https://doi.org/10.35845/kmuj.2026.24055

ORIGINAL ARTICLE

# Comparison of iron, zinc and ferritin among the mothers of small for gestational age and appropriate for gestational age: a case control study

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**Date Submitted:** May 29, 2025

**Date Revised:** February 18, 2026

**Date Accepted:** February 22, 2026

## ABSTRACT

**Objective:** To evaluate and compare the nutritional status of mothers of small for gestational age (SGA) and appropriate for gestational age (AGA) infants by assessing dietary intake and biochemical parameters, including serum iron, ferritin, and zinc levels.

**Methods:** This case-control study was conducted from October 2020 to June 2021 in tertiary care hospitals of Peshawar, Pakistan. Eighty postnatal mothers (40 SGA; 40 AGA), aged 15-35 years with singleton pregnancies, were enrolled. Socio-demographic, socioeconomic, and reproductive data were collected using structured questionnaires. Dietary intake was assessed through 24-hour recall and analyzed using WinDiet® software adapted for local foods. Anthropometric measurements were recorded for BMI calculation. Hemoglobin, serum iron, ferritin, and zinc levels were measured using standardized laboratory techniques. Data were analyzed using SPSS version 20.

**Results:** Among 80 mothers (Mean age: 24.75±5.06 years), 40% had a normal BMI. Maternal age and BMI did not differ significantly between groups; however, SGA mothers were significantly shorter and had lower pregnancy weight gain and fewer antenatal visits ($p<0.01$). Anemia was present in 48.8% of mothers, with iron deficiency observed in 50% and zinc deficiency in 37.5%, but no significant differences in biochemical parameters were found between groups. Dietary analysis revealed significantly lower energy, macronutrient, mineral (iron, zinc, calcium, magnesium, iodine), and vitamin intake among SGA mothers ($p<0.05$).

**Conclusion:** Although biochemical micronutrient levels were comparable, mothers of SGA infants had significantly poorer dietary intake. Maternal nutritional inadequacy may contribute to impaired fetal growth, emphasizing the need for strengthened antenatal nutritional interventions.

**Keywords:** Infant (MeSH); Infant, Small for Gestational Age (MeSH); Birth Weight (MeSH); Gestational Age (MeSH); Appropriate for gestational age (Non-MeSH); Nutritional Status (MeSH);Maternal nutritional status (Non-MeSH); Nutrients (MeSH); Iron (MeSH); Zinc (MeSH); Ferritins (MeSH).

**THIS ARTICLE MAY BE CITED AS:** Khan N, Fatima S, Nazli R, Haider J, Shams F. Comparison of iron, zinc and ferritin among the mothers of small for gestational age and appropriate for gestational age: a case control study. Khyber Med Univ J 2026;18(1):53-60. https://doi.org/10.35845/kmuj.2026.24055

## INTRODUCTION

Small for Gestational Age (SGA) is a crucial indicator of fetal health assessment during pregnancy. It implies that a fetus or newborn falls below the expected size range for their gestational age.[1] SGA is defined as, a baby having weight less than the 10th percentile for their gestational age, a maternal fundal height measurement less than 2.5cm from standard, or a birth weight under 2.5 kg (2500 grams) just after birth. [2,3] SGA infants are at a high risk of perinatal morbidity and mortality.[4] The risk factors for SGA are diverse and cover both maternal characteristics as well as pregnancy related complications. Maternal risk factors include short stature, low maternal weight, body mass index (BMI) <20kg/m,[2] poor socioeconomic status, poor nutrition, Asian ethnicity, and maternal history of being born SGA. Other factors like obesity, nulliparity, substance abuse (e.g., cocaine or cigarette smoking), stress (anxiety and depression), maternal medical conditions like chronic hypertension and diabetes are mainly associated with SGA.[5,6] Additionally, risk factors that develop during pregnancy are heavy bleeding in first trimester, placental abruption, placenta previa, hyperemesis, and eclampsia or pre-eclampsia, all contribute to the risk of SGA.[7] However, the consequences of SGA extend well beyond the neonatal period. SGA infants are at a high risk of experiencing long-term adverse outcomes, including neurocognitive impairment, behavioral issues, obesity, diabetes, hypertension, and cardiovascular diseases.[8,9]

Globally, over 30 million infants are born SGA, with a high prevalence in low- and middle-income countries (LMICs). South Asia accounts for about 34% of SGA cases. However, it is documented that majority of the SGA infants are born in India, Pakistan, Nigeria, and Bangladesh. [10,11] In Pakistan, 3-10% of pregnancies result in SGA fetuses.Bano R, et al., reported about 11.98% prevalence in Karachi, Pakistan.[12] Such a high prevalence emphasizes the urgent need for a comprehensive understanding of SGA and its determinants, especially in LMICs. Despite its significant public health impact, research exploring the determinants of SGA remains limited in LMICs, largely due to challenges in obtaining accurate gestational age assessment and reliable maternal data. Although some studies have reported the frequency of SGA in Pakistan, evidence regarding the nutritional status of mothers delivering SGA infants is scarce. To address this gap, the present study was conducted to investigate the nutritional status of mothers of SGA and appropriate for gestational age (AGA) newborns by assessing serum zinc, iron, and ferritin levels, aiming to clarify potential nutritional contributions to impaired fetal growth.

## METHODS

This study employed a case-control design, enrolling a total of 80 participants through purposive sampling technique, including 40 cases (mothers of small for gestational age infants) and 40 controls (mothers of appropriate for gestational age infants). Participants were recruited from tertiary care hospitals in Peshawar, Khyber Pakhtunkhwa, Pakistan, between October 2020 and June 2021. Healthy mothers aged 15-35 years with singleton pregnancy were included in the study while mothers with chronic or acute medical conditions (such as diabetes, hypertension, infectious or systemic diseases), multiple gestations (twins or higher-order pregnancies), and pregnancy-related complications that could independently affect fetal growth were excluded from the study.

Ethical approval was taken from the ethical review board of Khyber Medical University (KMU) Peshawar, under: ASRB001241/CI/IBMS and Advanced Study and Research Board (AS&RB) under: DIR/KMU-AS&RB/CI/001141. Informed consent was obtained from willing participants after clarifying study objectives. Socio-demographic and reproductive data was collected through predesigned questionnaires, while anthropometric measurements (height and weight) were taken for BMI calculation. Nutrient intake analysis was performed using WinDiet® software utilizing a nutrient composition database adapted for regional food items. Local recipes and commonly consumed Pakistani foods were manually incorporated into the database, and portion sizes were standardized using household measurement tools and gram-weight conversions for accurate nutrient quantification.

Blood sample (5mL) was aseptically collected from each participant by using disposable syringes. Blood was separated into EDTA and Gel vacutainers for complete blood count (CBC) and serum iron, ferritin, and zinc analysis, respectively.

CBC was done using an Automated Hematology Analyzer (Model Sysmex XN-350). Serum ferritin was analyzed through Enzyme-linked Immunoassay (ELISA) using a commercial kit (CALBIOTECH) based on sandwich ELISA. Serum iron was analyzed using an Iron Ferrozine kit from TERSACO Company, based on colorimetric techniques, with readings obtained at 562 nm using a Microlab 300 spectrometer. Serum zinc levels were measured using a Zinc 5-Br-PAPS kit from DIALAB Company, with colorimetric analysis conducted at 560 nm on a KenzaOne Automatic

**Table I: Comparison of socio-demographic data of SGA and AGA mothers**

| Parameters | | Total N=80% | SGA N=40% | AGA N=40% | p-value |
|---|---|---|---|---|---|
| Age Groups (Year) | <20 | 18(22.5) | 9 (22.5) | 9 (22.5) | 0.71 |
| | 21-25 | 32 (40.0) | 15 (37.5) | 17 (42.5) | |
| | 26-30 | 22 (27.5) | 13 (32.5) | 9 (22.5) | |
| | >30 | 8 (10.0) | 3 (7.5) | 5 (12.5) | |
| BMI (kg/m$^2$) | Underweight (<18) | 2 (2.5) | 2 (5) | 0 (0) | 0.12 |
| | Normal (18.5-24.9) | 32 (40) | 12 (30) | 20 (50) | |
| | Overweight (25.0-29.9) | 26 (32.5) | 13 (32.5) | 13 (32.5) | |
| | Obese (>30) | 20 (25) | 13 (32.5) | 7 (17.5) | |
| Maternal Education | Educated | 27 (33.8) | 11 (27.5) | 16 (40) | 0.24 |
| | Uneducated | 53 (66.3) | 29 (72.5) | 24 (60) | |
| Husband Occupation | Unemployed | 5 (6.3) | 4 (10) | 1 (2.5) | 0.05 |
| | Salaried | 25 (31.25) | 8 (20) | 17 (42.5) | |
| | Self employed | 50 (62.5) | 28 (70) | 22 (55) | |
| Socioeconomic Status | Low income | 63 (78.8) | 35 (87.5) | 28 (70) | 0.05 |
| | Middle income | 17 (21.3) | 5 (12.5) | 12 (30) | |
| Family System | Nuclear Family | 27 (33.8) | 16 (40) | 11 (27.5) | 0.34 |
| | Joint Family | 53 (66.3) | 24 (60) | 29 (72.5) | |
| Number of Children | ≤3 | 50 (62.5) | 24 (60) | 26 (65) | 0.64 |
| | >3 | 30 (37.5) | 16 (40) | 14 (35) | |
| Child Ordinal Position | ≤3 | 50 (62.5) | 24 (60) | 14 (35) | 0.64 |
| | >3 | 30 (37.5) | 16 (40) | 26 (65) | |
| Newborn Gender | Male | 44 (55) | 18 (45) | 26 (65) | 0.07 |
| | Female | 36 (45) | 22 (55) | 14 (35) | |
| Smoking | Smoking/Passive smoking | 25 (31.25) | 17 (68) | 8 (32) | 0.03* |
| | No Smoking | 55 (68.75) | 23 (41.8) | 32 (58.2) | |

Significant difference: *p< 0.05; SGA: Small for Gestational Age; AGA: Appropriate for Gestational Age

**Table II: Comparison of anthropometric data for SGA and AGA mothers**

| Parameters | Total (n=80) | SGA (n=40) | AGA (n=40) | p-value |
|---|---|---|---|---|
| Age (years) | 24.75±5.06 | 24.65±4.85 | 24.85±5.32 | 0.86 |
| Height (meters) | 1.53±0.13 | 1.49±0.13 | 1.57±0.12 | 0.009** |
| Weight (kg) | 62.33±12.0 | 61.45±11.86 | 63.20±12.28 | 0.51 |
| BMI (kg/m$^2$) | 26.8±6.14 | 27.94±6.84 | 25.68±5.18 | 0.10 |
| Baby Weight (kg) | 2.72±0.77 | 2.12±0.28 | 3.32±0.61 | <0.001*** |

Values are expressed as Mean±SD. Significant difference: ***p<0.001, **p<0.01; SGA: Small for Gestational Age; AGA: Appropriate for Gestational Age

**Table III: Comparison of reproductive history of SGA and AGA mothers**

| Parameters | | Total [n=80, f (%) | SGA [n=40, f (%) | AGA [n=40, f (%) | p-value |
|---|---|---|---|---|---|
| Gap During Pregnancies (Years) | <1.5 | 35 (43.8) | 20 (51.7) | 15 (42.9) | 0.28 |
| | >1.5 | 35 (43.8) | 14 (40) | 20 (60) | |
| | No Gap | 10 (12.5) | 6 (60) | 4 (40) | |
| Previous SGA History | Yes | 28 (35) | 23 (82.1) | 5 (17.9) | <0.001*** |
| | No | 52 (65) | 17 (32.7) | 35 (67.3) | |
| Parity | Primi (1) | 14 (17.5) | 9 (64.3) | 5 (35.7) | 0.24 |
| | Multi (>1) | 66 (82.5) | 31 (47) | 35 (53) | |
| Gravidity | Primi (1) | 10 (12.5) | 6 (60) | 4 (40) | 0.5 |
| | Multi (>1) | 70 (87.5) | 34 (48.6) | 36 (51.4) | |
| Abortion | Yes | 33 (41.3) | 19 (57.6) | 14 (42.4) | 0.26 |
| | No | 47 (58.8) | 21 (44.7) | 26 (55.3) | |
| Antenatal visits | No visit | 15 (18.8) | 10 (66.7) | 5 (33.3) | 0.003** |
| | ≤3 | 32 (40) | 21 (65.6) | 11 (34.4) | |
| | >3 | 33 (41.3) | 9 (27.3) | 24 (72.7) | |

Significant difference: **p<0.01, ***p<0.001; SGA: Small for Gestational Age; AGA: Appropriate for Gestational Age

**Table IV: Comparison of biochemical parameters of SGA and AGA mothers**

| Parameters | Total (n=80) | SGA (n=40) | AGA (n=40) | p-value |
|---|---|---|---|---|
| Hemoglobin (g/dL) | 11.8±1.50 | 11.9±1.59 | 11.8±1.44 | 0.84 |
| Serum Ferritin (ng/mL) | 21.45 (40.78) | 24.45 (36.55) | 17.7 (47.20) | 0.61 |
| Serum Iron (µg/dL) | 60.50 (52) | 57 (54) | 68.5 (52) | 0.58 |
| Serum Zinc (µg/dL) | 60 (7) | 60 (5) | 62 (12) | 0.22 |

SGA: Small for Gestational Age; AGA: Appropriate for Gestational Age Note: Values are expressed as mean±SD for normally distributed variables and median (IQR) for non-normally distributed variables. Independent sample t-test was used for parametric data and Mann-Whitney U test for nonparametric comparisons.

Chemistry Analyzer.

SPSS software version-20 was used for data entry and analysis. Means, standard deviations, frequencies, percentages, and various statistical tests, including t-tests, Mann-Whitney U tests, and Chi-square tests, were used based on data characteristics. Normality was assessed using the Kolmogorov-Smirnov test.

## RESULTS

In this study of eighty post-natal mothers aged 16-35 years (Mean±SD: 24.75±5.06 years), the socio-demographic data (Table I) revealed that 22.5% (18) of mothers were under 20 years, 40% (32) of the mothers were 21-25 years, 27.5% (22) were 26-30 years while, 10% (8) were over 30 years. The underweight mothers were only present in SGA group [2.5% (2)], 40% had normal Body Mass Index (BMI) with fewer in SGA group [SGA=30% (12), AGA=50% (20)]. In SGA group 72.5% (29) and in AGA group 60% (24) of mothers were uneducated. All mothers were housewives. However, 10% (4) of husbands in the SGA group were unemployed. Low-income status was predominant, especially in the SGA group [87.5% (35)]. Joint family system was common [SGA=60% (24), AGA=72.5% (29)]. A total of 55% of newborns were male, with a higher proportion in the AGA group [65% (26)]. Exposure to tobacco smoke was significant in the SGA group [68% (17), p< 0.05].

Anthropometric characteristics in Table II showed no significant difference in maternal age [SGA: 24.65±4.85, AGA: 24.85±5.32], but SGA mothers were significantly shorter [SGA: 1.49±0.13 m, AGA: 1.57±0.12 m, p<0.01] and their newborns weighed less [SGA: 2.12±0.28 kg, AGA: 3.32±0.61 kg, p<0.001].

Reproductive history (Table III) indicated a shorter pregnancy interval in the SGA group [51.7% (20)<1.5 years], a significant previous SGA history [SGA=82.1% (23), p<0.001], and lower weight gain during pregnancy [SGA=71.9% (23), p=0.005]. SGA mothers had fewer antenatal visits [p=0.003]. Nutritional status (Table IV & V) showed non-significant differences in Hemoglobin (Hb), serum iron, serum

**Table V: Comparison of biochemical parameter (deficiency vs normal)**

| Parameters | | Total | SGA | AGA |
|---|---|---|---|---|
| | | N (%) | N (%) | N (%) |
| Hemoglobin (g/dL) | <12 | 39 (48.8) | 17 (43.6) | 22 (56.4) |
| | ≥12 | 41 (51.3) | 23 (56.1) | 18 (43.9) |
| Serum Ferritin (ng/mL) | <12 | 29 (36.3) | 13 (44.8) | 16 (55.2) |
| | ≥12 | 51 (63.8) | 27 (53) | 24 (47) |
| Iron Deficiency Anemia (Hb <12g/dL, Ferritin< 12ng/mL) | Yes | 21 (26.3) | 9 (42.9) | 12 (57.1) |
| | No | 59 (73.8) | 31 (52.5) | 28 (47.5) |
| Serum Iron (μg/dL) | ≤60 | 40 (50) | 22 (55) | 18 (45) |
| | 60-150 | 32 (40) | 13 (40.7) | 19 (59.3) |
| | >150 | 8 (10) | 5 (62.5) | 3 (37.5) |
| Serum Zinc (μg/dL) | <60 | 30 (37.5) | 16 (53.4) | 14 (46.6) |
| | ≥60 | 50 (62.5) | 24 (48) | 26 (52) |

SGA: Small for Gestational Age; AGA: Appropriate for Gestational Age

ferritin and serum zinc levels. Anemia was present in 48.8% of mothers, with similar rates in both groups, and 36.3% had low serum ferritin levels. The prevalence of iron deficiency was 50%, with higher frequency in SGA group [55% (22)]. Zinc deficiency was 37.5% out of which 53.4% were SGA mothers.

The comparison of total energy, macronutrients, vitamins, and minerals intake between SGA and AGA mothers is shown in Table VI. SGA mothers had significantly lower daily energy intake (1065±411.5 kcal/day) compared to AGA mothers (1365±496 kcal/day, $p=0.006$). Macronutrient intake, including carbohydrates, proteins, fats, saturated fatty acids and poly-unsaturated fatty acids was also significantly lower in the SGA group ($p<0.05$). Mineral intake (iron, zinc, calcium, magnesium, sodium, iodine) was significantly lower in SGA mothers, except for chlorine and selenium. Vitamin intake was significantly lower in SGA mothers ($p<0.01$), except for vitamin D.

## DISCUSSION

In this study, we compared the nutritional and biochemical profiles of mothers delivering SGA infants with those delivering AGA infants in a tertiary care setting in Pakistan. Although no significant differences were observed in serum hemoglobin, iron, ferritin, or zinc levels between the two groups, mothers of SGA infants demonstrated significantly lower dietary intake of total energy, macronutrients, and several key micronutrients. Additionally, SGA mothers were significantly shorter, had lower pregnancy weight gain, and fewer antenatal visits. These findings suggest that maternal dietary inadequacy and suboptimal antenatal care, rather than isolated biochemical deficiencies, may play a contributory role in impaired fetal growth in this population. In our study, anemia prevalence was high, affecting 48.8% of mothers in both SGA and AGA groups. Mean hemoglobin levels were below 12 g/dL, reflecting the widespread issue reported in the National Nutrition Survey (NNS) 2018, which found 42.7% of reproductive-age females in Pakistan are anemic with 33% from Khyber Pakhtunkhwa (KP).[13] District-specific data from NNS 2018 indicated 29.7% of women in Peshawar had hemoglobin levels below 11.99 g/dL.[14] Ferritin deficiency was observed in 36.3% of our sample, while Iron Deficiency Anemia (IDA) was prevalent in 26.3%, both figures aligning closely with NNS 2018 findings as well.[13] However Ashraf F, et al., (2024) reported a 71.5% deficiency rate in Pakistan.[15] Our study found no significant difference in mean serum ferritin levels between SGA and AGA mothers, consistent with other studies,[16-18] though some report significant differences related to SGA outcomes.[19,20]

Additionally, zinc deficiency was prevalent in 37.5% of our sample, with a higher incidence among SGA mothers. Mean zinc concentration was lower in SGA mothers, consistent with findings by Ramya V, et al.,[21] These nutritional deficiencies underscore the critical public health challenge posed by inadequate dietary intake in low-income populations, contributing to adverse birth outcomes such as SGA and low birth weight.[22] We found no significant difference between pregnancy interval and SGA birth outcomes. Similar findings had been reported by other studies as well.[23,24] However, a significant difference was observed regarding previous SGA history, with 82.1% of SGA mothers having a history of SGA babies, similar to findings by Muhammad T, et al.[25]

Primiparous mothers were more common in the SGA group, aligning with Ramya V, et al.,[21] Additionally, more than half of the SGA mothers had a history of abortion, that is higher than AGA group, aligning with the studies of Badshah S, et al.,[26] and Shrestha S, et al.,[27] SGA mothers also had fewer antenatal visits than AGA mothers, emphasizing the importance of regular checkups.[27] The significantly lower intake of energy, essential macr-onutrients, minerals, and vitamins among mothers of SGA newborns highlights the potential role of maternal dietary insufficiency as a modifiable risk factor in impaired fetal growth and development. This findings are consistent with previous studies reporting lower macronutrient intake in SGA groups.[28-30]

Obesity was more frequent among SGA mothers, while AGA mothers were more likely to have normal weight, similar to Muhammad T, et al., findings.[25] SGA mothers were also shorter in stature, a significant difference, consistent with Khanam R, et al.,[31] and Kozuki N, et al.,[32] A significant proportion of SGA mothers (72.5%) had no formal education,

**Table VI: Comparison of dietary intake of SGA and AGA mothers**

| Parameters | | Total (n=80) | SGA (n=40) | AGA (n=40) | p-value |
|---|---|---|---|---|---|
| Total Energy (kcal/day) | | 1215.31±477.3 | 1065±411.5 | 1365±496 | 0.006** |
| Macronutrients | Carbohydrates (g) | 183.18±70.5 | 161.3±62.9 | 205±71.6 | 0.005** |
| | Proteins (g) | 39.74±17.2 | 33.7±15.1 | 45.8±17.2 | 0.001** |
| | Fats (g) | 47.12±21.23 | 38.3±17.04 | 55.9±21.5 | <0.001*** |
| | Saturated Fatty acid (g) | 8.68±5.96 | 7.2±5.8 | 10.2±5.8 | 0.002** |
| | Poly Unsaturated Fatty acid (g) | 9.27±7.63 | 7.53±4.7 | 11±9.4 | 0.01* |
| | Iron (mg/day) | 7.53±3.57 | 6.7±3.13 | 8.4±3.8 | 0.03* |
| | Zinc (mg/day) | 4.67±2.42 | 3.73±1.61 | 5.61±2.74 | <0.001*** |
| | Calcium (mg/day) | 675.8±286.8 | 547.2±242.1 | 804.4±272.2 | <0.001*** |
| | Magnesium (mg/day) | 158.32±61.86 | 132.2±52 | 184.4±60.4 | <0.001*** |
| | Sodium (mg/day) | 1776.17±893.1 | 1571±874 | 1981±875 | 0.01* |
| Minerals | Potassium (mg/day) | 1370.8±557.33 | 1179.6±585 | 1562±460 | <0.001*** |
| | Chlorine (mg/day) | 692.26±467.9 | 683.3±549 | 701.2±377 | 0.87 |
| | Phosphorous (mg/day) | 1045.74±410.4 | 900±373.6 | 1191±397.5 | <0.001** |
| | Copper (mg/day) | 0.662±0.28 | 0.55±0.23 | 0.77±0.28 | <0.001*** |
| | Manganese (mg/day) | 3.13±1.33 | 2.71±1.3 | 3.54±1.24 | 0.005** |
| | Selenium (µg/day) | 6.65±7.25 | 6.4±8.55 | 6.9±5.76 | 0.17 |
| | Iodine (µg/day) | 36.7±31.21 | 22±22.8 | 51.4±31.7 | <0.001*** |
| | Vitamin A (Retinol) (µg/day) | 372.35±340 | 274.7±237.6 | 470±397.6 | 0.004** |
| | Vitamin C (Ascorbic Acid) (mg/day) | 42.75±78.95 | 26.1±43.3 | 59.4±101 | 0.02* |
| Vitamins | Vitamin D (Calciferol) (µg/day) | 0.71±0.59 | 0.61±0.58 | 0.81±0.61 | 0.08 |
| | Vitamin E (Tocopherol) (mg/day) | 3.97±2.27 | 3.25±1.6 | 4.7±2.61 | 0.01* |
| | Vitamin B1 (Thiamine) (mg/day) | 0.98±0.43 | 0.84±0.36 | 1.12±0.44 | 0.003** |
| | Vitamin B2 (Riboflavin) (mg/day) | 0.52±0.26 | 0.37±0.16 | 0.67±0.25 | <0.001*** |
| | Vitamin B3 (Niacin) (mg/day) | 19.8±8.22 | 17.4±7.45 | 22.2±8.34 | 0.008** |
| | Vitamin B5 (Pantothenic Acid) (µg/day) | 1.46±0.78 | 1.16±0.76 | 1.77±0.68 | <0.001*** |
| | Vitamin B6 (Pyridoxine) (mg/day) | 0.54±0.29 | 0.46±0.28 | 0.62±0.28 | 0.01* |
| | Vitamin B7 (Biotin) (µg/day) | 11.59±7.22 | 8.53±6.45 | 14.6±6.69 | <0.001*** |
| | Vitamin B9 (Folic acid) (µg/day) | 119±53.13 | 94.03±42.3 | 143.9±51.5 | <0.001*** |
| | Vitamin B12 (Cobalamin) (µg/day) | 0.88±1.37 | 0.38±0.75 | 1.38±1.65 | <0.001*** |

Values are expressed as Mean±SD. Significant difference: *p<0.05, **p<0.01, ***p<0.001; SGA: Small for Gestational Age; AGA: Appropriate for Gestational Age

consistent with Anjum F,[24] However, Badshah S, et al.,[26] reported lower illiteracy rates among SGA mothers. Most of the SGA mothers came from low-income nuclear families, as reported in several studies.[24,25,27] Approximately one-third of mothers in our study were exposed to smoking during pregnancy, with high cases in SGA mothers, and this difference was statistically significant. Smoking exposure during pregnancy has been shown to impair placental blood flow, oxygen delivery, and nutrient transport, leading to restricted fetal growth and increased risk of SGA outcomes. Previous studies have similarly demonstrated that maternal smoking and passive smoke exposure during pregnancy are strong predictors of SGA and low birth weight outcomes.[30,33]

The findings of this study highlight a serious public health concern related to maternal nutritional deficiencies, particularly anemia, ferritin deficiency, IDA, and zinc deficiency, in both SGA and AGA mothers. These deficiencies, combined with low dietary intake, poor socioeconomic conditions, inadequate antenatal care, low education levels, and harmful lifestyle exposures, contribute significantly to adverse pregnancy outcomes. The results emphasize the need for early nutritional screening, targeted supplementation programs, dietary counseling, and strengthened antenatal care services, particularly in low-resource settings such as Khyber Pakhtunkhwa, Pakistan.

There is a need for intervention-based studies assessing the effectiveness of nutritional supplementation, dietary interventions, smoking cessation programs, and antenatal care strengthening strategies in reducing SGA prevalence. Integrating biomarker-based nutritional screening into routine maternal healthcare services may further improve early risk identification and pregnancy outcomes in high-risk populations.

### Limitations of the study

Despite the important findings, the study is limited by its case-control design and relatively small sample size, which may affect generalizability. Dietary intake assessment based on 24-hour recall may be subject to recall bias and day-to-day variation, and self-reported lifestyle factors such as smoking exposure may involve reporting bias.

### Recommendations

Future research should focus on large-scale longitudinal cohort studies to establish causal relationships between maternal nutritional status and SGA outcomes.

## CONCLUSION

In conclusion, this study highlights the critical nutritional status of SGA and AGA mothers, focusing on iron, zinc, and ferritin levels. Although biochemical micronutrient levels were comparable between groups, a high prevalence of anemia, iron deficiency, and zinc deficiency was observed overall. Mothers of SGA infants demonstrated significantly poorer dietary intake, suggesting that nutritional inadequacy rather than isolated biochemical deficiencies may contribute to impaired fetal growth. These findings highlight the importance of strengthening antenatal nutritional counseling and targeted dietary interventions, particularly in resource-limited settings.

## ACKNOWLEDGEMENT

The authors sincerely appreciate the guidance and support of Dr. Tasleem Akhtar throughout this journey and are grateful to the mothers who participated in this study.

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## AUTHORS' CONTRIBUTION

The following authors have made substantial contributions to the manuscript as under:

**NK:** Conception and study design, acquisition, analysis and interpretation of data, drafting the manuscript, critical review, approval of the final version to be published

**SF:** Study design, drafting the manuscript, approval of the final version to be published

**RN & FS:** Acquisition, analysis and interpretation of data, critical review, approval of the final version to be published

**JH:** Acquisition, analysis and interpretation of data, drafting the manuscript, approval of the final version to be published

*Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.*

## CONFLICT OF INTEREST

Authors declared no conflict of interest, whether financial or otherwise, that could influence the integrity, objectivity, or validity of their research work.

## GRANT SUPPORT AND FINANCIAL DISCLOSURE

Authors declared no specific grant for this research from any funding agency in the public, commercial or non-profit sectors.

## DATA SHARING STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.



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