

# Exploring the relationships between pre-pregnancy BMI, gestational weight gain, and nutritional intake: a real-world investigation in Shandong, China

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This study investigated the associations between gestational weight gain (GWG), pre-pregnancy body mass index (BMI), and prenatal diet quality in pregnant women from Shandong, China. We analyzed a sample of 532 early-stage pregnant women registered at an outpatient clinic. Diet quality was evaluated using the Chinese Healthy Dietary Index for Pregnancy (CHDI-P), encompassing three dimensions: diversity, adequacy, and limitation, with an overall score out of 100. Dietary intake was documented via 24-hour dietary recalls spanning three consecutive days and subsequently translated to a CHDI-P score. At the time of enrollment, BMI was measured on-site and classified as underweight ( $<18.5$ ), normal weight ( $18.5\text{--}24.9$ ), overweight ( $25.0\text{--}29.9$ ), and obese ( $\geq 30.0$ ). Pregnant women were also categorized into inadequate, adequate, and excessive weight gain groups based on their GWG. We employed a Tukey-adjusted generalized linear model to compare the CHDI-P scores between the pre-pregnancy BMI groups and GWG groups. The results revealed that the underweight group had significantly higher total scores and limitation total scores on the CHDI-P ( $P < 0.001$ ). Conversely, the overweight and obese groups were more susceptible to suboptimal dietary quality. Notably, the inadequate weight gain group displayed significantly elevated food adequacy scores compared to the other two groups ( $p < 0.05$ ). This indicates that greater GWGs do not necessarily align with principles of adequate nutrition.

# Exploring the Relationships Between Pre-Pregnancy BMI, Gestational Weight Gain, and Nutritional Intake: A Real-World Investigation in Shandong, China

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## Abstract:

This study investigated the associations between gestational weight gain (GWG), pre-pregnancy body mass index (BMI), and prenatal diet quality in pregnant women from Shandong, China. We analyzed a sample of 532 early-stage pregnant women registered at an outpatient clinic. Diet quality was evaluated using the Chinese Healthy Dietary Index for Pregnancy (CHDI-P), encompassing three dimensions: diversity, adequacy, and limitation, with an overall score out of 100. Dietary intake was documented via 24-hour dietary recalls spanning three consecutive days and subsequently translated to a CHDI-P score. At the time of enrollment, BMI was measured on-site and classified as underweight ( $<18.5$ ), normal weight ( $18.5\text{--}24.9$ ), overweight ( $25.0\text{--}29.9$ ), and obese ( $\geq 30.0$ ). Pregnant women were also categorized into inadequate, adequate, and excessive weight gain groups based on their GWG. We employed a Tukey-adjusted generalized linear model to compare the CHDI-P scores between the pre-pregnancy BMI groups and GWG groups. The results revealed that the underweight group had significantly higher total scores and limitation total scores on the CHDI-P ( $P<0.001$ ). Conversely, the overweight and obese groups were more susceptible to suboptimal dietary quality. Notably, the inadequate weight gain group displayed significantly elevated food adequacy scores compared to the other two groups ( $p<0.05$ ). This indicates that greater GWGs do not necessarily align with principles of adequate nutrition.

Key words: pregnant woman; pre-pregnancy BMI; gestational weight gain; nutritional assessment

# 1.Introduction

The profound association between maternal and newborn health has been acknowledged for an extended period, and endeavors to enhance health outcomes persist (Moller et al., 2019). The nutritional status of expectant mothers throughout gestation has consistently been a subject of interest, exerting significant influence on maternal health and pregnancy outcomes (de Freitas et al., 2022; Henriksen, 2006; Teede et al., 2022). Excessive nutrition or gestational overweight during gestation elevates the risk of fetal anomalies and augments the probability of diabetes in both mother and neonate(Henriksen, 2006). Frequent consumption of meat, sugared beverages, and sugary snacks heightens the risk of pre-eclampsia (Brantsæter et al., 2009), while a diet rich in fats and sugars correlates with an increased likelihood of preterm labor (Grieger et al., 2014). In economically underdeveloped regions, a prevalent issue is maternal underweight, primarily attributed to the insufficient caloric intake of expectant mothers. This deficiency heightens the risk of stillbirths, neonatal fatalities, and low birth weight (LBW) in neonates (Archana Patel et al., 2018).

Prior research has examined the prenatal dietary quality of expectant mothers. In the United States, the Healthy Eating Index-2010 score for these women stands at a mere 50.7 out of 100 (Shin et al., 2016). Notably, a majority of them fall short in consuming adequate fiber, grains, fruits, and vegetables, yet their sodium and fat consumption surpassed recommended levels (Laraia et al., 2007; Rifas-Shiman et al., 2009). This dietary imbalance correlates with the 22% obesity rate observed among pregnant women (Kim et al., 2007). A study examining a cohort of expectant mothers in Canada revealed analogous findings. Furthermore, it identified that women with lower educational backgrounds residing in urban areas exhibited an elevated risk of suboptimal dietary quality (Savard et al., 2019). In China, the predominant dietary concerns among expectant mothers across various regions include imbalances and insufficient intake of numerous micronutrients (Dong & Yin, 2018). Additionally, the prevalence of overweight and obesity has surpassed 20% of this demographic (Teede et al., 2022), presenting a significant challenge. Consequently, examining the prenatal nutritional and dietary patterns of expectant mothers and devising a well-balanced dietary plan promptly is crucial. Regrettably, the majority of research data in this domain originates from developed Western nations, with limited studies focusing on the Chinese population and primarily restricted to major cities such as Beijing (Sun et al., 2020). China's regional developmental disparities warrant attention. Empirical research from mid-sized cities and rural regions can offer a holistic insight into the dietary challenges confronting expectant mothers in the country.

A widely acknowledged measure of an expectant mother's nutritional status is the pre-pregnancy body mass index (BMI) (Laraia et al., 2007; Uno et al., 2016). Empirical research has established that both elevated and reduced BMI values influence pregnancy outcomes (Aji et al., 2022; Tang et al., 2021; Vats et al., 2021). Nonetheless, this metric has limitations, particularly its presumption of consistent dietary habits throughout gestation—a premise that is challenging to uphold (Forbes et al., 2018). Consequently, some scholars suggest that gestational weight gain (GWG) can more

dynamically reflect shifts in dietary quality, either as an alternative or in tandem with prenatal BMI, to assess the nutritional health of pregnant individuals (Cano-Ibáñez et al., 2020; Guelinckx et al., 2008). The objective of this research was to investigate the associations between both pre-pregnancy BMI and GWG with prenatal dietary quality within a mid-sized urban cohort. This exploration sought to identify a subgroup particularly susceptible to compromised dietary quality. We posited that expectant mothers with both pre-pregnancy BMI and GWG within standard parameters would exhibit superior prenatal dietary quality.

## 2. Methods

### 2.1 Participants

The participants in this study were expectant mothers who visited the obstetrics outpatient clinic at Jinan Maternal and Child Health Hospital in Shandong Province between January 2021 and December 2022. Participants had to meet the following criteria: (1) Chinese citizenship; (2) pregnancy  $\leq 12$  gestational weeks; (3) have a maternity record established at the institution and have undergone routine obstetric check-ups; (4) face-to-face completion of the survey; (5) plan to give birth at the hospital; and (6) provide signed informed consent. Exclusion criteria included: (1) non-local migrant populations unable to attend routine check-ups; (2) individuals with metabolic disorders or chronic conditions such as tumors or tuberculosis. The study protocol received approval from the Jinan Maternal and Child Ethics Committee Health Hospital (No.2023-1-029). All participating individuals furnished their signed, written informed consent.

### 2.2 Data collection

To guarantee the authenticity and validity of the data, the outpatient physician directly collects and confirms information from each expectant mother, rather than relying on patient self-reporting. A face-to-face interview was employed to gather demographic information from participants, encompassing age, educational attainment, occupation, parity, and household income. The height and weight of the expectant mothers were recorded during their initial antenatal visit, from which the pre-pregnancy BMI was derived. They can be categorized into four groups based on their pre-pregnancy BMI: underweight ( $< 18.5$ ), normal weight ( $18.5\text{--}24.9$ ), overweight ( $25.0\text{--}29.9$ ), and obese ( $\geq 30.0$ ) (WHO expert consultation, 2004). GWG was determined by calculating the difference between the initial pre-pregnancy weight and the final weight before childbirth. Following the Guidelines for Weight Monitoring and Evaluation in Pregnancy for Chinese Women (Rasmussen, K. M. et al., 2009), expectant mothers were classified into three categories—namely, inadequate weight gain, adequate weight gain, and excessive weight gain—according to their pre-

pregnancy BMI ranges.

## 2.3 Nutritional assessment

We assessed the dietary quality of expectant mothers using the Chinese Healthy Dietary Index for Pregnancy (CHDI-P) (M. Yang et al., 2023). The CHDI-P scale, rooted in the 2016 edition of the Dietary Guidelines for Pregnant Women in China (Y. X. Yang et al., 2018), provides a comprehensive three-dimensional evaluation of dietary quality. The first dimension, termed “diversity”, evaluates the consumption levels of four fundamental food groups, adhering to the core principle of dietary variety. These food groups include: grains, tubers and mixed beans; meat, poultry, fish, and eggs; vegetables and fruits; and dairy, soybeans, and nuts. The second dimension, termed “adequacy”, evaluates the sufficiency of beneficial food consumption among expectant mothers. Conversely, the third dimension, termed “limitation”, assesses excessive consumption of proven unhealthy foods. In this study, the version employed was tailored for women in early pregnancy, featuring score ranges of 0–12 for the diversity dimension, 0–55 for the adequacy dimension, and 0–33 for the limitation dimension, culminating in an aggregate score range of 0–100. Higher scores in the diversity and adequacy dimensions correspond to increased variety and quantity of beneficial foods consumed. Conversely, a higher score in the limitation dimension signifies reduced consumption of unhealthy foods. Therefore, lower scores are indicative of suboptimal eating habits and health.

Dietary intake data were gathered using a 24-hour dietary recall survey administered over three consecutive days. For the initial survey, both the type and quantity of food consumed were obtained through face-to-face interviews conducted by professionally trained clinicians. To enhance data accuracy, participants were aided in describing their food intake through the utilization of standardized containers (e.g., bowl, spoon, cup) and food imagery supplied by the hospital. To prioritize the safety of the expectant mothers, the subsequent surveys were conducted telephonically. To further refine data accuracy, participants were requested to furnish photographs of all consumed foods for investigator validation.

## 2.4 Statistical analysis

Descriptive statistics for count data are expressed as numbers and percentages, while continuous variables are represented by means and standard deviations. Between-group comparisons for count data were conducted using the Pearson's  $\chi^2$  test. For continuous variables, between-group differences were assessed using analysis of variance (ANOVA) or the Kruskal-Wallis test, contingent upon data normality. Generalized linear models were employed to adjust for confounding variables when comparing CHDI-P scores across groups. Covariates were selected based on prior research and included age, income, educational level, smoking status, energy intake, number of pregnancies and deliveries (Parker et al., 2019; Shin et al., 2016). Post hoc tests, using the Tukey-adjusted method, elucidated between-group disparities. All confidence intervals were

computed at the 95% level, and a p-value less than 0.05 was deemed statistically significant. Statistical analyses were executed using Python 3.6.0.

### 3.Results

#### 3.1 Baseline characteristics

A total of 532 expectant mothers were incorporated into the study and were segmented into four categories based on their pre-pregnancy BMI: underweight ( $<18.5$ ), normal weight ( $18.5\text{--}24.9$ ), overweight ( $25.0\text{--}29.9$ ), and obese ( $\geq 30.0$ ). The underweight cohort had an average age of 29.29 years (SD 4.53), notably younger than the other categories, with their GWG values notably surpassing those of the other groups. Significant differences were observed among the groups regarding body weight and GWG ( $p<0.001$ ). No statistically significant disparities were observed among the groups concerning education, family income, smoking habits, number of pregnancies or deliveries (Table 1).

Then, we categorized the data based on GWG into three groups: Inadequate, Adequate, and Excessive. Notably, those with adequate weight gain during pregnancy exhibited lower weights and pre-pregnancy BMI ( $p<0.001$ ). The remaining demographic characteristics showed no significant differences (Table 2).

#### 3.2 Associations between CHDI-P and pre-pregnancy BMI

In the multivariate adjustment model, we ultimately selected education level, household income, and number of deliveries as covariates. According to this model, the underweight group displayed the highest marginal mean of  $60.28\pm 0.99$  in CHDI-P total scores, while the obese group exhibited the lowest marginal mean of  $57.80\pm 1.11$  (Table 3). Post hoc analyses revealed significant differences in CHDI-P total scores among all groups ( $p<0.001$ ). Specifically, diversity total scores for both the overweight and obese groups were significantly lower than those for the normal weight group ( $p<0.001$ ). However, there were no significant differences in the adequacy total scores among the groups. Significant differences were observed in the limitation total scores among all groups ( $p<0.001$ ) (Table 5).

#### 3.3 Associations between CHDI-P and GWG

In the GWG model, covariates encompassed household income and the number of deliveries. The adequate and excessive group exhibited a marginal mean of 59.17 for CHDI-P total scores. Meanwhile, the marginal mean for the inadequate group stood at  $59.54\pm 0.92$ , marginally surpassing the values of the other two groups (Table 4). Post hoc analysis of inter-group differences

revealed no significant differences in CHDI-P total scores and diversity total scores among the groups. However, the adequacy total score for the inadequate group was significantly higher than that of both the adequate group ( $p=0.023$ ) and the excessive group ( $p=0.006$ ). Significant differences were observed across all groups in the limitation total scores ( $p<0.01$ ) (Table 6).

## 4. Discussion

This study explored the quality of prenatal diets among a convenience sample of pregnant women in Shandong, China. Additionally, we explored the associations between pre-pregnancy BMI, GWG, and maternal dietary quality. While the Alternative Healthy Eating Index for Pregnancy (AHEI-P) has been employed in previous research to quantitatively evaluate the dietary quality of pregnant women (Hsiao et al., 2019; Parker et al., 2019; Quansah et al., 2022). Our study sample was drawn from Shandong, China. Consequently, we utilized the CHDI-P scale, which is better tailored for Chinese pregnant women. Parker et al. determined that using the AHEI-P scale (Parker et al., 2019), the overall prenatal dietary quality of pregnant women was suboptimal, achieving a mean score of just 61.2 out of 130. Similarly, in our study, the average score for pregnant women aligned with this finding. Even after equiproportional conversion, the score indicates that the prenatal dietary quality of Chinese pregnant women remains less than ideal. Grouping by GWG did not manifest any significant differences in marginal means among the groups. Conversely, when categorized based on pre-pregnancy BMI, the underweight group had a score that exceeded the obese group by 2.5 points. While a shift of 5% in dietary quality score is necessary to deem it clinically significant (Miller et al., 2015), it is plausible to posit an association between pre-pregnancy BMI and dietary quality. Specifically, pregnant women with a BMI of  $\geq 25$  may be at an elevated risk for malnutrition.

In this study, the CHDI-P scale was employed to evaluate the nutritional quality of pregnant women's diets. This scale focuses on three primary dimensions: diversity, adequacy, and limitation. A diverse food intake, ensuring a broad spectrum of nutrients for both the expectant mother and the developing fetus, is fundamental to a healthy diet. Previous research has indicated that food diversity can mitigate the negative impacts of anemia and neonatal mortality linked to insufficient intake (Lander et al., 2019). Pregnant women exhibiting insufficient weight gain often have less varied diets, making their nutritional habits prime targets for intervention (Tebhani et al., 2021). In our study, however, there were no significant differences between groups, whether categorized by pre-pregnancy BMI or by GWG. Although the p-value for the comparison among the obese, overweight, and normal weight groups is below 0.05, the proximity of the confidence intervals for their differences to zero renders this distinction potentially insignificant. The average scores hovered around 10 out of a possible 12. One potential explanation for this might be that this portion of the scale lacks the granularity necessary to highlight nuanced differences. Alternatively, it could suggest that pregnant women in Shandong, China, generally maintain a commendable level of dietary diversity prior to pregnancy.

The adequacy of a pregnant woman's diet stands as a pivotal aspect in evaluating dietary quality.

The research conducted by Cano-Ibáñez et al. revealed that diets patterned after the Mediterranean typically exhibited greater nutrient adequacy and were associated with controlled GWG in pregnant women (Cano-Ibáñez et al., 2020). Another study indicated that diets with adequate nutrients significantly curtailed metabolic complications, such as gestational diabetes (Looman et al., 2019). In our research, when grouping by pre-pregnancy BMI, we observed no significant disparities in adequacy scores among the groups. However, the inadequate group registered a significantly higher score compared to the other two groups. These findings align with prior research, indicating that predicting dietary adequacy in pregnant women may be more effectively gauged using GWG. In underprivileged regions, the inadequacy among pregnant women is frequently linked to insufficient intake, primarily due to limited food accessibility resulting from economic constraints (Darling et al., 2023). Yantai, conversely, is one of the more affluent areas in China. Given the income level of the participants in our study, we postulate that the diet of the inadequate group was likely self-regulated. These women might have enhanced the quality of their food intake while potentially emphasizing physical activity to manage their weight (Teede et al., 2022).

Excessive consumption of unhealthy foods adversely affects the dietary well-being of pregnant women, making restriction a crucial aspect that warrants attention. In the CHDI-P, restricted foods encompass fried foods, sugary beverages, processed meats, alcohol, refined grains, and cooking oil. In this research, the underweight group achieved the highest scores in the limitation total, whereas the obese group recorded the lowest. A significant difference was observed across all groups. This pattern aligns with the overall trend observed in the CHDI-P total scores. While significant differences in scores were also evident when grouped by GWG, the extent of these differences was less marked compared to the pre-pregnancy BMI categorization. Previous studies provide substantial evidence on the detrimental effects of high-sugar, high-fat foods, and alcohol on pregnant women (Pennington et al., 2020; Sundermann et al., 2019; Witek et al., 2022). Our findings indicate that pregnant women with higher BMIs tend to consume more unhealthy foods. While there isn't a definitive cut-off value for CHDI-P, pregnant women in the overweight and obese categories should be made aware of the potential complications from consuming unhealthy foods compared to those with a normal BMI. Minimizing the consumption of harmful foods could be an effective strategy to reduce complications in obese pregnant women.

Our study examined the association between pre-pregnancy BMI, GWG, and dietary quality. However, a more holistic approach might involve integrating prenatal dietary quality instead of concentrating solely on either BMI or GWG. Both pre-pregnancy BMI and GWG proved valuable in distinguishing and predicting prenatal diet quality. Notably, pre-pregnancy BMI was more sensitive to overall diet quality and restriction of certain foods, whereas GWG was more indicative of dietary adequacy. It's important to highlight that the dietary quality we assessed pertains to the early stage of a woman's pregnancy, while the GWG was determined by the difference between the initial and pre-delivery weights. The dietary habits of pregnant women typically vary throughout the pregnancy. For initial dietary quality assessment, GWG may not be as effective an indicator as BMI, especially in the middle or later stages of pregnancy. This observation warrants further investigation in subsequent research.



The distinctiveness of this study lies in its exploration of the relationship between pre-pregnancy BMI, GWG, and prenatal dietary quality within a Chinese demographic. Comparing both BMI and GWG concurrently enhances our comprehension of this association. This study has some limitations. Firstly, the sample size was limited, primarily because participants were required to deliver at our hospital. This criterion might have introduced some bias. Nonetheless, this was necessary to ensure uniformity across this series of studies. Another notable observation was that pregnant women accompanied by their partners were more inclined to participate and less likely to drop out.

## 5. Conclusion

Our study underscores the significance of preconception BMI and GWG as critical factors in predicting prenatal diet quality. While there is a need for further research to validate the relationship between preconception BMI, GWG, and prenatal diet quality, our findings pinpoint pre-pregnancy overweight and obese women as a vulnerable group at heightened risk for suboptimal prenatal diet quality. Future interventions tailored for this group could achieve the most impact by curbing the consumption of unhealthy foods. The data from our study bolster the recommendation for women to attain a normal BMI prior to conception, given its correlation with superior dietary quality.

## Declarations

## Funding

The authors received no funding for this work.

## Author Contributions

Xingru Cao and Junmin Li spearheaded the conceptualization and design of the experiments, orchestrated the experimental procedures, and undertook a meticulous review and revision of the final manuscript. Ping Zhu and Xiaoge Huang took charge of liaising with participants, data collection, data refinement, and executing the statistical analysis. Juan Zhang and Xue Wang were entrusted with manuscript composition and data analysis.

# Reference

- Aji, A. S., Lipoeto, N. I., Yusrawati, Y., Malik, S. G., Kusmayanti, N. A., Susanto, I., Majidah, N. M., Nurunnayah, S., Alfiana, R. D., Wahyuningsih, W., & Vimalaswaran, K. S. (2022). Association between pre-pregnancy body mass index and gestational weight gain on pregnancy outcomes: A cohort study in Indonesian pregnant women. *BMC Pregnancy and Childbirth*, 22(1), 492. <https://doi.org/10.1186/s12884-022-04815-8>
- Archana Patel, Amber Abhijeet Prakash, Prabir Kumar Das, Swarnim Gupta, Yamini Vinod Pusdekar, & Patricia L Hibberd. (2018). Maternal anemia and underweight as determinants of pregnancy outcomes: Cohort study in eastern rural Maharashtra, India. *BMJ Open*, 8(8), e021623. <https://doi.org/10.1136/bmjopen-2018-021623>
- Brantsæter, A. L., Haugen, M., Samuelsen, S. O., Torjusen, H., Trogstad, L., Alexander, J., Magnus, P., & Meltzer, H. M. (2009). A Dietary Pattern Characterized by High Intake of Vegetables, Fruits, and Vegetable Oils Is Associated with Reduced Risk of Preeclampsia in Nulliparous Pregnant Norwegian Women, . *The Journal of Nutrition*, 139(6), 1162–1168. <https://doi.org/10.3945/jn.109.104968>
- Cano-Ibáñez, N., Martínez-Galiano, J. M., Luque-Fernández, M. A., Martín-Peláez, S., Bueno-Cavanillas, A., & Delgado-Rodríguez, M. (2020). Maternal Dietary Patterns during Pregnancy and Their Association with Gestational Weight Gain and Nutrient Adequacy. *International Journal of Environmental Research and Public Health*, 17(21). <https://doi.org/10.3390/ijerph17217908>
- Darling, A. M., Wang, D., Perumal, N., Liu, E., Wang, M., Ahmed, T., Christian, P., Dewey, K. G., Kac, G., Kennedy, S. H., Subramoney, V., Briggs, B., Fawzi, W. W., & members of the GWG Pooling Project Consortium. (2023). Risk factors for inadequate and excessive gestational weight gain in 25 low- and middle-income countries: An individual-level participant meta-analysis. *PLOS Medicine*, 20(7), e1004236. <https://doi.org/10.1371/journal.pmed.1004236>
- de Freitas, N. P. A., Carvalho, T. R., Gonçalves, C. C. R. A., da Silva, P. H. A., de Melo Romão, L. G., Kwak-Kim, J., & Cavalcante, M. B. (2022). The Dietary Inflammatory Index as a predictor of pregnancy outcomes: Systematic review and meta-analysis. *Journal of Reproductive Immunology*, 152, 103651. <https://doi.org/10.1016/j.jri.2022.103651>
- Dong, C., & Yin, S. (2018). The ten-year retrospect of nutrition and health status of pregnant women in China. *Zhonghua Yu Fang Yi Xue Za Zhi*, 52(1), 94–100. PubMed. <https://doi.org/10.3760/cma.j.issn.0253-9624.2018.01.019>
- Forbes, L. E., Graham, J. E., Berglund, C., & Bell, R. C. (2018). Dietary Change during Pregnancy and Women’s Reasons for Change. *Nutrients*, 10(8). <https://doi.org/10.3390/nu10081032>
- Grieger, J. A., Grzeskowiak, L. E., & Clifton, V. L. (2014). Preconception Dietary Patterns in Human Pregnancies Are Associated with Preterm Delivery. *The Journal of Nutrition*, 144(7), 1075–1080. <https://doi.org/10.3945/jn.114.190686>
- Guelinckx, I., Devlieger, R., Beckers, K., & Vansant, G. (2008). Maternal obesity: Pregnancy

- complications, gestational weight gain and nutrition. *Obesity Reviews*, 9(2), 140–150.  
<https://doi.org/10.1111/j.1467-789X.2007.00464.x>
- Henriksen, T. (2006). Nutrition and Pregnancy Outcome. *Nutrition Reviews*, 64(suppl\_2), S19–S23. <https://doi.org/10.1111/j.1753-4887.2006.tb00241.x>
- Hsiao, P. Y., Fung, J. L., Mitchell, D. C., Hartman, T. J., & Goldman, M. B. (2019). Dietary quality, as measured by the Alternative Healthy Eating Index for Pregnancy (AHEI-P), in couples planning their first pregnancy. *Public Health Nutrition*, 22(18), 3385–3394. Cambridge Core. <https://doi.org/10.1017/S1368980019001290>
- Kim, S. Y., Dietz, P. M., England, L., Morrow, B., & Callaghan, W. M. (2007). Trends in Pre-pregnancy Obesity in Nine States, 1993–2003. *Obesity*, 15(4), 986–993. <https://doi.org/10.1038/oby.2007.621>
- Lander, R. L., Hambidge, K. M., Westcott, J. E., Tejeda, G., Diba, T. S., Mastiholi, S. C., Khan, U. S., Garcés, A., Figueroa, L., Tshefu, A., Lokangaka, A., Goudar, S. S., Somannavar, M. S., Ali, S. A., Saleem, S., McClure, E. M., Krebs, N. F., & on behalf of the Women First Preconception Nutrition Trial Group. (2019). Pregnant Women in Four Low-Middle Income Countries Have a High Prevalence of Inadequate Dietary Intakes That Are Improved by Dietary Diversity. *Nutrients*, 11(7). <https://doi.org/10.3390/nu11071560>
- Laraia, B. A., Bodnar, L. M., & Siega-Riz, A. M. (2007). Pregravid body mass index is negatively associated with diet quality during pregnancy. *Public Health Nutrition*, 10(9), 920–926. Cambridge Core. <https://doi.org/10.1017/S1368980007657991>
- Looman, M., Schoenaker, D. A. J. M., Soedamah-Muthu, S. S., Mishra, G. D., Geelen, A., & Feskens, E. J. M. (2019). Pre-pregnancy dietary micronutrient adequacy is associated with lower risk of developing gestational diabetes in Australian women. *Nutrition Research*, 62, 32–40. <https://doi.org/10.1016/j.nutres.2018.11.006>
- Miller, P. E., Reedy, J., Kirkpatrick, S. I., & Krebs-Smith, S. M. (2015). The United States Food Supply Is Not Consistent with Dietary Guidance: Evidence from an Evaluation Using the Healthy Eating Index-2010. *Journal of the Academy of Nutrition and Dietetics*, 115(1), 95–100. <https://doi.org/10.1016/j.jand.2014.08.030>
- Moller, A.-B., Patten, J. H., Hanson, C., Morgan, A., Say, L., Diaz, T., & Moran, A. C. (2019). Monitoring maternal and newborn health outcomes globally: A brief history of key events and initiatives. *Tropical Medicine & International Health*, 24(12), 1342–1368. <https://doi.org/10.1111/tmi.13313>
- Parker, H. W., Tovar, A., McCurdy, K., & Vadiveloo, M. (2019). Associations between pre-pregnancy BMI, gestational weight gain, and prenatal diet quality in a national sample. *PLOS ONE*, 14(10), e0224034. <https://doi.org/10.1371/journal.pone.0224034>
- Pennington, K. A., Dong, Y., Ruano, S. H., van der Walt, N., Sangi-Haghpeykar, H., & Yallampalli, C. (2020). Brief high fat high sugar diet results in altered energy and fat metabolism during pregnancy in mice. *Scientific Reports*, 10(1), 20866. <https://doi.org/10.1038/s41598-020-77529-6>
- Quansah, D. Y., Schenk, S., Gilbert, L., Arhab, A., Gross, J., Marques-Vidal, P.-M., Gonzalez Rodriguez, E., Hans, D., Horsch, A., & Puder, J. J. (2022). Intuitive Eating Behavior, Diet

- 361 Quality and Metabolic Health in the Postpartum in Women with Gestational Diabetes.  
362 *Nutrients*, 14(20). <https://doi.org/10.3390/nu14204272>
- 363 Rasmussen, K. M., Yaktine, A. L., & Institute of Medicine (US) and National Research Council  
364 (US) Committee to Reexamine IOM Pregnancy Weight Guidelines. (2009). *Weight Gain*  
365 *During Pregnancy: Reexamining the Guidelines*. National Academies Press (US).
- 366 Rifas-Shiman, S. L., Rich-Edwards, J. W., Kleinman, K. P., Oken, E., & Gillman, M. W. (2009).  
367 Dietary Quality during Pregnancy Varies by Maternal Characteristics in Project Viva: A  
368 US Cohort. *Journal of the American Dietetic Association*, 109(6), 1004–1011.  
369 <https://doi.org/10.1016/j.jada.2009.03.001>
- 370 Savard, C., Lemieux, S., Carbonneau, É., Provencher, V., Gagnon, C., Robitaille, J., & Morisset,  
371 A.-S. (2019). Trimester-Specific Assessment of Diet Quality in a Sample of Canadian  
372 Pregnant Women. *International Journal of Environmental Research and Public Health*,  
373 16(3). <https://doi.org/10.3390/ijerph16030311>
- 374 Shin, D., Lee, K. W., & Song, W. O. (2016). Pre-Pregnancy Weight Status Is Associated with Diet  
375 Quality and Nutritional Biomarkers during Pregnancy. *Nutrients*, 8(3).  
376 <https://doi.org/10.3390/nu8030162>
- 377 Sun, Y., Shen, Z., Zhan, Y., Wang, Y., Ma, S., Zhang, S., Liu, J., Wu, S., Feng, Y., Chen, Y., Cai,  
378 S., Shi, Y., Ma, L., & Jiang, Y. (2020). Effects of pre-pregnancy body mass index and  
379 gestational weight gain on maternal and infant complications. *BMC Pregnancy and*  
380 *Childbirth*, 20(1), 390. <https://doi.org/10.1186/s12884-020-03071-y>
- 381 Sundermann, A. C., Zhao, S., Young, C. L., Lam, L., Jones, S. H., Velez Edwards, D. R., &  
382 Hartmann, K. E. (2019). Alcohol Use in Pregnancy and Miscarriage: A Systematic Review  
383 and Meta-Analysis. *Alcoholism: Clinical and Experimental Research*, 43(8), 1606–1616.  
384 <https://doi.org/10.1111/acer.14124>
- 385 Tang, J., Zhu, X., Chen, Y., Huang, D., Tiemeier, H., Chen, R., Bao, W., & Zhao, Q. (2021).  
386 Association of maternal pre-pregnancy low or increased body mass index with adverse  
387 pregnancy outcomes. *Scientific Reports*, 11(1), 3831. [https://doi.org/10.1038/s41598-021-](https://doi.org/10.1038/s41598-021-82064-z)  
388 [82064-z](https://doi.org/10.1038/s41598-021-82064-z)
- 389 Tebbani, F., Oulamara, H., & Agli, A. (2021). Food diversity and nutrient intake during pregnancy  
390 in relation to maternal weight gain. *Nutrition Clinique et Métabolisme*, 35(2), 93–99.  
391 <https://doi.org/10.1016/j.nupar.2020.09.001>
- 392 Teede, H. J., Bailey, C., Moran, L. J., Bahri Khomami, M., Enticott, J., Ranasinha, S., Rogozińska,  
393 E., Skouteris, H., Boyle, J. A., Thangaratinam, S., & Harrison, C. L. (2022). Association  
394 of Antenatal Diet and Physical Activity–Based Interventions With Gestational Weight  
395 Gain and Pregnancy Outcomes: A Systematic Review and Meta-analysis. *JAMA Internal*  
396 *Medicine*, 182(2), 106–114. <https://doi.org/10.1001/jamainternmed.2021.6373>
- 397 Uno, K., Takemi, Y., Hayashi, F., & Hosokawa, M. (2016). Nutritional status and dietary intake  
398 among pregnant women in relation to pre-pregnancy body mass index in Japan. *Nihon*  
399 *Koshu Eisei Zasshi*, 63(12), 738–749. PubMed. [https://doi.org/10.11236/jph.63.12\\_738](https://doi.org/10.11236/jph.63.12_738)
- 400 Vats, H., Saxena, R., Sachdeva, M. P., Walia, G. K., & Gupta, V. (2021). Impact of maternal pre-  
401 pregnancy body mass index on maternal, fetal and neonatal adverse outcomes in the

- worldwide populations: A systematic review and meta-analysis. *Obesity Research & Clinical Practice*, 15(6), 536–545. <https://doi.org/10.1016/j.orcp.2021.10.005>
- WHO expert consultation. (2004). Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *The Lancet*, 363(9403), 157–163. [https://doi.org/10.1016/S0140-6736\(03\)15268-3](https://doi.org/10.1016/S0140-6736(03)15268-3)
- Witek, K., Wydra, K., & Filip, M. (2022). A High-Sugar Diet Consumption, Metabolism and Health Impacts with a Focus on the Development of Substance Use Disorder: A Narrative Review. *Nutrients*, 14(14). <https://doi.org/10.3390/nu14142940>
- Yang, M., Feng, Q., Chen, C., Chen, S., Guo, Y., Su, D., Chen, H., Sun, H., Dong, H., & Zeng, G. (2023). Healthier diet associated with reduced risk of excessive gestational weight gain: A Chinese prospective cohort study. *Maternal & Child Nutrition*, 19(3), e13397. <https://doi.org/10.1111/mcn.13397>
- Yang, Y. X., Wang, X. L., Leong, P. M., Zhang, H. M., Yang, X. G., Kong, L. Z., Zhai, F. Y., Cheng, Y. Y., Guo, J. S., & Su, Y. X. (2018). New Chinese dietary guidelines: Healthy eating patterns and food-based dietary recommendations. *Asia Pacific Journal of Clinical Nutrition*, 27(4), 908–913. <https://search.informit.org/doi/10.3316/ielapa.762435308484087>

# **Table 1**(on next page)

Basic characteristics based on Pre-pregnancy BMI

1 Table 1 Basic characteristics based on Pre-pregnancy BMI

Characteristics	Pre-pregnancy BMI				p
	Underweight (n=24)	Normal weight (n=329)	Overweight (n=127)	Obese (n=52)	
Age (years)	29.29±4.53	31.34±4.18	32.03±4.71	32.31±4.53	0.017
Height (cm)	164.42±5.14	164.19±5.42	162.91±4.85	163.63±5.07	0.942
Weight (kg)	52.56±9.37	64.65±11.93	72.57±8.74	81.04±14.51	<0.001
GWG (kg)	15.77±5.09	13.93±4.63	12.75±4.20	12.02±5.09	<0.001
Basic metabolism (kcal/d)	1315.41±116.00	1310.64±150.00	1360.98±119.68	1363.81±137.76	<0.001
Educational level (N, %)					0.382
Secondary level or below	9(37.50)	83(25.23)	46(36.22)	14(26.92)	
College level	7(29.17)	93(28.27)	35(27.56)	14(26.92)	
University level	5(20.83)	88(26.75)	32(25.20)	15(28.85)	
Graduate level or above	3(12.50)	65(19.75)	14(11.02)	9(17.31)	
Household income (N, %)					0.395
<5000	2(8.33)	16(4.86)	8(6.30)	4(7.69)	
5000-10000	3(20.83)	59(17.93)	12(9.45)	5(9.62)	
10001-30000	14(58.33)	205(62.31)	87(68.50)	38(73.07)	
>30000	5(12.50)	49(14.89)	20(15.75)	5(9.62)	
Smokers (N, %)	2(8.33)	35(10.64)	11(8.66)	5(9.62)	0.922
Number of pregnancies	2[1,2]	2[1,2]	2[1,3]	2[1,3]	0.451
Number of deliveries	1[0,1]	1[1,1]	1[1,1]	1[0,1]	0.103

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# **Table 2**(on next page)

Basic characteristics based on GWG



1 Table 1 Basic characteristics based on GWG

Characteristics	GWG			p
	Inadequate (n=25)	Adequate (n=351)	Excessive (n=156)	
Age (years)	32.28±4.25	31.70±4.67	31.36±4.27	0.487
Height (cm)	163.20±3.96	162.56±5.23	164.46±4.62	0.614
Weight (kg)	69.30±9.80	62.36±10.57	69.80±13.54	<0.001
Pre-pregnancy BMI (kg/m <sup>2</sup> )	24.92±3.49	22.86±3.66	25.33±3.69	<0.001
Basic metabolism (kcal/d)	1335.76±97.51	1334.27±195.40	1326.05±119.20	0.816
Educational level (N, %)				0.524
Secondary level or below	6(24.00)	102(29.06)	42(26.92)	
College level	7(28.00)	100(28.49)	44(28.21)	
University level	9(36.00)	83(23.65)	48(30.77)	
Graduate level or above	3(12.00)	66(18.80)	22(14.10)	
Household income (N, %)				0.743
<5000	1(4.00)	20(5.70)	9(5.77)	
5000-10000	3(12.00)	56(15.95)	22(14.10)	
10001-30000	19(76.00)	228(64.96)	97(62.18)	
>30000	2(8.00)	47(13.39)	28(17.95)	
Smokers (N, %)	4(16)	34(9.68)	15(9.62)	0.587
Number of pregnancies	2[1,3]	2[1,3]	2[1,2]	0.502
Number of deliveries	1[1,2]	1[0,1]	1[1,1]	0.283

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# **Table 3**(on next page)

Multivariable adjusted CHDI-P scores by Pre-pregnancy BMI

Table 1 Multivariable adjusted CHDI-P scores by Pre-pregnancy BMI

	Total	Diversity total	Adequacy total	Limitation total
Multivariable-adjusted model—adjusted for educational level, household income and number of deliveries				
underweight	60.28±0.99	9.99±0.11	26.26±1.08	24.03±0.32
normal weight	59.46±0.99	10.00±0.21	26.26±1.01	23.19±0.38
overweight	58.85±0.98	9.99±0.20	26.21±1.00	22.64±0.34
obese	57.80±1.11	9.99±0.12	26.07±1.15	21.70±0.43

# **Table 4**(on next page)

Multivariable adjusted CHDI-P scores by GWG

1 Table 1 Multivariable adjusted CHDI-P scores by GWG

	Total	Diversity total	Adequacy total	Limitation total
Multivariable-adjusted model—adjusted for household income and number of deliveries				
inadequate	59.54±0.92	10.00±0.11	26.76±0.99	22.74±0.19
adequate	59.17±0.86	10.00±0.10	26.25±0.98	22.91±0.23
excessive	59.17±0.73	10.00±0.12	26.19±0.84	22.98±0.24

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# **Table 5**(on next page)

Post-hoc analysis of CHDI-P scores across BMI-based subgroups.

1 Table 1 Post-hoc analysis of CHDI-P scores across BMI-based subgroups.

	Total		Diversity total		Adequacy total		Limitation total	
	p	95% CI	p	95% CI	p	95% CI	p	95% CI
Obese-normal weight	<0.001	[-2.04, -1.27]	0.004	[-0.01, -0.00]	0.595	[-0.59, 0.21]	<0.001	[-1.64, -1.35]
Overweight-normal weight	<0.001	[-0.87, -0.33]	0.007	[-0.01, -0.00]	0.900	[-0.33, 0.22]	<0.001	[-0.66, -0.46]
Underweight-normal weight	<0.001	[0.28, 1.37]	0.804	[-0.01, 0.01]	0.900	[-0.57, 0.56]	<0.001	[0.63, 1.04]
Overweight-obese	<0.001	[0.63, 1.48]	0.709	[-0.00, 0.01]	0.836	[-0.30, 0.57]	<0.001	[0.78, 1.10]
Underweight-obese	<0.001	[1.85, 3.12]	0.546	[-0.00, 0.01]	0.876	[-0.47, 0.84]	<0.001	[2.10, 2.57]
Underweight-overweight	<0.001	[0.85, 2.00]	0.892	[-0.01, 0.01]	0.900	[-0.54, 0.64]	<0.001	[1.18, 1.61]

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# **Table 6**(on next page)

Post-hoc analysis of CHDI-P scores across GWG-based subgroups.



1 Table 1 Post-hoc analysis of CHDI-P scores across GWG-based subgroups.

	Total		Diversity total		Adequacy total		Limitation total	
	p	95% CI	p	95% CI	p	95% CI	p	95% CI
Excessive-adequate	0.900	[-0.18, 0.17]	0.308	[-0.00, 0.01]	0.739	[-0.26, 0.14]	0.004	[0.02, 0.13]
Inadequate-adequate	0.080	[-0.03, 0.76]	0.521	[-0.00, 0.01]	0.023	[0.06, 0.96]	0.003	[-0.29, -0.05]
Inadequate-excessive	0.061	[-0.01, 0.75]	0.887	[-0.00, 0.01]	0.006	[0.14, 1.00]	<0.001	[-0.36, -0.13]

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