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Trabajo Original

Pediatría

The influence of obesity and diet quality on fetal growth and perinatal outcome

Influencia de la obesidad y la calidad de la dieta en el crecimiento fetal y resultados perinatales

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Abstract

Background: maternal obesity is associated with an increase of both maternal and fetal complications as macrosomia.

Aim: to assess the quality of diet in a cohort of pregnant women in terms of Mediterranean diet (MD) adherence and to examine the association between diet quality, obesity, weight gain and fetal growth and perinatal complications.

Methods: Mediterranean Diet Adherence Screener (MEDAS) was applied to assess diet quality in 542 pregnant women. Fetal biometric measurements at third-trimester ultrasound were collected and perinatal outcomes were recorded.

Results: only 35 % of pregnant women presented a good quality of diet, in terms of adherence to MD. Diet quality significantly increased with lower values of body mass index (BMI) and higher maternal age. Higher BMI was significantly associated with a higher abdominal circumference and estimated fetal weight at the third trimester, a higher risk of hypertension disorder, induction of labor and a higher birthweight. A statistically significant association between diet quality and ultranosographic measures or perinatal outcome was not found. However, a higher weight gain across gestation was significantly associated with a higher risk of gestational diabetes, a higher gestational age at delivery and a higher birthweight.

Conclusion: most of our pregnant women did not showed a great diet quality, but there was no evidence that diet quality affected pregnancy complications. On the contrary, pre-pregnancy BMI was related to fetal and neonatal growth and obstetric outcomes, similarly to weight gain across gestation.

Keywords:

Fetal growth. Mediterranean diet. Obesity. Pregnancy. Gestational diabetes.

Resumen

Introducción: la obesidad materna se asocia con un aumento de complicaciones maternas y fetales, como la macrosomía.

Objetivo: evaluar la calidad de la dieta en una cohorte de mujeres embarazadas en términos de adherencia a la dieta mediterránea (DM) y examinar la asociación entre la calidad de la dieta, la obesidad, el aumento de peso y el crecimiento fetal y las complicaciones perinatales.

Métodos: se aplicó el Mediterranean Diet Adherence Screener (MEDAS) para evaluar la calidad de la dieta en 542 mujeres embarazadas. Se recogieron las medidas biométricas fetales en la ecografía del tercer trimestre y se registraron los resultados perinatales.

Resultados: solo el 35 % de las gestantes presentó una buena calidad de alimentación en términos de adherencia a la DM. La calidad de la dieta aumentó significativamente con valores más bajos de índice de masa corporal (IMC) y mayor edad materna. Un IMC más alto se asoció significativamente con una mayor circunferencia abdominal y peso fetal estimado en el tercer trimestre, un mayor riesgo de trastorno hipertensivo, inducción del parto y mayor peso al nacer. No se encontró una asociación estadísticamente significativa entre la calidad de la dieta y las medidas ecográficas o el resultado perinatal. Sin embargo, un mayor aumento de peso durante la gestación se asoció significativamente con un mayor riesgo de diabetes gestacional, mayor edad gestacional al momento del parto y mayor peso al nacer.

Conclusiones: la mayoría de nuestras gestantes no mostró una buena calidad de la dieta, pero no hubo evidencia de que la calidad de la dieta afectara las complicaciones del embarazo. Por el contrario, el IMC pregestacional se relacionó con el crecimiento fetal y neonatal y los resultados obstétricos, de manera similar al aumento de peso durante la gestación.

Palabras clave:

Crecimiento fetal. Dieta mediterránea. Obesidad. Embarazo. Diabetes gestacional.

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INTRODUCTION

Obesity is a disease that affects nearly every organ in our body and its prevalence is rising worldwide, becoming the most common medical condition in women of reproductive age (1).

In pregnancy, obesity is associated with an increase of both maternal and fetal complications (2). A higher risk of occult type 2 diabetes, gestational diabetes (GD) and pregnancy-related hypertension disorders has been documented. At delivery, several studies have described a higher rate of induction of labor, longer and more failed inductions and a higher rate of cesarean delivery (3). Regarding fetal complications, it exists a higher difficulty in measuring biometric parameters at fetal scans and in detecting fetal malformations, due to poor scans quality in obese women. Furthermore, some studies suggest an increased risk of macrosomia (4,5). In addition, there is an increasing evidence that maternal obesity and macrosomia may produce, through epigenetic mechanisms, long-term consequences for the newborn at childhood and adult life, including obesity, diabetes and cardiovascular diseases (6).

The preconception period is an ideal time to assess conditions that could influence health of the mother and the fetus. Pregnancy guidelines recommend a preconception visit in obese women to inform about obesity-related pregnancy complications, give dietetic counsel and promote physical activity (7). While the preconception period represents a key time point for weight optimization, during pregnancy the objective should be acquiring an appropriate weight gain and nutritional status. This can be reached by following a healthy diet and practicing exercise.

The primary objective of our study was to test the quality of diet in obese and non-obese pregnant women followed in our institution and, secondly, to examine the association between quality of diet, obesity and pregnancy common complications related to obesity.

MATERIAL AND METHODS

STUDY DESIGN AND PARTICIPANTS

This is a prospective observational study performed in our institution from January 1st 2019 to December 31st 2019. Pregnant women who were referred from the Primary Care center to attend second-trimester ultrasound and who met the inclusion criteria were invited to participate. Inclusion criteria were pregnant women between 19 and 24 weeks, single gestation and agreement to sign the informed consent. Exclusion criteria were GD diagnosed on first trimester of pregnancy or pre-gestational diabetes, presence of major fetal malformations and multiple pregnancy.

DIETARY ASSESSMENT

The adapted form of the 14-point Mediterranean Diet Adherence Screener (MEDAS) was applied to evaluate diet quality in terms of Mediterranean diet (MD) adherence (8). The compliance of each item provides +1 points and MEDAS score ranges from 0 to 14 points. As consumption of alcohol is not recommended during pregnancy, this item was removed and score ≥ 8 was considered as high adherence (9,10). The test was assessed after second-trimester ultrasound if women met the inclusion criteria, had no exclusion criteria, and the consent form was signed. At that moment, information about maternal characteristics was recorded from the medical history. Parity, last menstrual date, maternal age, pre-gestational weight and height were collected. Body mass index (BMI) was calculated as weight in kilograms/height in m^2. Obesity was defined as pregestational BMI ≥ 30. In addition, obstetric history, chronic diseases and medication use were collected.

STUDY OUTCOMES

The main outcome was the quality of diet in a cohort of pregnant women of our center at the second trimester of pregnancy, in terms of MD adherence. Secondary outcomes included fetal growth and pregnancy complications as GD or hypertension disorders, as well as labor induction, type of delivery, gestational age (GA) at delivery and neonatal weight.

DATA COLLECTION

Maternal outcomes were obtained after delivery, through the medical and obstetric record. Fetal biometric measurements, estimated fetal weight (EFW) and percentile at third-trimester ultrasound were also collected. Fetal percentile had been calculated using national reference curves (11). GD was defined as either fasting glucose > 125 mg/dl (7.0 mmol/l) or two abnormal values following a 100-g oral glucose tolerance test (fasting glucose ≥ 105 mg/dl [5,8 mmol/l], 190 mg/dl [10,6 mmol/l] at one hour, 165 mg/dl [9,2 mmol/l] at two hours, 145 mg/dl [8,1 mmol/l] at three hours), as per National Diabetes Data Group. Hypertension-related pregnancy disorders included gestational hypertension and preeclampsia. Gestational hypertension was defined as *de novo* blood pressure elevations (> 140/90 mmHg) after 20 weeks of gestation without other organ system dysfunction. Preeclampsia was defined as *de novo* blood pressure elevation after 20 weeks of gestation coupled with proteinuria or other end-organ dysfunction. Induction or spontaneous delivery, mode of delivery and birthweight (BW) were recorded.

STATISTICAL ANALYSIS

Data collection has been carried out in specific sheet being subsequently entered in database. Categorical variables were described using absolute frequencies and percentages, while discrete variables were described with mean and standard devi-

ation. Association between discrete variables was analyzed using lineal regression, while association with dichotomous variables was analyzed using logistic regression. We used the Bonferroni method to correct for multiple testing. All analyses were conducted with the version 15 of Stata.

ETHICAL ASPECTS

All the data were anonymized by the clinicians who acquired them before being analyzed. All women signed an informed consent. The research protocol was approved by the regional ethics committee (Ethics Committee for Clinical Research of the Hospital Universitari Parc Taulí), with reference CEIC 2019/509.

RESULTS

Data from 542 patients were collected. From the initial eligible cohort, 32 pregnancies were excluded because perinatal results could not be collected, and 510 women were included in the final analysis. Their main characteristics can be seen in table I. Briefly, 35 % of pregnant women presented an appropriate quality of diet (MEDAS ≥ 8). Obesity was present in 15 % of the population. Regarding obstetric complications, the incidence of GD and pregnancy-associated hypertension disorder was 11 % and 7 %, respectively.

Differences in maternal characteristics depending on quality of diet were observed. MEDAS score significantly increased with lower values of BMI ($p = 0.005$) (Fig. 1). Moreover, MEDAS score significantly increased with maternal age ($p < 0.001$) (Fig. 2). However, quality of diet was not associated with parity ($p = 0.51$) or foreign origin ($p = 0.76$).

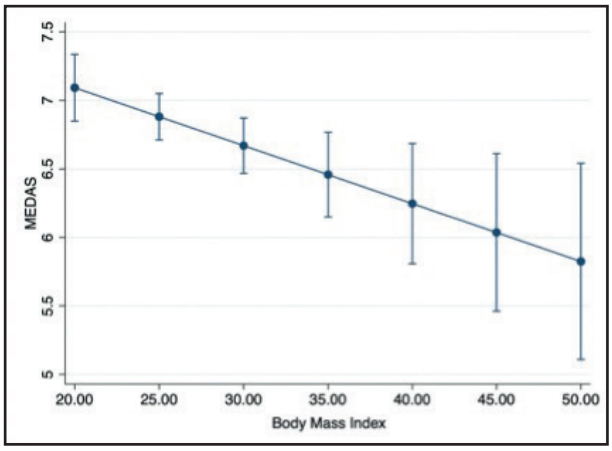

Figure 1.
Association between body mass index (BMI) and MEDAS score.

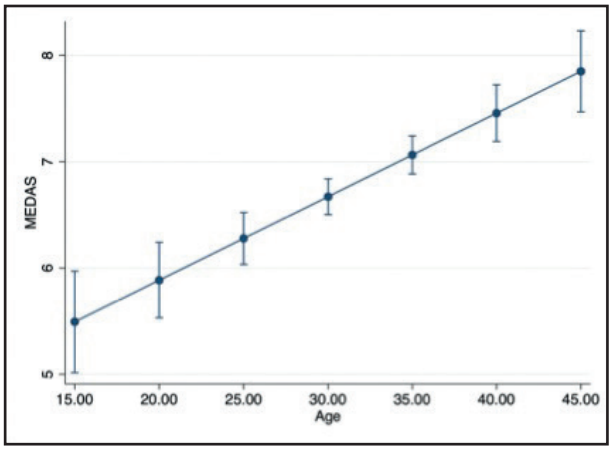

Figure 2.
Association between maternal age and MEDAS score.

Table I. Characteristics of the 510 pregnant women included in the study and comparison between non-obese and obese women

	Overall population n = 510	Non-obese n = 435	Obese n = 75	p
Maternal characteristics				
Age (years), mean (SD)	32 (6)	32 (6)	31 (7)	0.29
Nuliparity, n (%)	219 (43)	239 (55)	46 (62)	0.26
Foreign origin, n (%)	76 (15)	74 (17)	15	0.9
Hypertension, n (%)	6 (1.2)	1 (0.2)	1 (1.4)	0.17
Hypothyroidism, n (%)	38 (7.4)	28 (6.5)	11.1	0.17
BMI (kg/m^2), mean (SD)	26 (5.7)	23.8 (3.2)	34.2 (3.9)	*< 0.001*
MEDAS, mean (SD)	6.8 (1.9)	6.9 (1.9)	6.4 (1.8)	*0.02*
MEDAS ≥ 8, n (%)	185 (35)	165 (38)	22 (29)	0.16

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Table I (Cont.). Characteristics of the 510 pregnant women included in the study and comparison between non-obese and obese women

	Overall population n = 510	Non-obese n = 435	Obese n = 75	p
Ultrasonographic measures				
GA at ultrasound (weeks), mean(SD)	34.4 (0.9)	34 (0.9)	34 (0.7)	0.86
CC (mm), mean (SD)	308 (18)	308 (35)	304 (35)	0.21
AC (mm), mean (SD)	301 (17)	300 (17)	303 (16)	0.25
EFW (g), mean (SD)	2,373 (309)	2,356 (291)	2,386 (269)	0.4
Fetal percentile, mean (SD)	60 (26)	58 (26)	63 (28)	0.13
Perinatal results				
Weight gain (kg), mean (SD)	11.7 (5.7)	12.7 (5.1)	7.2 (5.7)	*< 0.001*
Gestational diabetes, n (%)	56 (11)	35 (8)	19 (26)	*< 0.001*
Pregnancy-associated hypertension disorders, n (%)	36 (7)	17 (4)	10 (14)	*< 0.001*
GA at delivery (weeks), mean (SD)	39.1 (1.4)	39.2 (1.6)	39.1 (1.4)	0.76
Induction of labor, n (%)	239 (47)	191 (44)	46 (61)	*0.014*
Cesarean section, n (%)	92 (18)	70 (16)	14 (19)	0.57
Instrumental delivery, n (%)	44 (9)	39 (9)	7 (9)	0.73
Birthweight (g), mean (SD)	3,281 (487)	3,252 (486)	3,302 (441)	0.42
Birthweight percentile, mean (SD)	52 (30)	50 (30)	53 (30)	0.48
SGA, n (%)	55 (11)	52 (12)	7 (10)	0.59
Macrosomia (> 4,000 g), n (%)	52 (10)	35 (8)	7 (10)	0.69

AC: abdominal circumference; BMI: body mass index; CC: cranial circumference; EFW: estimated fetal weight; MEDAS: Mediterranean Diet Adherence score; GA: gestational age; SD: standard deviation; SGA: small for gestational age.

ASSOCIATION BETWEEN BMI AND ULTRASONOGRAPHIC AND OBSTETRIC RESULTS

Association between BMI and ultrasonographic and perinatal results is shown in table II. When the association between BMI and ultrasonographic findings was analyzed, it was found that an increased BMI was significantly associated with increased values of abdominal circumference (AC), EFW (Fig. 3) and fetal percentile.

Regarding perinatal outcomes, vaginal delivery, GA at delivery and GD were not associated with BMI (association between GD and BMI lost statistical significance after correcting for multiple comparisons). An increased BMI was associated with a higher risk of pregnancy-associated hypertension disorder and induction of labor, and increased values of BW (Fig. 4) and BW percentile. An increased BMI was associated with decreased gestational weight gain ($p < 0.001$).

ASSOCIATION BETWEEN DIET QUALITY AND ULTRASONOGRAPHIC AND OBSTETRIC RESULTS

Association between MEDAS score and obstetric and perinatal outcomes are shown in table II. We did not find any statistically significant association between MEDAS score and ultranosographic measures or perinatal outcomes. Significant association between MEDAS score and gestational weight gain was not observed either.

Table II. Relation between BMI, diet quality, weight gain and ultrasonographic and perinatal results

Variables	BMI			Diet quality			Weight gain		
	Result	95 % CI	p	Result	95 % CI	p	Result	95 % CI	p
Ultrasound measures									
AC	*coef* 0.48	0.21-0.75	*< 0.001*	*coef* 0.33	-0.47-1.14	0.422	*coef* 0.11	-0.17-0.39	0.442
EFW	*coef* 8.25	3.51-13.01	*0.001*	*coef* 4.56	-9.8-18.98	0.534	*coef* 2.24	-2.67-7.16	0.373
Fetal percentile	*coef* 0.88	0.48-1.28	*< 0.001*	*coef* 0.14	-1.08-1.36	0.821	*coef* 0.2	-0.01-0.0051	0.192

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Table II (Cont.). Relation between BMI, diet quality, weight gain and ultrasonographic and perinatal results

Variables	BMI			Diet quality			Weight gain		
	Result	95 % CI	p	Result	95 % CI	p	Result	95 % CI	p
Perinatal outcome									
Gestational diabetes	OR 1.06	1.01-1.11	*0.011*	OR 0.99	0.85-1.15	0.922	OR 0.9	0.85-0.94	*< 0.001*
Hypertension disorders	OR 1.14	1.07-1.21	*< 0.001*	OR 0.91	0.74-1.11	0.354	OR 1.0	0.97-1.11	0.344
Vaginal delivery	OR 0.97	0.92-1.02	0.214	OR 0.9	0.77-1.04	0.167	OR 0.97	0.92-1.03	0.327
Induction of labor	OR 1.05	1.01-1.08	*0.004*	OR 1.06	0.97-1.16	0.191	OR 1.00	0.97-1.03	0.971
GA at delivery	*coef* 0.003	-0.021-0.028	0.771	*coef* 0.02	-0.06-0.089	0.793	*coef* 0.036	0.01-0.06	*0.006*
Birthweight	*coef* 14.60	7.21-21.99	*< 0.001*	*coef* 17.25	-4.82-39.82	0.125	*coef* 16.51	8.74-24.29	*< 0.001*
Birthweight percentile	*coef* 0.77	0.31-1.23	*< 0.001*	*coef* 0.96	-0.042-2.34	0.176	*coef* 0.88	0.39-1.36	*< 0.001*

AC: abdominal circumference; BMI: body mass index; coef: linear regression coefficient; 95 % CI: 95 % confidence interval; EFW: estimated fetal weight; GA: gestational age; OR: odds ratio.

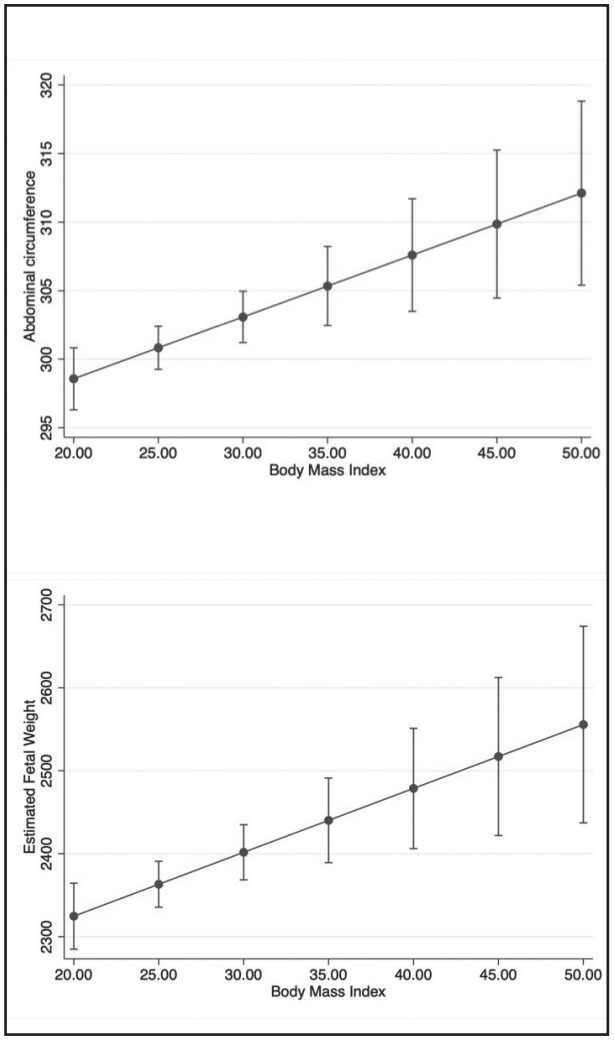

Figure 3.

Association between body mass index (BMI) and abdominal circumference and estimated fetal weight.

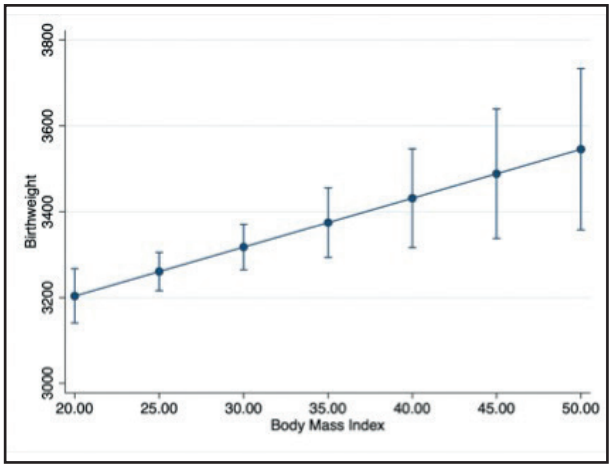

Figure 4.

Association between body mass index (BMI) and birthweight.

ASSOCIATION BETWEEN WEIGHT GAIN AND ULTRASONOGRAPHIC AND OBSTETRIC RESULTS

Association between weight gain and obstetric and perinatal outcomes is shown in table II. Any statistically significant association was found between weight gain and ultrasonographic measures. A higher weight gain across gestation was significantly associated with a higher risk of GD, a higher GA at delivery, a higher BW and a higher BW percentile.

DISCUSSION

In this prospective study, it was observed that only about a third of our pregnant women followed a healthy diet and

15 % presented obesity. Women with a better diet quality had a lower BMI and were older. Higher BMI was significantly associated with a higher fetal growth and a worse perinatal outcome, similarly to higher gestational weight gain. However, diet quality and ultranosographic measures or perinatal outcome were not found to be associated.

In our series, only 35 % of pregnant women followed a healthy diet, in terms of MD adherence. This percentage is low considering that pregnancy is a life period when lifestyle habits usually improve and diet is one of the modifiable behaviors that women can be motivated to change. Other studies investigating diet patterns during pregnancy in different countries like Spain, United States or Australia have also found suboptimal dietary results, in general characterized by being higher in saturated fats and lower in monounsaturated fatty acids, fiber, iron and folates (12-14).

Another remarkable finding of our study is that maternal age was positively associated with adherence to MD. This could be explained by a higher maturity and awareness on this issue with age. However, better results were not observed in multiparous mothers, who might have improved their diet quality previously. Other studies have shown similar maternal characteristics in women presenting a lower quality diet consumption, who were younger, less educated and had a higher pre-pregnancy BMI, while controversial results have been reported regarding to parity (15,16).

The present study confirms previous results (4,5,17,18) suggesting the association between maternal obesity and fetal overgrowth. A higher BMI was associated with higher EFW and fetal percentile at the third trimester due to a higher AC, and leading to a higher BW and BW percentile. A meta-analysis by Gaudet et al. (4) described the association between maternal obesity and macrosomia and large for gestational age (LGA) at birth. Relationship between obesity and fetal growth during gestation has been less evaluated. Some authors have found positive association between BMI and biometric measures and EFW, starting at mid pregnancy and increasing with GA (5,18). The potential mechanism for increased fetal growth might be related to the greater insulin resistance in those women, resulting in higher fetal glucose exposure and insulin levels, which may lead to overnutrition and overgrowth of the fetus. Evidence from experimental studies has suggested that maternal obesity creates an intrauterine environment with higher levels of insulin resistance, chronic inflammation and oxidative stress, which predispose these fetuses to obesity and cardiometabolic disorders in later life (19,20). A worse diet quality in these obese women, which has been demonstrated in our study, might also play a role in the process.

Our study confirms the association between BMI and common pregnancy complications as hypertension disorders. Although association between BMI and GD has been described in other studies, it did not reach statistically significant association (21).

Contrary to BMI, in our sample, no differences were observed depending on the diet quality, fetal growth and perinatal outcomes. To the best of our knowledge, there are no studies evaluating the association between diet quality and fetal growth, but several authors have reported a lack of association between diet quality and weight at birth (10,22,23). However, there is agreement in the literature at the highest risk of GD in case of poor MD adherence (22-26). Regarding hypertension disorders, previous data are controversial. Schnoenaker et al. (27) found a negative association between MD pre-pregnancy pattern and the risk of developing hypertensive disorders of pregnancy in a cohort of 3,582 Australian women. However, the group of St. Carlos Gestational Diabetes Mellitus Prevention Study (22,28) did not find a reduced risk of gestational hypertension and preeclampsia in pregnant women with good MD adherence. The divergences between our results and those reported by other authors could be explained by the different moment when the food questionnaire was applied. In most of the reports, women were interviewed before pregnancy or at the first trimester while, in our study, we did it at 20-22 weeks of pregnancy. This suggests that the optimization of diet has ideally to take place prior to pregnancy, as well as it happens with BMI. A recent meta-analysis (29) about the effect of dietary interventions on pregnancy concluded that diet intervention does not reduce the risk of GD and hypertension disorders. Women, specially the obese, should be encouraged to modify food habits prior to pregnancy, as well as to improve weight, decreasing the risk of obesity-related complications and improving fetal growth.

However, differences were observed regarding weight gain across gestation. Women with a higher weight gain presented a higher BW and BW percentile, a higher GA at delivery and a higher risk of GD. These findings support the recent evidence that gestational weight gain acts as an added independent factor for adverse obstetric outcome, which has a cumulative effect during gestation (18,30). The importance of improving pre-gestational BMI is clear, but when a woman is already pregnant, a limited weight gain during pregnancy should also be recommended. In other words, in the course of pregnancy, it would be necessary to recommend a diet with good quality for its global advantages at any vital time of life, but also to ensure quantities that allow a correct weight gain.

One of the strengths of the present study was its prospective performance on a healthy sample of pregnant women at our institution, which could be representative to Spanish low-risk pregnant population. Another strength is having used a great easy questionnaire for global assessment of MD adherence, which allows one to capture diet as a whole and in a short time.

A number of limitations of the study should be considered. First, the food questionnaire was completed by women themselves and could be biased by women's answers. Secondly, the questionnaire was the same for all women and diet characteristics of women of other cultures were not taken into account; some women could have a good quality of diet different than the MD, which was not represented by the punctuation of the test. However, although a considered part of our population was from a foreign origin, the majority came from countries with a MD such as Morocco. In addition, differences in diet quality were not found regarding foreign origin. However, differences could exist depending on sociocultural status, which was not registered. Another limitation is that the questionnaire was assessed at the

second trimester of pregnancy with the purpose of reflecting diet quality at the first half of pregnancy. It would be better to apply the questionnaire every trimester of pregnancy, because diet habits could change during pregnancy.

On summary, the majority of our pregnant population did not showed a great diet quality, but there was no evidence that diet quality affects pregnancy complications. However, pre-pregnancy BMI was related to fetal and neonatal growth and obstetric outcomes, as well as gestational weight gain. Future efforts should be focused on education about diet and other habits of future mothers at the preconception period, in order to get pregnant with the right weight and an established good food quality.

REFERENCES

1. Poston L, Caleyachetty R, Cnattingius S, Corvalán C, Uauy R, Herring S, et al. Preconceptional and maternal obesity: epidemiology and health consequences. Lancet Diabetes Endocrinol 2016;4:1025-36. DOI: 10.1016/S2213-8587(16)30217-0
2. Lisonkova S, Muraca GM, Potts J, Liauw J, Chan WS, Skoll A, et al. Association between prepregnancy body mass index and severe maternal morbidity. JAMA 2017;318:1777-86. DOI: 10.1001/jama.2017.16191
3. Wolfe KB, Rossi RA, Warshak CR. The effect of maternal obesity on the rate of failed induction of labor. Am J Obstet Gynecol 2011;205:128.e1. DOI: 10.1016/j.ajog.2011.03.051
4. Gaudet L, Ferraro ZM, Wen SW, Walker M. Maternal obesity and occurrence of fetal macrosomia: a systematic review and meta-analysis. Biomed Res Int 2014;2014:640291. DOI: 10.1155/2014/640291
5. Zhang C, Hediger ML, Albert PS, Grewal J, Sciscione A, Grobman WA, et al. Association of maternal obesity with longitudinal ultrasonographic measures of fetal growth: findings from the NICHD Fetal Growth Studies-Singletons. JAMA Pediatrics 2018;172:24-31. DOI: 10.1001/jamapediatrics.2017.3785
6. Field CJ. Early risk determinants and later health outcomes: implications for research prioritization and the food supply. Summary of the workshop. Am J Clin Nutr 2009;89:1533S-9S. DOI: 10.3945/ajcn.2009.27113H
7. McAuliffe FM, Killeen SL, Jacob CM, Hanson MA, Hadar E, McIntyre HD, et al. Management of prepregnancy, pregnancy, and postpartum obesity from the FIGO Pregnancy and Non-Communicable Diseases Committee: a FIGO guideline. Int J Gynecol Obstet 2020;151:16-36. DOI: 10.1002/ijgo.13334
8. Estruch R, Ros E, Salas-Salvadó J, Covas MI, Corella D, Arós F, et al. Primary prevention of cardiovascular disease with a Mediterranean diet. N Engl J Med 2013;368:1279-90. DOI: 10.1056/NEJMoa1200303
9. Assaf-Balut C, García de la Torre N, Durán A, Fuentes A, Bordiu M, Del Valle E, et al. A Mediterranean diet with additional extra virgin oil and pistachios reduces the incidence of gestational diabetes mellitus (GDM): a randomized clinical trial: The St. Carlos GDM prevention study. PLoS ONE 2017;12:e0185873. DOI: 10.1371/journal.pone.0185873
10. Tomaino L, Reyes D, Reyes A, García L, Ramos M, Serra L. Adherence to Mediterranean diet is not associated with birthweight. Results for a sample of Canarian pregnant women. Nutr Hosp 2020;37(1):86-92.
11. Figueras F, Meler E, Iraola A, Eixarch E, Coll O, Figueras J, et al. Customized birthweight standards for a Spanish population. Eur J Obstet Gynecol Reprod Biol 2008;136:20-4. DOI: 10.1016/j.ejogrb.2006.12.015
12. Gesteiro E, Rodríguez Bernal B, Bastida S, Sánchez-Muniz FJ. Maternal diets with low healthy eating index or Mediterranean diet adherence scores are associated with high cord-blood insulin levels and insulin resistance markers at birth. Eur J Clin Nutr 2012;66:1008-15. DOI: 10.1038/ejcn.2012.92
13. Hure A, Young A, Smith R, Collins C. Diet and pregnancy status in Australian women. Public Health Nutr 2009;12:853-61. DOI: 10.1017/S1368980008003212
14. Rifas-Shiman SL, Rich-Edwards JW, Kleinman KP, Oken E, Gillman MW. American Dietetic Association. Dietary quality during pregnancy varies by maternal characteristics in Project Viva: a US cohort. J Am Diet Assoc 2009;109:1004-11. DOI: 10.1016/j.jada.2009.03.001
15. Martin JC, Zhou SJ, Flynn AC, Malek L, Greco R, Moran L. The assessment of diet quality and its effects on health outcomes pre-pregnancy and during pregnancy. Semin Reprod Med 2016;34:83-92. DOI: 10.1055/s-0036-1571353
16. Bodnar LM, Siega-Riz AM. A diet quality index for pregnancy detects variation in diet and differences by sociodemographic factors. Public Health Nutr 2002;5:801-9. DOI: 10.1079/PHN2002348
17. Ehrenberg HM, Mercer BM, Catalano PM. The influence of obesity and diabetes on the prevalence of macrosomia. Am J Obstet Gynecol 2004;191:964-8. DOI: 10.1016/j.ajog.2004.05.052
18. Ay L, Kruithof CJ, Bakker R, Witteman JC, Moll HA, Hofman A. Maternal anthropometrics are associated with fetal size in different periods of pregnancy and at birth: The Generation R Study. BJOG 2009;116:953-63. DOI: 10.1111/j.1471-0528.2009.02143.x
19. Denison FC, Roberts KA, Barr SM, Norman JE. Obesity, pregnancy, inflammation, and vascular function. Reproduction 2010;140:373-85. DOI: 10.1530/REP-10-0074
20. Gaillard R, Rifas-Shiman SL, Perng W, Oken E, Gillman MW. Maternal inflammation during pregnancy and childhood adiposity. Obesity 2016;24:1320-7. DOI: 10.1002/oby.21484
21. Yao D, Chang Q, Wu QJ, Gao SY, Zhao H, Liu YS, et al. Relationship between maternal central obesity and the risk of gestational diabetes mellitus: a systematic review and meta-analysis of cohort studies. J Diabetes Res 2020;2020:6303820. DOI: 10.1155/2020/6303820
22. Melero V, García de la Torre N, Assaf-Balut C, Jiménez I, Del Valle L, Durán A, et al. Effect of a Mediterranean diet-based nutritional intervention on the risk of developing gestational diabetes mellitus and other maternal-fetal adverse events in Hispanic women residents in Spain. Nutrients 2020;12:3505. DOI: 10.3390/nu12113505
23. Al Wattar BH, Dodds J, Placzek A, Beresford L, Spyreli E, Moore A, et al. ESTEEM study group. Mediterranean-style diet in pregnant women with metabolic risk factors (ESTEEM): a pragmatic multicentre randomised trial. PLoS Med 2019;16:e1002857. DOI: 10.1371/journal.pmed.1002857
24. Tobias DK, Zhang C, Chavarro J, Bowers K, Rich-Edwards J, Rosner B, et al. Prepregnancy adherence to dietary patterns and lower risk of gestational diabetes mellitus. Am J Clin Nutr 2012;96:289-95. DOI: 10.3945/ajcn.111.028266
25. García de la Torre N, Assaf-Balut C, Jiménez I, Del Valle L, Durán A, Fuentes M. Effectiveness of following Mediterranean diet recommendations in the real world in the incidence of gestational diabetes mellitus (GDM) and adverse maternal-foetal outcomes: a prospective, universal, interventional study with a single group. The St Carlos Study. Nutrients 2019;28:1210. DOI: 10.3390/nu11061210
26. Karamanos B, Thanopoulou A, Anastasiou E, Assaad-Khalil S, Albache N, Bachaoui M, et al. MGSD-GDM Study Group. Relation of the Mediterranean diet with the incidence of gestational diabetes. Eur J Clin Nutr 2014;68:8-13. DOI: 10.1038/ejcn.2013.177
27. Schoenacker DA, Sabita S, Callaway LK, Mishra GD. Prepregnancy dietary patterns and risk of developing hypertensive disorders of pregnancy: results from the Australian Longitudinal Study on Women's Health. Am J Clin Nutr 2015;102:94-101. DOI: 10.3945/ajcn.114.102475
28. Assaf-Balut C, García de la Torre N, Duran A, Fuentes M, Bordiu E, Del Valle L, et al. A Mediterranean diet with an enhanced consumption of extra virgin olive oil and pistachios improves pregnancy outcomes in women without gestational diabetes mellitus: a sub-analysis of the St. Carlos Gestational Diabetes Mellitus Prevention Study. Ann Nutr Metab 2019;74:69-79. DOI: 10.1159/000495793
29. International Weight Management in Pregnancy (i-WIP) Collaborative Group. Effect of diet and physical activity based interventions in pregnancy on gestational weight gain and pregnancy outcomes: meta-analysis of individual participant data from randomised trials. BMJ 2017;19:358:j3119. DOI: 10.1136/bmj.j3119
30. Santos S, Voerman E, Amiano P, Barros H, Beilin LJ, Bergströmet 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. DOI: 10.1111/1471-0528.15661