

Narrative Review

Maternal Diet and Interactions with Nutritional Evaluation during Pregnancy

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Synopsis

Training the health team to identify maternal nutritional deficiencies with appropriate tools and guidance to better eating habits are key points for a healthy pregnancy.

Abstract

This narrative review aims to describe the knowledge regarding nutritional evaluation and monitoring in pregnant women. We discuss care provided by non-specialists in nutrition, regarding dietary information and risks during pregnancy, from a theoretical or conceptual viewpoint. A narrative review was conducted following a literature search when scientific databases were investigated, including SciELO, LILACS, Medline, PubMed, theses, government reports, books and book chapters. Finally, the material was fully read, categorized, and critically analyzed. National and international protocols of antenatal nutritional care were included and discussed. Different protocols describe the complexity of evaluating and monitoring nutrition among pregnant women during the antenatal period according to each country. The understanding of social conditions and eating habits has an important role in providing nutritional advice during pregnancy. The lack of dietitians in care overwhelms the healthcare workers and characterizes a missed opportunity. Therefore, it is important to consider rapid support tools that can track adverse nutritional status, and ways to recommend a diet that meets eating habit dynamics, according to the reality of each public health system.

1. INTRODUCTION

Antenatal care is a pathway for the prevention of adverse maternal or perinatal health conditions. In 2015 alone, 300 thousand deaths were directly related to pregnancy, and more than 2.5 million stillbirths were registered worldwide. These results were related to conditions considered potentially avoidable by antenatal health care [1]. As soon as the woman tests positive for pregnancy, the nutrition care is defined by each trimester by the protocols to determine nutritional status classification and nutrient requirement according to the characteristics of the pregnancy [2].

Initially, prepregnancy weight or maternal weight measured until the 12th week of gestation is used for nutritional status classification and weight gain recommendation during pregnancy. Particularly in the context of low- and lower and upper-middle-income countries (LMIC), a delay in seeking the first antenatal consultation frequently occurs. Therefore, clinical records on weight during early pregnancy are unavailable [3]. Pre-gestational weight, although it is self-reported, is rarely questioned. As a result, the Body Mass Index (BMI) is not calculated to determine weight gain. Furthermore, in obesity or overweight, the BMI derived from weight and height by self-report has a greater tendency to be underestimated [4]. In contrast, there is a tendency to overestimate height and underestimate weight, with significant differences between countries and age groups [5]. The gaps for procedures used to assess nutritional status are frequently left blank, and only weight is usually measured during routine antenatal care.

In dietary assessment, different techniques may be applied or even a combination of techniques (inquiries). Each method provides the necessary accuracy to meet research objectives. The most common method is the 24-hour Dietary Recall, due to its low cost and simple application [6]. For nutritional adequacy, there are some more specific recommendations, i.e., individual menus that can only be elaborated by a dietitian, or recommendations of dietary guidelines developed for application in public health. These methods may be applied by technicians or any healthcare worker [7–9]. It is commonly recommended that when a high-risk or pathological condition is diagnosed in pregnancy that may require dietary care, the pregnant woman is referred from a basic unit to specialized services with highly qualified workers [10]. Tracking and referral of pregnant women to specialized facilities supporting nutrition in all of its aspects are important factors in weight control, reduction in the development of diabetes, hypertensive disorders and low birth weight of the newborn [11,12].

2. METHODS

This review was performed from the need to carry out a general standard approach to nutritional assessment techniques aimed at professionals who are not specialists in nutrition during prenatal care. It was based on discussions with health professionals and also personal experiences of the authors who took part in the multicenter Preterm SAMBA cohort study, focusing on pregnant women's diet. The Preterm SAMBA study simultaneously collected data in 5 obstetric centres in three regions of Brazil between July 2015 and July 2018. It analyzed 1,200 nulliparous women to identify clinical, biological and sociodemographic predictors for the occurrence of preterm birth [13,14].

The information used to write this review article was collected from national and international protocols for antenatal nutritional care. Searches were carried out in

scientific databases, including SciELO, LILACS, Medline, PubMed, government reports, recommendations from scientific societies of nutrition and obstetrics and gynecology, and official booklets using specific Mesh terms and keywords for diet and nutrition during pregnancy and its variations. The selected material was fully investigated, and the different methods and their limitations were analyzed. Barriers to the process were discussed, describing the different instruments for collecting nutritional information for surveillance and monitoring of pregnancy.

3. RESULTS AND DISCUSSION

3.1. Assessment of nutritional status in pregnant women: different approaches during follow-up

Nutritional assessment in pregnant women begins by classifying nutritional status, which allows the follow-up of weight measurements during pregnancy. This phase has undergone various recommendations and adjustments over time [15]. The importance of body composition expressed by weight is clear, and it is described by diverse studies as fundamental for pregnancy follow-up to reduce or prevent pregnancy-related complications [16,17]. The classification of maternal nutritional status according to the Institute of Medicine (IOM) is based on the calculation of the BMI, measuring height and pre-pregnancy weight, and on the World Health Organization (WHO) classification of nutritional status to evaluate initial pregnancy risk and follow-up of total weight gain during pregnancy [18]. IOM recommendations may not apply to every population worldwide. To classify Asian pregnant women, for instance, there are specific recommendations, using lower cut-off points to categorize overweight and obesity [19]. Comparative studies on weight gain assessment between IOM recommendations and Chinese National Guidelines have been corroborated. The conclusion was that results were better, when using lower cut-off points for overweight and obese Asian women and contributed to the recommendation of adequate weight gain in pregnancy [20,21]. In the United Kingdom, the NICE guideline recommends for weight manager assess and monitor weight to prevent obesity and overweight, which first measures height, weight and processes the calculus of body mass index can be done at the beginning of the schedule of antenatal appointments at 5 weeks [22]

In Brazil, nutritional status is classified by a mixed system: IOM guidelines with pre-gestational weight and the curve of Atalah is also used when initial weight information is missing [23,24]. In addition to the curves proposed by the IOM, two other non-official curves have been proposed to assess weight gain in Brazilian pregnant women [25,26]. These studies suggest that, although the IOM curves are very useful to guide inadequacies, the topic is not exhausted and there is room for different recommendations according to the Brazilian population.

After inadequate weight gain is confirmed, nutritional management protocols recommend a better investigation of pathological conditions, that are associated with nutrition. Consultations are rescheduled at shorter intervals than usual [2]. However, to determine weight gain, it is necessary to have measured or self-reported the pre-gestational weight of the woman. Maternal weight measured before the end of the first trimester may also be used [27].

An alternative to evaluate nutritional status that does not depend on women's memory is the mid-upper arm circumference (MUAC). MUAC is considered a marker of

body protein reserve and is associated with nutritional status. For this reason, several middle- and low-income countries or under-resourced settings use MUAC and its guidelines as a tracking tool for the risk of nutritional inadequacy during pregnancy [28]. Various studies of pregnant women have reported that MUAC is a valid and reproducible measure in nutritional follow-up. It is highly correlated with BMI and useful for tracking inadequacies of nutritional status [29–31].

Anthropometric assessment may be measured by BMI or MUAC, with cut-off points adjusted to each population, as well as the indication of categories for nutritional status [32]. Studies in high-income countries tend to use BMI as a reference marker to assess adequate gestational weight gain, while LMIC associate both tools or use only MUAC. A recent study compared the use of both measurements, demonstrating that MUAC is a good marker for weight gain, either excess or insufficient. The authors concluded that the adoption of MUAC measurement in routine antenatal care may assist health workers in counselling and follow-up of weight gain during pregnancy, especially in middle-income countries [33].

The South African guideline determines that two MUAC measurements should be used as cut-off points for maternal gestational risk (≥ 33 cm and < 23 cm). According to MUAC cut-off points, counselling is related to surveillance of conditions associated with obesity or malnutrition, to assure a healthy dietary pattern [34]. Measurements differ according to the characteristics of each population. In countries with a high prevalence of malnutrition such as Ethiopia, the cut-off point for MUAC < 21 cm was reported as extremely underweight [35].

3.2. Socioeconomic characteristics and their influence on maternal dietary pattern

Follow-up of maternal nutritional status entails understanding dietary habits. It is also necessary to consider the influence of socioeconomic factors on food selection and meal characteristics. Regional cuisine is unique and it is expressed by various influences. Therefore, it represents a differential in health care, since medical care follows similar types of treatment techniques, irrespective of the cultural habits of the population. A specialist in nutrition needs to evaluate a significant and diversified group of foods and diets, according to the geographical region [36].

Regional cuisine has a strong influence on the consumer habits of each population. This knowledge proposes a new approach to dietary assessment. It values food combinations that compose a meal, describing a dietary pattern, instead of evaluating each nutrient alone [37]. This assessment used hypothesis testing methods that may have been developed “a priori”, based on previously developed dietary patterns that describe regional habits, such as the Mediterranean Diet or Western pattern. Or it used an “a posteriori” model that employed exploratory statistical methods in a certain region and culture. New unknown dietary patterns can emerge. The advantage of this dietary assessment is that when a combination of frequently consumed foods is composed, it is possible to understand the dietary pattern that best reflects changes in feeding behaviour, related to the health of a population [38,39].

New dietary patterns may explain inadequacies in food intake and have drawn the attention of health professionals to the prevention of adverse conditions. A Dutch study of 3,374 pregnant women sought new dietary patterns in that community (*a posteriori*) and described the results after three patterns were found: 1. Vegetables, oil and fish; 2. Nuts, cereals rich in fibres and soy; 3. Margarine, sugar and savoury snacks. In addition

to these new patterns, researchers compared a previously known pattern (*a priori*), which was based on official dietary recommendations. Results showed that the “*a posteriori*” patterns had a better relationship with excess or adequate weight gain. In contrast, the *a posteriori* pattern was not associated with gestational weight gain [40].

Other patterns were reported in a cohort from Poland, with 1,306 pregnant women evaluated in the second trimester of pregnancy. In that study, the patterns identified were classified according to food characteristics that added a higher or lower quality to the meal. The classification resulted in: the “Prudent” category, with a predominance of fruits, vegetables, whole grains, chicken and low-fat dairy products; the “Western” category, containing a larger amount of refined grains and lower amount of whole grains, in addition to processed meat and potatoes. An intermediate pattern between the first two categories resulted in the “Mixed” diet. Comparatively, the Prudent diet had a higher percentage of adherence in high-income, older, married women, with a higher level of education, and weight gain within the recommended value. In the Western diet, the highest percentage was composed of younger, single women, with fewer years of schooling, low income, BMI classification of malnutrition and weight gain above the recommended value. Finally, in the Mixed diet, only percentage differences were highlighted for the classification of pregestational obesity and insufficient total weight gain during pregnancy. The authors conclude by reinforcing the importance of sociodemographic factors associated with dietary patterns in monitoring gestational weight [41].

In addition to understanding the patterns defined by dietary habits, health professionals should read the NOVA food classification system, which distinguishes food processing levels, categorized into three food groups: unprocessed or minimally processed (UMPF), processed (PF) and ultra-processed food (UPF) [42].

This categorization expresses and differentiates the quality of a meal along with its health impact. This concept unveiled the bad quality that food groups were unable to show, highlighting foods rich in calories, sodium and sugars and poor in beneficial nutrients. The higher frequency of UPF intake has triggered a global pandemic of obesity and malnutrition known as “hidden hunger” [43].

It is fundamental to know the dietary patterns of pregnant women since these women have an increased nutrient requirement. A recent review evaluated evidence of malnutrition and low intake of iodine, vitamin D and iron in pregnant women, showing the effects of a diet poor in nutrients and rich in calories in this population, exposing women to the risk of adverse outcomes that are aggravated by high rates of obesity [44].

Nutritional status profoundly influences nutrient metabolism, and maternal health, and affects fetal nutrition even if indirectly. The maternal protein-energy reduction affects intrauterine growth. However, low food protein intake couldn't be replaced by high-density protein supplements with disappointingly small effects. [45]. In contrast, pregnant obese have significantly lower levels of vitamins B6, C, E, and folate, whereas a higher C-reactive protein and interleukin-6 levels and a higher ratio of oxidized to reduced glutathione compared with non-obese pregnant women. In a conclusion, obese nutritional status increases inflammation and oxidative stress and reduces levels of nutritional antioxidant defenses. That lower antioxidant defences combined with increased oxidative stress and inflammation may contribute to the adverse outcomes in obese women [46].

The characteristics of dietary patterns undergo complex cultural influences, due to race/ethnicity and income in the decisions to buy, prepare and consume food [47]. Differences between income level and maternal nutritional status were observed in a Brazilian study, with low income for women classified as low weight, and higher income for women classified as overweight or obese [26]. Even in high-income countries, the high price of healthy food is challenging for underprivileged individuals. Impoverished people end up making bad dietary choices from a nutritional standpoint. Therefore, the United States Department of Agriculture (USDA) created several assistance programs and the most encompassing program is the Supplemental Nutrition Assistance Program (SNAP). SNAP financially benefits more than 46 million Americans to improve nutrition in low-income families [48].

However, the habit of eating a healthy diet is complex and goes beyond vitamin and mineral intake. It entails rituals of time, flavours and memories of meals from different cultures and cuisines. The culinary roots in Brazil or “traditional Brazilian cuisine” are represented by the combination of rice and beans. “Western” culture patterns are associated with this classical combination, such as UPF, rich in fats, sodium and sugar, and poor in micronutrients. This behaviour is mainly influenced by the middle-income population, since in Brazil there is a close relationship between higher income level and UPF intake, with foods such as pizza, soft drinks, savoury snacks and sweets. In lower-income individuals of each region, there is a classical predominance of rice, fish or corn consumption [49].

In nutrition, socioeconomic inequality is not a recent issue. Each country’s region carries a dietary pattern that has received different influences according to the food price of the region. The cost of healthy diets contributes to socioeconomic inequalities in a region. This is an important factor to consider in food and public health policies [50].

In contrast, another European study compared race/ethnicity and income to nutritional characteristics in 7,511 nulliparous women. The result was a low-quality diet in black non-Hispanic women, Hispanics or those with less schooling. The authors suggest a guideline to understand these aspects, promoting a higher intake of whole grains, green leaves and vegetables and the reduction in highly processed food [51]. This study reinforced the hypothesis that differentiation of ethnicities in dietary assessment may result in the addition of new information.

The interconnection between sociodemographic and cultural factors appears to aggregate and influence food choices. A closer look at the evaluation and comprehension of maternal nutrition is necessary.

3.3. Trimesters in nutritional care: a brief summary

Insufficient micronutrient intake is prevalent and affects around 2 billion individuals across the world, including pregnant women [52]. Insufficient intake of more than one micronutrient accounts for one of the greatest public health problems in pregnant women in many countries, and factors are associated with difficulty in food access, seasonality, cultural practices, along with infections that decrease adequate nutrient absorption [53].

According to the National Research Council, in the first trimester of pregnancy intense metabolic activities occur, and the Maternal Basal Metabolic Rate (BMR) increases by 15 to 20% from the third month onwards, due to increased cardiac and renal functions [54]. Trimesters of pregnancy show different management, energy and nutrient requirements in the maternal diet. Nausea is a condition that may lead to the rejection of certain foods, and it affects up to 80% of pregnant women during this period [55]. In addition, the dietary habits of pregnant women are influenced by a change in taste. New eating habits arise and alter food choices [56]. However, small changes in calories and nutrient intake may not be perceived in the assessment through dietary surveys [57].

In the second trimester of pregnancy, environmental factors, such as gestational weight gain and the lifestyle of the pregnant woman exert a greater influence. These factors may be decisive for the development of complications in pregnancy. During this period, dietary counselling for inadequate diet patterns reduce the risk for gestational diabetes mellitus (GDM) [58]. Maternal BMI was also shown to affect the birth of heavier and larger infants, and influence the birth weight of the infant [59]. Diets that are considered healthy correlate with a lower risk of blood pressure disorders, while malnutrition raises the risk of gestational hypertension considerably. A healthy dietary pattern also reduces the birth of small-for-gestational-age infants as well as preterm births [60]. In contrast, in the third trimester, maternal diet is associated with BMI, parity and food intake pattern, increasing the weight and height of newborn infants [61]

3.3. Diet assessment: different instruments for diet assessment

To evaluate diet, data collection techniques may differ according to the aim of the investigation. The first step is to define whether the diet is intended to provide retrospective or prospective data and whether the duration of data collection is short or long. Finally, evaluate whether the study aims to associate a diet and its specific components with certain occurrences or investigation of specific nutrients. Using these tools, it is possible to find the group of nutrients contained in the diet or dietary pattern that can best characterize food intake (Box 1).

To evaluate nutrients during a short period, the 24-hour Dietary Recall (24HR) or Food Record (FR) are used (also named food diary). Both describe total food intake by weight or household measurement. In the 24-hour Dietary Recall, the interviewer records food intake in the last 24 hours. This can be done in more than one inquiry, recommending that it should include weekdays and weekends. The FR is recorded in real-time by the interviewee and includes total food intake during 3, 5 or up to 7 days. The Food Frequency Questionnaire (FFQ) is a retrospective method applied by the interviewer, consisting in knowing the usual intake of food groups, covering a long period. In addition, there is a mixture of techniques known as Diet History, which included the 24HR, the 3-day FR and a checklist of food intake in the last month [6,62].

Some considerations are food variations and typical recipes for the population. For any method chosen, it is important to take into account the selection of reference food tables of each country with regional food contained in nutrition software or FFQ, and whether it has been validated for the population of interest to obtain information on intake [63–65].

Energy consumption is associated with the risk of disease-related to weight. Therefore, errors in the assessment of calories intake may influence the result of the

study. Individuals alter their nutrient intake, thus total energy intake should be adjusted in epidemiological studies to control confounding factors and reduce external variation to predict the effects of the dietary intervention [66]. Certain models measure energy intake in epidemiological analyses. Nutrient intake and total energy are evaluated by regression analysis and total energy is added to a nutrient density model [67]. When the chosen assessment tool refers to one food, the adjustment should be taken into consideration.

Maternal diet exerts an influence that extends beyond conception and childbirth. Nutritional deficiencies may have devastating consequences for mother and child that involve intergenerational effects. An Indian study (2006- 2016) associated height with age in newborns of mothers offered dietary support from a local program. The index of infant height improved from 13 to 32% [68].

4. CONCLUSION

There is no one best tool, each nutritional assessment method meets different goals of the investigation and types of study. It is crucial to establish a chosen method of assessment of nutrition, train the health team to identify nutritional adversities and provide guidance to better eating habits and support any nutrient deficiency, using already existent tools and recommendations for specific situations.

There is an urgent need for clinical public health measures to provide proper micronutrient intake to women not only during pregnancy but as early as in adolescence. In Conclusion, nutritional antenatal care in pregnant women encompasses the understanding of a combination of social, cultural and economic conditions, that are specific to each population. The possible lack of nutritionists in outpatient facilities in LMIC may overwhelm healthcare workers. It is important to take into account rapid support tools that can track adverse nutritional status, and ways to recommend a diet that meets eating habit dynamics, according to the reality of each public health system. There is still a lack of consensus over the adequate anthropometric follow-up of women during pregnancy.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

MJM, RTS, RCP, MCV and JGC. designed the study. MJM wrote the first draft of the manuscript, reviewed initially by JGC and then by all authors who read, revised and approved the final version submitted for publication. All authors have read and agreed to the published version of the manuscript

DATA AVAILABILITYH STATEMENT

Data sharing is not applicable to this article as no new data were cre-ated or analyzed in this study

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REFERENCES

1. Tunçalp Ö, Pena-Rosas J, Lawrie T, Bucagu M, Oladapo O, Portela A, et al. WHO recommendations on antenatal care for a positive pregnancy experience-going beyond survival. *BJOG* 2017;124:860–2.
2. Institute of Medicine (US) Committee on Nutritional Status During Pregnancy and Lactation. Nutrition During Pregnancy: Part I Weight Gain: Part II Nutrient Supplements. Washington (DC): National Academies Press (US); 1990. 12, Assessment of Nutrient Needs. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK235239/>
3. Moller AB, Petzold M, Chou D, Say L. Early antenatal care visit: a systematic analysis of regional and global levels and trends of coverage from 1990 to 2013. *Lancet Glob Health* 2017; 5(10):e977–83.
4. Maukonen M, Männistö S, Tolonen H. A comparison of measured versus self-reported anthropometrics for assessing obesity in adults: a literature review. *Scand J Public Health* 2018; 46(5):565–79.
5. Krul AJ, Daanen HAM, Choi H. Self-reported and measured weight, height and body mass index (BMI) in Italy, the Netherlands and North America. *Eur J Public Health* 2011; 21:414–9.
6. Willett WC. Nutritional Epidemiology. 3rd ed. Oxford: Oxford University Press; 2012.
7. BRASIL. Conselho Federal de Nutricionistas. RESOLUÇÃO CFN Nº 600. 2018. Available from: https://www.cfn.org.br/wp-content/uploads/resolucoes/Res_304_2003.htm Access on Feb 04th 2023.
8. Conselho Federal Nutrição - CFN. Livroto de Atenção Primária à Saúde: o papel do nutricionista na atenção primária à saúde. 1st ed. Sistema CFN-CRN, editor. Brasília: Conselho Federal de Nutrição; 2008. p. 36. Available from chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.cfn.org.br/wp-content/uploads/repositorioa/posicao_do_cfn/63.pdf Access on Feb 04th 2023.
9. Ministério da Saúde do Brasil. Secretaria de Atenção à Saúde. Departamento de Atenção Básica. *Guia Alimentar para a População Brasileira*. Ministério da Saúde. Brasília; 2014. Available from chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://bvsms.saude.gov.br/bvs/publicacoes/guia_alimentar_populacao_brasileira_2ed.pdf Access on Feb 04th 2023.
10. Ministério da Saúde do Brasil. *Manual Técnico de Assistência Pré-natal*. 3rd ed. Brasília: Ministério da Saúde; 2000. p. 66. Available from chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://bvsms.saude.gov.br/bvs/publicacoes/cd04_11.pdf Access on Feb 04th 2023.
11. Rasmussen L, Poulsen CW, Kampmann U, Smedegaard SB, Ovesen PG, Fuglsang J. Diet and Healthy Lifestyle in the Management of Gestational Diabetes Mellitus. *Nutrients* 2020; 12(10):3050.
12. Girard AW, Olude O. Nutrition Education and Counselling Provided during Pregnancy: Effects on Maternal, Neonatal and Child Health Outcomes. *Paediatr*

Perinat Epidemiol 2012; 26:191–204.

13. Cecatti JG, Souza RT, Sulek K, Costa ML, Kenny LC, McCowan LM, et al. Use of metabolomics for the identification and validation of clinical biomarkers for preterm birth: Preterm SAMBA. *BMC Pregnancy Childbirth* 2016; 16:212.
14. Souza RT, Cecatti JG, Costa ML, Mayrink J, Pacagnella RC, Passini R, et al. Planning, implementing, and running a multicentre preterm birth study with biobank resources in Brazil: The preterm SAMBA study. *Biomed Res Int* 2019; 2019:5476350.
15. Rasmussen KM, Catalano PM, Yaktine AL. New guidelines for weight gain during pregnancy: what obstetrician/gynecologists should know. *Curr Opin Obstet Gynecol* 2009; 21:521–6.
16. Widen EM, Gallagher D. Body composition changes in pregnancy: Measurement, predictors and outcomes. *Eur J Clin Nutr* 2014; 68(6):643-52.
17. Pigatti Silva F, Souza RT, Cecatti JG, Passini R, Tedesco RP, Lajos GJ, et al. Role of Body Mass Index and gestational weight gain on preterm birth and adverse perinatal outcomes. *Sci Rep* 2019; 9(1):13093.
18. Rasmussen KM, Yaktine AL, Institute of Medicine (US), National Research Council (US) Committee to Reexamine IOM Pregnancy Weight Guidelines. *Weight Gain During Pregnancy: Reexamining the Guidelines*. Washington (DC): National Academies Press (US); 2009.
19. Obstetrics Subgroup, Chinese Society of Obstetrics and Gynecology, Chinese Medical Association. Guideline of preconception and prenatal care (2018). *Zhonghua Fu Chan Ke Za Zhi*; 2018;53:7–13.
20. Chen D, Zhou X, Yan S, Li W, Yang X, Lv C, et al. Optimal Gestational Weight Gain for Tibetans Based on Prepregnancy Body Mass Index. *Sci Rep* 2020;10:1–8.
21. Morisaki N, Nagata C, Jwa SC, Sago H, Saito S, Oken E, et al. Pre-pregnancy BMI-specific optimal gestational weight gain for women in Japan. *J Epidemiol* 2017; 27:492–8.
22. National Institute for Health and Care Excellence. Antenatal care: Routine care for the healthy pregnant woman. NICE Clin. Guidel. London; 2021. Available from: www.nice.org.uk/guidance/ng201
23. Atalah E, Castillo C, Castro R, Aldea A. Propuesta de un nuevo estándar de evaluación nutricional en embarazadas [Proposal of a new standard for the nutritional assessment of pregnant women]. *Rev Med Chil*. 1997; 125:1429–36.
24. Institute of Medicine and National Research Council. *Weight gain during pregnancy: reexamining the guidelines*. Washingt Natl Acad Press. 2009;1:2.
25. Morais SS, Ide M, Morgan AM, Surita FG. A novel body mass index reference range - an observational study. *Clinics (Sao Paulo)* 2017; 72(11):698–707.
26. Kac G, Carilho TRB, Rasmussen KM, Reichenheim ME, Farias DR, Hutcheon JA, et al. Gestational weight gain charts: results from the Brazilian Maternal and Child

Nutrition Consortium. *Am J Clin Nutr* 2021;113:1351–60.

27. López LB, Calvo EB, Poy MS, del Valle Balmaceda Y, Cámara K. Changes in skinfolds and mid-upper arm circumference during pregnancy in Argentine women. *Matern Child Nutr* 2011; 7:253–62.
28. Ververs MT, Antierens A, Sackl A, Staderini N, Captier V. Which Anthropometric Indicators Identify a Pregnant Woman as Acutely Malnourished and Predict Adverse Birth Outcomes in the Humanitarian Context? *PLoS Curr* 2013; 5:ecurrents.dis.54a8b618c1bc031ea140e3f2934599c8.
29. Shah P, Belsey M, Health C, Planning F, de Onis M, Pradilla A, et al. Maternal anthropometry and pregnancy outcomes. *Bull World Health Organ* 1995;73 Suppl:1-98.
30. Pan American Health Organization, World Health Organization. Ultra-processed food and drink products in Latin America: Trends, impact on obesity, policy implications. 2015. Available from: <https://iris.paho.org/handle/10665.2/7699> Access on Feb 04th 2023.
31. Das P, Khatun A, Bose K, Chakraborty R. The validity of mid-upper arm circumference as an indicator of low BMI in population screening for undernutrition: A study among adult slum dwellers in eastern India. *Public Health Nutr.* 2018; 21:2575–83.
32. Tang AM, Chung M, Dong K, Terrin N, Edmonds A, Assefa N, et al. Determining a Global Mid-Upper Arm Circumference Cutoff to Assess Malnutrition in Pregnant Women. Washington, DC; 2016. Available from chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/<https://www.fantaproject.org/sites/default/files/resources/FANTA-MUAC-cutoffs-pregnant-women-June2016.pdf> Access on Feb 04th 2023.
33. Ng CM, Badon SE, Dhivyalosini M, Hamid JJM, Rohana AJ, Teoh AN, et al. Associations of pre-pregnancy body mass index, middle-upper arm circumference, and gestational weight gain. *Sex Reprod Healthc.* 2019;20:60–5.
34. National Department of Health. Guidelines for Maternity Care in South Africa. South African Gov. Republic of South Africa; 2016. Available from <https://www.knowledgehub.org.za/elibrary/guidelines-maternity-care-south-africa-2016> Access on Feb 04th 2023.
35. Gebre B, Biadgilign S, Taddese Z, Legesse T, Letebo M. Determinants of malnutrition among pregnant and lactating women under humanitarian setting in Ethiopia. *BMC Nutr* 2018;4:1–8.
36. Fox M. Global Food Practices, Cultural Competency, and Dietetics. *J Acad Nutr Diet* 2015; 115:S16–20.
37. Jacobs DR, Steffen LM. Nutrients, foods, and dietary patterns as exposures in research: a framework for food synergy. *Am J Clin Nutr* 2003;78:508–21.
38. Hoffmann K, Schulze MB, Schienkiewitz A, Nöthlings U, Boeing H. Application of a New Statistical Method to Derive Dietary Patterns in Nutritional Epidemiology. *Am*

J Epidemiol 2004; 159:935–44.

39. Messina M, Lampe JW, Birt DF, Appel LJ, Pivonka E, Berry B, et al. Reductionism and the narrowing nutrition perspective: Time for reevaluation and emphasis on food synergy. *J Am Diet Assoc* 2001; 101:1416–9.
40. Leermakers ETM, van den Hooven EH, Franco OH, Jaddoe VWV, Moll HA, Kiefte-de Jong JC, et al. A priori and a posteriori derived dietary patterns in infancy and cardiometabolic health in childhood: The role of body composition. *Clin Nutr* 2018; 37:1589–95.
41. Wesołowska E, Jankowska A, Trafalska E, Kałużny P, Grzesiak M, Dominowska J, et al. Sociodemographic, lifestyle, environmental and pregnancy-related determinants of dietary patterns during pregnancy. *Int J Environ Res Public Health* 2019; 16(5):754.
42. Monteiro CA, Cannon G, Levy R, Moubarac J-C, Jaime P, Martins AP, et al. NOVA. The star shines bright. *World Nutr* 2016; 7:28–38.
43. Monteiro CA, Moubarac JC, Levy RB, Canella DS, Da Costa Louzada ML, Cannon G. Household availability of ultra-processed foods and obesity in nineteen European countries. *Public Health Nutr* 2018; 21:18–26.
44. Kiely ME, McCarthy EK, Hennessy A. Iron, iodine and vitamin D deficiencies during pregnancy: epidemiology, risk factors and developmental impacts. *Proc Nutr Soc* 2021; 80(3):290–302.
45. Fall CHD, Yajnik CS, Rao S, Davies A a, Brown N, Farrant HJW. Micronutrients and Fetal Growth. *J Nutr* 2003; 133:1747S.1756S.
46. Sen S, Iyer C, Meydani SN. Obesity during pregnancy alters maternal oxidant balance and micronutrient status. *J Perinatol* 2014; 34:105–11.
47. Zhang Q, Wang Y. Socioeconomic and Racial/Ethnic Disparity in Americans' Adherence to Federal Dietary Recommendations. *J Acad Nutr Diet* 2012; 112:614–6.
48. Committee on Examination of the Adequacy of Food Resources and SNAP Allotments; Food and Nutrition Board; Committee on National Statistics; Institute of Medicine; National Research Council; Caswell JA, Yaktine AL, editors. Supplemental Nutrition Assistance Program: Examining the Evidence to Define Benefit Adequacy. National Academies Press; 2013;1–222.
49. Brasil, Ministerio da Saude. Política Nacional de Alimentação e Nutrição. Brasília: Ministério da Saúde. Secr. Atenção à Saúde. Dep. Atenção Básica, 2013. Available from chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://bvsms.saude.gov.br/bvs/publicacoes/politica_nacional_alimentacao_nutricao.pdf Access on Feb 04th 2023.
50. Monsivais P, Aggarwal A, Drewnowski A. Are socio-economic disparities in diet quality explained by diet cost? *J Epidemiol Community Health* 2012; 66:530–5.
51. Bodnar LM, Simhan HN, Parker CB, Meier H, Mercer BM, Grobman WA, et al. Racial

- or Ethnic and Socioeconomic Inequalities in Adherence to National Dietary Guidance in a Large Cohort of US Pregnant Women. *J Acad Nutr Diet* 2017; 117:867-877.e3.
52. Haddad L, Achadi E, Bendeck MA, Ahuja A, Bhatia K, Bhutta Z, et al. The Global Nutrition Report 2014: Actions and Accountability to Accelerate the World's Progress on Nutrition. *J Nutr* 2015; 145:663–71.
 53. Christian P. Micronutrients, birth weight, and survival. *Annu Rev Nutr* 2010; 30:83–104.
 54. National Research Council. Recommended Dietary Allowances. 10th ed. Washington, D.C.: National Academies Press; 1989. Available from: <http://www.nap.edu/catalog/1349>
 55. Lee NM, Saha S. Nausea and Vomiting of Pregnancy. *Gastroenterol Clin* 2011; 40:309–34.
 56. Weenen H, Olsen A, Nanou E, Moreau E, Nambiar S, Vereijken C, et al. Changes in Taste Threshold, Perceived Intensity, Liking, and Preference in Pregnant Women: a Literature Review. *Chemosens Percept* 2018;12:1–17.
 57. Godfrey KM, Barker DJ. Fetal programming and adult health. *Public Health Nutr* 2001;4:611–24.
 58. Silva-Zolezzi I, Samuel TM, Spieldenner J. Maternal nutrition: opportunities in the prevention of gestational diabetes. *Nutr Rev* 2017; 75:32–50.
 59. Bang SW, Lee SS. The factors affecting pregnancy outcomes in the second trimester pregnant women. *Nutr Res Pract* 2009; 3:134-40.
 60. Abdollahi S, Soltani S, de Souza RJ, Forbes SC, Toupchian O, Salehi-Abargouei A. Associations between Maternal Dietary Patterns and Perinatal Outcomes: A Systematic Review and Meta-Analysis of Cohort Studies. *Adv Nutr* 2021; 12:1332–52.
 61. 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(12):1613-1619.
 62. Fisberg RM, Slater B, Marchioni DM, Martini LA. Inquéritos Alimentares: métodos e bases científicos. 1st ed. Barueri-SP: Manole; 2005.
 63. Thompson FE, Subar AF. Dietary Assessment Methodology. *Nutr Prev Treat Dis* 2017; 5–48.
 64. Deharveng G, Charrondière U, Slimani N, Southgate D, Riboli E. Comparison of nutrients in the food composition tables available in the nine European countries participating in EPIC. *Eur J Clin Nutr* 1999; 53:60–79.
 65. FAO. Dietary Assessment: A resource guide to method selection and application in low resource settings. FAO. Rome, Italy: FAO; 2018.
 66. Willett WC, Howe GR, Kushi LH. Adjustment for total energy intake in

epidemiologic studies. *Am J Clin Nutr* 1997; 65:1220S-1228S.

67. Shim J-S, Oh K, Kim HC. Dietary assessment methods in epidemiologic studies. *Epidemiol Health* 2014; 36:e2014009.

68. Chakrabarti S, Scott SP, Alderman H, Menon P, Gilligan DO. Intergenerational nutrition benefits of India's national school feeding program. *Nat Commun* 2021;12:4248.

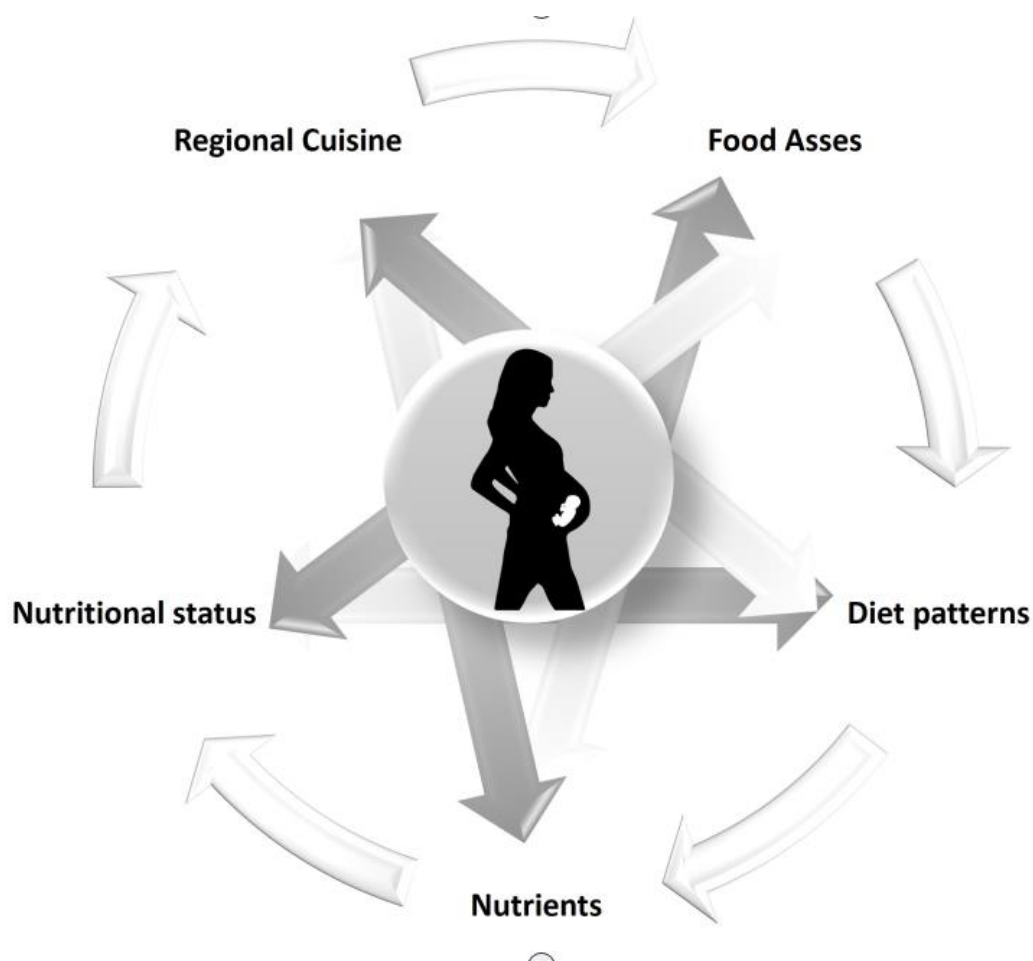


FIGURE 1 Interrelationships between food and nutritional effects during pregnancy (Preterm SAMBA study, Brazil, 2018). Regional cuisine is influenced by food access, which is related to the purchasing power, family income, and offer of food. All these conditions can be related to and affected by diet patterns directly impacting nutrient intakes. Nutrients in food are defined by macronutrients, micronutrients, and calories that will define their nutritional status during pregnancy. This framework reflects the power of the interaction between diet, income, food, habits, nutrients, and outcome.

Box 1: Points to consider at the time of selecting the nutritional assessment method.
(Modified from the Preterm SAMBA study, Brazil, 2018)

Method	Advantages	Disadvantages
24HR	<ul style="list-style-type: none"> Rapid application Does not influence individual intake Applied more frequently, it estimates the usual diet Informs details about the nutrient Low cost No need to be literate Encompasses different age groups and physiological status It may be applied to any population Does not require validation 	<ul style="list-style-type: none"> Information collected depends on specific software analysis. Need to interpret house measurement by food tables and requires time Depends on the interviewee's memory Needs a positive rapport between interviewee and interviewer Individually does not estimate the usual diet Variation in estimated portion size Trained interviewer required Possible interviewer bias To assess usual intake needs to be applied more than one time and on different days
FR	<ul style="list-style-type: none"> Does not depend on the interviewee's memory Measures intake in real-time Good accuracy, when the food is weighed Its self-reported, not require the interviewer 	<ul style="list-style-type: none"> Requires weighing food or training interviewees to quantify intake May influence the interviewee's diet Depends on the cooperation and trust between the interviewer/interviewee Demands time Hinders the evaluation of the illiterate Are necessary for multiple days to analyze the usual intake
FFQ	<ul style="list-style-type: none"> A good tool for epidemiological studies Estimates usual food intake for a relatively long period Simple to apply Does not interfere with the interviewee's food intake Low cost Characterizes the interviewee according to the result Reduces interpersonal and daily variation 	<ul style="list-style-type: none"> Depends on the interviewee's memory Requires validation for specific populations Illiterates may find the application difficult Requires interviewer training Not able to accurately quantify specific nutrients and interactions Requires proper evaluation of questionnaires
DH	<ul style="list-style-type: none"> The main application is for clinical practice Reduces daily variations Seasonal evaluation is made Assesses usual consumption qualitatively and quantitatively 	<ul style="list-style-type: none"> Requires dietitian for application Depends on the interviewee's memory Long application time Demands multiple days of the usual intake Requires to be literate It is necessary for a good relationship between the interviewer/interviewee Must convert house measurement by food tables It is a costly method and often it is not applicable in large-scale population studies

24-hour Dietary Recall– 24HR, Food Record – FR, Food Frequency Questionnaire –FFQ, Diet History- FH.
Sources: Inquéritos Alimentares: métodos e bases científicos, Brazil, 2005; Dietary assessment methods in epidemiologic studies, Korea, 2014; Consumo alimentar: guia para avaliação, Brazil, 2019; Dietary assessment: A resource guide to method selection and application in low resource settings, Rome, 2018.