Received: 20 January 2019 | Revised: 28 October 2019 | Accepted: 6 November 2019
DOI: 10.1111/aogs.13768

ORIGINAL RESEARCH ARTICLE

AOGS Acta Obstetricia et Gynecologica Scandinavica

Assessing maternal dietary quality in early pregnancy in the programming of intrauterine fetal growth

Rachel A. K. Kennedy[1,2] | Ciara M. E. Reynolds[1] | Eimer G. O'Malley[1] | Michael J. Turner[1]

[1]UCD Center for Human Reproduction, Coombe Women and Infants University Hospital, Dublin, Ireland
[2]School of Biological Sciences, Dublin Institute of Technology, Dublin, Ireland

Correspondence
Rachel A. K. Kennedy, UCD Center for Human Reproduction, Coombe Women and Infants University Hospital, Cork Street, Dublin 8, Ireland.
Email: rachel_kennedy@live.ie

Funding information
This work was partly funded through a Dublin Institute of Technology Fiosraigh Scholarship provided to author RAKK.

Abstract

Introduction: It is established globally that a healthy maternal diet during pregnancy is important in programming fetal growth and development. The assessment of maternal dietary intake, however, is challenging both in clinical practice and in research studies. The aim of this study was to compare three individual dietary quality scores in early pregnancy based on European, American and World Health Organization (WHO) nutrient recommendations for the identification of suboptimal fetal growth.

Material and methods: Women were recruited conveniently at their first antenatal hospital visit and completed a supervised 4-day diet history. The results were dichotomized into those women meeting and those not meeting macronutrient and micronutrient recommendations from the European Food Safety Authority (EFSA), WHO and the Institute of Medicine (USA). Composite nutrient scores were derived. The relation between the three individual dietary scores in early pregnancy and subsequent birthweight and small-for-gestational-age was compared using regression analyses.

Results: Of the 202 women, the mean age was 32.2 (SD 5.0) years and 44.6% were nulliparas. The mean dietary quality scores were: EFSA 9.4 (SD 3.1), WHO 8.5 (SD 3.7) and USA 9.6 (SD 3.6). On multivariable regression, there was a positive relation between the EFSA (β = 44.7, 95% CI 17.0-72.4, P = 0.002), WHO (β = 39.2, 95% CI 17.2-61.1, P = 0.001), and USA (β = 40.0 95% CI 17.6-62.3, P = 0.001) score and birthweight. All three scores were positively associated with birthweight centiles. However, only those in the lowest quartile of the EFSA score were more likely to be small-for-gestational-age (odds ratio 2.8, 95% CI 1.1-7.4, P = 0.03).

Conclusions: This study found that a dietary quality score based on European nutrient recommendations was better than other international recommendations at identifying in early pregnancy those women at risk of suboptimal fetal growth.

KEYWORDS
birthweight, dietary quality, dietary recommendations for pregnancy, intrauterine fetal growth, maternal diet

Abbreviations: CI, confidence interval; EFSA, European Food Safety Authority; SGA, small-for-gestational-age; USA, United States of America Institute of Medicine; WHO, World Health Organization.

 © 2019 Nordic Federation of Societies of Obstetrics and Gynecology

1 | INTRODUCTION

Maternal dietary intakes and the provision of essential nutrients to the fetus during pregnancy are determinants of fetal growth and development.[1] If the fetus does not receive the appropriate nutrition during pregnancy, this may lead to permanent structural, physiological and metabolic changes in the offspring.[2] In the short term, offspring with restricted growth, such as those born small-for-gestational-age (SGA, ie <10th centile) are at increased risk of mortality and morbidity. For instance, growth-restricted infants are at increased risk of severe fetal distress, cerebral damage and infant death.[3] Longer-term evidence suggests that an adverse intrauterine environment, including inadequate nutrition provision to the fetus, may predispose the offspring to lifelong cardio-metabolic complications.[4]

Previous epidemiological studies examining the relation between maternal diet and pregnancy outcomes have usually focused on the effects of singular nutrients.[5] However, this method has certain limitations. Foods are not consumed in isolation by individuals. Also, as a result of the high correlation between certain nutrients, it is challenging to separate their effects.[6] Single-nutrient analyses may not account for the potential confounding effects of dietary patterns.[6]

Furthermore, the effect of a single nutrient may be too small to detect.[7] The cumulative effects of multiple nutrients may be more measurable. Due to the complexity of nutrient interaction, the inter-related nature of nutrients, and the consumption of nutrients and foods at the same time, research on the impact of the diet as a whole on health and pregnancy outcomes may be more insightful.[1] By examining patterns of dietary intakes, which mirror dietary practices of free-living individuals more closely, this may be more representative of habitual eating practices.

There is a dearth of evidence examining maternal dietary quality as assessed through dietary quality scores and their relation with fetal growth. To our knowledge, to date, no study has compared nutrient recommendations as individual dietary quality scores from various health bodies and their relation with fetal growth.

The aim of this study was to develop and compare three individual dietary quality scores in early pregnancy based on European, American and World Health Organization (WHO) nutrient recommendations respectively for the identification of suboptimal fetal growth.

2 | MATERIAL AND METHODS

Women were recruited at their convenience between October 2015 and January 2017 as they presented for antenatal care to the Coombe Women and Infants University Hospital. It is one of the largest maternity hospitals in Europe and accepts women from all socio-economic groups across the urban-rural divide including those privately insured. The hospital cares for over 8000 infants weighing ≥500 g each year.[8]

Key message

This study found that a dietary quality score based on European dietary recommendations was better than other international recommendations at identifying in early pregnancy those women at risk of suboptimal fetal growth.

This study was a secondary analysis of a randomized controlled trial conducted by the same researcher.[9] A single researcher (RK) screened women individually for eligibility in the antenatal booking clinic at their first appointment and subsequently invited women to participate in the study if they met the inclusion criteria. Recruitment was conducted Monday to Friday during morning antenatal clinics.

All women recruited to the study had sonographic confirmation of a singleton pregnancy and were <18 weeks of gestation. Women were excluded if they were unable to give informed written consent. Clinical and sociodemographic details were routinely collected and computerized by a trained midwife at the first visit and again immediately after delivery.

At the first antenatal visit, women's height was measured to the nearest cm and weight was measured to the nearest 0.1 kg by a trained researcher (RK). Body mass index was then calculated. To assess habitual food and nutrient intakes the same researcher (RK, registered dietitian) conducted a supervised 4-day, retrospective diet history with all women to limit inter-observer variability. Women were asked to provide descriptions of all foods and beverages consumed, including brand names where possible, and their methods of preparation and cooking were recorded. For composite dishes, each ingredient used in the recipe was quantified. All portion sizes were also quantified using standard household measures (eg cups and spoons). Two weekdays and two weekend days of the previous week were included in the 4-day history.

Women completed a questionnaire that collected additional data on lifestyle factors including self-reported alcohol consumption, nausea and vomiting levels (PUQE score) and self-reported quality of life. A physical activity level was estimated for each woman. These levels ranged from 1.45 metabolic equivalents (seated work with no option of moving around and no strenuous leisure-time activity); up to 2.20 metabolic equivalents (strenuous work or highly active leisure time).[10]

Birthweight was measured by a midwife and documented within 30 minutes of birth. Customized birthweight centiles were calculated subsequently using the New Global Bulk Centile Calculator v8.0.1, 2018 (Perinatal Institute for Maternal and Child Health, http://www.perinatal.org.uk/). Women's weight, height, ethnicity, parity and infant gender, gestational age at birth and birthweight were entered into the calculator. Small-for-gestational-age babies were identified (ie those <10th centile for birthweight).[11]

Maternal dietary intake data from the diet histories were entered into Nutritics Version 3.7 University Edition (Nutritics Ltd, Dublin, Ireland) to convert the reported food intakes into nutrient intakes. Average daily nutrient intakes for the 4-day period were then calculated. The food composition tables used in NUTRITICS are based on McCance and Widdowson's Food Composition Tables (7th edition, and supplemental volumes).[12]

Three individual nutrition scores were developed, and included nutrients that were considered important in pregnancy for maternal and neonatal outcomes.[1,13,14] Women were classified as those either meeting or not meeting recommended daily intake guidelines for dietary macronutrients and micronutrients based on (a) European Food Safety Authority (EFSA) guidelines, (b) WHO guidelines and (c) USA Institute of Medicine guidelines.[15-22] An overview of each guideline's nutrient recommendations and the nutrients included in each score are outlined in Table 2.

Where possible, for the cut-off point for each nutrient included in each individual score, the recommended value for Population Reference Intake was used, ie the level of nutrient intake that is adequate for the majority of people in a population group. Where a Population Reference Intake was not provided, an Adequate Intake value was used, ie the value estimated when a Population Reference Intake cannot be determined. An Adequate Intake is the average observed daily level of intake by a population group(s) of seemingly healthy people that is considered to be adequate. Reference Intake ranges were used for macronutrients as required. Reference Intake ranges for macronutrients are the ranges of intakes that are adequate to maintain health and are linked with a lower risk of certain chronic diseases (EFSA 2017). A recommendation by EFSA (2017) has not yet been released in relation to sodium, therefore, the recommendation from WHO was used.[15,21]

If a woman met the recommendation for an individual macronutrient or micronutrient included in the nutrient score, they received 1 point per recommendation, whereas if they were not meeting the recommendations, they received 0 points. The individual nutrients within each score were added to provide a total dietary quality score as a continuous variable. Each score was also divided into quartiles, with the lowest quartile representing women with the lowest dietary quality. The EFSA dietary quality score and the USA score consisted of a total of 23 nutrients. The WHO score included a total of 19 nutrients.

2.1 | Statistical analyses

Data analysis was carried out using SPSS version 24.0 (IBM Corporation, Armonk, NY, USA). The normality of continuous variables was evaluated by determination of the kurtosis and skewness of the distribution, visual analysis of their histograms and interpretation of their Kolmogorov-Smirnov statistics. Descriptive statistics were used to describe the study participants' characteristics.

Simple linear regression was used to assess the relation between each dietary quality score (EFSA, WHO, USA) and birthweight. Multivariable linear regression was used to control for potential confounding variables where appropriate.[1,13] Simple linear regression was used to determine the relation between each dietary quality score and the birthweight centiles. Binary logistic regression was used to examine the relation between the lowest quartile of each dietary quality score and babies born SGA. In all statistics, a P value of <0.05 was considered statistically significant.

2.2 | Ethical approval

This study received ethical approval from the Hospital's Research Ethics Committee (Study no. 6-2015) and from the Dublin Institute of Technology Research Ethics Committee[15-45].

3 | RESULTS

Of the 415 women who were screened for eligibility, 63 women did not meet the inclusion criteria. A further 47 women declined study participation. Of those eligible to participate, 86.6% agreed (n = 305); however, 55 women did not return after their scan to complete enrolment. A total of 250 women were recruited to the primary study.[9] Of these, 202 women had food diaries, questionnaires and matching neonatal outcome data that were included in this study. Table 1 outlines the study population characteristics. Women were aged 19-43 years of age. The mean gestation at recruitment and data collection was 12.4 (SD 1.6) weeks.

Table 2 outlines the nutrient recommendation guidelines from EFSA, WHO and USA. The mean EFSA score was 9.4 (SD 3.1) with women's scores ranging from 3 to 19 points on the scale out of a maximum score of 23 points. The mean USA score was 9.6 (SD 3.6) with women's scores ranging from 1 to 19 points on the scale out of a maximum of 23 points. The mean WHO score was 8.5 (SD 3.7) with women's scores ranging from 0 to 16 points out of a maximum of 19 points.

On simple linear regression, there was a positive relation between EFSA score and birthweight (β = 42.9, 95% CI 17.4-68.3, P = 0.001). There was also a positive relation between the WHO score and birthweight (β = 40.6, 95% CI 19.1-62.1, P < 0.001) and the USA score and birthweight (β = 41.7, 95% CI 19.7-63.7, P < 0.001). These relations persisted on multivariable analysis (Table 3).

The study results showed a positive relation between EFSA score and birthweight centiles (β = 2.1, 95% CI 0.9-3.4, P = 0.001). A positive relation was identified between the WHO score and birthweight centiles (β = 2.0, 95% CI 0.9-3.1, P < 0.001) and the USA score and birthweight centiles (β = 2.0, 95% CI 0.9-3.1, P < 0.001).

Table 4 outlines the relation between the lowest quartile of each score and SGA on binary logistic regression. On binary logistic regression, babies born to women in the lowest quartile for the EFSA score were more likely to be SGA (odds ratio [OR] 2.8, 95% CI 1.1-7.4, P = 0.03). However, there was no relation between the lowest quartile of the WHO score or the USA score and SGA (Table 4).

TABLE 1 Maternal and neonatal characteristics of the study population (n = 202)

	n, mean, median	%, SD, IQR
Maternal characteristics		
Age (years); (mean, SD)	32.2	5.0
Nulliparas (n, %)	90	44.6
BMI (kg/m^2); (mean, SD)	26.2	5.8
BMI category[a]		
Underweight	5	2.5
Normal weight	94	46.5
Overweight	59	29.2
Obese (n, %)	44	21.8
Smokers (n, %)	16	7.9
Drink alcohol habitually (n, %)[b]	171	84.7
Prepregnancy FA (n, %)	112	55.4
Planned pregnancy (n, %)	149	73.8
Third-level education (n, %)[c]	145	75.5
Gestational diabetes mellitus (n, %)[d]	10	5
Nausea and vomiting score (PUQE score) (median, IQR)	5	3
Quality of life score (mean, SD)	7	1.9
Physical activity level[e]		
1.45	19	10.4
1.60	39	21.3
1.75	52	28.4
1.90	57	31.1
2.05	14	7.7
2.20	2	1.1
Neonatal characteristics		
Females (n, %)	95	47.0
Birthweight (g); (mean, SD)	3523.9	588.5
SGA (n, %)[f]	19	9.4
LBW (n, %)	7	3.5
Delivered <37 weeks' gestation (n, %)	8	4.0

Abbreviations: BMI, body mass index; FA, folic acid; IQR, interquartile range; LBW, low birthweight (<2500 g); PUQE, Pregnancy-Unique Quantification of Emesis and Nausea; SD, standard deviation; SGA, small-for-gestational-age (<10th centile).

[a]Obesity, defined as those with a BMI ≥ 30.0 kg/m^2, in accordance with the World Health Organization (WHO).

[b]Prior to pregnancy.

[c]n = 192

[d]n = 201; WHO (2013) diagnostic criteria used.[30]

[e]n = 183

[f]n = 200

4 | DISCUSSION

This study found that all three dietary guidelines when formulated as a composite dietary quality score were positively associated with birthweight. However, the EFSA score was the only dietary quality score to identify that women with the lowest dietary quality are more likely to deliver an SGA baby. This indicates that when applied in a European population, the most recent EFSA guidelines are preferable to assess maternal dietary quality compared with the guidelines of WHO or USA in order to identify women who are more likely to deliver an SGA infant. This is important in clinical practice because it may help to identify those women whose offspring could benefit from dietary interventions if fetal growth can be optimized. Evidence has shown that identification of SGA before delivery, when combined with appropriate monitoring for women at risk of delivering SGA infants, resulted in a four-fold decreased risk of adverse fetal outcomes.[3]

Increasing evidence suggests that maternal nutrition influences fetal growth and development and may program the long-term health status of the offspring.[5,23] If a suboptimal intrauterine environment is created, such as inappropriate nutrition provision, during critical periods of fetal development, this may cause permanent physiological alterations and thus change the health trajectory of the fetus.[23] The optimum timing for pregnancy dietary intervention has also yet to be defined. To date, there is scant evidence examining the relation between dietary quality indices and neonatal outcomes. Furthermore, because of the diversity of the methodologies used in the existing studies, they are challenging to compare.

In our study, all dietary quality scores were positively associated with birthweight and produced similar coefficients. Hence, the differences in associations between all 3 scores were not clinically significant in terms of grams difference of birthweight observed. However, there was a difference in OR seen between those who were in the lowest dietary quartile for EFSA score (OR 2.8) compared with that of the WHO score (OR 1.8) and USA score (OR 1.3).

In an American study (n = 862), the relation between maternal dietary quality at 24-28 weeks' gestation and fetal growth was assessed.[24] Women completed a self-administered food frequency questionnaire to assess dietary intakes. Women's dietary quality was then assessed as adherence of women's dietary intakes to the Alternative Healthy Eating Index, which is formulated based on USA guidelines. The aforementioned study found that as maternal dietary quality increased, the offspring was less likely to be SGA. However, the study did not find a statistical difference between quartiles of dietary quality and SGA. Similarly, our study found that when USA nutrition recommendations were formulated into a composite dietary quality score, there was a linear relation between dietary quality and birthweight and birthweight centiles; however, there was no relation between the lowest quartile of the USA dietary quality score and SGA.

TABLE 2 Nutrient guidelines of European Food Safety Authority (EFSA), World Health Organization (WHO), US Institute of Medicine (USA) and the nutrients included in each respective nutrient score

Nutrient	EFSA recommendation	PRI, AI, RI	WHO recommendations	PRI, AI, RI	USA (IOM) recommendations[h]	PRI, AI
Macronutrients						
Protein (g/kg/d)	+1 g/d[a]	PRI	+1 g/d[a]	PRI	10-35 (% of energy)	RI
Carbohydrate (% of energy)	45-60	RI	55-75	RI	45-65	RI
Fat (% of energy)	20-35	RI	15-35	RI	20-35	RI
Micronutrients						
Vitamin A (µg)	700	PRI	800	PRI	770	PRI
Vitamin C (mg)	105	PRI	55	RNI	85	PRI
Vitamin B1 (Thiamine) (mg)	0.1[b]	PRI	1.4	RNI	1.4	PRI
Vitamin B2 (Riboflavin) (mg)	1.9	PRI	1.4	RNI	1.4	PRI
Vitamin B3 (Niacin) (NE, mg)	1.6[b]	PRI	18	RNI	18	PRI
Vitamin B5 (Pantothenic acid) (mg)	5	AI	6	PRI	6	AI
Vitamin B6 (mg)	1.8	PRI	1.9	PRI	1.9	PRI
Vitamin B7 (Biotin) (µg)	40	AI	30	PRI	30	AI
Vitamin B12 (Cobalamin) (µg)	4.5	AI	2.6	PRI	2.6	PRI
Folate (µg DFEs)	600	AI	600	PRI	600	PRI
Vitamin D (µg)	15	AI	5	PRI	15	PRI
Iodine (µg)	200	AI	200	PRI	220	PRI
Iron (mg)	16	PRI	–[f]	PRI	27	PRI
Copper (mg)	1.5	AI	–	–	1.0	PRI
Calcium (mg)	950/1000[c]	PRI	–	–	1000	PRI
Potassium (mg)	3500	AI	3510	AI	4700	AI
Zinc (mg)	+1.6[d]	PRI	3.4/5.5/11.0[g]	PRI	11	PRI
Magnesium (mg)	300	AI	220	PRI	350 (19-30 y) 360 (31-50 y)	PRI PRI
Sodium (mg)	2000[e]	–	2000	–	1500	AI
Phosphorus (mg)	550	AI	–	–	700	PRI

Note: Nutrition recommendations based on EFSA guidelines (2017), apart from sodium, which is based on WHO (2012).

Abbreviations: AI, Adequate Intake, the average observed daily level of intake by a population group (or groups) of apparently healthy people that is assumed to be adequate; DFEs, Dietary folate equivalents; NE, niacin equivalent; PRI, population reference intake, the level of nutrient intake that is adequate for the majority of people in a population group; RI, reference intake range, ranges of intakes that are adequate for maintaining health and associated with a low risk of selected chronic diseases.

[a]In addition to the PRI for protein of non-pregnant, non-lactating women, if second trimester, +9 g/d.

[b](mg/MJ)

[c]18-24 years – 1000 mg, ≥25 years – 950 mg

[d]In addition to the PRIs for non-pregnant, non-lactating women.

[e]Based on WHO recommendations.

[f]WHO guidelines state: "No figures are given for dietary iron requirements in pregnant women because the iron balance in pregnancy depends not only on the properties of the diet but also and especially on the amounts of stored iron".

[g]High bioavailability, 3.4; Moderate bioavailability, 5.5; Low bioavailability, 11.0.

[h]For USA Institute of Medicine age-specific guidelines, those 19 years+ were selected as our study population age range was 19-43 years of age.

In a Norwegian study (n = 66 597) a diet score to quantify adherence to a healthy and environmentally friendly New Nordic Diet was developed.[25] This study derived data from the Norwegian Mother and Child Cohort Study (MoBa) where participants were recruited nationwide in Norway from 1999 to 2008. Participants completed a baseline questionnaire at 17 weeks of gestation and a

TABLE 3 Multiple linear regression between each guideline score and birthweight (n = 202)

	Unstandardized coefficients		Standardized coefficients	95% CI		
	B	SE	β	Lower bound	Upper bound	*P*
Birthweight						
Model 1						
EFSA (continuous)	44.7	14.1	0.22	17.0	72.4	0.002
Parity	−26.7	83.17	−0.02	−190.7	137.4	0.75
BMI	10.6	7.1	0.10	−3.5	24.6	0.14
Prepregnancy FA	−119.5	84.9	−0.10	−286.9	48.0	0.16
Smoking	−48.3	157.3	−0.02	−358.5	261.9	0.76
Infant gender	23.3	82.5	0.02	−139.4	186.1	0.78
Gestational age at birth	−0.2	0.4	−0.03	−1.0	0.7	0.63
Model 2						
WHO (continuous)	39.2	11.1	0.25	17.2	61.1	0.001
Parity	−28.7	82.7	−0.02	−191.8	134.4	0.73
BMI	9.7	7.1	0.10	−4.3	23.7	0.17
Prepregnancy FA	−113.9	84.4	−0.10	−280.3	52.6	0.18
Smoking	−87.5	156.6	−0.04	−396.4	221.4	.58
Infant gender	24.5	82.9	0.02	−137.2	186.1	.77
Gestational age at birth	−0.3	0.4	−0.04	−1.1	0.6	0.56
Model 3						
USA (continuous)	40.0	11.4	0.25	17.6	62.3	0.001
Parity	−22.3	82.7	−0.02	−185.4	140.8	0.79
BMI	9.8	7.1	0.10	−4.2	23.8	0.17
Prepregnancy FA	−116.5	84.4	−0.10	−283.0	49.9	0.17
Smoking	−79.2	156.5	−0.04	−388.0	229.5	0.61
Infant gender	22.7	82.0	0.02	−139.1	184.5	0.78
Gestational age at birth	−0.2	0.4	−0.03	−1.1	0.6	0.63

Abbreviations: BMI, body mass index; EFSA, European Food Safety Authority guidelines; SE, standard error; USA, United States of America (Institute of Medicine) guidelines; WHO, World Health Organization guidelines.

TABLE 4 Binary logistic regression between the lowest quartile of each dietary guideline and small-for-gestational-age (n = 200)

				95% CI		
	B	SE	OR	Lower bound	Upper bound	*P*
EFSA (lowest quartile)	1.0	0.5	2.8	1.1	7.4	0.03
WHO (lowest quartile)	0.6	0.5	1.8	0.7	4.5	0.24
USA (lowest quartile)	0.2	0.5	1.3	0.5	3.4	0.64

Abbreviations: EFSA, European Food Safety Authority guidelines; OR, odds ratio; USA, United States of America (Institute of Medicine) guidelines; WHO, World Health Organization guidelines;

Small-for-gestational-age defined as <10th centile for birthweight.

food frequency questionnaire around 22 weeks of gestation. The authors found that a high New Nordic Diet score, compared with a low score, was associated with reduced likelihood of the offspring being born SGA. Similar to our findings, the authors identified that a lower dietary quality was associated with SGA; however, this study differed to ours in terms of the time-point and methods used for dietary data collection.

The relation between lower maternal dietary quality and restricted fetal growth for weight were also highlighted in a study conducted in Spain (n = 787).[13] This study assessed maternal dietary quality in the first trimester of pregnancy and used a food frequency questionnaire to assess nutrient intakes. A modified version of the alternative healthy eating index was used to determine maternal dietary quality. The results demonstrated that babies born to women in the 4th quintile for dietary quality were heavier and longer than those in the lowest quintile. Furthermore, women with the highest dietary scores had a lower risk of delivering an infant that was fetally growth-restricted for weight than women in the lowest quintile.

In a small pilot study (n = 41) assessing dietary quality and fetal growth using the Healthy Eating Index (HEI-2010), which is formulated based on the 2010 Dietary Guidelines for Americans, a 10-point lower HEI-2010 score was associated with 200 g higher infant birthweight.[26] In contrast, an American study (n = 893) found that when dietary quality was assessed in the third trimester using the Alternative Healthy Eating Index for Pregnancy and the Alternate Mediterranean Diet, there was no relation with neonatal outcomes at birth, including birthweight and SGA.[14]

A limitation of our study is that it was confined to one country in Europe, which may limit the generalizability of the results. The EFSA score may also be a stronger or weaker predictor in other countries where women's dietary and supplement intakes differ during pregnancy.[27] Supplement data were not included in the final analysis. Hence, further research is needed to determine if the addition of nutrition supplement data decreases the differences in fetal growth attributable to inadequate nutrient intakes in early pregnancy. A further limitation of the study was that the WHO nutrient score did not contain all 23 nutrients included in the EFSA and USA scores because nutrient recommendations on the full 23 variables included in the EFSA and USA scores were not available. A total of 19 nutrients were included in the WHO score, which could account for some variability in the results. This study had a relatively small sample of SGA babies, so future studies may consider recruitment of women who are at increased risk of delivering an SGA infant and examine if the relation between the EFSA dietary quality score and SGA persists in this cohort. A potential limitation of this study was that information on gestational weight gain was not collected.

A strength of the study is that all the participants had sonographic dating of the pregnancy, so weight-for-gestational-age was calculated accurately.[28] All dietary data were collected by a single trained researcher (RK). Advantages of an interview-led diet history include quantification of portion sizes and cooking methods by a trained individual, which may reduce unintentional dietary misreporting. However, this method can be more costly to conduct and introduce a risk of interviewer bias.[29] Participants may also be inclined to report consumption of foods they deem socially acceptable. Finally, the study population was similar to that of the wider hospital population (see Supplementary material, Table S1).

To our knowledge, this is the first study to develop individual dietary quality scores using the latest European guidelines devised by EFSA, WHO guidelines and USA guidelines, and to examine their individual relations with fetal growth. Our study highlights that dietary quality in early pregnancy influences fetal growth and so dietary education in early pregnancy should be prioritized to ensure that women are adequately meeting European dietary recommendations. Further research is needed to examine the relation between the EFSA score and fetal growth as pregnancy advances.

5 | CONCLUSION

This study found that a dietary quality score based on European dietary recommendations was better than other international recommendations at identifying in early pregnancy those women at risk of suboptimal fetal growth. Whether European recommendations are superior in other settings remains to be determined but our findings show the advantages of using EFSA recommendations in a European clinical practice and research.

CONFLICT OF INTEREST

None.

ORCID

Rachel A. K. Kennedy https://orcid.org/0000-0003-4311-115X

REFERENCES

1. Grieger JA, Clifton VL. A review of the impact of dietary intakes in human pregnancy on infant birthweight. *Nutrients*. 2014;7:153-178.
2. Perrone S, Tataranno M, Santacroce A, et al. Fetal programming, maternal nutrition, and oxidative stress hypothesis. *J Pediatr Biochem*. 2016;6:96-102.
3. Lindqvist PG, Molin J. Does antenatal identification of small-for-gestational age fetuses significantly improve their outcome? *Ultrasound Obstet Gynecol*. 2005;25:258-264.
4. Barker DJ. Early growth and cardiovascular disease. *Arch Dis Child*. 1999;80:305-307.
5. Mcgowan C, McAulliffe F. Maternal dietary patterns and associated nutrient intakes during each trimester of pregnancy. *Public Health Nutr*. 2013;16:97-107.
6. Miller PE, Lazarus P, Lesko SM, et al. Diet index-based and empirically derived dietary patterns are associated with colorectal cancer risk. *J Nutr*. 2010;140:1267-1273.
7. Sacks FM, Obarzanek E, Windhauser MM, et al. Rational and design of the Dietary Approaches to Stop Hypertension Trial (DASH): a multicenter controlled-feeding study of dietary patterns to lower blood pressure. *Ann Epidemiol*. 1994;5:108-118.
8. Coombe Women and Infants University Hospital. Annual Clinical Report.Dublin: Ireland; 2016.
9. Kennedy RAK, Reynolds CM, Cawley S, O'Malley E, McCartney DM, Turner MJ. A web-based dietary intervention in early pregnancy and neonatal outcomes: a randomized controlled trial. *J Public Health (Oxf)*. 2019;41:371-378.
10. Food and Agricultural Organisation/World Health Organization/United Nations University. Human Energy Requirements.Report of a Joint FAO/WHO/UNU Expert Consultation. Rome: Food and Agricultural Organisation; 2001.
11. Graz MB, Tolsa JF, Fumeaux CJ. Being small for gestational age: does it matter for the neurodevelopment of premature infants? A cohort study. *PLoS ONE One*. 2015;10:e0125769.
12. McCance RA, Widdowson EM. *Food Standards Agency McCance and Widdowson's The Composition of Foods*, 6th edn. Great Britain: Royal Society of Chemistry; 2002.

13. Rodríguez-Bernal CL, Rebagliato M, Iñiguez C, et al. Diet quality in early pregnancy and its effects on foetal growth outcomes: the Infancia y Medio Ambiente [Childhood and Environment] Mother and Child Cohort Study in Spain. *Am J Clin Nutr*. 2010;91:1659-1666.
14. Poon AK, Yeung E, Boghossian N, Albert PS, Zhang C. Maternal dietary patterns during third trimester in association with birthweight characteristics and early infant growth. *Scientifica (Cairo)*. 2013;2013:786409.
15. European Food Safety Authority. *Dietary Reference Values for Nutrients: Summary Report*. EFSA supporting publication; 2017.
16. World Health Organization, Food and Agriculture Organization of the United Nations. *Carbohydrates in Human Nutrition: Report of a Joint FAO/WHO Expert Consultation*. Italy: FAO; 1997.
17. World Health Organization, Food and Agricultural Organization of the United Nations. *Vitamin and Mineral Requirements in Human Nutrition*, 2nd edn. Italy: WHO; 2004.
18. World Health Organization, United Nations University. *Protein and amino acid requirements in human nutrition: Report of a joint WHO/FAO/UNU expert consultation*. Geneva, Switzerland: WHO Press; 2007. Report 935.
19. Joint FAO. *Fats and Fatty Acids in Human Nutrition: Report of an Expert Consultation*. Rome: FAO; 2008.
20. World Health Organization. *Guideline: Potassium Intake for Adults and Children*. Geneva: World Health Organization (WHO); 2012.
21. World Health Organization. *Guideline: Sodium Intake for Adults and Children*. Geneva: World Health Organization (WHO); 2012.
22. Institute of Medicine (US) Subcommittee on Interpretation and Uses of Dietary Reference Intakes; Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. DRI Dietary Reference Intakes: Applications in Dietary Assessment. Washington, DC: National Academies Press (US); 2000. SUMMARY TABLES: Dietary Reference Intakes. Available at: https://www.ncbi.nlm.nih.gov/books/NBK222881/ (Accessed January 10, 2019).
23. Dunford AR, Sangster JM. Maternal and paternal periconceptional nutrition as an indicator of offspring metabolic syndrome risk in later life through epigenetic imprinting: a systematic review. *Diabetes Metab Syndr*. 2017;11:S655-S662.
24. Emond JA, Karagas MR, Baker ER, Gilbert-Diamond D. Better diet quality during pregnancy is associated with a reduced likelihood of an infant born small for gestational age: an analysis of the prospective New Hampshire Birth Cohort Study. *J Nutr*. 2018;148:22-30.
25. Hillesund ER, Bere E, Haugen M, Overby NC. Development of a New Nordic Diet score and its association with gestational weight gain and fetal growth - a study performed in the Norwegian Mother and Child Cohort Study (MoBa). *Public Health Nutr*. 2014;17:1-11.
26. Grandy M, Snowden JM, Boone-Heinonen J, Purnell JQ, Thornburg KL, Marshall NE. Poorer maternal diet quality and increased birth weight. *J Matern Fetal Neonatal Med*. 2018;31:1613-1619.
27. Blumfield ML, Hure AJ, Macdonald-Wicks L, Smith R, Collins CE. Micronutrient intakes during pregnancy in developed countries: a systematic review and meta-analysis. *Nutr Rev*. 2013;71:118-132.
28. Lynch CD, Zhang J. The research implications of the selection of a gestational age estimation method. *Paediatr Perinat Epidemiol*. 2007;21:86-96.
29. Shim JS, Oh K, Kim HC. Dietary assessment methods in epidemiologic studies. *Epidemiology and Health*. 2014;36:e2014009.
30. World Health Organization. *Diagnostic Criteria and Classification of Hyperglycaemia First Detected in Pregnancy*. Geneva, Switzerland: World Health Organization; 2013.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Kennedy RAK, Reynolds CME, O'Malley EG, Turner MJ. Assessing maternal dietary quality in early pregnancy in the programming of intrauterine fetal growth. *Acta Obstet Gynecol Scand*. 2020;99:510–517. https://doi.org/10.1111/aogs.13768