3 884)	13.2(1 167)	8,842	32.04	31.49-32.59
	CEA	8.30(163)	15.17(299)	48.86(963)	12.84(253)	1,971	7.14	6.84-7.45
Total		13.05(3 602)	15.12(4 174)	46.91(12 946)	9.13(2 522)	27,600		
40 weeks								
Category	**Chart**	**BW <2500 g**	**BW <3000 g**	**BL <50 cm**	**BW ≥4000 g**	**Total in each nutritional status**		
						n	**(%)**	**95%CI**
Underweight	RM	10.40(532)	22.18(1 134)	57.27(2 928)	3.46(177)	5,113	18.53	18.07-18.98
	CEA	13.66(299)	23.85(522)	60.71(1 329)	3.02(66)	2,189	7.93	7.61-8.25
Normal	RM	5.82(329)	17.87(1 009)	49.44(2 792)	5.26(297)	5,647	20.46	19.98-20.94
	CEA	5.65(970)	15.89(2 726)	47.5(8 150)	7(1201)	17,157	62.16	61.59-62.74
Overweight	RM	4.88(137)	14.6(410)	45.53(1 279)	7.37(207)	2,809	10.18	9.82-10.53
	CEA	4.16(247)	10.13(602)	38.72(2 301)	15.99(950)	5,943	21.53	21.05-22.02
Obese	RM	11.27 (803)	11.55(1 621)	42.38(5 947)	13.12(1 841)	14,031	50.83	50.25-51.43
	CEA	12.33(285)	14.02(324)	50.45(1 166)	13.2(305)	2,311	8.37	8.05-8.70
Total		13.05(3 602)	15.12(4 174)	46.91(12 946)	9.13(2 522)	27,600		

*McNemar's $\chi 2$ test: P values were not significant for all comparisons

Sensitivity values were higher for the RM chart for all the performed comparisons (Table 4). Although the specificity values were higher for the CEA chart, the sum of sensitivity and specificity values was higher for the RM chart. PPV and NPV were also higher for the RM chart in all comparisons (Table 4).

Table 4 Sensitivity (Se), specificity (Sp), positive and negative predictive values (PPV and NPV) for both charts corresponding to each target event: birth weight (BW) <2500 g and <3000 g, birth length (BL) <50 cm, and BW >4000 g, at each category of maternal nutritional status as diagnosed by the RM chart and the CEA chart in the total sample from the Sotero del Rio Hospital, Santiago, Chile, 2000–2004, at the beginning (10 weeks) and at the end of pregnancy (40 weeks) (n = 27600)

10 weeks					
Outcome	**Chart**	**Se**	**Sp**	**PPV**	**NPV**
BW < 2500 g	RM	0.15	0.85	0.15	0.15
	CEA	0.06	0.94	0.06	0.06
BW < 3000 g	RM	0.18	0.86	0.18	0.14
	CEA	0.07	0.94	0.07	0.06
BL < 50 cm	RM	0.16	0.87	0.16	0.14
	CEA	0.07	0.94	0.07	0.06
BW ≥ 4000 g	RM	0.46	0.69	0.46	0.31
	CEA	0.1	0.93	0.1	0.07
40 weeks					
Outcome	**Chart**	**Se**	**Sp**	**PPV**	**NPV**
BW < 2500 g	RM	0.3	0.82	0.3	0.18
	CEA	0.17	0.93	0.17	0.07
BW < 3000 g	RM	0.27	0.83	0.27	0.17
	CEA	0.13	0.93	0.13	0.07
BL < 50 cm	RM	0.23	0.85	0.23	0.15
	CEA	0.1	0.94	0.1	0.06
BW ≥ 4000 g	RM	0.73	0.51	0.73	0.49
	CEA	0.12	0.92	0.12	0.08

Discussion

Similar to the RM chart, the CEA chart was developed using weight for height values, i.e., BMI, for the entire gestation.[3,8] However, the CEA and the RM charts differ significantly with respect to the criteria applied to define the limits of the area of "adequate BMI" or "normal" maternal nutrition status. In the RM chart the area of normal BMI throughout pregnancy was based on obstetric outcomes from 1,745 healthy adult women and their singleton babies delivered at 39–41 weeks of gestation.[3] In contrast, the CEA chart used just percentile values, with extremely low or extremely high BMI values defining underweight or overweight mothers.[8] This approach led to a definition of a normal area proportionally much larger than in the RM chart.[3,8] Consequently, a percentage of underweight and obese women were considered nutritionally "normal" despite being at risk of an impaired fetal growth.

The percentages of newborns with length <50 cm, weight <2500 g or <3000 g and weight >4000 g diagnosed by the two charts were similar. However, the absolute number of newborns with signs of intrauterine growth impairment were higher in women considered to be underweight or obese by the RM chart than the CEA chart. The latter is consistent with the fact that sensitivity values, were higher in the RM chart than in the CEA chart. The higher sensitivity of the RM chart than the CEA chart means that in a higher extent women presenting the diagnosis of underweight or obese truly deliver BW <2500 g, BW <3000 g or BW >4000 g, respectively.[28]

Thus, the CEA chart failed to identify women who might had benefited from nutritional counseling during gestation. The public health relevance of this finding is stressed by the fact that babies who have suffered intrauterine growth impairment have a higher incidence of neonatal morbidity and mortality and the consequent expenses in health care.[29]

The RM chart also performs better than the CEA chart in almost all outcomes when values of the sum of sensitivity and specificity are compared. The only exception was BW < 2500 g when the sum of those indicators in week 10 had a value of 1 meaning that for this outcome the test was not useful, but the expected gain in diagnostic certainty increases as the values of this sum increases.[30] In addition, all PPV and NPV values were higher in the RM chart, thus indicating a higher accuracy in disease diagnosis.[31] From an epidemiological point of view, the adequate recognition of a subset of pregnant women associated with a higher number of at-risk neonates with altered BW and BL using a diagnostic instrument such as the RM chart is preferable.

Since experimental studies concerning maternal nutrition have many practical difficulties, most comparisons among pregnant women cohorts have been done without randomization. From this perspective, present results have the limitation that they were obtained in an observational study. However, the intergroup comparison was made using a high number of subjects from the same population of women. Although the population selected for this study is from Chile, anthropometric information for pregnant women 10-49 years old has been reported as similar in Argentina with data from two important public maternity hospitals located in the capital cities of both countries -Buenos Aires and Santiago-, showing that mean and SD values for height were the same, presenting 1.56 ± 0.06 m; obesity was slightly higher in Chile.[32]

To better assess the influence of maternal nutrition on neonatal anthropometry, we analyzed a subsample of healthy-term mothers. Interestingly, it produced a new nutritional distribution of women, probably due to the exclusion of women with preterm deliveries and other gestational morbidities. Thus, while the proportion of women classified as undernourished by both gestational weight charts was higher in this sub-sample of healthy women, the proportion of women with obesity was lower. Notably, this strategy allows us to identify underweight during pregnancy as an important factor to predict risky BL and BW newborns in a clearer way than in the total sample.

Prenatal activities to promote adequate fetal growth in women diagnosed as underweight and obese are primary aims for health personnel in Latin American countries. Those activities include weight gain monitoring, quality and quantity of diet surveillance, nutritional education, and iron and folic acid supplementation.[26,27] An increase in the frequency of babies with BW <3000 g and BL <50 cm has been observed in Chile after 2005, the year when the RM Chart was replaced by the AEA Chart,[33] suggesting a causal relationship. The discontinuation of the RM guidelines has probably meant a decreased ability to diagnose and intervene in subsets of pregnant women at risk of having neonates with altered size at birth.

Conclusion

The selection of weight gain charts for pregnant women must be based in fetal outcomes as the key parameter for defining "normal" areas of maternal BMI at the beginning and at the end of gestation. As shown in this and previous studies, to underestimate the impact of a maternal low BMI or an excessive BMI determines significant differences in the risk of delivering babies with either low or excessive birth weight. In turn, birth weight <2500 g and <3000 g and height <50 cm at birth, or birth weight >4000 g implies a higher risk of morbidity and mortality.[19–21] In addition, altered fetal growth is associated with a higher risk of developing chronic diseases such obesity, arterial hypertension, and diabetes later in life.[19,34]

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Conflicts of interest

The authors declare that they have no competing interests.

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