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Systematic Review

Maternal Vitamin A and Zinc Status in Relation to Placental Physiology and Fetal Growth Outcomes: A Systematic Review

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ABSTRACT

Maternal micronutrient status influences placental function and fetal development. Vitamin A and zinc contribute to cellular differentiation, immune regulation, antioxidant defense, nutrient transport, and fetal growth; however, their associations with placental and neonatal outcomes remain heterogeneous across populations and study designs. **Objectives:** To systematically synthesize contemporary evidence on maternal vitamin A and zinc status in relation to placental physiology, maternal–fetal micronutrient transfer, fetal growth, and neonatal outcomes, while evaluating the consistency, methodological quality, and limitations of the available evidence. **Methods:** This systematic review followed PRISMA 2020 guidance. Primary human studies published from January 2020 to December 2025 were identified from PubMed/MEDLINE, Scopus, and Web of Science. Reviews, meta-analyses, pilot studies, case reports, and case series were excluded. Study selection, data extraction, and risk-of-bias assessment were performed independently by two reviewers. **Results:** Out of 358 records identified, 19 studies were included, comprising 12 predominantly examining zinc and seven examining vitamin A. Zinc status was most frequently associated with birth weight, small-for-gestational-age status, neonatal anthropometry, and maternal–fetal zinc transfer, although some studies reported discordant or inverse associations. Vitamin A studies supported associations with placental retinol transfer and fetal-growth regulation, including nonlinear relationships. **Conclusions:** Maternal vitamin A and zinc status are associated with placental nutrient handling and fetal growth, but the available evidence is heterogeneous and predominantly observational. Zinc showed comparatively consistent relationships with birth weight and SGA, whereas vitamin A was more closely related to retinol transfer and fetal growth regulation.

INTRODUCTION

Adequate maternal nutrition is essential for normal pregnancy, placental function, and fetal development. Fetal growth depends on maternal nutrient availability, metabolism, and transfer across the placenta [1]. Micronutrient deficiencies remain common in populations with limited dietary diversity and increased nutritional demands during pregnancy [2]. Among these nutrients, vitamin A and zinc are particularly important because both contribute to cellular proliferation, differentiation, immune regulation, antioxidant defense, and tissue development [3]. Disturbances in maternal micronutrient status may therefore influence maternal health, placental physiology, and fetal growth simultaneously [4]. Vitamin A is essential for embryogenesis, organ development, cellular differentiation, and regulation of gene expression through retinoid signaling. Maternal vitamin A status has been evaluated using dietary intake, serum or plasma retinol, retinol-binding protein, and paired maternal–cord measurements [5]. Previous studies have reported associations between vitamin A indicators and birth weight, fetal-growth patterns, neonatal anthropometry, and placental retinol transfer [6]. Importantly, emerging

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evidence suggests that these relationships may be nonlinear, indicating that both inadequate and excessive vitamin A status may be unfavorable [7, 8]. Importantly, emerging evidence suggests that the relationship may not be strictly linear, indicating that both deficiency and excessive concentrations may be undesirable. Zinc is required for DNA and protein synthesis, cell division, enzyme activity, immune function, and tissue growth. Maternal serum zinc, dietary zinc intake, supplementation, and cord-blood zinc have been associated with birth weight, small-for-gestational-age status, neonatal anthropometry, and preterm outcomes [3, 9]. Placental zinc transport is actively regulated, suggesting that maternal zinc status alone may not fully explain fetal zinc availability or growth outcomes [10, 11].

Although vitamin A and zinc have distinct biological functions, both participate in placental development and fetal tissue growth. However, most available studies have evaluated these micronutrients separately, and direct evidence of a biological interaction between them remains limited. In addition, variation in study design, gestational timing of measurement, biological specimens, exposure definitions, confounding control, and outcome assessment complicates interpretation. Cross-sectional and case-control studies may also be more vulnerable to reverse causation and selection bias than prospective cohort studies, further contributing to uncertainty in the evidence. This study aimed to provide a broad synthesis of contemporary primary evidence on maternal vitamin A and zinc status and their relationships with placental physiology and fetal and neonatal growth. Specifically, the review sought to: (1) characterize the associations of maternal vitamin A and zinc with maternal–fetal micronutrient transfer, birth weight, SGA/LGA, neonatal anthropometry, and related pregnancy outcomes; (2) compare the direction and consistency of findings across different study designs and biological measurements; (3) evaluate methodological quality and risk of bias using design-specific JBI tools; and (4) identify major evidence gaps and priorities for future prospective research.

METHODS

This systematic review was conducted to synthesize contemporary evidence regarding maternal vitamin A and zinc status in relation to placental physiology, maternal–fetal micronutrient transfer, and fetal and neonatal growth outcomes. The review was designed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [12]. As substantial clinical and methodological heterogeneity was identified across the eligible studies, quantitative meta-analysis was considered inappropriate. Therefore, the findings were synthesized narratively in accordance with the principles of the Synthesis Without Meta-analysis (SWiM) reporting guidance. The review was not prospectively registered in PROSPERO or another systematic-review registry. Registration was considered after the review process had progressed beyond the stage appropriate for prospective registration; nevertheless, the eligibility criteria and methodological procedures were predefined and are reported transparently in accordance with PRISMA 2020. A total of 358 records were identified through PubMed/MEDLINE, Scopus, and Web of Science. After removal of 68 duplicates, 290 records underwent title and abstract screening. Out of these, 211 were excluded, 79 full-text reports were sought, six could not be retrieved, and 73 full texts were assessed for eligibility. After excluding 54 reports, 19 primary studies were included in the qualitative synthesis (Figure 1).

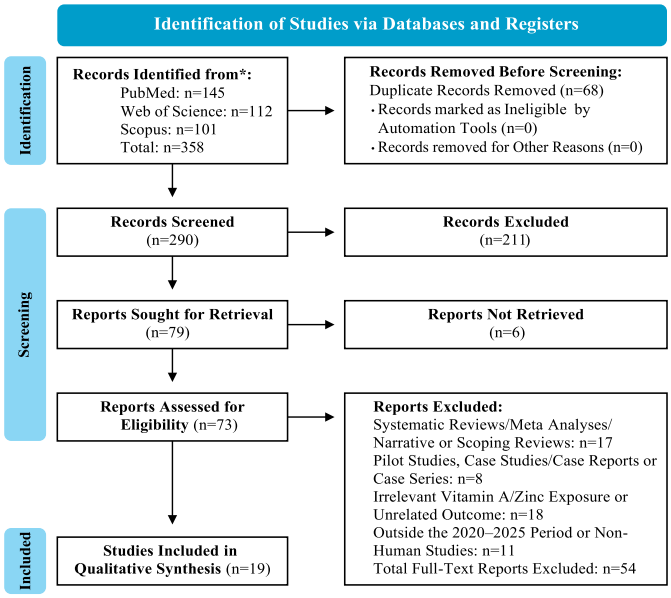


Figure 1: PRISMA 2020 Illustrating the Identification, Screening, Eligibility Assessment, And Final Inclusion of Studies in the Systematic Review

A systematic literature search was performed to identify relevant original studies published from January 2020 to December 2025. Electronic searches were conducted in PubMed/MEDLINE, Scopus, and Web of Science. The final database search was conducted on 31 December 2025. Reference lists of eligible full-text articles were additionally screened to identify potentially relevant studies not captured during the electronic search. The search strategy combined Medical Subject Headings (MeSH), database-specific indexing terms, and free-text terms related to vitamin A, zinc, pregnancy, placenta, maternal–fetal transfer, and fetal growth. Search terms included combinations of "vitamin A," "retinol," "retinol-binding protein," "zinc," "maternal zinc," "maternal micronutrients," "pregnancy," "pregnant women," "placenta," "placental function," "placental transfer,"

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"maternal-fetal transfer," "cord blood," "fetal growth," "fetal growth restriction," "small for gestational age," "birth weight," "low birth weight," "large for gestational age," "neonatal anthropometry," "birth length," "head circumference," and "ponderal index." Boolean operators AND and OR were used as appropriate for individual databases. Searches were restricted to human pregnancy studies published during the predefined 2020–2025 period. Only articles published in English were included. Grey-literature databases and trial registries were not searched because the review was restricted to peer-reviewed primary studies containing sufficient methodological and outcome data for critical appraisal. Formal statistical assessment of publication bias was not performed because quantitative pooling was not undertaken; however, the possibility of selective publication and reporting was considered during interpretation of the evidence. The detailed database search strategy is presented (Table 1).

Table 1: Database Search Strategy

Database	Search Strategy	Limits
PubMed/ MEDLINE	("vitamin A" OR retinol OR "retinol -binding protein") AND (zinc OR " maternal zinc" OR "maternal micronutrients") AND (pregnancy OR "pregnant women") AND (placenta OR "placental function" OR "placental transfer" OR " maternal-fetal transfer" OR "cord blood" OR "fetal growth" OR "fetal growth restriction" OR "small for gestational age" OR "birth weight" OR "low birth weight" OR "large for gestational age" OR "neonatal anthropometry")	Human pregnancy; January 2020–December 2025
Scopus	TITLE-ABS-KEY terms related to vitamin A/retinol, zinc, pregnancy, placenta, maternal–fetal transfer, fetal growth, birth weight, SGA/ LGA, and neonatal anthropometry, combined using AND/OR	January 2020–December 2025
Web of Science	Topic terms related to vitamin A/retinol, zinc, pregnancy, placental function/transfer, fetal growth, cord blood, birth weight, SGA/LGA, and neonatal anthropometry, combined using AND/OR	January 2020–December 2025

Inclusion criteria: Original primary studies with pregnant women, mother–infant pairs, cord blood, neonates, or placental tissues that investigated maternal vitamin A and/or zinc status, intake, supplementation, circulating/cord concentrations, or transfer of micronutrients from mother to child. Eligible designs: prospective/retrospective cohort, case-control, analytical cross-sectional, comparative observational, and other original observational maternal–infant study designs. Vitamin A and zinc did not have to be tested together; either vitamin A or zinc could be tested, and then compared among common outcome domains. Studies were required to report on at least one placenta/fetal/neonatal or pregnancy outcome, such as micronutrient transfer, cord blood status, estimated fetal weight, FGR, SGA, LGA, birth weight, low birth weight, birth length, head circumference, ponderal index, neonatal anthropometry, preterm birth, and other pregnancy outcomes that may relate to placental function. Exclusion Criteria: Systematic reviews, meta-analyses, narrative/scoping reviews, pilot studies, case reports/series, editorials, letters, conference abstracts with inadequate primary data, protocols, commentaries, and others that are not original publications. Excluded: studies published prior to January 2020 or after December 2025; non-human studies; studies that did not have outcomes related to vitamin A or zinc; and studies with no maternal, placental, fetal, or neonatal outcomes. Two reviewers independently studied and selected the studies. Titles and abstracts were then narrowed to the pre-defined eligibility criteria after the removal of duplicates. The potentially relevant reports were then independently evaluated for their full text. Any disputes in terms of eligibility for the studies were resolved by discussion and consensus among the reviewers. A structured data-extraction framework was developed according to the objectives of the review. Extracted information included first author, year of publication, country, study design, sample size, micronutrient investigated, type of exposure or biochemical assessment, gestational timing of measurement where available, and principal placental, fetal, neonatal, or pregnancy outcome. For vitamin A studies, data relating to maternal dietary retinol intake, serum or plasma vitamin A or retinol, retinol-binding protein, and maternal–cord retinol measurements were collected. For zinc studies, maternal serum zinc, dietary zinc intake, zinc supplementation, neonatal or umbilical-cord zinc, and measures of maternal–fetal zinc transfer were extracted. Where available, outcome data included birth weight, low birth weight, SGA, AGA, LGA, fetal or neonatal growth, birth length, head circumference, ponderal index, estimated fetal weight, preterm birth, micronutrient transfer between mother and fetus, and placental retinol- or zinc-related outcomes. Quantitative findings, including means or medians with measurement units, effect estimates, correlation coefficients, confidence intervals, and p-values, were extracted when reported by the original studies. Data extraction was performed independently by two reviewers, and discrepancies were resolved through discussion and consensus. A total of 19 primary studies, including 12 predominantly examining zinc and seven examining vitamin A, were included in the qualitative synthesis. The

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Joanna Briggs Institute (JBI) Critical Appraisal Tools were used to assess methodological quality and risk of bias. The JBI Checklist for Cohort Studies was applied to prospective, retrospective, longitudinal, and cohort-substudy designs; the JBI Checklist for Case-Control Studies was applied to case-control and nested case-control studies; and the JBI Checklist for Analytical Cross-Sectional Studies was applied to analytical cross-sectional and comparable cross-sectional observational studies. The principal appraisal domains included participant selection, validity and reliability of exposure measurement, outcome ascertainment, identification and control of confounding factors, and appropriateness of statistical analysis. Risk-of-bias assessment was conducted independently by two reviewers, with disagreements resolved through discussion and consensus. Overall risk of bias was classified as low, moderate, or high by considering the pattern, severity, and methodological importance of the individual JBI domain judgments rather than relying solely on a numerical score. Studies were classified as low risk when the major methodological domains were adequately addressed, and no important concern regarding participant selection, measurement, outcome assessment, or confounding was identified. Moderate risk was assigned when one or more methodological concerns were present but were unlikely to invalidate the principal findings. High risk was assigned when substantial selection bias, inadequate control of confounding, serious measurement concerns, or major design limitations could materially influence the study findings. Thus, the overall judgment reflected the likely impact of methodological limitations on interpretation rather than a simple total checklist score.

A quantitative meta-analysis was not undertaken because of considerable heterogeneity in study populations, designs, exposure definitions, micronutrient assessments, biological samples, gestational timing of measurement, and reported outcomes. Vitamin A was assessed using dietary retinol intake, serum or plasma vitamin A or retinol concentrations, retinol-binding protein, and maternal–cord measurements. Zinc was assessed using maternal or neonatal serum or plasma concentrations, cord-blood concentrations, dietary intake, and supplementation. Outcomes also varied substantially and included placental or maternal–fetal nutrient transfer, birth weight, SGA/LGA, neonatal anthropometry, preterm birth, and later developmental outcomes. A narrative synthesis was performed in a structured manner. Studies were sorted into micronutrient exposure and then into the outcome domains (birth weight, LBW, SGA/FGR, preterm birth, neonatal anthropometry, transfer of zinc from mother to fetus, transfer of retinol from mother to fetus, vitamin A-related fetal growth). Studies were not weighted equally – larger studies, prospective designs, more precise quantitative estimates, and lower risk of bias were given more weight, with smaller/high-risk studies interpreted with caution. Where available, the following were considered: effect size, direction, precision, confidence intervals, significance, and consistency. Discordant, inverse, or null findings were preserved and discussed with design, sample size, gestational timing, specimen, exposure assessment and outcome definition, and confounding. Overall direction was similar when high-risk studies were assigned less weight (qualitative sensitivity check – not formal quantitative) – see narrative. The results of the vitamin A and zinc analyses were reported independently without assuming any synergism or interaction, unless such interaction/synergism was tested in an associated study.

RESULTS

The included studies were published between 2020 and 2025 and represented populations from Africa, Asia, Australia, Europe, and North America. Study designs included prospective cohorts, cross-sectional studies, case-control studies, and maternal–infant observational studies. Sample sizes ranged from 21 to 1,244 mother–infant pairs. Twelve studies primarily evaluated zinc and seven evaluated vitamin A. Tehe study shows substantial heterogeneity in study design, biological sample, exposure measurement, and outcome assessment. This variability limited direct comparison across studies and supported the use of narrative rather than quantitative synthesis (Table 2).

Table 2: Characteristics of Included Studies

Sr. No.	References	Country	Study Design	Sample Size	Micro -Nutrient Exposure	Assessment	Main Outcome
1	[13]	Malawi	Nested Case-Control	181	Zinc	Maternal Serum Zinc	Spontaneous Preterm Birth
2	[14]	Ethiopia	Prospective Cohort	341	Zinc	Maternal Serum Zinc	Birth Weight
3	[15]	India	Comparative Observational	200	Zinc	Neonatal Serum Zinc	SGA vs AGA
4	[16]	Australia	Prospective cohort	103	Vitamin A	Dietary Retinol Intake	Fetal and Birth Weight
5	[17]	Iran	Cross-sectional comparative	200	Zinc	Supplementation/Serum Zinc	Birth Weight
6	[18]	Thailand	Prospective Observational	117	Zinc	Maternal and Cord Zinc	Maternal–Fetal Transfer

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7	[19]	Nigeria	Cross-Sectional	200	Zinc	Cord Serum Zinc	SGA/AGA, Birth Weight
8	[20]	Türkiye	Prospective Cohort	44	Vitamin A	Maternal/Cord Retinol-RBP	Placental Retinol Transfer
9	[21]	Uganda	Prospective Cohort/Substudy	1,244	Vitamin A	Maternal RBP	Birth Weight/Anthropometry
10	[22]	China	Prospective Cohort	637	Vitamin A	Maternal Serum Vitamin A	Birth Weight, SGA, LGA
11	[23]	Ethiopia	Cross-Sectional	432	Zinc	Maternal Serum Zinc	Maternal Zinc Deficiency
12	[24]	Iran	Case-Control	84	Zinc	Maternal Serum Zinc	Preterm Labor
13	[25]	Palestine	Case-Control	160	Zinc	Serum/Dietary Zinc	Pregnancy-Induced Hypertension
14	[26]	Pakistan	Cross-Sectional	382	Zinc	Maternal Serum Zinc	Low Birth Weight
15	[27]	Iran	Cross-Sectional Substudy	112	Zinc	Cord Zinc	Birth Weight/Anthropometry
16	[28]	USA	Maternal–Infant Observational	21	Vitamin A	Maternal/Cord Retinol	Retinol Transfer
17	[29]	Bangladesh	Case-Control	60	Zinc	Maternal/Cord Zinc	Low Birth Weight
18	[30]	Norway	Longitudinal Cohort/Post-Hoc	119	Vitamin A	Maternal Retinol	Offspring Skeletal Growth
19	[31]	China	Maternal–Infant Observational	442	Vitamin A	Third-Trimester Vitamin A	Ponderal Index/Fetal Growth

Most zinc studies showed that lower maternal or neonatal zinc status was associated with poorer fetal growth, particularly lower birth weight and SGA. However, discordant findings were also identified, including higher maternal serum zinc among women with spontaneous preterm birth in Chiudzu *et al.* [13] and an inverse correlation between cord zinc and birth weight in Amini *et al.* [27] (Table 3).

Table 3: Summary of Maternal Vitamin A and Zinc Status and Main Outcomes

References	Micronutrient	Main Finding	Statistical Result	Direction
[13]	Zinc	Higher Maternal Zinc in Spontaneous Preterm Birth	Adverse/opposite	Significant Association
[14]	Zinc	Maternal Zinc Associated with Birth Weight	Beneficial	Association Reported
[15]	Zinc	Lower Zinc In SGA then AGA Neonates	Beneficial	Significant Difference
[17]	Zinc	Higher Maternal Zinc Associated with Greater Birth Weight	Beneficial	Birth Weight p=0.008; Maternal Zinc p<0.001
[19]	Zinc	Cord Zinc Lower In SGA; Positively Related to Birth Weight	Beneficial	r=0.33, p<0.001
[20]	Vitamin A	Maternal Retinol Related to Placental Transfer	Positive	Association Demonstrated
[21]	Vitamin A	Maternal RBP Related to Neonatal Anthropometry	Predominantly positive	Significant For Some Indices
[24]	Zinc	Lower Zinc Associated with Preterm Labor	Adverse deficiency effect	Significant
[26]	Zinc	Lower Maternal Zinc in LBW Group	Beneficial	63.88 ± 10.95 vs 83.83 ± 8.57 µg/dL; p<0.001
[27]	Zinc	Cord Zinc Inversely Related to Birth Weight	Inverse	r=−0.249, p=0.008
[28]	Vitamin A	Lower Retinol in Twin Pregnancies	Reduced Availability	Maternal difference p=0.002
[29]	Zinc	Maternal Zinc Positively Correlated with Birth Weight	Beneficial	r≈0.41, p=0.001
[31]	Vitamin A	Nonlinear Relation with Ponderal Index	Threshold	Threshold association

The overall zinc evidence favored a positive relationship between adequate zinc status and fetal growth, although the direction was not uniform across all studies. Vitamin A findings were more consistently related to placental retinol transfer and fetal-growth regulation rather than a simple linear relationship with birth size. Evidence for zinc was comparatively stronger for birth weight and SGA, whereas vitamin A evidence was more closely related to maternal–fetal retinol transfer and regulation of fetal growth. Importantly, vitamin A and zinc were interpreted separately because the included studies did not directly demonstrate a combined or synergistic effect (Table 4).

Table 4: Overall Synthesis of Evidence

Outcome Domain	Micronutrient	Overall Pattern	Consistency
Birth Weight/LBW	Zinc	Lower Zinc Commonly Associated with Lower Birth Weight	Moderate
SGA/Fetal Growth Restriction	Zinc	Lower Zinc Frequently Observed in SGA	Moderate
Preterm Birth/Labor	Zinc	Altered Zinc Associated with Preterm Outcomes	Low–moderate
Neonatal Anthropometry	Zinc	Associations Varied by Measure	Moderate
Maternal–Fetal Transfer	Zinc	Maternal Status Related To Cord/Neonatal Zinc	Moderate
Placental Retinol Transfer	Vitamin A	Maternal Retinol Influenced Fetal Availability	Moderate
Birth Weight/Fetal Growth	Vitamin A	Associations with Growth Measures	Moderate
Nonlinear Effects	Vitamin A	Both Low and High Status May be Unfavorable	Limited
Combined Vitamin A–Zinc Effect	Vitamin A + Zinc	Direct Synergistic Evidence Insufficient	Limited

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Four studies were judged to have low overall risk of bias, 13 moderate risk, and two high risks. The main concerns were selection bias, residual confounding, cross-sectional design, and small sample size (Table 5).

Table 5: Risk-of-Bias Assessment

References	JBI Appraisal Design	Selection Bias	Exposure Measurement	Outcome Measurement	Confounding	Overall Risk
[13]	Case-Control	Low	Low	Low	Moderate	Moderate
[14]	Cohort	Low	Low	Low	Low	Low
[15]	Analytical Cross-Sectional	Moderate	Low	Low	Moderate	Moderate
[16]	Cohort	Low	Moderate	Low	Moderate	Moderate
[17]	Analytical Cross-Sectional	Moderate	Low	Low	Moderate	Moderate
[18]	Cohort	Low	Low	Low	Low	Low
[19]	Analytical Cross-Sectional	Moderate	Low	Low	Moderate	Moderate
[20]	Cohort	Moderate	Low	Low	Moderate	Moderate
[21]	Cohort	Low	Low	Low	Low	Low
[22]	Cohort	Low	Low	Low	Low	Low
[23]	Analytical Cross-Sectional	Moderate	Low	Low	Moderate	Moderate
[24]	Case-Control	Moderate	Low	Low	Moderate	Moderate
[25]	Case-Control	Moderate	Low	Low	Moderate	Moderate
[26]	Analytical Cross-Sectional	Moderate	Low	Low	Moderate	Moderate
[27]	Analytical Cross-Sectional	Moderate	Low	Low	Moderate	Moderate
[28]	Analytical Observational	High	Low	Low	Moderate	High
[29]	Case-Control	Moderate	Low	Low	Moderate	Moderate
[30]	Longitudinal Cohort/post-Hoc	Moderate	Low	Low	High	High
[31]	Analytical Observational	Low	Low	Low	Moderate	Moderate

The qualitative sensitivity assessment indicated that the overall direction of evidence remained broadly similar when the two high-risk-of-bias studies were given reduced interpretive weight. Consequently, the main conclusions were driven primarily by the larger and methodologically stronger studies rather than by the high-risk studies

DISCUSSION

The present systematic review found that maternal vitamin A and zinc status was associated with several placental, fetal, and neonatal outcomes. Zinc was more frequently investigated and showed relatively consistent associations with birth weight and small-for-gestational-age status, whereas vitamin A studies more often addressed retinol transfer and regulation of fetal growth. For zinc, most included studies suggested that lower maternal or neonatal concentrations were associated with poorer fetal growth. Gupta *et al.* reported lower zinc concentrations among SGA neonates [15], while Agbonlahor *et al.* demonstrated a positive relationship between cord zinc and birth weight [19]. Karim *et al.* and Mahmood and Deeba similarly reported lower maternal zinc status in pregnancies resulting in low-birth-weight neonates. However, the evidence was not uniform [26, 29]. Chiudzu *et al.* reported higher maternal zinc among women who subsequently experienced spontaneous preterm birth [13], whereas Amini *et al.* found an inverse association between cord zinc and birth weight. These discordant findings may reflect differences in gestational timing of assessment, biological specimens, baseline nutritional status, maternal inflammation, population characteristics, and residual confounding [27]. Maternal serum, neonatal serum, and cord-blood zinc represent different physiological compartments and therefore should not be interpreted as interchangeable measures of exposure. Study design also contributed substantially to the heterogeneity of the evidence. Prospective cohort studies provide stronger information on temporality because micronutrient status is generally assessed before the pregnancy or neonatal outcome occurs. In contrast, cross-sectional studies measure exposure and outcome at approximately the same time and therefore cannot establish whether altered micronutrient status preceded the outcome, increasing the possibility of reverse causation. Case-control studies are useful for examining uncommon adverse outcomes but remain vulnerable to selection bias and differences in exposure assessment between cases and controls. For this reason, findings from larger prospective studies and studies with lower risk of bias were given greater interpretive weight than findings from smaller cross-sectional or high-risk studies. Vitamin A findings were also heterogeneous but suggested an important role in maternal–fetal retinol transfer and fetal-growth regulation. Tekgündüz *et al.* demonstrated an association between maternal retinol status and placental transfer [20], while Mezzano *et al.* reported relationships between maternal retinol-binding protein and neonatal anthropometry [21]. Akbar *et al.* found lower maternal retinol concentrations in

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twin pregnancies, supporting the possibility of altered vitamin A availability under greater fetal demand [28]. Jiafen *et al.* further reported a nonlinear relationship between maternal vitamin A and neonatal ponderal index. Collectively, these findings suggest that vitamin A may operate within an optimal physiological range rather than through a simple linear "higher is better" relationship [31]. Rohmawati *et al.* reported associations of maternal zinc intake and serum zinc with neonatal growth [32], while other external studies described links between maternal zinc status, placental nutrient-signaling pathways, and placental zinc transporters [32-35]. External vitamin A studies also reported adaptive placental retinol transfer and relationships between maternal and cord vitamin A status [31-33]. The present review does not support a direct synergistic effect of vitamin A and zinc. The two micronutrients were therefore interpreted separately because the included studies generally examined one micronutrient at a time and did not directly test interaction between them. The qualitative sensitivity assessment also showed that the overall direction of evidence remained broadly similar when the two high-risk-of-bias studies were given reduced interpretive weight. Nevertheless, the predominance of observational evidence, variability in exposure assessment, and inconsistent adjustment for confounding. were noted.

Considerable heterogeneity existed in study design, biological samples, gestational timing of micronutrient measurement, exposure definitions, and fetal or neonatal outcomes, which prevented quantitative pooling. Most included studies were observational, limiting causal inference and increasing the possibility of residual confounding and reverse causation. Future studies should use well-designed prospective cohorts with serial measurements of maternal serum, cord blood, and placental biomarkers across gestation. Standardized definitions of vitamin A and zinc status and consistent reporting of effect estimates with confidence intervals would improve comparability. Studies should also evaluate placental transporter activity and fetal-growth trajectories longitudinally.

CONCLUSIONS

Maternal vitamin A and zinc status is associated with placental nutrient handling and fetal growth, but the available evidence is heterogeneous and does not establish causality. Zinc showed comparatively consistent associations with birth weight and SGA, whereas vitamin A was more closely related to maternal–fetal retinol transfer and regulation of fetal growth. Discordant findings, variation in study design, and differences in biological samples and timing of measurement limit the strength of inference.

Authors' Contribution

Conceptualization: SA[1]
Methodology: KS, LK
Formal analysis: SA[1]
Writing and Drafting: SA[1], KS, LK, SA[2], NF, SN
Review and Editing: SA[1], KS, LK, SA[2], NF, SN

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflict of Interest

All the authors declare no conflict of interest.

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