Association between Maternal Dietary Patterns and Macrosomia Risk: A Prospective Cohort Study

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Abstract. (1) Background: While dietary interventions offer advantages over conventional medical treatments in some contexts, evidence specifically linking maternal dietary patterns to macrosomia risk remains limited. (2) Method: This prospective cohort investigation enrolled pregnant women residing in Xi'an, China, between December 2023 and February 2024. A validated semi-quantitative food frequency instrument assessed maternal dietary intake. Through factor analysis, predominant dietary patterns were extracted. Neonatal macrosomia was operationally defined as a birth weight of ≥4000 grams, regardless of gestational duration. Poisson regression models were used to estimate risk ratios (RRs) with 95% confidence intervals (CIs) for macrosomia across dietary pattern score quartiles. Stratified analyses and interaction tests were performed for established confounders. (3) Results: Among 1,796 enrolled pregnant women, 1,687 (mean age: 31.0 years) completed the study. Macrosomia was identified in 117 neonates (6.94%). Factor analysis yielded four distinct dietary patterns. Following multivariable adjustment, participants in the highest quartile of the "poultry-offal" and "aquatic-nut" patterns exhibited significantly elevated macrosomia risk-75% and 82% higher, respectively-relative to the lowest quartile (P-trend<0.01). In contrast, Q4 of the "vegetable-fruit" pattern demonstrated a 74% risk reduction versus Q1 (p-trend<0.001). Significant modifying effects of pre-pregnancy BMI and household income were identified for the "staple grain-root" pattern (p-interaction<0.05). (4) Conclusions: High consumption of dark/light green vegetables and fruits conferred marked protection against macrosomia. In contrast, diets rich in poultry, offal, marine fish, freshwater fish, eggs, and nuts were associated with elevated risk. There associations may vary by pre-pregnancy BMI and annual household income. These findings lend epidemiological support to the potential for dietary modifications as a preventive strategy against macrosomia.

Keywords: Macrosomia; Pregnancy; Dietary Patterns; Food-Frequency Questionnaires; Factor Analysis.

1. Introduction

Macrosomia, clinically defined as birth weight >4000g reflecting pathological fetal overgrowth [1], represents a major perinatal health challenge. It elevates risks of neonatal mortality (obstetric trauma, fractures, asphyxia) and maternal morbidity/mortality (emergency cesarean section, instrumental delivery, shoulder dystocia and trauma to the birth canal, bladder, perineum and anal sphincter) [2]. Furthermore, macrosomia infants face an increased susceptibility to long-term metabolic sequelae, such as obesity, type 2 diabetes, and cardiovascular disease in later life [3-5]. According to the current studies, macrosomia accounts for 7% in China [6]. The incidence rate is even higher abroad, at approximately 15.1% [7]. Given that therapeutic interventions post-onset are limited, as macrosomia fundamentally stems from fetal nutrient oversupply, preventive strategies are vital. Therefore, the identification of modifiable determinants influencing macrosomia risk is critically important for developing effective public health interventions [8].

Dietary intake represents a key modifiable factor warranting investigation for its potential role in macrosomia prevention. However, human nutrition involves complex consumption patterns rather than isolated nutrients, driven by habitual dietary practices. While prior research suggests potential links between specific nutrients and fetal growth, investigations have largely focused on single nutrient effects, failing to capture the inherent complexity of overall dietary habits. For example, substantial research has examined the association of maternal vitamin D status with macrosomia [9-11]. Elevated gestational cholesterol consumption (predominantly egg-derived) demonstrates positive correlations with both birth weight augmentation and large-for-gestational-age (LGA) incidence [12]. However, human nutrition operates through integrated dietary configurations rather than isolated nutrients. Existing studies have indeed associated certain dietary patterns with altered macrosomia risk. For instance, elimination of potatoes from plant-based diets diminished this association [13]. Contrastingly, one study in South Americans identified a 4-fold LGA risk elevation with diets abundant in processed foods and confectionery [14]. Nevertheless, significant limitations persist within the current evidence base. Much of the existing research is derived from populations in high-income Western countries or specific geographic regions, utilizes predominantly cross-sectional designs limiting causal inference, and often lacks comprehensive assessment of diverse dietary patterns [15,16]. These gaps underscore the need for further investigation employing robust methodologies in varied populations.

A notable paucity of data exists regarding the specific association between dietary patterns and macrosomia risk within populations residing in Northwest China. Considering that dietary patterns derived by factor analysis could reflect actual eating habits [17], this investigation aimed to characterize predominant gestational dietary patterns and investigate their relationships with macrosomia incidence. The study may establish foundational evidence for culturally-tailored prenatal nutrition strategies targeting macrosomia-related perinatal complications.

2. Materials and Methods

2.1 Study Population

Data from a prospective cohort design conducted at Northwest Women's and Children's Hospital (December 2023–February 2024) were analyzed to elucidate association between regional dietary characteristics and maternal-fetal health outcomes. This investigation seeks to inform preventive strategies against birth defects and advance evidence-based initiatives for optimized pregnancy management and neonatal well-being.

Pregnant women aged 20-49 years agreed to participate in the study were eligible for inclusion. Exclusion criteria comprised: (1) neurocognitive disorders impairing comprehension, (2) nonadherence to research protocols, or (3) questionnaire non-completion.

Sociodemographic characteristics, anthropometric measurements, and lifestyle factors were ascertained through structured electronic and self-administered questionnaires at the enrollment. Obstetric data were abstracted from medical records. In this cohort study, among 1,796 administered questionnaires, outliers, incomplete data filling, and obviously incorrect data were excluded and 1,687 were completed and validated, yielding a 93.9% response rate.

This investigation strictly adhered to Declaration of Helsinki principles. All participants were informed about the research objectives beforehand and signed an informed consent form.

2.2 Assessment of Dietary Intakes

Dietary intake was quantified using a modified 108-item semi-quantitative food frequency questionnaire (FFQ), adapted from validated instruments for prenatal nutrition assessment in Western China's rural communities [18, 19]. This modified FFQ demonstrated reliability and validity coefficients of 0.40-0.80. Ten principal food categories were evaluated: cereals, vegetables and derivatives, legumes and products, fungi, algae, fruits, meat, nuts, eggs, dairy products, beverages (including alcoholic), and confectionery/baked goods. Edible oil types and nutritional supplement usage (including folic acid, calcium, iron, Docosahexaenoic Acid (DHA), probiotics, vitamin D, and plant/animal-derived oils) were documented to quantify intake frequency, dosage, and brand-specific consumption patterns. Standardized portion sizes were established for all listed food items.

Participants retrospectively reported average consumption over the preceding month, assisted by visual portion guides. Consumption frequencies were categorized across nine ordinal levels ranging from <1 serving/month to ≥6 servings/day. These values were converted to daily servings.

2.3 Identification of Dietary Pattern Assessment

Dietary pattern derivation employed factor analysis of aggregated food groups. Food items from the FFQ were consolidated based on nutritional homology and functional characteristics, with intake summations standardized to g/day. Factor analysis suitability was confirmed through Kaiser-Meyer-Olkin (KMO>0.6) and Bartlett's sphericity tests [20].

Factor retention was guided by eigenvalue magnitude (>1.0), scree plot inflection, cumulative variance, and nutritional interpretability. Varimax rotation maximized factor loading variance. Food groups with loadings >|0.35| were retained, and patterns were named according to dominant food groups (2-3 highest loadings) informed by nutritional principles.

Pattern scores were calculated as the summed products of standardized food group intakes (g/day) and their factor loadings. Higher scores indicated stronger pattern adherence. Scores were categorized into quartiles (Q1-Q4) for subsequent analyses.

2.4 Outcome Definition

Neonatal birth weights were obtained using calibrated digital scales, with macrosomia cases identified through medical record abstraction. Per American College of Obstetricians and Gynecologists (ACOG) criteria [1], neonates weighing ≥4000 g at delivery were classified as macrosomia irrespective of gestational age.

2.5 Assessment of Covariates

Participant characteristics were systematically abstracted from structured questionnaires and electronic medical records. Data collection encompassed demographic parameters (age; occupational categorization as homemakers/unemployed, employed professionals, or stay-at-home mothers; educational attainment stratified as primary/middle school, high school, or college/university; annual household income tiers: ≤3,000, 3,000-5,000, 5,000-8,000, ≥8,000 RMB), lifestyle factors (dichotomized smoking status, secondhand smoke exposure, physical activity levels, and sleep disturbances), pregnancy-related metrics (gestational weeks, pre-pregnancy Body mass index (BMI), gestational weight gain, pregestational diabetes status, delivery mode categorized as vaginal or cesarean, postpartum hemorrhage incidence, hypertensive disorders, gestational diabetes mellitus, and the usage of dietary supplement), obstetric history (prior miscarriage events) and familial diabetes predisposition.

BMI was derived anthropometrically using the formula: weight(kg)/ height^2(m^2). Through causal directed acyclic graphs and established epidemiological criteria, all aforementioned variables-including demographic indicators, lifestyle exposures, obstetric parameters, and medical histories-were operationally defined as potential confounders in analytical models.

2.6 Statistical Analysis

Normality diagnostics employed Shapiro-Wilk tests and quantile-quantile plots. Gaussian-distributed continuous variables were presented as mean ± standard deviation and analyzed with independent t-tests, while non-normal distributions necessitated median and interquartile range (IQR) and Wilcoxon rank-sum tests. Categorical data were summarized as frequencies (percentages) and evaluated via χ^2 tests.

Dietary pattern scores underwent quartile stratification (Q1-Q4). Poisson regression models were used to estimate relative risks (RRs) with 95% confidence intervals (CIs). Model 1 was unadjusted; Model 2 controlled for educational attainment, pre-pregnancy weight gain, miscarriage history, pregestational diabetes, vigorous physical activity, folic acid supplementation, and delivery mode; Model 3 additionally adjusted for gestational age, pre-pregnancy BMI, maternal age, occupation, secondhand smoke exposure, smoking status, household income, diabetes family history, moderate/low-intensity physical activity, sleep disturbances, postpartum hemorrhage, DHA/vitamin D/probiotics/iron/calcium supplementation, hypertensive disorders, and gestational diabetes. Quartile trends were assessed by modeling scores as continuous variables.

Restricted cubic splines (RCS) with three knots (25th, 50th, 75th percentiles) examined dose-response relationships between dietary patterns and macrosomia. Sensitivity analyses included stratified assessments by: maternal age (<30/≥30 years), gestational weeks (<28/≥28), pre-pregnancy BMI (<24/≥24 kg/m²), weight gain (<11.9/≥11.9 kg), education (≤high school/≥college), occupation (unemployed/employed), household income (<5,000/≥5,000 RMB), secondhand smoke exposure, delivery mode, and supplement use (vitamin D/calcium).

Data management employed Epidata 3.0 software, with statistical processing conducted in SPSS statistical 27 software (IBM Corp, Armonk, NY) and R (version 4.3.2; R Development Core Team). Significance for bivariate testing was defined as $P<0.05$ (two-tailed).

3. Results

3.1 Participant Characteristics

This study enrolled 1,687 pregnant women, with macrosomia identified in 117 cases (6.94%). Participant characteristics are presented in **Table 1**. Median ages (IQR), pre-gestational BMI, and gestational age were 31.0 (29.0-33.0) years, 22.2 (19.9-24.8) kg/m², and 29.0 (24.0-34.0) weeks, respectively.

Significant between-group differences (macrosomia vs non-macrosomia) were observed for pre-pregnancy weight gain, educational attainment, miscarriage history, pregestational diabetes, vigorous physical activity, folic acid supplementation, and delivery mode. Women whose infants had macrosomia (median age 31.0 [29.0-33.5] years) demonstrated greater pre-pregnancy weight gain and higher rates of vigorous physical activity ($P<0.05$). Prevalence of prior miscarriage (36.8% vs controls) and pregestational diabetes (25.6% vs controls) was elevated in the macrosomia group. Conversely, lower educational attainment and reduced folic acid supplementation were noted in this group ($P<0.05$). Cesarean delivery rates were higher among macrosomia cases (41.0% vs 27.8%).

Comparable distributions were demonstrated across maternal characteristics including: maternal age, gestational weeks, pre-pregnancy BMI, occupation, secondhand smoke exposure, smoking status, household income, diabetes family history, sleep disturbances, postpartum hemorrhage, probiotic/iron/calcium supplementation, hypertensive disorders, or gestational diabetes ($P>0.05$).

3.2 Types of Dietary Patterns

Factor analysis suitability was confirmed by a Kaiser-Meyer-Olkin statistic of 0.696 and statistically significant Bartlett's sphericity test ($P<0.001$), indicating appropriate data structure and substantial inter-food-group correlations. Four factors with eigenvalues exceeding 1.0 were retained **(Table S2)**. Based on scree plot inflection **(Figure S1)**, factor interpretability, and cumulative variance (>25% threshold), four dietary patterns accounting for 29.6% of total variance were extracted, with eigenvalues of 2.188, 1.945, 1.916, and 1.656 contributing 8.4%, 7.5%, 7.4%, and 6.4% respectively. Food groups exhibiting factor loadings >|0.35| were retained in each pattern **(Table S3)**, with patterns named according to dominant food groups (2-3 highest loadings) informed by nutritional principles.

The poultry-offal pattern was characterized by poultry, offal, marine fish, shrimp, crabs, and soy milk; the staple grain-root pattern was dominated by rice, noodles, coarse grains, tubers, and dried legumes; the plant-based pattern primarily comprised dark/light green vegetables and fruits; the aquatic-nut pattern featured freshwater fish, eggs, skim milk, and nuts. Dietary pattern scores were derived by summing standardized food group intakes multiplied by factor loadings, where higher scores indicated stronger adherence to respective dietary patterns.

3.3 Distribution of Characteristics Stratified by Dietary Patterns

The poultry-offal dietary pattern exhibited significant quartile-based variations in age, method of delivery, probiotic intake and Fe supplement use ($P<0.05$) **(Table S4)**. For the staple grain and root dietary pattern, differential distributions emerged across quartiles including pre-pregnancy BMI, smoking, annual household income, moderate physical activity, low physical activity, DHA supplements, probiotic intake, Fe supplement use and Ca supplement use **(Table S5)**. Quartile stratification of the vegetable and fruit dietary pattern revealed significant differences in pre-pregnancy weight gain, low physical activity and probiotic intake **(Table S6)**. The freshwater fish and nut dietary pattern manifested clinically relevant variations in: weeks of pregnancy, pre-pregnancy BMI, educational level, smoking, folic acid intake, method of delivery, DHA supplements, Fe supplement use, Ca supplement use, hypertension disorder during pregnancy and gestational diabetes mellitus **(Table S7)**.

3.4 Associations between Dietary Patterns and Macrosomia Risk

Associations between four dietary patterns and macrosomia risk are presented in **Table 2**. In the unadjusted model (Model 1), significantly elevated macrosomia odds were observed for the highest versus lowest quartiles of poultry-offal (OR=1.56, 95%CI: 0.93-2.61) and aquatic-nut patterns (OR=1.70, 1.03-2.81), whereas the plant-based pattern demonstrated protective effects (OR=0.28, 0.14-0.53). Following adjustment for educational attainment, pre-pregnancy weight gain, miscarriage history, pregestational diabetes, vigorous physical activity, folic acid supplementation, and delivery mode (Model 2), these associations were strengthened: poultry-offal OR=1.64 (0.97-2.78; P=0.013), plant-based OR=0.28 (0.14-0.53; $P<0.001$), aquatic-nut OR=1.71 (1.03-2.85; P=0.019), with persistent null association for grain-root pattern (OR=1.01, 0.60-1.68; P=0.677). In the fully adjusted model (Model 3), macrosomia risk was significantly increased in the highest quartile (Q4) versus Q1 for poultry-offal (OR=1.75, 1.03-2.99; P=0.007) and aquatic-nut patterns (OR=1.82, 1.07-3.10; P=0.008). Conversely, the plant-based pattern showed substantial risk reduction (OR=0.26, 0.13-0.50; $P<0.001$). No significant risk alteration was observed for grain-root pattern (OR=0.87, 0.51-1.49; P=0.981). Statistically significant trend associations ($P<0.05$) were confirmed for poultry-offal, plant-based, and aquatic-nut patterns.

Figure 1 illustrates the linear relationship between four different dietary patterns' index scores with macrosomia risk. For the staple grain and root dietary pattern, no significant linear (P=0.964) or non-linear (P=0.934) association with macrosomia risk was observed. The freshwater fish and nut pattern demonstrated non-significant linear trends (P=0.140). Vegetable and fruit pattern scores exhibited a strong linear inverse relationship with macrosomia risk ($P<0.001$), though significant non-linearity was detected (P=0.042). In contrast, poultry meat and animal offal pattern scores showed significant linear trends (P=0.004).

3.5 Subgroup Analysis

Sensitivity models evaluated potential effect modification for major confounding factors, including age, weeks of pregnancy, pre-pregnancy BMI, pre-pregnancy weight gain, educational level, occupation, exposure to second-hand smoke, annual household income, smoking, history of miscarriage, pre-gestational diabetes, family history of diabetes, physical activity, sleep disorders, folic acid intake, method of delivery, postpartum hemorrhage, DHA supplements, vitamin D intake, probiotic intake, Fe supplement use, Ca supplement use, hypertension disorder during pregnancy and gestational diabetes mellitus. In the staple grain-root dietary pattern, pre-pregnancy BMI and annual household income exhibited substantial effect modification (interaction $P<0.05$) **(Table S9)**.

4. Discussion

In this regional cohort study conducted in Northwest China, four distinct maternal dietary patterns were identified: (1) poultry meat and organ offal, (2) staple grains and tubers, (3) vegetables and fruits, and (4) freshwater fish and nuts. Significant associations between these eating patterns and macrosomia risk were observed. Specifically, the diet rich in vegetables and fruits was inversely related with macrosomia incidence, whereas patterns characterized by high intake of poultry, organ meats, aquatic products (marine/freshwater fish, shrimp, crab), eggs, and nuts demonstrated positive associations. These associations were more pronounced among women with elevated pre-pregnancy BMI and higher household income. Collectively, these observations advance understanding of diet-driven fetal overgrowth and provide actionable epidemiological evidence for regionally tailored nutritional interventions targeting high-risk maternal subpopulations.

These findings were supported by prior evidence. A cross-sectional study in 2016 revealed a positive association between dietary cholesterol consumed by pregnant females and the prevalence ratio of LGA [21]. In addition, a prospective cohort study conducted in China demonstrated that egg-derived cholesterol intake in the first and third trimesters was positively linked to LGA [12]. Ramesh D Potdar demonstrated higher intake of green leafy vegetables, fruit and milk consumed before or during pregnancy increase infant birth weight compared with a low intake of potato and onion [22]. Several studies reported that the Low Glycemic Index (LGI) diet and the dietary approaches to Stop Hypertension (DASH) diet significantly reduced the incidence of macrosomia [23-26]. However, previous studies focused predominantly on isolated dietary components rather than holistic patterns. Given that human diets represent complex interplays of multiple nutrients and food groups, this study provides novel insights into the relationship between integrated dietary patterns and macrosomia in a Northwest Chinese cohort.

The “Poultry Meat and Organ Offal” dietary pattern-characterized by high consumption of poultry, organ meats, marine fish, soy milk, shrimp, and crab-was associated with an increased risk of macrosomia. This association may be attributable to following primary mechanisms: Firstly, these foods represent concentrated sources of bioavailable animal protein, vitamins (such as vitamin A and B12), and minerals (particularly heme iron). This observation aligns with prior evidence linking elevated animal protein intake to higher birth weights in protein-deficient populations [27]. High-quality animal-derived proteins contribute to fetal tissue synthesis while supporting maternal metabolic demands [28], and provide essential micronutrients that potentiate fetal growth. Secondly, marine species in this pattern deliver substantial n-3 polyunsaturated fatty acids (EPA/DHA). Elevated maternal n-3 Long Chain Polyunsaturated Fatty Acid (LCPUFA) levels have been previously associated with LGA infants [29], suggesting a plausible biological pathway for accelerated fetal growth.

The “Freshwater Fish and Nuts” dietary pattern-characterized by high consumption of freshwater fish, nuts, eggs, and fruit juice-was associated with increased macrosomia risk. This finding aligns with longitudinal evidence linking maternal seafood intake to elevated birth weights, particularly with freshwater species and shellfish [30]. Nuts represent concentrated sources of fats (40-60% unsaturated fatty acids [UFAs], predominantly MUFAs/PUFAs) and protein (8-20%) [31], while egg yolks (e.g., large 65g specimen ≈237mg cholesterol) frequently exceed recommended cholesterol limits [32]. Critically, maternal dietary lipid profiles have been mechanistically associated with fetal growth parameters [33], and positive dose-dependent relationships between prenatal cholesterol intake and LGA births are well-documented [21].

In contrast to risk-associated patterns, the “Vegetables and Fruits” dietary pattern-characterized by high consumption of green vegetables and fruits-demonstrated a significant inverse association with macrosomia incidence. This protective effect aligns with both the 2015-2020 US and 2022 Chinese Dietary Guidelines. The observed benefit may be explained through two interrelated mechanisms: Firstly, placental circulatory establishment elevates reactive oxygen species (ROS) and superoxide levels [34], triggering cytokine activation and maternal inflammatory responses that induce oxidative stress[35]. Maternal obesity-a condition mechanistically linked to oxidative stress and inflammatory dysregulation-is an established risk factor for LGA infants [36]. Diets rich in antioxidant sources (fruits/vegetables) have been consistently associated with appropriate-for-gestational-age births [37], potentially counteracting these pathways. Secondly, plant-based components merit consideration. While direct evidence linking maternal plant protein intake to birth weight remains limited [38], its metabolic properties-notably reduced branched-chain and sulfur-containing amino acids-enhance insulin sensitivity and energy expenditure [39, 40]. These foods additionally exhibit favorable energy density and fiber content, which regulate satiety signaling and metabolic homeostasis to support healthy weight maintenance [41].

This prospective cohort study examined associations between maternal eating patterns and macrosomia risk, adjusting for comprehensive potential confounders. The analysis revealed a protective association for the "Vegetables and Fruits" pattern, whereas both "Poultry Meat and Organ Offal" and "Freshwater Fish and Nuts" patterns demonstrated adverse associations with macrosomia among Northwest Chinese pregnant women. These findings may inform antenatal nutrition guidelines and macrosomia prevention strategies.

However, several limitations warrant acknowledgment. First, dietary intake among pregnant participants was assessed using the FFQ. While potential misclassification may occur due to inherent subjectivity and imprecision in portion size estimation, its application in deriving dietary patterns facilitated relative ranking by food group consumption, thus remaining appropriate for this purpose. Second, maternal dietary data were collected via self-reported questionnaires, which are subject to recall bias [42-44] and preclude the capture of dietary changes during pregnancy, but evidence suggesting relative stability in maternal diets across gestation [45,46]. Third, dietary patterns in pregnant women were derived using factor analysis which is inherently subjective and sample-dependent, potentially limiting generalizability. Nevertheless, factor analysis provides a holistic assessment of dietary intake by integrating relationships among multiple foods and nutrients, rather than examining isolated components. Thus, it enables a more comprehensive representation of actual dietary habits and identification of underlying associations between overall dietary structure and health outcomes. Fourth, despite controlling for a large number of confounding factors, there are still some unmeasured factors that were not included in the analysis and may affect the results of the study. Future studies should incorporate genetic markers and nutritional biomarkers. Fifth, generalizability may be limited by the regional cohort; multi-center studies across diverse populations are recommended. Finally, as an observational design, causal inference is precluded-randomized controlled trials are needed for causal verification.

5. Conclusion

In conclusion, distinct maternal dietary patterns were observed to associate with macrosomia risk. Increased consumption of green vegetables and fruits is recommended as essential components of prenatal nutrition. Conversely, reduced intake of animal-derived products (poultry, organ meats, eggs, aquatic products) and nuts-along with minimization of sugar-sweetened beverages and ultra-processed foods-is advised. These findings may provide the formulation of evidence-based clinical guidelines and public health interventions for macrosomia prevention through antenatal dietary modification.

Author Contributions

Y.W., Z.G., L.Z., X.X. and T.W. contributed to data collection and management. Y.W. and Z.G. conducted the data analysis. Y.W. conceptualized the manuscript framework, executed scientific visualization, and coordinated project administration. All co-authors engaged in iterative critical appraisal and provided unanimous endorsement of the submission-ready manuscript.

Informed Consent Statement

Written consent, based on informed understanding, was acquired from all study participants.

Data Availability Statement

Due to restrictions on data protection, these materials can only be provided upon request. Requests for access to these materials should be sent via email to the corresponding author of this study.

Conflicts of Interest:

The authors declare no conflicts of interest.

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