

Association between Body Mass Index and Gestational Weight Gain with Obstetric and Neonatal Complications in Pregnant Women with Gestational Diabetes



Índice de Massa Corporal e Ganho Ponderal Associado a Complicações Obstétricas e Neonatais na Diabetes Gestacional

Juliana CHEN-XU¹, Ângela COELHO¹

Acta Med Port 2022 Oct;35(10):718-728 • <https://doi.org/10.20344/amp.15896>

ABSTRACT

Introduction: Gestational diabetes is a condition that predisposes to complications during pregnancy and to the newborn. The aim of this study was to assess the association between body mass index and gestational weight gain and obstetric and neonatal complications in pregnant women with gestational diabetes.

Material and Methods: Retrospective cohort study involving 13 467 singleton pregnancies with gestational diabetes, diagnosed between 2014 and 2018, in Portugal. This sample was distributed according to the World Health Organization body mass index categories (underweight, normal, overweight, or obese) and according to the Institute of Medicine guidelines for gestational weight gain groups (adequate, insufficient, or excessive). Binomial and multinomial logistic regression models were applied to determine risk factors for complications in pregnant women with gestational diabetes. Data analysis was performed with SPSS version 25.

Results: Pregestational overweight and obesity were associated with an increased risk of maternal morbidity (aOR: 1.31; aOR: 2.42), gestational hypertension (aOR: 1.56; aOR: 2.79) and caesarean section (aOR: 1.22; aOR: 1.77) whilst reducing the risk for small for gestational age [aOR: 0.73; aOR: 0.64 (Fenton chart); aOR: 0.69; aOR: 0.66 (Portuguese chart)]. Obesity alone was associated with increased preeclampsia events (aOR: 3.05), respiratory distress syndrome (aOR: 1.69), admission to neonatal intensive care unit (aOR: 1.54), macrosomia (aOR: 2.18), and large for gestational age [aOR: 2.03 (Fenton); aOR: 1.87 (Portuguese)] and decreased risk of low birthweight newborns (aOR: 0.62). Insufficient gestational weight gain was associated with a decreased risk of gestational hypertension (aOR: 0.69), preeclampsia (aOR: 0.44), Caesarean section (aOR: 0.81) and large for gestational age [aOR: 0.74 (Portuguese)] and increased risk of low birthweight (aOR: 1.36) and small for gestational age [aOR: 1.40 (Fenton)]. Excessive gestational weight gain was associated with increased risk of gestational hypertension (aOR: 1.53), hydramnios (aOR: 2.05), macrosomia (aOR: 2.02), and large for gestational age [aOR: 1.94 (Fenton); aOR: 1.92 (Portuguese)].

Conclusion: Pregestational overweight and obesity, as well as excessive weight gain are associated with an increased risk of certain obstetric and neonatal complications. It is essential to have an appropriate pre-conceptional surveillance and a close follow-up during pregnancy in order to reduce the associated risks and the probable predisposition of these newborns to severe outcomes.

Keywords: Body Mass Index; Gestational Diabetes; Gestational Weight Gain; Infant, Newborn; Postpartum Period; Pregnancy Complications

RESUMO

Introdução: A diabetes gestacional é uma condição que predispõe a complicações maternas durante a gravidez e ao recém-nascido. Este estudo visa analisar o impacto do índice de massa corporal e do ganho ponderal durante a gravidez na ocorrência de complicações obstétricas e neonatais das diabéticas gestacionais.

Material e Métodos: Estudo retrospectivo de coorte que envolveu 13 467 grávidas com gestações únicas e diagnosticadas com diabetes gestacional, entre 2014 e 2018, em Portugal. A amostra foi distribuída de acordo com os critérios da Organização Mundial da Saúde para as categorias de índice de massa corporal (baixo peso, normal, excesso de peso e obesidade) e de acordo com as guidelines do Instituto de Medicina Americano para ganho ponderal gestacional (adequado, insuficiente ou excessivo). Foram usados modelos de regressão binomial e multinomial para determinar os fatores de risco de complicações na diabetes gestacional. A análise estatística foi realizada a partir do SPSS versão 25.

Resultados: Excesso ponderal e obesidade pré-gestacionais aumentaram o risco de morbidade materna (aOR: 1,31 e aOR: 2,42), hipertensão gestacional (aOR: 1,56 e aOR: 2,79) e realização de cesarianas (aOR: 1,22 e aOR: 1,77), contudo diminuíram o risco para recém-nascidos pequenos para idade gestacional [aOR: 0,73; aOR: 0,64 (curvas Fenton) e aOR: 0,69; aOR: 0,66 (curvas portuguesas)]. A obesidade esteve associada a um risco aumentado de eventos de pré-eclampsia (aOR: 3,05), síndrome de dificuldade respiratória neonatal (aOR: 1,69), internamentos em cuidados intensivos neonatais (aOR: 1,54), macrosomia (aOR: 2,18) e grandes para idade gestacional [aOR: 2,03 (Fenton) e aOR: 1,87 (portuguesas)] e foi associada a menor risco de recém-nascidos com baixo peso à nascença (aOR: 0,62). O ganho ponderal insuficiente estava associado a um risco mais baixo de hipertensão gestacional (aOR: 0,69), pré-eclampsia (aOR: 0,44), cesarianas (aOR: 0,81) e grandes para idade gestacional (aOR: 0,74 [portuguesas]) e esteve associado a maior risco de baixo peso à nascença (aOR: 1,36) e pequeno para idade gestacional [aOR: 1,40 (Fenton)]. O ganho ponderal excessivo teve maior associação com hipertensão gestacional (aOR: 1,53), hidrâmnios (aOR: 2,05), macrosomia (aOR: 2,02) e grandes para idade gestacional [aOR: 1,94 (Fenton) e aOR: 1,92 (portuguesas)].

Conclusão: Tanto o excesso de peso e obesidade pré-gestacional, como o ganho ponderal excessivo estiveram associados a um risco aumentado de determinadas complicações obstétricas e neonatais. É fundamental apresentar uma vigilância na preconcepção apropriada e um acompanhamento apertado da gravidez de modo a reduzir os riscos associados e a predisposição destes

1. Internal Medicine Department, Centro Hospitalar de Póvoa de Varzim/Vila do Conde, Póvoa de Varzim, Portugal.

✉ **Autor correspondente:** Juliana Chen Xu. jchenxu@chpvc.min-saude.pt

Recebido/Received: 06/02/2021 - **Aceite/Accepted:** 22/02/2022 - **Publicado Online/Published Online:** 26/04/2022 - **Publicado/Published:** 03/10/2022

Copyright © Ordem dos Médicos 2022



recém-nascidos a patologias diversas.

Palavras-chave: Complicações na Gravidez; Diabetes Gestacional; Ganho de Peso na Gestação; Índice de Massa Corporal; Período Pós-Parto; Recém-Nascido

INTRODUCTION

During pregnancy, physiological changes occur that predispose pregnant women to maternal complications and increase the risk of neonatal morbidity and mortality. Gestational diabetes (GD) is a metabolic change diagnosed during gestation which causes intolerance to carbohydrates due to pancreatic insufficiency and insulin resistance induced by the secretion of placental diabetogenic hormones.^{1,2}

The prevalence of GD has been increasing worldwide and in Portugal it is about 6.5% to 7.5%.³ This increase may be explained by the stricter diagnostic criteria established in 2011 by the Portuguese Directorate-General of Health, the Direção Geral de Saúde (DGS), and by the International Association of Diabetes and Pregnancy Study Groups (IADPSG), associated with an increase in the incidence of obesity within the Portuguese population.⁴

The anthropometric characteristics such as pregestational body mass index (BMI) and total weight gain at the end of pregnancy may foresee the pregnancy pathway and the neonatal outcomes. They may increase the probability and severity of certain complications during pregnancy, during delivery and to the newborn.⁵⁻⁷ Many studies, mostly carried out in normal pregnancies and a few in gestational diabetes, have shown the association of pregestational BMI and gestational weight gain with complications such as gestational hypertension,^{8,12,13,16-20} preeclampsia,¹⁴ caesarean delivery,^{8,13,14,22} macrosomia,^{9-11,15-20,22} large for gestational age (LGA),^{9,10,12,14-22} admission into a neonatal intensive care unit,¹³ and many other outcomes.

There is currently lack of data about gestational diabetes in Portugal, and hospital follow-up is still in its early phase, with no streamlined guidelines for pregnant patients with diabetes.

Therefore, the goal of this study is to evaluate the association between pregestational BMI and the final gestational weight gain (GWG), and the occurrence of maternal and neonatal complications in GD pregnant women and their newborns, in Portugal. Additionally, we will also evaluate the effect of previous BMI and GWG on postpartum reclassification of GD patients.²³⁻²⁶

MATERIAL AND METHODS

We performed an observational cohort study following the STROBE reporting guidelines (Strengthening the Reporting of Observational Studies in Epidemiology).

Ethics committee approval was not required because this study involved the analysis of a national dataset obtained from the Portuguese Diabetes Society where the data are properly anonymized and informed consent was obtained at the time of original data collection.

We analyzed retrospective data from pregnant women diagnosed with GD or with previous/*de novo* diabetes mellitus followed-up in public healthcare institutions between January 2014 and December 2018. The data used was

collected from the national registry of GD that is under the responsibility of the Diabetes and Pregnancy Study Groups implemented by the Portuguese Diabetes Society in which some of the maternity health centers and hospitals in Portugal are represented. The data was collected by hospital volunteers via analysis of electronic health records and directly during patient interviews.

Participants' selection criteria

For this study, we analyzed data from pregnant patients followed in hospital outpatient care for chronic or *de novo* glucose metabolism anomaly, between 2014 and 2018. The diagnosis was based on the DGS-IADPSG criteria, through fasting glucose ≥ 92 mg/dL or through oral glucose tolerance test (OGTT) taken between week 24 and 28 (0' ≥ 92 mg/dL and/or 60' ≥ 180 mg/dL and/or 120' ≥ 153 mg/dL). A total of 17 959 pregnant women were identified.

We excluded underaged pregnant patients (under 18 years of age), patients with no data on BMI and GWG available for consultation (missing data), previous or *de novo* diagnosis of diabetes mellitus [fasting glucose values or OGTT 0' ≥ 126 mg/dL or occasional glucose values (OGTT 60' and 120') ≥ 200 mg/dL], and multifetal pregnancies. Additionally, we decided to exclude the participants that demonstrated more than three standard deviations from the GWG mean (10.6 ± 5.9 kg, and therefore participants that showed GWG above 28.3 kg and below -7.1 kg were excluded). Hence, our sample consisted in the information of 13 467 pregnant women and their corresponding newborns (Fig. 1).

Analysis of variables and primary and secondary outcomes

The following participant information were analyzed: age (years-old), academic degree (none or unknown, primary until fourth or sixth grade, primary until ninth grade, secondary until twelfth grade and higher education), calculated BMI from pregestational weight and height, first-degree family history of diabetes mellitus, number of previous abortions/deliveries and gestations, previous GD/macrosomia, diagnosis made from fasting glucose or OGTT, gestational week of diagnosis, week of first hospital appointment, number of weeks from diagnosis until first appointment, GWG (kg), treatment used [diet and exercise (non-pharmacological), only insulin, only oral hypoglycaemic drug (OHD) or insulin and OHD], daily insulin units, and daily dosage of OHD (metformin) in milligrams.

The calculated pregestational BMI was categorized according to the World Health Organization (WHO) criteria as underweight (< 18.5 kg/m²), normal (18.5 – 24.9 kg/m²), overweight (25 – 29.9 kg/m²), and obese (≥ 30 kg/m²).

GWG was estimated from the difference between weight at delivery or at the last appointment before

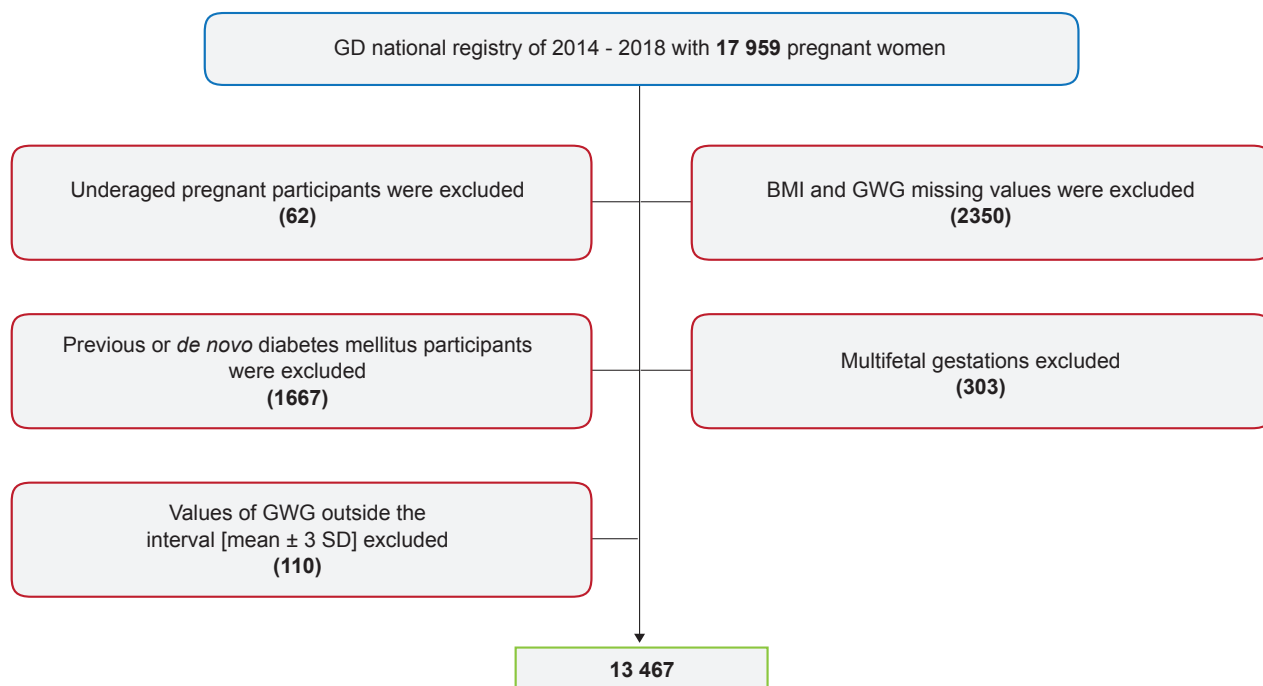


Figure 1 – Flowchart of the final sample

delivery, and pregestational weight. It was then categorized into adequate, insufficient, and excessive as recommended by the Institute of Medicine (IOM), within each BMI category. Therefore, GWG was considered adequate if it was within the range of 12.5 – 18 kg for underweight, 11.5 – 16 kg for normal weight, 7 – 11.5 kg overweight and 5 – 9 kg for obese, and insufficient or excessive when the values were, respectively, below or above the intervals indicated for each category.

We also analyzed delivery information: week of delivery, type of delivery (eutocia or dystocia, Caesarean delivery), type of Caesarean delivery (urgent or elective), and newborn characteristics, like weight (g).

As for study outcomes, we evaluated the occurrence of maternal and neonatal complications and reclassification at six to eight weeks postpartum regarding the pregestational BMI and GWG of the GD population in Portugal. Pregnancy complications included maternal morbidity that comprised at least one of the following secondary outcomes: abortion, gestational arterial hypertension (gHT), preeclampsia, hydramnios, fetal death and Caesarean delivery. Another primary outcome was the development of neonatal complications, such as neonatal morbidity or mortality. Secondary outcomes to neonatal morbidity were: neonatal hypoglycaemia, hyperbilirubinemia, respiratory distress syndrome (RDS), admission to the neonatal intensive care unit (NICU), premature (delivery at < 37 gestational weeks), large for gestational age (LGA; weight above the 90th percentile), small for gestational age (SGA; weight below the 10th percentile), macrosomia (birthweight \geq 4000 g), low birthweight (< 2500 g), trauma at delivery, and congenital abnormalities. LGA and SGA were characterized according

to the Fenton charts and the Portuguese population adapted charts. Regarding postnatal reclassification, we evaluated the impact of pregestational BMI and GWG group on the development of impaired fasting glucose, impaired glucose tolerance, and postnatal diabetes mellitus.

Statistical analysis

Statistical analysis was performed through Statistical Package for Social Science (SPSS®) software, 25.0 version. Continuous variables were defined by mean and standard deviations (SD), after checking for symmetry of distributions by observing histograms. Medians and percentiles P25 and P75 were presented otherwise. Considering our sample size, we checked histograms, symmetry, and kurtosis to assess normal distribution of continuous variables. Categorical variables were defined by total number and frequency (%). When needed, continuous variables were transformed into dichotomous categorical variables, like prematurity and macrosomia.

As for the variable inferential analysis, we used non-parametric Kruskal-Wallis and Mann-Whitney U tests when it involved one continuous non-normal distributed variable and a categorical variable. For categorical variables, we used the χ^2 test or the Fisher's exact test (dichotomic variables and \geq 20% cells with expected count < 5).

To assess associations, we used binomial and multinomial logistic regression to obtain crude and adjusted odds ratios (aOR) with the confidence intervals at 95% (CI 95%). The association of the main variables (BMI category and GWG group) was adjusted for maternal age, number of previous abortions/deliveries, first-degree family history of diabetes mellitus, previous macrosomia, diagnosis through

fasting glucose, number of weeks between diagnosis and first hospital appointment, week of delivery, and treatment used for GD (diet and exercise versus insulin versus OHD). These variables were selected after analysis of univariable association between each of the covariates and each of the outcomes (dependent variables). At the end, only the ones with statistically significant association were selected (p value < 0.05). After selection, we applied the forward likelihood ratio for the binomial logistic regression and forward stepwise for the multinomial logistic regression that calculated the aOR after checking the interaction of the chosen covariates.

All tests with statistical significance were bilateral, considering a p value of < 0.05 as statistically significant.

RESULTS

Sample characterization

The characteristics of our sample are shown in Table 1.

Regarding BMI, 41.2% ($n = 5550$) presented a normal pregestational BMI, 1.9% ($n = 261$) were underweight, and almost 57% ($n = 7656$) were overweight to obese participants.

As for GWG, only 32.5% ($n = 4372$) of the participants had adequate gain according to IOM criteria, whilst 38.9% ($n = 5245$) had insufficient gain and 28.6% ($n = 3850$) had excessive GWG.

It is worthy of note that overweight and obese participants had higher percentage of first-degree family history of diabetes mellitus (46.8%, $n = 1865$ and 49.4%, $n = 1725$, respectively), and history of previous GD (19.5%, $n = 546$ and 21.3%, $n = 554$, respectively) and macrosomia (7.6%, $n = 212$ and 11%, $n = 283$, respectively). These participants also showed higher incidence of excessive GWG (38.6%, $n = 1569$ and 36.2%, $n = 1302$, respectively) and need for pharmacological therapy for the treatment of GD (42.6%, $n = 1702$ and 56%, $n = 1982$, respectively), as well as higher daily dosage of insulin (mean of 20.6 ± 16.9 U/day and 24.2 ± 22.6 U/day, respectively) and/or OHD (mean of 1387.4 ± 633.6 mg/day and 1510.6 ± 736.6 mg/day, respectively) compared with normal or underweight groups [Appendix 1, Table 1 (Appendix 1: https://www.actamedicaportuguesa.com/revista/index.php/amp/article/view/15896/Appendix_01.pdf)].

Diagnosis and management of gestational diabetes

Almost half of the patients were diagnosed with GD through fasting glucose (46.9%, $n = 6320$), whilst the rest were diagnosed through OGTT (51.6%, $n = 6945$).

As for the treatment used in GD, 59.4% ($n = 7856$) of the participants achieved glycemic control (after analyzing fasting and postprandial glycemic records), with only diet and physical activity, whilst the rest required OHD and/or insulin therapy.

Pregnant women with excessive GWG required a higher daily dosage of insulin (mean of 23.3 ± 22.9 U/day) in order to control GD compared to those with adequate (mean of 20.3 ± 15.6 U/day) or insufficient gain (mean of 19 ± 16.5

U/day) [Appendix 1, Table 2 (Appendix 1: https://www.actamedicaportuguesa.com/revista/index.php/amp/article/view/15896/Appendix_01.pdf)].

The distribution of the sample, according to its characteristics, in each BMI category and GWG group, as well as the inferential analysis, can be ascertained in Appendix 1, as Tables 1 and 2 (Appendix 1: https://www.actamedicaportuguesa.com/revista/index.php/amp/article/view/15896/Appendix_01.pdf).

Maternal and neonatal complications

Previously overweight or obese participants and patients with excessive GWG had higher number of deliveries by caesarean section, especially as urgent deliveries [Appendix 1, Tables 3 and 4 (Appendix 1: https://www.actamedicaportuguesa.com/revista/index.php/amp/article/view/15896/Appendix_01.pdf)].

As for the newborns, their weight increased with increasing BMI categories. Excessive GWG was also associated with higher birthweight [mean of 3318 ± 493.3 g in Appendix 1, Table 2 (Appendix 1: https://www.actamedicaportuguesa.com/revista/index.php/amp/article/view/15896/Appendix_01.pdf)].

The inferential analysis of BMI categories and obstetric complications showed that global maternal morbidity, especially preeclampsia, gHT, and caesarean section were differently affected within the BMI categories, with statistical significance (Table 2). We found that pregestational overweight and obesity were associated with an increased risk of maternal morbidity (aOR: 1.31; CI 95%: 1.06 - 1.61 and aOR: 2.42; CI 95%: 1.99 - 2.94, respectively), gHT (aOR: 1.56; CI 95%: 1.05 - 2.31 and aOR: 2.79; CI 95%: 1.94 - 4.02, respectively), and caesarean section (aOR: 1.22; CI 95%: 1.02 - 1.46 and aOR: 1.77; CI 95%: 1.48 - 2.11, respectively). There was only a positive association between pregestational obese participants and risk for preeclampsia, with statistical significance (aOR: 3.05; CI 95%: 1.93 - 4.82) (Table 4).

When analyzing GWG, all maternal complications demonstrated statistically significant differences between the various groups, apart from fetal mortality (Table 3). However, the logistic regression analysis showed that insufficient GWG was associated with decreased occurrence of gHT (aOR: 0.69; CI 95%: 0.48 - 0.98), preeclampsia (aOR: 0.44; CI 95%: 0.28 - 0.68), and caesarean section (aOR: 0.81; CI 95%: 0.69 - 0.96). On the other hand, an excessive GWG increased the risk of gestational hypertension (aOR: 1.53; CI 95%: 1.11 - 2.12) and hydramnios (aOR: 2.05; CI 95%: 1.19 - 3.53) (Table 5).

Regarding neonatal complications, neonatal morbidity such as hyperbilirubinemia, prematurity, macrosomia or low birthweight, LGA or SGA, and trauma during delivery, there were statistically significant differences between the BMI groups (Table 2). Participants with pregestational obesity showed higher probability of their newborns developing RDS (aOR: 1.69; CI 95%: 1.14 - 2.51), being admitted in NICU (aOR: 1.54; CI 95%: 1.19 - 1.99), having macrosomia

Table 1 – Sample characteristics: mothers and their newborns (n = 13 467)

Characteristics	p value
Maternal age , mean ± SD (years old)	33.3 ± 5.3
median (P25; P75)	34.0 (30; 37)
Maternal academic qualification , n (%)	11 608 (86.2%)
None or unknown	69 (0.6%)
Primary (4 th - 6 th grade)	947 (8.2%)
Primary (9 th grade)	2648 (22.8%)
High school (12 th grade)	3983 (34.3%)
Higher education	3961 (34.1%)
Maternal BMI , mean ± SD (kg/m ²)	27.0 ± 5.8
median (P25; P75)	25.9 (22.7; 30.4)
Underweight (< 18.5), n (%)	261 (1.9%)
Normal (18.5 - 24.9), n (%)	5550 (41.2%)
Overweight (25 - 29.9), n (%)	4064 (30.2%)
Obese (≥ 30), n (%)	3592 (26.7%)
1st degree familial diabetes mellitus , n (%)	13 195 (98.0%)
Yes	5798 (43.9%)
Number of previous abortions , mean ± SD (units)	0.4 ± 0.7
median (P25; P75)	0 (0; 1)
Number of previous deliveries , mean ± SD (units)	0.8 ± 0.9
median (P25; P75)	1 (0; 1)
Number of gestations , mean ± SD (units)	2.2 ± 1.2
median (P25; P75)	2 (1; 3)
Previous gestacional diabetes , n (%)	8822 (65.5%)
Yes	1659 (18.8%)
Previous macrosomia , n (%)	8746 (64.9%)
Yes	668 (7.6%)
Fasting glucose diagnosis , n (%)	6320 (46.9%)
Mean ± SD (mg/dL); median (P25; P75)	96.7 ± 5.4; 95 (93; 98)
Diagnosis by OGTT , n (%)	6945 (51.6%)
OGTT 0' mean ± SD (mg/dL); median (P25; P75)	82.3 ± 11.0; 81 (75; 92)
OGTT 60' mean ± SD (mg/dL); median (P25; P75)	167.6 ± 25.1; 175 (154; 186)
OGTT 120' mean ± SD (mg/dL); median (P25; P75)	146.4 ± 26.8; 154 (129; 164)
Week of diagnosis , mean ± SD	18.0 ± 8.8
median (P25; P75)	24 (9; 26)
Week of 1st hospital appointment , mean ± SD	23.4 ± 8.4
median (P25; P75)	26 (15; 30)
Weeks from diagnosis until 1st appointment , mean ± SD	5.3 ± 4.7
median (P25; P75)	4 (2; 7)
Gestational weight gain , mean ± SD (kg)	10.5 ± 5.4
median (P25; P75)	11.0 (7; 14.4)
Adequate, n (%)	4372 (32.5%)
Insufficient, n (%)	5245 (38.9%)
Excessive, n (%)	3850 (28.6%)
Treatment of GD , n (%)	
Diet and exercise, n (%)	7856 (59.4%)
Only insulin, n (%)	3143 (23.8%)
Only OHD, n (%)	1495 (11.3%)
Insulin and OHD, n (%)	729 (5.5%)
Daily dosage of insulin , mean ± SD (units)	20.7 ± 18.7
median (P25; P75)	15 (8; 27)
Daily dosage of metformin , mean ± SD (g)	1414.6 ± 681.7
median (P25; P75)	1400 (1000; 2000)
Week of delivery , mean ± SD; median (P25; P75)	38.5 ± 1.5; 39 (38; 39)
Eutocic delivery , n (%)	6585 (48.9%)
Dystocic delivery , n (%)	6560 (48.7%)
Caesarean section, n (%)	4348 (66.3%)
Urgent, n (%)	2170 (49.9%)
Elective, n (%)	1805 (41.5%)
Birthweight of newborn , mean ± SD (g)	3180.7 ± 489.4
median (P25; P75)	3200 (2900; 3480)

BMI: body mass index; GD: gestational diabetes; n: number; OGTT: oral glucose tolerance test; OHD: oral hypoglycaemic drug; P25: percentile 25; P75: percentile 75; SD: standard deviation; 0': zero minutes; 60': 60 minutes; 120': 120 minutes

Table 2 – Association between maternal and neonatal complications and pregestational BMI (according to WHO)

Variables	BMI categories				p value
	Underweight ($< 18.5 \text{ kg/m}^2$) (n = 261)	Normal ($18.5 - 24.9 \text{ kg/m}^2$) (n = 5550)	Overweight ($25 - 29.9 \text{ kg/m}^2$) (n = 4064)	Obesity ($\geq 30 \text{ kg/m}^2$) (n = 3592)	
Maternal morbidity, n (%)*	26 (10.0%)	601 (10.8%)	602 (14.8%)	813 (22.6%)	< 0.001
Abortion, n (%)	0 (0%)	16 (0.3%)	12 (0.3%)	8 (0.2%)	0.757
Gestational hypertension, n (%)	3 (1.1%)	136 (2.5%)	166 (4.1%)	243 (6.8%)	< 0.001
Preeclampsia, n (%)	2 (0.8%)	90 (1.6%)	112 (2.8%)	161 (4.5%)	< 0.001
Hydramnios, n (%)	6 (2.3%)	102 (1.8%)	95 (2.3%)	91 (2.5%)	0.131
Fetal death, n (%)	1 (0.4%)	9 (0.2%)	12 (0.3%)	10 (0.3%)	0.496
Caesarean section, n (%)	60 (23.0%)	1552 (28.0%)	1323 (32.6%)	1413 (39.3%)	< 0.001
Neonatal death, n (%)	0 (0%)	8 (0.1%)	8 (0.2%)	5 (0.1%)	0.763
Neonatal morbidity, n (%)	42 (16.1%)	973 (17.5%)	740 (18.2%)	739 (20.6%)	0.015
Neonatal hypoglycaemia, n (%)	9 (3.4%)	215 (3.9%)	178 (4.4%)	157 (4.4%)	0.768
Hyperbilirubinemia, n (%)	25 (9.6%)	572 (10.3%)	450 (11.1%)	450 (12.5%)	0.034
Respiratory distress syndrome, n (%)	4 (1.5%)	155 (2.8%)	123 (3.0%)	131 (3.6%)	0.151
NICU hospitalization, n (%)	20 (7.7%)	362 (6.5%)	273 (6.7%)	275 (7.7%)	0.387
Prematurity (< 37 weeks), n (%)	33 (12.6%)	357 (6.4%)	284 (7.0%)	223 (6.2%)	0.001
Macrosomia (≥ 4000 g), n (%)	1 (0.4%)	124 (2.2%)	153 (3.8%)	233 (6.5%)	< 0.001
Low birthweight (< 2500 g), n (%)	36 (13.8%)	442 (8.0%)	288 (7.1%)	199 (5.5%)	< 0.001
Large for gestational age (Fenton charts), n (%)	1 (0.4%)	130 (2.3%)	156 (3.8%)	248 (6.9%)	< 0.001
Large for gestational age (Portuguese charts), n (%)	7 (2.7%)	384 (6.9%)	433 (10.7%)	627 (17.5%)	< 0.001
Small for gestational age (Fenton charts), n (%)	50 (19.2%)	807 (14.5%)	428 (10.5%)	306 (8.5%)	< 0.001
Small for gestational age (Portuguese charts), n (%)	51 (19.5%)	696 (12.5%)	362 (8.9%)	258 (7.2%)	< 0.001
Trauma during delivery, n (%)	1 (0.4%)	68 (1.4%)	64 (1.7%)	74 (2.3%)	0.007
Congenital abnormalities, n (%)	8 (3.1%)	216 (3.9%)	156 (3.8%)	117 (3.3%)	0.248
Postpartum reclassification†					
Normal, n (%)	155 (59.4%)	3663 (66.0%)	2650 (65.2%)	2232 (62.1%)	< 0.001
Impaired fasting glucose, n (%)	1 (0.4%)	23 (0.4%)	30 (0.7%)	37 (1.0%)	< 0.001
Impaired glucose tolerance, n (%)	11 (4.2%)	179 (3.2%)	148 (3.6%)	158 (4.4%)	< 0.001
Diabetes mellitus, n (%)	3 (1.1%)	14 (0.3%)	26 (0.6%)	17 (0.5%)	< 0.001

BMI: body mass index; NICU: neonatal intensive care unit; n: number; WHO: World Health Organization

*: besides the ones listed below, includes other complications such as infections, deep vein thrombosis, hematologic disorders, coagulation disorders, hepatic cholestasis, endocrine disorders, flares of autoimmune diseases or *de novo*, asthma exacerbations, renal lithiasis, and others.

†: the missing data of postpartum reclassification are not represented in the Table

(aOR: 2.18; CI 95%: 1.47 - 3.25) or being LGA, and equally regardless of the use of the Fenton or Portuguese chart criteria (aOR: 2.03; CI 95%: 1.35 - 3.07 and aOR: 1.87; CI 95%: 1.44 - 2.41, respectively). In this sequence, previous overweight or obese was associated with a decreased risk of SGA in both Fenton and Portuguese charts (aOR: 0.73; CI 95%: 0.57 - 0.94; aOR: 0.64; CI 95%: 0.49 - 0.84 and aOR: 0.69; CI 95%: 0.52 - 0.92; aOR: 0.66; CI 95%: 0.49 - 0.90) and obesity alone was associated with decreased risk for low birthweight (aOR: 0.62; CI 95%: 0.47 - 0.83) (Table 4).

Regarding GWG, all neonatal complications showed statistically significant differences between the groups (Table 3).

When facing an excessive GWG, the risk of macrosomia (aOR: 2.02; CI 95%: 1.40 - 2.91) and LGA by Fenton

and Portuguese charts (aOR: 1.94; CI 95%: 1.35 - 2.78 and aOR: 1.92; CI 95%: 1.51 - 2.45, respectively) were increased. Despite that, insufficient GWG was associated with an increased risk of low birthweight (aOR: 1.36; CI 95%: 1.06 - 1.74) and SGA according to the Fenton charts (aOR: 1.40; CI 95%: 1.09 - 1.79) and decreased risk of LGA according to Portuguese charts (aOR: 0.74; CI 95%: 0.57 - 0.96) (Table 5).

Moreover, different categories of BMI and GWG groups affected the postpartum reclassification (Tables 2 and 3). Previously underweight, overweight, and obese patients were more associated with glycemic abnormalities during reclassification. Excessive GWG was associated with impaired fasting glucose, whilst insufficient GWG was associated with impaired glucose tolerance and diabetes mellitus. Nonetheless, after examining the association by logistic

Table 3 – Association between maternal and neonatal complications and GWG (according to IOM)

Variables	GWG			p value
	Adequate (n = 4372)	Insufficient (n = 5245)	Excessive (n = 3850)	
Maternal morbidity, n (%)*	639 (14.6%)	724 (13.8%)	679 (17.6%)	< 0.001
Abortion, n (%)	7 (0.2%)	26 (0.5%)	3 (0.1%)	< 0.001
Gestational hypertension, n (%)	164 (3.8%)	157 (3.0%)	227 (5.9%)	< 0.001
Preeclampsia, n (%)	123 (2.8%)	99 (1.9%)	143 (3.7%)	< 0.001
Hydramnios, n (%)	87 (2.0%)	90 (1.7%)	117 (3.0%)	< 0.001
Fetal death, n (%)	11 (0.3%)	14 (0.3%)	7 (0.2%)	0.694
Caesarean section, n (%)	1415 (32.4%)	1516 (28.9%)	1417 (36.8%)	< 0.001
Neonatal death, n (%)	5 (0.1%)	9 (0.2%)	7 (0.2%)	0.003
Neonatal morbidity, n (%)	834 (19.1%)	909 (17.3%)	751 (19.5%)	< 0.001
Neonatal hypoglycaemia, n (%)	173 (4.0%)	221 (4.2%)	165 (4.3%)	0.044
Hyperbilirubinemia, n (%)	501 (11.5%)	536 (10.2%)	460 (11.9%)	0.001
Respiratory distress syndrome, n (%)	119 (2.7%)	162 (3.1%)	132 (3.4%)	0.007
NICU hospitalization, n (%)	284 (6.5%)	367 (7.0%)	279 (7.2%)	0.022
Prematurity (< 37 weeks), n (%)	292 (6.7%)	402 (7.7%)	203 (5.3%)	< 0.001
Macrosomia (≥ 4000 g), n (%)	130 (3.0%)	104 (2.0%)	277 (7.2%)	< 0.001
Low birthweight (< 2500 g), n (%)	286 (6.5%)	492 (9.4%)	187 (4.9%)	< 0.001
Large for gestational age (Fenton charts), n (%)	146 (3.3%)	114 (2.2%)	275 (7.1%)	< 0.001
Large for gestational age (Portuguese charts), n (%)	428 (9.8%)	341 (6.5%)	682 (17.7%)	< 0.001
Small for gestational age (Fenton charts), n (%)	479 (11.0%)	784 (14.9%)	328 (8.5%)	< 0.001
Small for gestational age (Portuguese charts), n (%)	416 (9.5%)	674 (12.9%)	277 (7.2%)	< 0.001
Trauma during delivery, n (%)	60 (1.5%)	60 (1.3%)	87 (2.5%)	< 0.001
Congenital abnormalities, n (%)	176 (4.0%)	173 (3.3%)	148 (3.8%)	< 0.001
Postpartum reclassification†				
Normal, n (%)	2858 (65.4%)	3518 (67.1%)	2324 (60.4%)	< 0.001
Impaired fasting glucose, n (%)	31 (0.7%)	29 (0.6%)	31 (0.8%)	< 0.001
Impaired glucose tolerance, n (%)	155 (3.5%)	212 (4.0%)	129 (3.4%)	< 0.001
Diabetes mellitus, n (%)	18 (0.4%)	26 (0.5%)	16 (0.4%)	< 0.001

GWG: gestational weight gain; IOM: Institute of Medicine; NICU: neonatal intensive care unit; n: number

*: besides the ones listed below, includes other complications such as infections, deep vein thrombosis, hematologic disorders, coagulation disorders, hepatic cholestasis, endocrine disorders, flares of autoimmune diseases or *de novo*, asthma exacerbations, renal lithiasis, and others.

†: the missing data of postpartum reclassification are not represented in the Table

regression analysis, only crude [Appendix 1, Table 3 (Appendix 1: https://www.actamedicaportuguesa.com/revista/index.php/amp/article/view/15896/Appendix_01.pdf)], and not adjusted, associations showed that being overweight was associated with an increased risk of impaired fasting glucose (OR: 1.80; CI 95%: 1.05 - 3.11) and diabetes mellitus (OR: 2.57; CI 95%: 1.34 - 4.93) at postpartum reclassification. As for pregestational obesity, it was associated with an increased odds of impaired fasting glucose (OR: 2.64; CI 95%: 1.57 - 4.45) and impaired glucose tolerance (OR: 1.45; CI 95%: 1.16 - 1.81) at reclassification. The underweight category had a very high odds of being reclassified as diabetic at postpartum (OR: 5.06; CI 95%: 1.44 - 17.80) [Appendix 1, Table 3 (Appendix 1: https://www.actamedicaportuguesa.com/revista/index.php/amp/article/view/15896/Appendix_01.pdf)].

Regarding the different GWG categories, no association

with statistical significance was demonstrated via multinomial logistic regression [Appendix 1, Table 4 (Appendix 1: https://www.actamedicaportuguesa.com/revista/index.php/amp/article/view/15896/Appendix_01.pdf)].

DISCUSSION

Our study showed that BMI above 25 kg/m² was associated with an increased risk of maternal morbidity, such as gestational hypertension and Caesarean delivery whilst being associated with a decreased risk of small for gestational age newborns, which corroborates the findings made by Gonçalves *et al.*⁸ BMI equal or higher than 30 kg/m² was associated with an increased risk of preeclampsia, a very serious condition threatening the life of both mother and child. Additionally, pregestational obesity was associated with a higher number of RDS events, NICU hospitalization, macrosomia and LGA newborns, even though with a smaller

Table 4 – Adjusted association* by logistic regression between pregnancy and neonatal complications and pregestational BMI (according to WHO)

Dichotomous and multinomial outcomes†	BMI categories			p value
	Underweight (< 18.5 kg/m ²) aOR (CI 95%)	Normal (18.5 - 24.9 kg/m ²) aOR (CI 95%)	Overweight (25 - 29.9 kg/m ²) aOR (CI 95%)	
Maternal morbidity				
Gestational hypertension	0.87 (0.43 - 1.76)	1.00	1.31 (1.06 - 1.61)	0.012
Preeclampsia	0.92 (0.22 - 3.90)	1.00	1.56 (1.05 - 2.31)	0.029
Hydramnios	0.62 (0.08 - 4.91)	1.00	1.54 (0.94 - 2.54)	0.088
	2.03 (0.42 - 9.81)	1.00	0.87 (0.48 - 1.57)	0.642
Caesarean section	1.22 (0.67 - 2.23)	1.00	1.22 (1.02 - 1.46)	0.032
Neonatal morbidity				
Neonatal hyperbilirubinemia	0.74 (0.42 - 1.30)	1.00	0.97 (0.82 - 1.15)	0.762
Respiratory distress syndrome	0.74 (0.37 - 1.50)	1.00	1.01 (0.82 - 1.24)	0.923
NICU hospitalization	0.36 (0.04 - 2.99)	1.00	1.10 (0.71 - 1.70)	0.665
Prematurity (< 37 weeks)	1.15 (0.51 - 2.60)	1.00	1.14 (0.87 - 1.49)	0.347
Macrosomia (≥ 4000 g)	0.92 (0.28 - 3.00)	1.00	1.25 (0.90 - 1.74)	0.178
Low birthweight (< 2500 g)	0.00 (0.00)	1.00	1.19 (0.77 - 1.84)	0.442
Large for gestational age (Fenton charts)	1.48 (0.75 - 2.91)	1.00	0.92 (0.71 - 1.18)	0.500
Large for gestational age (Portuguese charts)	0.00 (0.00)	1.00	1.26 (0.81 - 1.97)	0.305
Small for gestational age (Fenton charts)	0.19 (0.03 - 1.47)	1.00	1.05 (0.80 - 1.38)	0.731
Small for gestational age (Portuguese charts)	1.31 (0.67 - 2.58)	1.00	0.73 (0.57 - 0.94)	0.016
Trauma during delivery	1.54 (0.75 - 3.15)	1.00	0.69 (0.52 - 0.92)	0.012
	0.00 (0.00)	1.00	1.22 (0.72 - 2.06)	0.458
Postpartum reclassification†				
Normal	1.00	1.00	1.00	1.00
Impaired fasting glucose	1.39 (0.18 - 10.94)	1.00	1.03 (0.52 - 2.07)	0.928
Impaired glucose tolerance	0.00 (0.00)	1.00	1.16 (0.78 - 1.73)	0.473
Diabetes mellitus	3.66 (0.67 - 20.05)	1.00	1.35 (0.60 - 3.06)	0.469
				0.233

aOR: adjusted odds ratio; BMI: body mass index; CI 95%: confidence intervals at 95%; NICU: neonatal intensive care unit; WHO: World Health Organization
 * : adjusted for maternal age, number of previous abortions/deliveries, first-degree family history of diabetes, previous macrosomia, fasting glucose, weeks between diagnosis and 1st hospital appointment, GD treatment, GWG group and week of delivery.
 † : postpartum reclassification was analyzed as a multinomial outcome. All other classifications were compared with the standard, the "normal" classification.

number of low birthweight newborns.

With regards to GWG groups according to IOM, the analysis demonstrated that insufficient weight gain was associated with lower risk of gestational hypertension, preeclampsia, caesarean section and LGA babies (only those defined by the Portuguese charts). However, insufficient weight gain was associated with a higher odd of low birthweight and SGA according to the Fenton charts, which concurs with the study of Gonçalves *et al.*⁸ These results reflect the prospective study of Lima *et al* based on a population of pregnant women in Sweden, demonstrating that previously obese participants with insufficient GWG would be associated with a reduced risk of preeclampsia, caesarean deliveries and LGA newborns, although they would be associated, on the other hand, with an increased risk of SGA newborns.¹⁴

Regarding excessive GWG, it was associated with higher risk of gestational hypertension, hydramnios, macrosomia, and LGA (according to both the Fenton and the Portuguese charts) newborns, as seen in many other studies.¹⁶⁻²⁰

About postpartum reclassification, only the crude associations demonstrated statistically significant differences that were lost after adjustment for other variables. This means that the presence of such association was possible due to the presence of other risk factors, such as maternal age, family history of diabetes and treatment used for GD. By comparison between crude and adjusted ORs, we may say that there was a confounding effect in our study, and therefore adjusted OR should be prioritized.

It is important to mention the limitations of our work. Because of its retrospective nature, based on data previously present in the national registry of GD, we observed missing

data and lack of consistency as well as high variability in the data collected, leading to an information bias due to the variability of the observer and the interviewer.

The information contained in the registry is not representative of the whole country, because the participation of each hospital/maternity hospital in terms of data collection is not mandatory and most of the peripheral hospitals are not represented in the registry, demonstrating a selection bias by participation bias.

Most of the maternal information was self-reported, leading to an information bias caused by measurement, memory, and social desirability bias.

In order to reduce the limitations of the study and the amount of biases, it is necessary to develop prospective studies with previous standardized data collection procedures and training of the personnel involved in this process.

CONCLUSION

Both pregestational BMI and GWG have a significant impact on maternal and neonatal outcomes during pregnancy and the postnatal period in women diagnosed with gestational diabetes. Our findings suggested positive associations between BMI and GWG and gestational hypertension, preeclampsia, hydramnios, caesarean delivery, RDS, NICU admission, birthweight, and LGA/SGA.

When comparing pregestational BMI and GWG, the first was more significantly associated with obstetric and neonatal complications, similar to the meta-analysis of LifeCycle Project-Maternal Obesity and Childhood Outcomes Study Group.²⁷ Nonetheless, they are independent risk factor predictors that need monitoring and control to minimize the complications in GD pregnant women.

Table 5 – Adjusted association* by logistic regression between maternal and neonatal complications and GWG (according to IOM)

Dichotomous outcomes	GWG				
	Adequate aOR (CI 95%)	Insufficient aOR (CI 95%)	p value	Excessive aOR (CI 95%)	p value
Maternal morbidity	1.00	0.86 (0.71 - 1.04)	0.119	1.14 (0.94 - 1.39)	0.189
Abortion	1.00	0.00 (0.00)	0.982	2.05 (0.17 - 24.62)	0.570
Gestational hypertension	1.00	0.69 (0.48 - 0.98)	0.039	1.53 (1.11 - 2.12)	0.010
Preeclampsia	1.00	0.44 (0.28 - 0.68)	< 0.001	1.26 (0.86 - 1.85)	0.237
Hydramnios	1.00	0.98 (0.55 - 1.72)	0.933	2.05 (1.19 - 3.53)	0.010
Caesarean section	1.00	0.81 (0.69 - 0.96)	0.015	1.15 (0.96 - 1.37)	0.138
Neonatal complications					
Prematurity (< 37 weeks)	1.00	1.07 (0.79 - 1.44)	0.673	0.93 (0.66 - 1.31)	0.671
Macrosomia (≥ 4000 g)	1.00	0.72 (0.47 - 1.09)	0.120	2.02 (1.40 - 2.91)	< 0.001
Low birthweight (< 2500 g)	1.00	1.36 (1.06 - 1.74)	0.016	0.85 (0.63 - 1.14)	0.278
Large for gestational age (Fenton charts)	1.00	0.74 (0.49 - 1.11)	0.143	1.94 (1.35 - 2.78)	< 0.001
Large for gestational age (Portuguese charts)	1.00	0.74 (0.57 - 0.96)	0.021	1.92 (1.51 - 2.45)	< 0.001
Small for gestational age (Fenton charts)	1.00	1.40 (1.09 - 1.79)	0.007	0.97 (0.72 - 1.31)	0.864
Small for gestational age (Portuguese charts)	1.00	1.19 (0.90 - 1.56)	0.219	0.97 (0.70 - 1.36)	0.869
Trauma during delivery	1.00	0.61 (0.36 - 1.06)	0.077	1.40 (0.87 - 2.26)	0.170

aOR: adjusted odds ratio; CI 95%: confidence intervals at 95%; GWG: gestational weight gain; IOM: Institute of Medicine; NICU: neonatal intensive care unit

*: adjusted for maternal age, number of previous abortions/deliveries, first degree family history of diabetes, previous macrosomia, fasting glucose, weeks between diagnosis and first hospital appointment, GD treatment, BMI category and week of delivery.

In conclusion, an adequate surveillance before conception and a strict follow-up during pregnancy are essential, to reduce risks and to decrease the predisposition of these newborns to severe outcomes.

ACKNOWLEDGEMENTS

To all the elements that contributed to the construction of the national registry of GD, and José Chen-Xu (MD MSc), and Ugonna Nwankpa (MD BSc), for helping with the linguistic and recommending types of article assembly.

AUTHORS' CONTRIBUTION

JCX: contributed to conception and design, acquisition of data, analysis, and interpretation of data, drafting and revising the article and giving the final approval of the version to be published. This author, as guarantor, accepts full responsibility for the work.

ÂC: contributed to conception and design, acquisition of data, revising the article and providing the final approval of the version to be published.

REFERENCES

- Carocha A, Rijo C, Amaral N, Aleixo F, Rocha T. Diabetes gestacional – rastreio pós-parto, Acta Med Port. 2012;25:165-8.
- Silva AL, Amaral AR, Oliveira DS, Martins L, Silva MR, Silva JC. Neonatal outcomes according to different therapies for gestational diabetes mellitus. J Pediatr. 2017;93:87-93.
- Collier A, Abraham EC, Armstrong J, Godwin J, Monteath K, Lindsay R. Reported prevalence of gestational diabetes in Scotland: The relationship with obesity, age, socioeconomic status, smoking and macrosomia, and how many are we missing? J Diabetes Investig. 2017;8:161-67.
- Sociedade Portuguesa de Endocrinologia Diabetes e Metabolismo, Sociedade Portuguesa de Diabetologia, Sociedade Portuguesa de Obstetrícia e Medicina Materno-Fetal, Secção de Neonatologia da Sociedade Portuguesa de Pediatria. Relatório de Consenso sobre Diabetes e Gravidez. Lisboa: SPEDM, SPD, SPOMMF, Secção de Neonatologia da Sociedade Portuguesa de Pediatria; 2011.
- Aiken C, Hone L, Murphy HR, Meek CL. Improving outcomes in gestational diabetes: does gestational weight gain matter? Diabetic Med. 2019;36:167–76.
- Bouvier D, Forest JC, Dion-Buteau E, Bernard N, Bujold E, Pereira B, et al. Association of maternal weight and gestational weight gain with maternal and neonate outcomes: a prospective cohort study. J Clin Med. 2019;8:2074.
- Enomoto K, Aoki S, Toma R, Fujiwara K, Sakamaki K, Hirahara F. Pregnancy outcomes based on pre-pregnancy body mass index in Japanese women. PLoS ONE 2016;11:e0157081.
- Gonçalves CV, Mendoza-Sassi RA, Cesar JA, Castro NB, Bortolomed AP. Índice de massa corporal e ganho de peso gestacional como fatores preditores de complicações e do desfecho da gravidez. Rev Bras Ginecol Obstet. 2012;34:304-9.
- Xu Q, Ge Z, Hu J, Shen S, Bi Y, Zhu D. The association of gestational weight gain and adverse pregnancy outcomes in women with gestational diabetes mellitus. Endocr Pract. 2019;25:1137-50.
- Xie YJ, Peng R, Han L, Zhou X, Xiong Z, Zhang Y, et al. Associations of neonatal high birth weight with maternal pre-pregnancy body mass index and gestational weight gain: a case-control study in women from Chongqing, China. BMJ Open. 2016;6:e010935.
- Wang N, Ding Y, Wu J. Effects of pre-pregnancy body mass index and gestational weight gain on neonatal birth weight in women with gestational diabetes mellitus. Early Hum Dev. 2018;124:17-21.
- Santos S, Voerman E, Amiano P, Barros H, Beilin LJ, Bergstrom A, et al. Impact of maternal body mass index and gestational weight gain on pregnancy complications: an individual participant data meta-analysis of European, North American and Australian cohorts. BJOG. 2019;126:984-95.
- Miranda A, Fernandes V, Marques M, Castro L, Fernandes O, Pereira ML. Diabetes gestacional: avaliação dos desfechos maternos, fetais e neonatais. Rev Port Endocrinol, Diab Metabol. 2017;12:36-44.
- Lima RJ, Batista RF, Ribeiro MR, Ribeiro CC, Simões VM, Neto PM, et al. Prepregnancy body mass index, gestational weight gain, and birth weight in the BRISA cohort. Rev Saude Publica. 2018;52:46.
- Liu L, Ma Y, Wang N, Lin W, Liu Y, Wen D. Maternal body mass index and risk of neonatal adverse outcomes in China: a systematic review and meta-analysis. BMC Pregnancy Childbirth. 2019;19:105.
- Bianchi C, de Gennaro G, Romano M, Aragona M, Battini L, del Prato S, et al. Pre-pregnancy obesity, gestational diabetes or gestational weight gain: Which is the strongest predictor of pregnancy outcomes? Diabetes Res Clin Pract. 2018;144:286–93.
- Macri F, Pitocco D, di Pasquo E, Salvi S, Rizzi A, di Leo M, et al. Gestational weight gain as an independent risk factor for adverse pregnancy outcomes in women with gestational diabetes. Eur Rev Med Pharmacol Sci. 2018;22:4403-10.
- Mimoso G, Oliveira G. Morbilidade neonatal e diabetes gestacional. Acta Med Port. 2017;30:589-98.
- Pongcharoen T, Gowachirapant S, Wecharak P, Sangket N, Winichagoon P. Pre-pregnancy body mass index and gestational weight gain in Thai pregnant women as risks for low birth weight and macrosomia. Asia Pac J Clin Nutr. 2016;25:810-7.
- Santos S, Eekhout I, Voerman E, Gaillard R, Barros H, Charles MA, et al. Gestational weight gain charts for different body mass index groups for women in Europe, North America, and Oceania. BMC Med. 2018;16:201.
- Kong L, Nilsson IA, Gissler M, Lavebratt C. Associations of maternal diabetes and body mass index with offspring birth weight and prematurity. JAMA Pediatr. 2019;173:371–8.
- Gou BH, Guan HM, Bi YX, Ding BJ. Gestational diabetes: weight gain during pregnancy and its relationship to pregnancy outcomes. Chin Med J. 2019;132:154-60.
- Alves JM, Stollmeier A, Leite IG, Pilger CG, Detsch JC, Radominski RB, et al. Postpartum reclassification of glycemic status in women with gestational diabetes mellitus and associated risk factors. Rev Bras Ginecol Obstet. 2016;38:381-90.
- Costa A, Carmona F, Martinez-Roman S, Quintó L, Levy I, Conget I. Post-partum reclassification of glucose tolerance in women previously diagnosed with gestational diabetes mellitus. Diabet Med. 2000;17:595-8.
- Lin CH, Wen SF, Wu YH, Huang YY, Huang MJ. The postpartum metabolic outcome of women with previous gestational diabetes mellitus. Chang Gung Med J. 2005;28:794-800.
- Moon JH, Kwak SH, Jung HS, Choi SH, Lim S, Cho YM, et al. Weight

PROTECTION OF HUMANS AND ANIMALS

The authors declare that the procedures were followed according to the regulations established by the Clinical Research and Ethics Committee and to the Helsinki Declaration of the World Medical Association updated in 2013.

DATA CONFIDENTIALITY

The authors declare having followed the protocols in use at their working center regarding patients' data publication.

COMPETING INTERESTS

The authors declare not having any competing interests related to this paper.

FUNDING SOURCES

No financial aid was received for this article.

- gain and progression to type 2 diabetes in women with a history of gestational diabetes mellitus. *J Clin Endocrinol Metab.* 2015;100:3548-55.
27. LifeCycle Project-Maternal Obesity and Childhood Outcomes Study Group, Voerman E, Santos S, Inskip H, Amiano P, Barros H, et al. Association of gestational weight gain with adverse maternal and infant outcomes. *JAMA.* 2019;321:1702-15.
 28. Huang X, Li X, Gao C, Liu J, Chen Z, Sheng L, et al. Gestational weight gain as an independent risk factor for macrosomia in women with intermediate state gestational blood glucose. *Endocr Pract.* 2019;25:1158-65.
 29. Abreu LR, Shirley MK, Castro NP, Euclides VV, Bergamaschi DP, Luzia LA, et al. Gestational diabetes mellitus, prepregnancy body mass index, and gestational weight gain as risk factors for increased fat mass in Brazilian newborns. *PLoS ONE* 2019;14:e0221971.
 30. Goldstein RF, Abell SK, Ranasinha S, Misso M, Boyle JA, Black MH, et al. Association of gestational weight gain with maternal and infant outcomes: a systematic review and meta-analysis. *JAMA.* 2017;317:2207-25.
 31. McWhorter KL, Bowers K, Dolan LM, Deka R, Jackson CL, Khoury JC. Impact of gestational weight gain and prepregnancy body mass index on the prevalence of large-for-gestational age infants in two cohorts of women with type 1 insulin-dependent diabetes: a cross-sectional population study. *BMJ Open.* 2018;8:e019617.
 32. Basraon SK, Mele L, Myatt L, Roberts JM, Hauth JC, Leveno KJ, et al. Relationship of early pregnancy waist-to-hip ratio versus body mass index with gestational diabetes mellitus and insulin resistance. *Am J Perinatol.* 2016;33:114-121.