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# Nutritional and biochemical status of pregnant women giving birth to low-birth-weight newborns in El Jadida Province, Morocco: a case-control study

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*Palabras clave:*

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RESUMEN

**Objetivo**: Evaluar la calidad de la dieta y el estado bioquímico de mujeres embarazadas que dieron a luz a recién nacidos con peso normal o bajo peso al nacer. **Sujetos y métodos**: Este estudio de casos y controles incluyó a 400 mujeres en el momento del parto, divididas en dos grupos: 200 controles que dieron a luz a recién nacidos con peso normal y 200 casos que dieron a luz a recién nacidos con bajo peso al nacer (BPN). La ingesta dietética y la calidad de la dieta se evaluaron utilizando el Nutrient Adequacy Ratio (NAR) y el Mean Adequacy Ratio (MAR). Los parámetros bioquímicos previos al parto se midieron y se compararon entre los dos grupos. La mayoría de los casos de bajo peso al nacer se asociaron con partos prematuros, mientras que todas las mujeres del grupo control dieron a luz a término. **Resultados**: La altura del fondo uterino fue significativamente menor en los casos que en los controles (25.69 vs. 31.83 cm; p<0.001). Los casos también presentaron valores significativamente más bajos (p<0.001) de NAR para micronutrientes clave tales como el calcio (0.34 vs. 0.58), los folatos (0.48 vs. 0.68), el hierro (0.50 vs. 0.64) y la vitamina B1 (0.53 vs. 0.87). La calidad global de la dieta, evaluada mediante el MAR, fue significativamente inferior en los casos respecto a los controles (0.70 vs. 0.85; p< 0.001). **Conclusión**: Las mujeres embarazadas que dieron a luz a recién nacidos con bajo peso tienen una menor calidad de la dieta y un estado micronutricional deteriorado, especialmente en relación con el hierro, el calcio y los folatos. La suplementación temprana y continua con hierro podría mejorar el estado nutricional materno y contribuir a mejores resultados del embarazo.

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*Keywords:*

Low birth weight
Dietary quality
NAR
MAR
Anaemia
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Morocco

ABSTRACT

**Aims**: To better understand the dietary quality and biochemical status of pregnant women delivering normal- or low-birth-weight newborns. **Subjects and Methods**: This case–control study included 400 women at delivery, divided into two groups: 200 controls with normal-weight newborns and 200 cases with low-birth-weight (LBW) newborns. Dietary intake and diet quality were assessed using the Nutrient Adequacy Ratio (NAR) and the Mean Adequacy Ratio (MAR). Pre-delivery biochemical and anthropometric parameters were measured and compared between the two groups. Most LBW cases were associated with preterm birth, whereas all controls delivered at term. **Results**: Fundal height was significantly lower in cases than in controls (25.69 vs. 31.83 cm; p<0.001). Cases also had significantly lower nutrient adequacy ratios (NARs) for calcium (0.34 vs. 0.58), folates (0.48 vs. 0.68), iron (0.50 vs. 0.64) and thiamine (0.53 vs. 0.87; all p<0.001). Overall dietary quality, assessed using the mean adequacy ratio (MAR), was significantly lower in cases than in controls (0.70 vs. 0.85 p<0.001). **Conclusion**: Pregnant women delivering LBW newborns have poorer dietary quality and impaired micronutrient status, particularly for iron, calcium, folates and thiamine. Early and continuous iron supplementation may improve maternal nutritional status and contribute to better pregnancy outcomes.

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## Introduction

Low birth weight (LBW) is defined by the World Health Organization (WHO) as a birth weight below 2500 g, regardless of gestational age (WHO, 2019). It represents a major public health problem associated with increased neonatal mortality and morbidity, including impaired cognitive and physical development, learning difficulties, sensory deficits, and a higher risk of chronic diseases in adulthood (Gette et al., 2025). In addition**,** the importance of adequate nutrition from conception to two years of age has been widely recognized as a critical window for growth and development, commonly referred to as the "first 1,000 days" (WHO, 2013). Nutritional deficiencies during pregnancy and early life may have long-term consequences on health, growth, and human capital.

LBW mainly results from two biological mechanisms: prematurity and intrauterine growth restriction (IUGR). A clear understanding of the determinants of these mechanisms is essential for developing effective prevention strategies. Reducing the prevalence of LBW by 30% between 2012 and 2025 is one of the six global nutrition targets endorsed by the World Health Assembly (WHO, 2014). However, achieving this objective remains challenging, particularly in low- and middle-income countries. In Morocco, the prevalence of LBW remains relatively high, reaching 17.3% (Blencowe et al., 2019) , highlighting the need to better understand its underlying determinants, particularly maternal nutrition and socioeconomic factors.

Maternal diet during pregnancy plays a key role in foetal growth and pregnancy outcomes (Xue et al., 2024). Micronutrient deficiencies, particularly in iron, folates, zinc, calcium, and magnesium, have been associated with adverse outcomes, including LBW (Darmaun, 2020). Diet quality indices, such as the Nutrient Adequacy Ratio (NAR) and the Mean Adequacy Ratio (MAR), are widely used to assess nutrient adequacy in relation to recommended dietary intakes (El–Jamal et al., 2022). These indices provide a global and quantitative evaluation of diet quality and have been shown to be reliable indicators of maternal nutritional status (Sow et al., 2018). In Morocco, national strategies such as the National Nutrition Program have emphasized improving maternal nutrition and reducing micronutrient deficiencies (Ministry of Health, 2021). However, data linking dietary quality, biochemical status, and LBW remain limited (WHO, 2020).

The present study aims to compare the dietary quality and biochemical status of pregnant women delivering LBW newborns with those delivering normal-weight newborns in the province of El Jadida. Specifically, the study evaluates NAR and MAR indices, assesses selected biochemical parameters (haemoglobin, ferritin, C-reactive protein 'CRP', zinc, and magnesium), and examines their associations with maternal and nutritional characteristics.

## Material and methods

***Sampling***

The study was conducted at the maternity ward of El Jadida Provincial Hospital in the Casablanca-Settat region over a period from March 10, 2018 to December 31, 2019. This hospital represents a second-level public health structure serving both urban and rural populations. This analytical case-control study included 400 pregnant women recruited at the time of delivery. The sample size of 400 women (200 cases and 200 controls) with a 1:1 ratio was chosen to ensure a balanced comparison between groups and to provide sufficient statistical power to detect meaningful differences. Participants were divided into two groups: cases and controls:

- A control group including 200 women who delivered normal-weight newborns (2500–4000 g) (WHO, 2014).
- A case group including 200 women who delivered low-birth-weight (LBW) newborns (<2500 g) (WHO, 2014).

Participants were recruited consecutively among eligible women admitted for delivery during the study period, corresponding to a non-probability convenience sampling approach. Included in this study were all postpartum women who delivered live singleton newborns. Stillbirths, intrauterine foetal deaths, and multiple pregnancies were excluded. Dietary intake data were calculated using the BILNUT software (version 2.01, Nutrisoft, France).

***Information collection***

***Sociodemographic and gestational data***

Data were collected using a structured questionnaire, allowing the collection of information on sociodemographic characteristics and gestational factors.

***Nutritional assessment***

Dietary intake was evaluated using a semi-quantitative food frequency questionnaire administered to the participants to capture habitual food consumption patterns. The frequency of food intake was reported on a daily, weekly, or monthly basis, and portion sizes were estimated using standard household measures. Daily nutrient intake was calculated by multiplying the frequency of consumption of each food item by its corresponding nutrient composition (Michels & Willett, 2009).

Daily nutrient intake was calculated by combining consumption frequency and portion size with food composition data obtained from the Bilnut 2.01 SCDA Nutrisoft software, France. Total intake was further assessed using the 24-hour dietary recall method, conducted one day before childbirth to reflect recent intake while minimizing recall bias and potential dietary modifications due to labour-related symptoms such as nausea and vomiting. Nutrient values were verified and aligned with updated international food composition databases (FAO/CIQUAL) (Vincent et al., 2020) to improve accuracy and relevance.

***Diet quality indices (NAR/MAR)***

Diet quality was assessed using the Nutrient Adequacy Ratio (NAR) and the Mean Adequacy Ratio (MAR). The NAR was calculated for each nutrient (i) as the ratio of individual intake to the corresponding recommended nutrient intake (RNI) for pregnant women:

$$\text{NAR (i)} = \frac{\text{Intake of nutrient (i)}}{\text{Recommended intake of nutrient (i)}}$$

When NAR values exceeded 1.0, they were truncated to 1.0 to avoid overestimation, according to standard methodology (Waijers, Feskens & Ocke, 2007).

The Mean Adequacy Ratio (MAR) is an overall index used to assess the adequacy of dietary intake in relation to recommended nutritional requirements. It reflects the combined adequacy of multiple nutrients simultaneously. For each nutrient, the Nutrient Adequacy Ratio (NAR) is truncated at 1.0 when intake exceeds the recommended nutrient intake (RNI), in order to avoid overestimation, as described by (Hatløy, Torheim & Oshaug, 1998). The MAR is then calculated as the mean of these truncated NAR values.

$$\text{MAR} = \frac{\Sigma\ \text{NAR(i)}}{\text{Number of nutrients (n)}}$$

***Biochemical measurements***

Venous blood samples were collected before delivery using EDTA anticoagulant tubes and dry tubes. Haemoglobin was measured using a Sysmex XT-4000i analyser by the cyanmethemoglobin method, a reference method recommended by international standards (Yuan & Zhuang, 2024). Serum magnesium was determined using the xylidyl blue method on a DIRUI CS-1200 analyser (Barbour & Davidson, 1988). CRP was measured using immunoturbidimetry/nephelometry methods (De & Gogate, 1996). Serum ferritin was determined by spectrophotometry, and serum zinc was measured using the colorimetric Bromo-PAPS method (Makino, 1991). The determination of serum ferritin was carried out by turbidimetry; the concentration of ferritin (SF) is determined by spectrophotometry at the wavelength of 540 nm (Zwart et al., 1996). The dosage of zinc is made by the colorimetric method of Makino (1991) based on the interaction of zinc with BROMO-PAPS in an alkaline medium and the resulting coloured complex is measured spectrophotometrically at a wavelength of 560 nm (Makino, 1991).

***Anthropometric measurements***

Maternal weight and height were measured at admission before delivery using standardized procedures. Body mass index (BMI) was calculated as weight (kg) divided by height squared ($m^2$). Given the known limitations of BMI interpretation during pregnancy, BMI was used for descriptive purposes only and interpreted with caution (WHO, 2018).

***Ethical considerations***

The study received approval from the Moroccan Ministry of Health ethics committee on March 8, 2018 (approval number 1934). All participants provided free and informed consent after receiving detailed information about the study objectives and procedures. Participation was voluntary, and women were free to withdraw at any time.

***Statistical analysis***

Data were entered and checked for completeness and consistency using Microsoft Excel. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). Categorical variables were summarized as frequencies and percentages and compared using Pearson's chi-square test; Fisher's exact test was used when expected cell counts were small. Continuous variables are presented as mean ± standard error (SE). Comparisons between cases and controls were performed using the independent-samples t-test, with Welch's correction when the assumption of equal variances was not met. One-way analysis of variance (ANOVA) was used for comparisons involving more than two groups. When the overall ANOVA indicated a statistically significant difference among groups, post-hoc pairwise comparisons were performed to identify the groups responsible for the observed difference. Tukey's Honestly Significant Difference (HSD) test was used when the assumption of homogeneity of variances was satisfied, whereas the Games–Howell test was applied when this assumption was violated. In Table 6, different superscript letters indicate statistically significant pairwise differences between groups, whereas groups sharing at least one common superscript letter are not significantly different. Linear associations between continuous variables were assessed using Pearson's correlation coefficient. All statistical tests were two-sided, and a p-value <0.05 was considered statistically significant.

## Results

The socio-demographic and anthropometric characteristics of the study population are presented in Table 1. The mean age of women was similar between controls and cases (25.78 ± 0.40 years vs. 26.13 ± 0.43 years; p=0.315). Maternal weight did not differ significantly between groups (73.91 ± 0.55 kg vs 67.41 ± 0.53 kg; p=0.328), whereas maternal height was significantly lower in cases than in controls (1.600 ± 0.002 m vs. 1.630 ± 0.003 m; p <0.001). Significant differences were also observed in BMI distribution (p <0.001), with a higher proportion of normal BMI among cases and a lower prevalence of obesity compared to controls. Mean fundal height was significantly lower in cases than in controls (25.69 ± 0.13 vs. 31.83 ± 0.06 cm; p <0.001). Mean fundal height was significantly lower in cases than in controls (25.69 ± 0.13 vs. 31.83 ± 0.06 cm; p <0.001). Most LBW cases were associated with preterm birth, whereas all controls delivered at term.

Socioeconomic characteristics indicated greater vulnerability among cases, with a higher proportion of rural residence (84% vs. 77.5%), lower educational attainment, larger household size (5.53 ± 0.18 vs. 4.40 ± 0.15 persons per household; p=0.004), and a higher proportion of low-income households (77.5% vs. 54%; p <0.001). Primiparity was more frequent among cases than controls (56.5% vs. 45.5%; p=0.036).

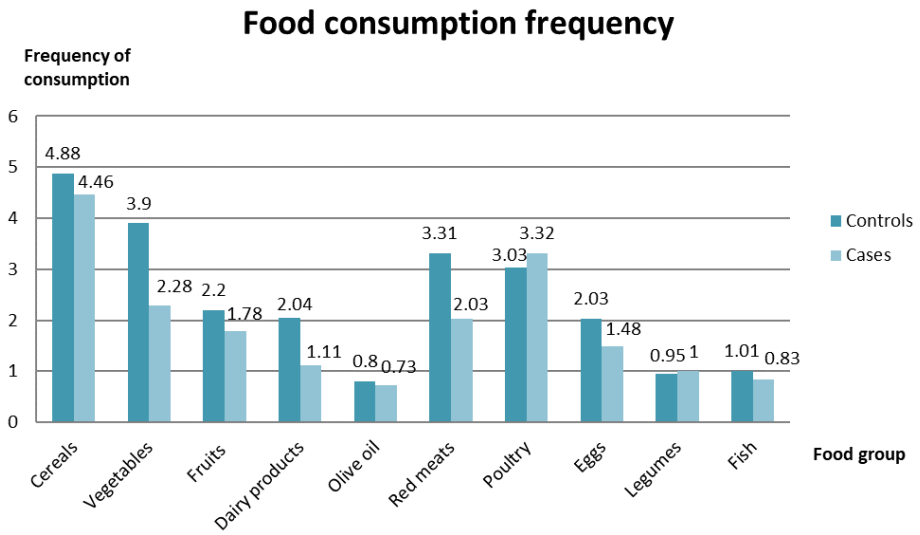


**Figure 1.** Mean consumption frequency of food groups in controls and cases.

**Table 1.** Socio-demographic and obstetrical characteristics of the study population.

| Socio-demographic characteristics n(%) | Controls (n=200) | Cases (n=200) | p-value |
|---|---|---|---|
| **Age of women (years)*** | 25.78±0.40 | 26.13±0.43 | 0.315 |
| **Age range** | | | |
| <18 years old | 11(5.5) | 20(10) | |
| 18-35 years old | 170(85) | 148(74) | **0.024** |
| ≥35 years old | 19(9.5) | 32(16) | |
| **Residence** | | | |
| Urban | 45(22.5) | 32(16) | 0.128 |
| Rural | 155(77.5) | 168(84) | |
| **Level of studies** | | | |
| No formal education | 99(49.5) | 122(61) | |
| Primary education | 56(28) | 47(23.5) | **0.029** |
| Secondary education | 33(16.5) | 28(14) | |
| Tertiary education | 12(6) | 3(1.5) | |
| **Mean (mean ± SE) family size*** | 4.40±0.15 | 5.53±0.18 | **0.004** |
| **Household size (number of members)** | | | |
| <6 | 148(74) | 100(50) | |
| 6 – 9 | 36(18) | 72(36) | **< 0.001** |
| >9 | 16(8) | 28(14) | |
| **Monthly income level (Moroccan Dirham, MAD)** | | | |
| Low (<3000 DH) | 108(54) | 155(77.5) | |
| Medium (3000 – 5000 DH) | 74(37) | 36(18) | **<0.001** |
| High (≥5000 DH) | 18(9) | 9(4.5) | |
| **Women's FH (mean ± ES) (cm)*** | 31.83±0.06 | 25.69±0.13 | **<0.001** |
| **Women's parity** | | | |
| Primiparous | 91(45.5) | 113(56.5) | **0.036** |
| Multipara | 113(54.5) | 87(43.5) | |
| **Anthropometric characteristics*** | | | |
| Weight (mean ± ES) of women (kg) | 73.91±0.55 | 67.41±0.53 | 0.328 |
| Height (mean ± ES) of women (m) | 1.63±0.003 | 1.60±0.002 | **<0.001** |
| **BMI classes** | | | |
| Normal weight | 32(16) | 75(37.5) | |
| Overweight | 110(55) | 100(50) | **< 0.001** |
| Obesity | 58(29) | 25(12.5) | |

n(%): Number/percentage; SE: Standard error; BMI: Body Mass Index; DH: Dirhams; FH: Fundal Height Index; Chi2 test; student test for independent samples. *: asterisk denotes data expressed as mean ± SE.

As illustrated in Figure 1, the frequency of consumption of most food groups was higher among controls than among cases, particularly for vegetables, fruits, dairy products, and red meats. Cereals were the most frequently consumed food group in both groups. In contrast, poultry consumption was slightly higher among cases, while legumes and fish were consumed less frequently in both groups. Overall, these findings

suggest a less diverse and less frequent consumption of nutrient-rich foods among women who delivered LBW newborns.

As shown in Table 2, the daily consumption of most food categories was higher among controls than among cases. The analysis of the different types of food consumed per day in the controls and the cases shows a high respective consumption of cereals (548.66 vs. 494.08 g/day), dairy products (132.20 vs. 76.48 g/day), fruits (219.68 vs. 143.46 g/day) and vegetables (366.96 vs. 272.78 g/day). Statistically significant between-group differences were observed for eggs, fish, and oleaginous products, with higher consumption among controls than among cases: eggs (32.81 ± 1.49 vs. 24.02 ± 1.21 g/day; p <0.001), fish (50.07 ± 1.86 vs. 32.25 ± 1.27 g/day; p <0.001), and oleaginous products (49.96 ± 1.08 vs. 46.40 ± 1.17 g/day; p=0.027). Legume consumption did not differ significantly between controls and cases (29.40 ± 1.37 vs. 28.71 ± 0.84 g/day; p =0.666).

**Table 2.** Overall food and tea consumption by category among cases and controls.

| Categories of food consumed (g/day) | Total population (n=400) | Controls (n=200) | Cases (n=200) | p-value |
|---|---|---|---|---|
| **Cereals** | 521.37 ± 5.44 | 548.66 ± 8.76 | 494.08 ± 5.89 | **<0.001** |
| **Vegetables** | 319.87 ± 4.74 | 366.96 ± 6.80 | 272.78 ± 4.65 | **0.002** |
| **Fruits** | 181.57 ± 4.13 | 219.68 ± 5.87 | 143.46 ± 4.40 | **0.028** |
| **Dairy products** | 104.34 ± 2.87 | 132.20 ± 3.93 | 76.48 ± 3.14 | 0.097 |
| **Oil seed products** | 48.17 ± 0.80 | 49.95 ± 1.08 | 46.40 ± 1.17 | **0.026** |
| **Red meats** | 41.64 ± 1.01 | 48.68 ± 1.40 | 34.60 ± 1.28 | 0.077 |
| **Fish** | 41.15 ± 1.20 | 50.06 ± 1.85 | 32.25 ± 1.27 | **0.004** |
| **Poultry** | 35.63 ± 0.81 | 35.41 ± 1.22 | 35.86 ± 1.07 | 0.818 |
| **Legumes** | 29.05 ± 0.80 | 29.40 ± 1.36 | 28.71 ± 0.83 | **0.001** |
| **Eggs** | 28.50 ± 0.98 | 32.80 ± 1.48 | 24.02 ± 1.21 | **< 0.001** |
| **Tea (glasses/day)** | 2.54 ± 0.05 | 2.02 ± 0.05 | 3.06 ± 0.06 | 0.862 |

Student test for independent sample; p<0.05.

**Table 3.** Comparison of Mean MAR and NAR values among cases, controls, and the general population.

| Energy and nutrients | Controls (n=200) (Mean ±SE) | Cases (n=200) (Mean ±SE) | General population (n=400) (Mean ±SE) | p-value |
|---|---|---|---|---|
| **MAR** | 0.84±0.004 | 0.70±0.004 | 0.77±0.004 | **0.041** |
| **NAR Energy** | 1.04±0.02 | 0.95±0.01 | 0.99±0.01 | **<0.001** |
| **NAR Proteins** | 1.50±0.07 | 1.30±0.05 | 1.4±0.06 | **0.001** |
| **NAR Carbohydrates** | 1.93±0.04 | 1.82±0.03 | 1.87±0.03 | 0.05 |
| **NAR vit. B1** | 1.01±0.02 | 0.53±0.01 | 0.77±0.01 | **<0.001** |
| **NAR vit. C** | 1.30±0.04 | 0.63±0.02 | 0.96±0.03 | **<0.001** |
| **NAR vit. E** | 1.30±0.01 | 0.93±0.01 | 1.11±0.01 | **<0.001** |
| **NAR Phosphorus** | 2.42±0.04 | 1.55±0.05 | 1.98±0.04 | **0.011** |
| **NAR Calcium** | 0.60±0.02 | 0.34±0.01 | 0.47±0.01 | **<0.001** |
| **NAR Iron** | 0.66±0.01 | 0.50±0.01 | 0.58±0.01 | **<0.001** |
| **NAR Folate** | 0.68±0.011 | 0.48±0.009 | 0.58±0.01 | 0.103 |
| **NAR Magnesium** | 1.31±0.02 | 0.93±0.02 | 1.12±0.02 | **0.001** |
| **NAR Zinc** | 0.81±0.01 | 0.77±0.01 | 0.79±0.01 | 0.09 |

n: Number; SE: Standard error; vit.: Vitamin; Student test for independent sample; p<0.05.

Diet quality indices (Table 3) showed that the Mean Adequacy Ratio (MAR) was significantly higher in controls than in cases (0.840 ± 0.004 vs. 0.700 ± 0.004; p=0.041), indicating better overall dietary adequacy. In both groups, the lowest Nutrient Adequacy Ratio (NAR) values were observed for calcium, iron, and folates, with consistently lower values in cases.

Biochemical parameters (Table 4) revealed significantly lower haemoglobin and ferritin levels in cases compared to controls (p <0.05), along with higher CRP levels (p <0.001). No significant difference was observed in magnesium levels (p=0.286).

**Table 4.** Comparison of biochemical analyses of cases and controls.

| Biochemical analyses | Controls (n=200) (Mean ± SE) | Cases (n=200) (Mean ± SE) | p-value |
|---|---|---|---|
| **Haemoglobin (g/dL)** | 11.49±0.09 | 9.85±0.07 | **0.015** |
| **Ferritin (µg/L)** | 23.14±0.51 | 11.19±0.33 | < **0.001** |
| **CRP (mg/L)** | 3.71±0.66 | 10.08±0.98 | < **0.001** |
| **Magnesium (mg/dL)** | 19.79±0.18 | 19.17±0.18 | 0.286 |
| **Zinc (µmol/L)** | 12.04±0.10 | 11.48±0.08 | < **0.001** |

n: Number; SE: Standard Error; student test for independent samples; p<0.05

**Table 5.** Correlation of biochemical measurements with maternal characteristics, food groups, and MAR/NAR values in cases (n=200) and controls (n=200).

| Biochemical measurements | Hb (g/dL) | | SF (µg/L) | | Zn (µmol/L) | | Mg (mg/dL) | |
|---|---|---|---|---|---|---|---|---|
| | Controls | Cases | Controls | Cases | Controls | Cases | Controls | Cases |
| **Characteristics of mothers** | | | | | | | | |
| Gestational age | **0.222**** | **0.222**** | -0.022 | **0.070*** | 0.019 | -0.016 | -0.013 | -0.003 |
| Female weight | -0.109 | 0.032 | 0.006 | **0.191*** | -0.012 | -0.015 | 0.083 | 0.082 |
| BMI | -0.046 | 0.049 | 0.017 | **0.183**** | 0.03 | -0.049 | 0.05 | 0.085 |
| **Categories of food consumed (g/day) and tea (glasses/day)** | | | | | | | | |
| Cereals | -0.055 | 0.042 | **0.185*** | 0.05 | -0.019 | 0.044 | -0.038 | **0.214**** |
| Red meats | -0.015 | -0.022 | 0.039 | -0.013 | **0.226**** | **0.218**** | **0.199**** | 0.013 |
| Eggs | -0.064 | -0.005 | **-0.148*** | -0.051 | **0.248**** | **0.172*** | 0.063 | 0.056 |
| Fish | -0.021 | -0.054 | 0.043 | -0.028 | 0.03 | 0.038 | **0.215**** | 0.097 |
| Fruits | 0.016 | -0.133 | 0.05 | -0.087 | 0.072 | -0.122 | **0.145*** | **0.140*** |
| Tea | -0.003 | **-0.153*** | -0.057 | **-0.152*** | -0.051 | -0.003 | -0.048 | -0.066 |
| **Energy and nutrient supply** | | | | | | | | |
| MAR | **0.183**** | 0.041 | **0.267**** | -0.103 | 0.007 | **0.145*** | 0.128 | 0.06 |
| NAR Energy | 0.027 | 0.01 | 0 | -0.008 | -0.048 | 0.033 | -0.137 | **0.145*** |
| NAR Vit. B1 | 0.051 | 0.119 | 0.113 | -0.076 | -0.105 | 0.057 | **0.170*** | -0.001 |
| NAR Phosphorus | 0.046 | 0.001 | -0.029 | 0.074 | 0.039 | 0.068 | -0.008 | **-0.165*** |
| NAR Iron | **0.147*** | 0.032 | **0.394**** | 0.024 | 0.101 | 0.136 | 0.05 | -0.044 |
| NAR Magnesium | -0.046 | -0.021 | **-0.145*** | 0.055 | 0.008 | 0.021 | 0.061 | -0.073 |
| NAR Zinc | **0.338**** | -0.044 | **0.291**** | **-0.159*** | 0.13 | 0.105 | 0.075 | **0.150*** |
| NAR vit. C | 0.039 | 0.061 | **0.179*** | -0.121 | -0.1 | 0.043 | 0.059 | 0.035 |

Hb: Haemoglobin; SF: Serum ferritin; Zn: Zinc; Mg: Magnesium; BMI: Body Mass Index; vit.: Vitamin; Pearson correlation; *p<0.05; ** p<0.01.

Several statistically significant correlations were identified in Table 5 between biochemical parameters, maternal characteristics, and dietary variables. In controls, serum ferritin was positively correlated with cereal intake (r = 0.185; p <0.05) and negatively correlated with egg consumption (r = -0.148; p <0.05). Magnesium levels were positively correlated with red meat (r=0.199), fish (r=0.215), and fruit consumption (r=0.145). In cases, tea consumption was negatively correlated with haemoglobin (r=-0.153) and ferritin levels (r=-0.152). Zinc levels were positively associated with red meat and egg consumption in both groups.

As shown in Table 6, among cases, haemoglobin concentrations differed significantly according to the stage of iron supplementation initiation (ANOVA, p <0.001), with higher mean haemoglobin levels observed in women who initiated supplementation in the first trimester (10.60 ± 0.21 g/dL) than in those who initiated supplementation in the third trimester (9.12 ± 0.12 g/dL). Regarding supplementation pattern, mean haemoglobin and ferritin concentrations were numerically higher in women receiving continuous iron supplementation than in those receiving intermittent supplementation; however, these differences were not statistically significant (p=0.93 and p=0.08, respectively).

**Table 6.** Haemoglobin and ferritin levels according to supplementation stage and pattern among controls and cases.

| Administration of supplementation | Controls (n=200) | | | | | Cases (n=200) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | Hb (g/dL) (mean±SE) | P-value | SF (µg/L) (mean±SE) | p-value | n | Hb (g/dL) (mean±SE) | p-value | SF (µg/L) (mean±SE) | p-value |
| **Supplementation stage** | | | | | | | | | | |
| No supplementation | 97 | 11.40±0.14$^{a}$ | **< 0.001** | 22.94±1.26$^{ab}$ | **0.011** | 102 | 9.85±0.11$^{a}$ | **< 0.001** | 10.52±0.42$^{b}$ | **0.001** |
| 1st trimester | 38 | 11.92±0.18$^{a}$ | | 27.61±1.84$^{a}$ | | 34 | 10.60±0.21$^{a}$ | | 14.19±0.94$^{a}$ | |
| 2nd trimester | 45 | 11.74±0.13$^{a}$ | | 23.04±1.43$^{ab}$ | | 25 | 9.98±0.12$^{a}$ | | 11.12±0.72$^{ab}$ | |
| 3rd trimester | 20 | 10.52±0.34$^{b}$ | | 16.85±2.80$^{b}$ | | 39 | 9.12±0.12$^{b}$ | | 10.40±0.77$^{b}$ | |
| **Nature of supplementation** | | | | | | | | | | |
| Keep on going | 61 | 11.73±0.15 | 0.498 | 26.07±1.36 | 0.154 | 27 | 10±0.20 | 0.93 | 14.19±0.94 | **0.08** |
| Intermittent | 42 | 11.34±0.19 | | 19.82±1.80 | | 71 | 9.80±0.13 | | 11.12±0.72 | |

n: Number; SE: Standard Error; Hb: Haemoglobin; SF: Ferritin; One-way ANOVA followed by Tukey's HSD post-hoc test was used for comparisons across iron supplementation stages. The independent-samples Student's t-test was used for comparisons according to supplementation pattern. Different superscript letters indicate statistically significant differences between groups, whereas groups sharing at least one common superscript letter are not significantly different. A p-value <0.05 was considered statistically significant.

## Discussion

This study highlights the multifactorial nature of low birth weight (LBW), involving the combined effects of maternal nutritional inadequacy, haematological status, and socioeconomic vulnerability. The socioeconomic disparities observed between cases and controls are consistent with recent studies showing that low maternal education, limited income, and poor living conditions are major determinants of adverse pregnancy outcomes, including LBW (Thomson et al., 2021; Simoncic et al., 2022). These factors may reduce access to adequate nutrition and prenatal care, thereby increasing the risk of foetal growth restriction (Aga & Woldeamanuel, 2025).

Maternal anthropometric indicators, particularly BMI, did not provide meaningful discrimination between groups. This finding aligns with previous studies suggesting that BMI during pregnancy has limited interpretability due to physiological changes such as gestational weight gain and fluid retention (Deputy et al., 2015; WHO, 2018).

Dietary assessment showed that pregnant women who delivered LBW newborns had poorer dietary adequacy, particularly for key micronutrients such as iron, calcium, and folates. Similar findings have been reported in a Cochrane systematic review

including pregnant women from low- and middle-income countries, which highlighted the importance of adequate micronutrient intake during pregnancy (Keats et al., 2019). The significantly lower MAR observed in cases reflects insufficient overall diet quality, which is consistent with previous research indicating that inadequate maternal nutrition is strongly associated with impaired foetal growth and LBW (Karimi et al., 2022; Islam et al., 2023).

One of the most important findings of this study is the higher prevalence of anaemia among cases. Similarly, Belete et al. (2025), in a systematic review and meta-analysis including 21 studies and 51,923 pregnant women from seven sub-Saharan African countries, reported that maternal anaemia was significantly associated with an increased risk of low birth weight, with anaemic women being more than three times as likely to deliver LBW newborns compared with non-anaemic women (OR = 3.37; 95% CI: 2.66-4.27). These findings further support the hypothesis that maternal anaemia is an important determinant of adverse birth outcomes and may represent a key biological pathway linking poor maternal nutritional status to low birth weight.

Tea consumption, although weakly correlated with haemoglobin and ferritin levels, remains biologically plausible. Polyphenols contained in tea are known to inhibit non-haem iron absorption, which may contribute to iron deficiency in populations with already low dietary iron intake (Piskin et al., 2022). However, given the low magnitude of the correlations observed in this study, these findings should be interpreted cautiously (Akoglu, 2018). Early initiation and regular iron supplementation were associated with improved haematological parameters. This finding is consistent with recent studies highlighting the importance of early supplementation in reducing anaemia and improving pregnancy outcomes (Díaz-Torres, Díaz-López & Arija, 2024). These results emphasize that both timing and adherence are critical components of effective maternal health interventions.

In contrast, the role of other micronutrients such as zinc and magnesium remains less clear in this study. Although deficiencies were observed, no significant association with LBW was identified. Similar inconsistencies have been reported in the literature, suggesting that the independent contribution of these micronutrients may be limited or influenced by confounding factors (Oh, Keats & Bhutta, 2020; Ren et al., 2023).

Overall, these findings confirm that LBW is driven by a complex interaction of nutritional, biological, and socioeconomic determinants. This highlights the need for integrated strategies combining nutritional interventions, early supplementation of iron, and improved socioeconomic conditions (Victora et al., 2021).

## Limitations of the Study

This study has several limitations. First, its case-control design does not allow causal inference. Second, dietary intake was assessed using self-reported methods, which may be subject to recall bias. Moreover, data collection during late pregnancy, a period often accompanied by anxiety and fatigue, may have affected the accuracy of participants' dietary reporting. Third, the study population was hospital-based, which may limit the generalizability of the findings. In addition, the observed socioeconomic differences between groups may introduce residual confounding. Finally, most observed correlations were weak, limiting the strength of the associations.

## Strengths of the Study

Despite these limitations, the study has several strengths, including a relatively large sample size, the use of both dietary and biochemical assessments, and the focus on a relevant public health issue in Morocco. The case-control design also enabled an efficient comparison of maternal characteristics and dietary exposures between women who delivered LBW newborns and controls. The relatively large sample size may have provided sufficient statistical power to detect significant between-group differences; however, population representativeness depends primarily on the sampling and recruitment procedures rather than on sample size alone.

## Conclusion

This study demonstrates that low birth weight (LBW) is significantly associated with poor maternal dietary adequacy, impaired iron-related biomarkers, and unfavourable socioeconomic conditions. Women who delivered LBW newborns exhibited lower diet

quality, particularly for key micronutrients such as iron, calcium, and folates, along with a higher prevalence of anaemia. Although pregnant women receiving early and regular iron supplementation tended to show higher haemoglobin and ferritin levels, these differences were not statistically significant. Therefore, the potential benefits of iron supplementation on haematological status should be interpreted with caution and warrant further investigation.

These results emphasize the need for integrated maternal health strategies, including early nutritional screening, improved dietary counselling, and targeted interventions for vulnerable populations. Strengthening prenatal care with a focus on nutrition and anaemia prevention may contribute to reducing the burden of LBW in similar settings.

## Perspectives of the Study

Future studies should include a more socioeconomically diverse population, particularly pregnant women with higher educational and income levels, and should recruit participants from both public and private healthcare facilities. Such an approach would improve the representativeness of the study population and allow a more comprehensive assessment of the independent determinants of low birth weight. In addition, multivariate analyses, longitudinal prospective cohort studies, and intervention studies are needed to clarify causal relationships and evaluate the impact of maternal diet quality and nutritional interventions on birth outcomes.

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