ICOG CAMPUS

Indian College of Obstetricians & Gynaecologists Academic Wing of FOGSI

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President FOGSI ICOG

Dr. Parag Biniwale
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Dr. Suvarna Khadilkar
Secretary General FOGSI

Dr. Sarita Bhalerao
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Improving Birth Outcomes:

Advancing Protocols from IFA to Multi-Micronutrient Supplementation

IFA: Iron, Folic Acid

Editor-in-chief
Dr. Parag Biniwale
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Editors
Dr. Vidya Thobbi & Dr. JB Sharma
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This book is dedicated

to the mothers who carry life, to the children who represent our future, and to the clinicians who shape their health and destiny.

About the Editors

DR. VIDYA THOBBI, MD FICOG FKCOG, is a distinguished Professor and Former Head of the Department of Obstetrics and Gynecology at Al-Ameen Medical College in Vijayapur, Bijapur, Karnataka, India. With over 30 years of experience, she is not only a skilled obstetrician and gynecologist but also a dedicated teacher for both postgraduate and undergraduate students.

Dr. Thobbi serves as a member of the Governing Council of ICOG and has been elected as the Vice President of FOGSI 2026 South Zone. She previously held the position of President of KSOGA in 2023 and chaired the Food Drugs and Medico-Surgical Equipment Committee for FOGSI from 2018 to 2020.

Throughout her career, she has occupied numerous prestigious roles within FOGSI Societies and has organized various conferences, webinars, and awareness programs focused on Nutrition. In recognition of her contributions, she received the FOGSI Champion Award in 2019 and the Best FOGSI Committee Award Dr. Mehroo Dara Hansotia in 2020.

Her scholarly work includes contributions to several books, FOGSI FOCUS, ICOG CAMPUS, and presentations at both national and international conferences. Additionally, she serves as an advisory faculty member on the Boards of Rajiv Gandhi University of Health Sciences.

DR. JB SHARMA, MD DNB, FRCOG FAMS PhD FNScA, previously served as a Professor in the Department of Obstetrics and Gynecology at AIIMS, and at Maulana Azad Medical College, New Delhi, India. He currently is the Head of Department of Obstetrics and Gynecology at Yashoda Medicity, Indirapuram, Delhi NCR, India. He has also worked at St. Bartholomew's Hospital, Homerton University Hospital and Whipps Cross University Hospital, London, U.K. for 4 years.

He is a member of the Governing Council of ICOG and has been the Chairperson of Urogynecology Committee of FOGSI 2020-2022.

His notable positions and accomplishments include Dr BC Roy Award from the Hon'ble President of India in 2015 for his research contributions in Obstetrics and Gynecology. Also he is Labhsetwar Awardee. He has authored approximately 425 publications in both indexed and non-indexed journals, with 225 of these appearing in peer-reviewed indexed national and international journals. Furthermore, he is the author of the 'Textbook of Obstetrics', 'Textbook of Gynecology', and 'Midwifery & Obstetrical Nursing'. He has been awarded the ICMR's Amrut Mody Unichem Prize for his research on 'Anaemia during Pregnancy'.

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President’s Message

Federation of Obstetric and Gynecological Societies of India (FOGSI)

Indian College of Obstetricians and Gynecologists (ICOG)

It gives me immense pride and joy to present this scholarly publication of the Indian College of Obstetricians and Gynecologists (ICOG) titled “Improving Birth Outcomes: Advancing Protocols from IFA to Multi -Micronutrient Supplementation”. This work reflects a timely and vital contribution to women’s health, addressing an area often overlooked yet central to safe motherhood—maternal nutrition.

Nutrition during pregnancy is not just a matter of individual well-being; it is a foundation for the health of the nation. Maternal undernutrition and deficiencies continue to be major contributors to maternal and neonatal morbidity, mortality, and the long-term health trajectory of future generations. In India, where both undernutrition and overnutrition coexist, the responsibility of the gynecologist extends beyond clinical care to becoming advocates, counsellors, and implementers of evidence-based nutrition strategies.

The chapters in this volume—from the hidden crisis of pregnancy nutrition, urban dietary challenges, maternal malnutrition, to the pressing need for multiple micronutrient supplementation (MMS)—highlight the evolving scientific consensus and practical solutions that must be integrated into antenatal and everyday obstetric practice. The emphasis on trimester-specific needs, the importance of precision nutrition, and the call to move beyond iron-folic acid–centric care are all aligned with global goals of improving maternal and child health outcomes.

As President of FOGSI, I am delighted that ICOG continues to set academic benchmarks by curating such comprehensive and forward-looking resources. This book will undoubtedly serve as an essential reference for every practicing gynecologist, guiding us to translate knowledge into action and policy into practice.

I congratulate the editors, contributors, and the ICOG team for their dedication and scholarship. May this book inspire each one of us to place nutrition at the heart of obstetric care and ensure that every pregnancy is nurtured with dignity, science, and compassion.

With best wishes,

Dr. Sunita Tandulwadkar
President, FOGSI (2025)
President ICOG (2025)

Chairperson’s Message

India is currently grappling with a significant malnutrition crisis, with nearly 25% of women of reproductive age being undernourished, indicated by a body mass index (BMI) of less than 18.5 kg/m. Conversely, there is a rising incidence of obesity.

It is estimated that approximately one-third of women of reproductive age and nearly half of pregnant women worldwide are anemic. The World Health Organization (WHO) has categorized India as a nation experiencing severe anemia among pregnant women. Men and women possess distinct nutritional requirements due to biological differences. Hormonal fluctuations related to menstruation, childbirth, and menopause increase women’s susceptibility to anemia, osteoporosis, and various nutritional deficiencies. Furthermore, in developing countries, women are more prone to nutritional inadequacies due to socio-economic factors such as low social standing, poverty, and lack of education. Additionally, disparities in household responsibilities can further expose women to the risk of malnutrition.

According to UNICEF, the diets of Indian women often fall short of fulfilling their nutritional needs. Therefore, it is crucial for us, as healthcare providers for women, to comprehend these needs and challenges. This ICOG CAMPUS addresses various facets of nutritional issues and will serve as a valuable resource for clinicians. I would like to express my gratitude to all the authors who have contributed to the topic of Nutrition in Pregnancy.

Special thanks to our Governing Council Members, Dr. Vidya Thobbi and Dr. JB Sharma, for their efforts in compiling these articles, and to Dr. Sunita Tandulwadkar, President FOGSI, for her unwavering support.

Happy reading!

Dr. Parag Biniwale
Chairperson ICOG

Secretary’s Message

The right to food is a fundamental human right. Adequate nutrition is crucial for health and development. This ICOG CAMPUS emphasizes the significance of dietary components that are required in minimal quantities, which are appropriately referred to as micronutrients. These include vitamins and minerals that the body needs for optimal functioning. Although they are required in small amounts, deficiencies in these nutrients can lead to severe and life-threatening health issues, particularly during critical growth and development stages such as pregnancy and childhood.

This ICOG CAMPUS highlights the lesser-known consequences of micronutrient deficiencies, often termed “Hidden Hunger,” which can have subtle effects on the human body and may be challenging to diagnose and treat.
This book contains dedicated chapters addressing all micronutrient deficiencies during pregnancy, along with strategies for prevention and management.

I extend my congratulations to the Editors, Dr. Vidya Thobbi and Dr. JB Sharma, as well as the knowledgeable authors for their exceptional work in creating this book. It serves as an enlightening resource for healthcare professionals, public health workers, and the general public regarding the significance of micronutrient malnutrition, aiding women in breaking the intergenerational cycle of malnutrition.

Have a fruitful reading.

Dr. Sarita Bhalerao
Secretary ICOG

Editor’s Desk

We are filled with pride and enthusiasm as we write from the Editor’s desk to introduce this ICOG CAMPUS focused on Pregnancy Nutrition: What Every Obstetrician and Gynecologist Must Know.

The First 1000 Days - from conception to a child’s second birthday - represent a critical window for establishing lifelong health. Adequate nutrition during this period supports fetal development, strengthens immunity, & enhances cognitive outcomes, significantly impacting future health & well-being. The first 300 days (from conception to birth) are particularly pivotal. We as health care providers for the pregnant woman play a crucial role in shaping maternal & fetal health during this phase.

The diets of both urban & rural women in India are often carbohydrate-rich but lack essential micronutrients. Studies reveal that one in every two pregnant women has deficiencies in 7-8 key micronutrients. These deficiencies contribute to approximately 60% of adverse pregnancy outcomes.

India has significantly higher rates of adverse pregnancy outcomes, such as preterm delivery (PTD), low birth weight (LBW), intrauterine growth restriction (IUGR), pre-eclampsia (PE), & gestational diabetes mellitus (GDM), compared to developed nations. For over two decades, developed countries have been prescribing multi[1] micronutrient (MMN) supplementation along with fortified foods to pregnant women. The data emphasize the urgent need for India to transition from the traditional Iron, Folate & Calcium (IFC) supplementation model to an advanced MMN-based approach for improving pregnancy outcomes.

Multi-Micronutrients (MMN) supplementation is aligned with the latest clinical guidelines of ICMR & WHO ensuring enhanced maternal & fetal health.

It is essential to improve the awareness of healthcare professionals in both public and private sectors to deliver high-quality, evidence-based nutrition services for mothers, infants, and young children, thereby fostering a mother-baby friendly health system environment.

We recognized the pressing need to establish a dedicated ICOG CAMPUS on Nutrition in Pregnancy for the benefit of our esteemed FOGSI colleagues. We express our gratitude to President FOGSI Dr. Sunita Tandulwadkar for her unwavering support and encouragement in this endeavor, as well as for composing the President’s message for the ICOG CAMPUS.

We express our gratitude to Chairperson ICOG Dr. Parag Biniwale for his inspiration, encouragement, and for contributing a chapter as well as the Chairperson ICOG message for this ICOG CAMPUS.

We extend our thanks to Secretary ICOG Dr. Sarita Bhalerao for her unwavering support and for giving us the opportunity to compile the topics for this ICOG CAMPUS.

We are also grateful to all the distinguished and dedicated colleagues from across the nation who have contributed to the various chapters of this ICOG CAMPUS, addressing significant aspects of nutrition in women during pregnancy in their articles.

We trust that the esteemed FOGSIANS and readers will find this ICOG CAMPUS beneficial in their clinical practice.

We sincerely apologize for any errors. We extend our heartfelt gratitude to Surbhi Gupta, PlusPlus Lifesciences, the creators of TRIMACARE, for their assistance in producing this dedicated ICOG CAMPUS.

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Preface

India stands at the crossroads of both opportunity and challenge in maternal health. We are the nation with the highest number of pregnancies in the world, yet we also carry a disproportionate burden of preterm birth, low birth weight, maternal anaemia, and gestational diabetes. Despite decades of progress, the latest NFHS-5 survey still shows that more than half of our pregnant women are anaemic, and the prevalence of low birth weight remains stagnant at nearly 18%. These statistics are not merely numbers — they reflect millions of lives at risk and families burdened by preventable adversity.

For over seventy years, iron–folic acid (IFA) supplementation has been the cornerstone of antenatal nutrition policy. Introduced to combat maternal anaemia and neural tube defects, it was revolutionary in its time. But India today faces a new reality: the challenge is no longer only anaemia, but the wider spectrum of micronutrient deficiencies, also known as "hidden hunger." Urban Indian women, who appear food-secure and often of normal weight, are now presenting with low vitamin B12, vitamin D, zinc, and iodine levels. This is the well-recognised "thin-fat phenotype" — women who may look nourished but harbour profound metabolic vulnerabilities.

The consequences are intergenerational. The Developmental Origins of Health and Disease (DOHaD) framework and Barker's hypothesis demonstrate how nutritional deprivation during pregnancy leads to epigenetic programming of the fetus, increasing susceptibility to non-communicable diseases later in life. When we fail to address these deficiencies, we are not only compromising the immediate pregnancy but also shaping a future of higher cardiovascular disease, diabetes, and metabolic disorders in the next generation.

The evidence for Multiple Micronutrient Supplementation (MMS) is now compelling. A Cochrane review and pooled analyses confirm that MMS reduces low birth weight, small-for-gestational-age infants, and preterm birth, without increasing maternal or neonatal risks. Importantly, the Indian Council of Medical Research (ICMR) has recently introduced an India-specific MMS formulation, tailored to our local nutritional gaps. This includes iron, folate, vitamin B12, vitamin D, zinc, and other critical micronutrients in balanced doses. This is a historic step forward — one that aligns international science with India's clinical realities.

For clinicians, the message is clear: MMS is not a "magic pill," but a nutritional foundation for every pregnancy. It is not meant to replace dietary counselling, but to complement it. While behaviour change and dietary diversity remain long-term goals, supplementation is the immediate, clinician-controlled intervention that can transform outcomes today. MMS allows us to address hidden hunger comprehensively, while also reducing pill burden and improving compliance compared with multiple single-nutrient prescriptions.

This book arrives at exactly the right moment. It synthesises global science, national policy, and the daily realities of urban obstetric practice into a clear and actionable narrative. It challenges us to move beyond outdated paradigms of IFA alone, and to embrace a nutrition-first, precision approach in antenatal care. For gynaecologists across India, it provides not only evidence but also the practical guidance to lead this transformation.

As obstetricians, we have always carried the responsibility of safeguarding mothers and newborns. Today, we also have the privilege of reshaping the future health of our nation through the choices we make in antenatal nutrition. I commend this book to every practitioner — as a guide, a resource, and a call to action.

Dr. Hema Divakar
Division Director FIGO Well Women @ FIGO
FOGSI's Ambassador to FIGO 2024-25

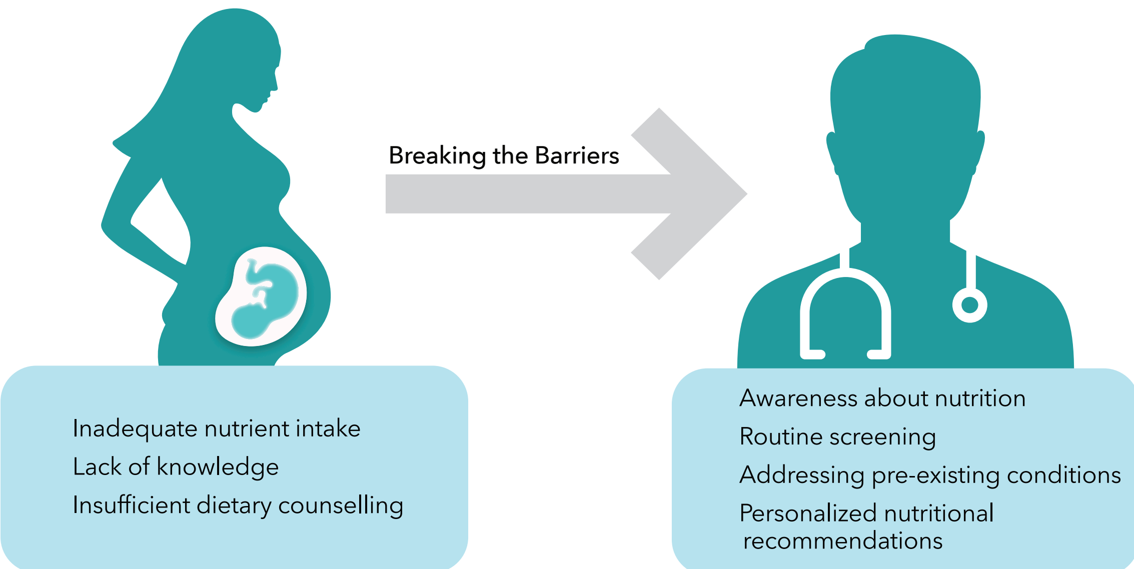
Content

Improving Birth Outcomes: Advancing Protocols from IFA to Multi-Micronutrient Supplementation

01

The Hidden Crisis: Why Pregnancy Nutrition Deserves a Front Seat

Dr. JB Sharma & Dr. RS Sharma



1.1 Maternal Nutrition: A Critical Public Health Concern

Pregnancy offers a critical and irreplaceable opportunity to optimize both maternal and child health outcomes. Yet, despite advances in obstetric care, nutrition continues to be a significantly overlooked pillar of antenatal services (1, 2). In India, this oversight has particularly grave consequences, undernutrition, micronutrient deficiencies, and inadequate dietary counselling persist with alarming frequency. The implications extend beyond pregnancy - poor maternal nutrition contributes not only to immediate maternal morbidity and mortality but also fuels a cycle of intergenerational malnutrition, resulting in low birth weight, stunted childhood growth, and increased risk of chronic diseases in adulthood (3).

1.1.2 The Silent Epidemic in Indian Maternal Health

The most recent National Family Health Survey (NFHS-5) reveals troubling data: 57% of pregnant women are anaemic, nearly 19% begin pregnancy underweight, and 18% of newborns are classified as low birth weight (IIPS & ICF, 2021). Iron–folic acid (IFA) supplementation, a cornerstone of national policy, is poorly adhered to - with only 30% of women consuming IFA for the recommended minimum of 100 days (MoHFW, 2021).

According to the Food Safety and Standards Authority of India (FSSAI), the country now faces a public health crisis defined by widespread micronutrient deficiencies. Alarmingly, nearly half of the world's population suffering from micronutrient insufficiency resides in India (4).

With 34% of its population residing in urban areas, India is undergoing rapid urbanization. However, this shift has introduced a new set of nutritional challenges. The 'triple burden' of malnutrition, comprising undernutrition, hidden hunger (micronutrient deficiencies), and the rise of overweight and obesity, now characterizes the nutritional landscape in urban India (5).

This nutritional divide is stark: nearly 40% of pregnant women enter pregnancy underweight, while 25% are overweight or obese. These opposing extremes highlight the complexity of nutritional disparities across socio-economic and geographic strata.

The National Nutrition Monitoring Bureau (NNMB) found that less than 50% of pregnant women in India meet the dietary requirements for key nutrients like iron, folic acid, protein, and vitamins A and C. Contributing factors include early and repeated pregnancies, systemic poverty, caste-based discrimination, and deeply rooted gender inequalities (6).

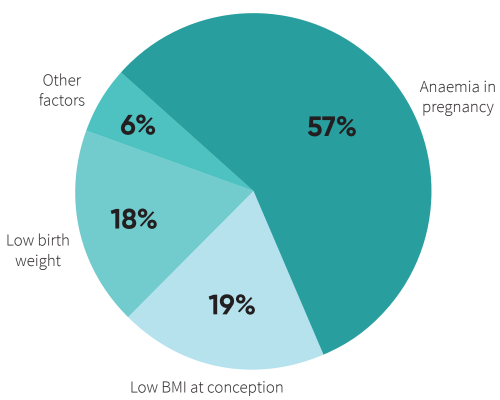
The surge in consumption of low-cost, energy-dense foods, high in sugars and unhealthy fats is exacerbating the rise of overweight and non-communicable diseases among urban Indian women (6).

Nutrient deficiencies vary among population groups due to differences in dietary habits. Monotonous diets, especially in rural areas, further limit micronutrient adequacy. Socio-economic and demographic factors, such as maternal age, occupation, and household characteristics, also play a role.

Table 1: The table represents Maternal Nutrition Indicators in India (NFHS-5)

Indicators	India (%)	Best-Performing State (%)	Worst-Performing State (%)
Pregnant women anaemic	57.0	36	66
Women (15-49) underweight (BMI < 18.5 kg/m2)	18.7	11	25
Low birth weight (<2.5 kg)	18.2	9	23
IFA tablets consumed ≥100 days (during pregnancy)	30.0	55	10

Figure 1: The figure represents the Silent Epidemic in Maternal Health



Case Study 1: *The Anaemia Trap - A 22-year old primigravida from rural Bihar presented at 30 weeks with a haemoglobin of 6.8 g/dL. Despite attending three antenatal visits, she never received dietary counselling and stopped IFA tablets due to side effects.*
She delivered preterm at 34 weeks with a lowbirthweight infant. This starkly illustrates the dangerous gap between prescription and adherence, and the urgent need for culturally sensitive nutrition counselling (7).

1.1.3 Association between Hidden Hunger and Adverse Pregnancy Outcomes

Unaddressed micronutrient deficiencies not only hamper maternal health but also jeopardize child development and perpetuate intergenerational cycles of malnutrition. Some of the short and long-term adverse pregnancy outcomes of gestational micronutrient deficiency include (8,9):

Short-term adverse effects

- Miscarriage
- Stillbirth
- Congenital disabilities
- Preterm birth
- Small size for gestational age
- Low birth weight

Long-term adverse effects

- Altered growth and body composition
- Compromised cardiometabolic, pulmonary, and immune function
- Poor neurodevelopment and cognition

Recognizing these patterns, authorities such as the WHO and the ICMR now recommend multi-micronutrient supplementation (MMS) in pregnancy, alongside iron and folic acid.

1.2 The Nutrition Blind Spot in Obstetric Practice

1.2.1. Gaps in Maternal Nutrition Framework

The National Population Policy (2002) and India's 10th and 11th Five-Year Plans highlight nutrition as a key part of maternal and child health. The policies show a strong belief that education and empowerment, particularly for women, are crucial for better maternal and child health(10, 11).

The Indian government has implemented several nutrition-based interventions to improve pregnancy and birth outcomes, including educational campaigns, monitoring weight gain during pregnancy, prenatal iron–folic acid (IFA) supplementation, supplementary food programs, and fortified food programs. However, we still lag due to gaps in the maternal nutrition framework, such as (12):

- Inadequate maternal nutrient intake
- Early, frequent, and closely spaced pregnancies
- Persistent financial barriers
- Limited knowledge of nutritional requirements across pregnancy stages
- Insufficient, often absent, dietary counselling

1.2.2. Barriers to Effective Nutrition Education

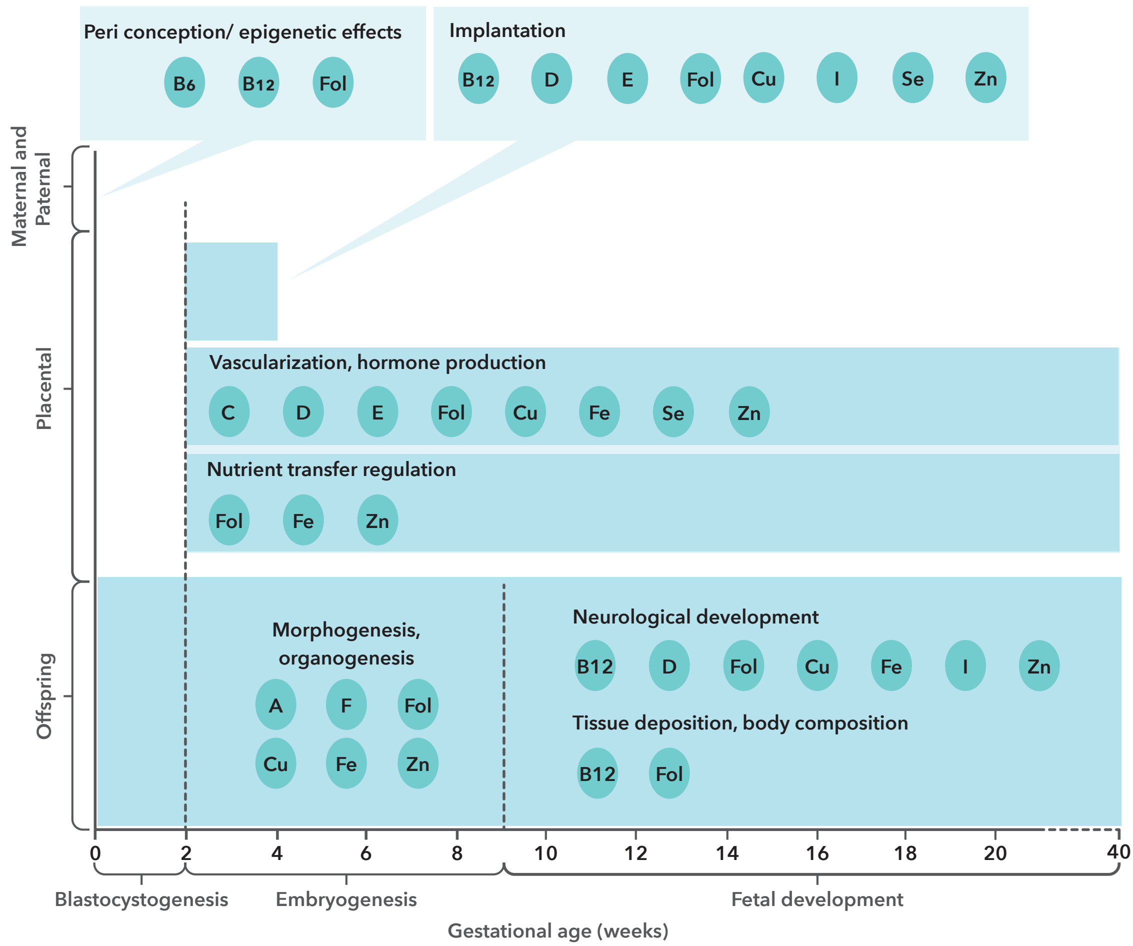
Research on medical pedagogies tended to focus on the role of the learner. Most medical curricula emphasized the memorization of human anatomy and rarely engaged in systemic analysis for students to consider how patients might exist within complex systems, such as food and its biochemistry, which has a significant impact on long-term wellbeing and patient outcomes.

Some of the barriers to effective nutrition include (13):

- Shortage of medical faculty with specialized expertise
- Frequent changes in course instructors
- Competing teaching priorities

- Resistance to curricular change
- Integrating nutrition education into already dense curricula may challenge the breadth of medical training
- Challenges in covering a broad knowledge of nutrition practices and dietary needs vary across the globe

Figure 2: The figure represents the function and timing of micronutrients that affect outcomes in offspring (10).



1.2.3. Barriers in Obstetrics Care Services (OCS) and Guidelines Implementation

The World Health Organization (WHO) identified five major OCS-related obstacles, namely (14):

1. Poverty
2. Lack of information
3. Distance to healthcare facilities
4. Inadequate and poor OCS
5. Cultural beliefs and practices

OCS barriers in India are categorized into demand-side and supply-side issues. Lack of knowledge, awareness, women's autonomy, traditional and alternative practices, fear and stigma, influence of family members, long distance to health facility, financial constraints, poor quality of health service, and poor attitudes of medical staff are some of the demand-side barriers.

On the other hand, shortages of drugs, medical equipment, and human resources, as well as a lack of physical infrastructure, are prominent barriers on the supply side. All these barriers aggravate among the socially and economically disadvantaged ethnic minority groups (16).

Table 2: The table represents WHO vs. Indian Guidelines for Maternal Nutrition (6).

Intervention	WHO Recommendation	Indian Guideline (MoHFW/ICMR-NIN)	Gap in Practice
Iron-folic acid	30-60 mg iron + 0.4 mg folic acid daily	100 mg elemental iron + 0.5 mg folic daily	Low compliance, inconsistent follow-up
Calcium	1.5-2 g daily from 20 weeks gestation	1 g daily from 14-20 weeks gestation	Often not provided systematically
Weight monitoring	At every ANC visit	At every ANC visit	Often recorded without counselling
Dietary counselling	At least once per trimester	At every ANC visit	Rarely personalised; time constraints
Vitamin D	Supplement in high-risk populations	Not routine	Deficiency often undiagnosed
Vitamin B12	Supplement in vegetarian diets	Not routine	Overlooked in vegetarian populations

MoHFW: Ministry of Health and Family Welfare; ICMR-NIM: Indian Council of Medical Research-National Institute of Nutrition; ANC: Antenatal Care

***Case Study 2:** Calcium Neglect: A 28-year-old woman from Uttar Pradesh developed eclampsia at 34 weeks' gestation. Although she had attended antenatal visits, she never received calcium supplementation, despite guidelines recommending initiation between 14 and 20 weeks. A post-event review revealed the lapse as a systemic oversight at the district hospital.*

1.2.4 Barriers to Providing Nutrition Counselling by Obstetrician & Gynecologist (O&G)

Obstetric care in India increasingly emphasizes technological interventions, such as ultrasound, doppler studies, and advanced fetal monitoring; however, basic nutritional assessment often remains an afterthought (15).

Most O&G recognized the value of nutrition counselling by a registered dietitian nutritionist (RDN) and frequently made referrals. However, concerns about patient cost and limited patient interest were noted as barriers. Time constraints during appointments and limited provider expertise in detailed nutrition care were additional challenges. Integrating RDN referrals, while addressing patient-related barriers, could enhance the delivery of comprehensive nutrition during pregnancy (16).

The ranking of perceived barriers to the delivery of dietary counselling is as follows (14):

- Lack of time
- Patient non-compliance
- Inadequate teaching materials
- Lack of counselling training
- Lack of knowledge
- Inadequate reimbursement
- Low physician confidence

General recommendations for dietary intake during pregnancy emphasize the importance of a balanced diet that meets both macro- and micronutrient requirements, while managing caloric intake in relation to energy expenditure and gestational weight gain guidelines.

During pregnancy, individuals are often highly motivated to improve their diet to support both maternal and fetal health outcomes. Despite the vital role of nutrition, many pregnant individuals fail to meet the recommended intake levels for several essential micronutrients, even when using dietary supplements (16).

This gap is often due to limited awareness of nutritional guidelines, which is further exacerbated by inadequate guidance from healthcare providers. In the absence of professional support, pregnant individuals may rely on advice from family, friends, books, magazines, or online sources, which may not always be accurate or evidence-based.

Obstetrician-gynecologists (OB/GYNs) play a pivotal role in evaluating the nutritional status of pregnant patients and guiding them toward reliable resources while respecting their individual dietary preferences and choices (16).

OB/GYNs build long-term trusting relationships with their patients. During pregnancy, a patient typically has between 8 and 14 prenatal visits, providing frequent opportunities for OB/GYNs to promote healthy eating patterns that not only support pregnancy outcomes but also contribute to long-term, lasting dietary habits.

1.3 Recommendations for Improving Nutrition During Pregnancy

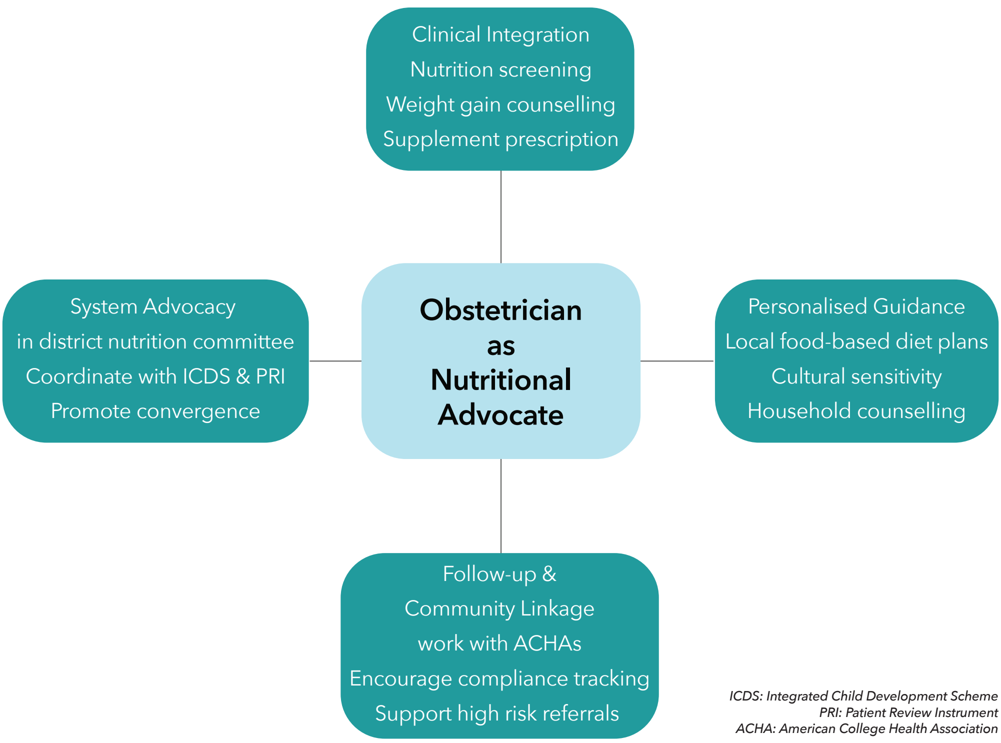
1.3.1 Integrating Nutritional Counselling in Antenatal Care Services

Obstetricians play a vital role in delivering nutrition counselling to address key aspects of maternal nutrition, such as improving dietary quality and ensuring adequate micronutrient intake. Empowerment-based counselling allows women to actively engage in identifying their own nutritional goals and to develop personal strategies to achieve them (17).

Nutrition counselling during pregnancy is most effective when it follows an empowerment-based approach, emphasizing two-way, interactive education.

This method enhances women's ability to act on the guidance provided, helping them make informed dietary choices that benefit both maternal and foetal health. Such programs also foster supportive environments by addressing the material, financial, and social factors that influence dietary behaviours, thereby enabling women to implement and sustain positive nutritional changes (17).

Figure 3: The figure shows a framework for obstetrics and gynaecologists as nutritional advocates



ICDS: Integrated Child Development Scheme
PRI: Patient Review Instrument
ACHA: American College Health Association

***Case Study 3**: The Power of Integrated Care: In Kerala, a district hospital piloted a "Nutrition-first ANC Model," where every antenatal visit included 10 minutes of diet counselling by an obstetrician or trained nurse, with community ASHAs following up at home. Within one year, IFA adherence rose from 42% to 78%, and the proportion of anaemic pregnancies fell by 12%.*

Integrating health education into nutrition counselling can significantly reduce the risk of nutrition-related complications throughout pregnancy, labour, and delivery. The core element of this counselling is clear, targeted communication aimed at increasing awareness of the importance of a balanced, nutritious diet. It also encourages the use of necessary dietary supplements, including fortified foods and micronutrients when appropriate.

These interventions not only improve knowledge but also aim to impact attitudes and behaviors positively. This is especially true for accessing antenatal care (ANC) services, opting for health facility-based deliveries, attending post-natal care, and adopting proper infant and young child feeding practices (17).

Over time, empowerment-focused counselling leads to improved dietary behaviours, including greater dietary diversity and better adherence to micronutrient supplementation. These behaviour changes are essential for achieving broader health impacts. Furthermore, such counselling helps ensure that women are more likely to seek quality antenatal care, opt for institutional deliveries, attend postnatal care visits, and practice optimal feeding of infants and young children (17).

Effective nutrition counselling contributes to improved maternal and child health outcomes. It can reduce the risk of pregnancy-related complications, maternal anaemia, stillbirths, and perinatal mortality. By promoting sustained behavior change and supporting women in their nutritional decisions, obstetricians play a critical role in advancing both immediate and long-term health for mothers and their babies (17).

1.3.2 Emphasis on Nutritional Supplementation

While nutritional counselling and behaviour change should remain ongoing priorities, they are inherently long-term and influenced by complex social factors in urban India. This is where the prescription of multiple micronutrient supplements (MMS) can offer a critical advantage. As a clinician-controlled intervention, MMS provides an immediate, evidence-backed tool to improve maternal nutrient intake, especially for key vitamins and minerals like iron, folate, zinc, and vitamin A. The use of MMS has been associated with reductions in low birth weight, preterm births, and maternal anaemia.

By prescribing MMS alongside sustained counselling efforts, antenatal care providers can achieve a dual objective: driving gradual behaviour change while simultaneously exerting direct clinical control over nutritional outcomes. In doing so, obstetricians are not only addressing gaps in current practice, they are reshaping antenatal care as a space of proactive, but life affirming support for every woman they serve.

1.3.3 Policy and Practice Recommendations

a) Embed Nutrition in ANC Protocols: Make dietary assessment and counselling a mandatory part of every visit (18).
b) Expand Obstetric Nutrition Training: Incorporate dedicated nutrition modules into postgraduate curricula (18).
c) Leverage Technology: Use mobile reminders and digital counselling tools to reinforce adherence.
d) Strengthen Supply Chains: Ensure uninterrupted availability of IFA, calcium, vitamin D, B12, and MMS supplements (18).
e) Monitor and incentivize compliance: Use ANC cards and digital health platforms to track supplementation uptake (18).

Conclusion

Maternal nutrition is foundational to the complete physical and physiological development of the foetus. Yet, India's current maternal health ecosystem faces serious nutritional challenges, ranging from inadequate nutrient intake and insufficient dietary counselling to the compounded effects of early or multiple pregnancies and financial limitations. These gaps are further complicated by systemic barriers faced by obstetricians and gynaecologists themselves, including time constraints, training gaps, and unclear role boundaries in nutrition counselling.

The latest data from NFHS-5 and other key studies underscore an urgent call to action. The "triple burden" of malnutrition; undernutrition, hidden hunger, and the rising incidence of obesity is now a defining challenge in urban India. Our obstetric care systems, while clinically advanced, remain nutritionally under-equipped.

To address this, obstetricians must lead with a **nutrition-first approach.** This includes promoting multi-micronutrient supplementation (MMS), integrating routine nutritional screening into antenatal care, and delivering personalized advice that empowers women to make informed decisions.

Every antenatal visit is a missed opportunity if nutrition is not addressed. As clinicians, we have the privilege and responsibility to transform these visits into moments of empowerment. By doing so, we shift from simply treating illness to truly nurturing life, ensuring that mothers feel supported, confident, and well-prepared for the journey ahead.

Summary

1. Maternal nutrition as a foundation: Nutrition during pregnancy is critical for foetal growth and maternal well-being, with deficiencies leading to long-term intergenerational effects such as low birth weight, stunting, and chronic disease risk.

2. Current burden in India: NFHS-5 data reveal alarming gaps: over half of pregnant women are anaemic, nearly one-fifth begin pregnancy underweight, and 18% of newborns are low birth weight. Urban India additionally faces the "triple burden" of malnutrition—undernutrition, micronutrient deficiencies, and obesity.

3. Systemic barriers: Contributing factors include inadequate dietary intake, repeated pregnancies, poverty, and gender inequity. Obstetricians and gynaecologists themselves face constraints such as limited time, inadequate nutrition training, and lack of clarity around their role in dietary counselling.

4. Gaps in current obstetric practice: While antenatal care is advancing technologically, nutrition remains under-addressed, limiting the effectiveness of maternal and child health interventions.

5. The empowerment role of OB-GYNs: Obstetricians can integrate nutrition-first strategies through awareness-building, routine nutritional screening, personalised dietary guidance, and addressing pre-existing nutritional conditions.

6. Policy alignment and urgency: WHO, ICMR, and FOGSI now recognise the need for multiple micronutrient supplementation (MMS) to address persistent deficiencies and reduce adverse outcomes, highlighting a global and national consensus shift.

7. Nutrition counselling and MMS as dual pillars: While long-term counselling and behaviour change remain essential, MMS offers clinicians an immediate, controllable intervention to improve nutrient intake and reduce risks like anaemia, preterm birth, and low birth weight, helping transform every antenatal visit into a moment of empowerment.

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02

Urban Maternal Nutrition in India: A Clinical Perspective for Gynecologists

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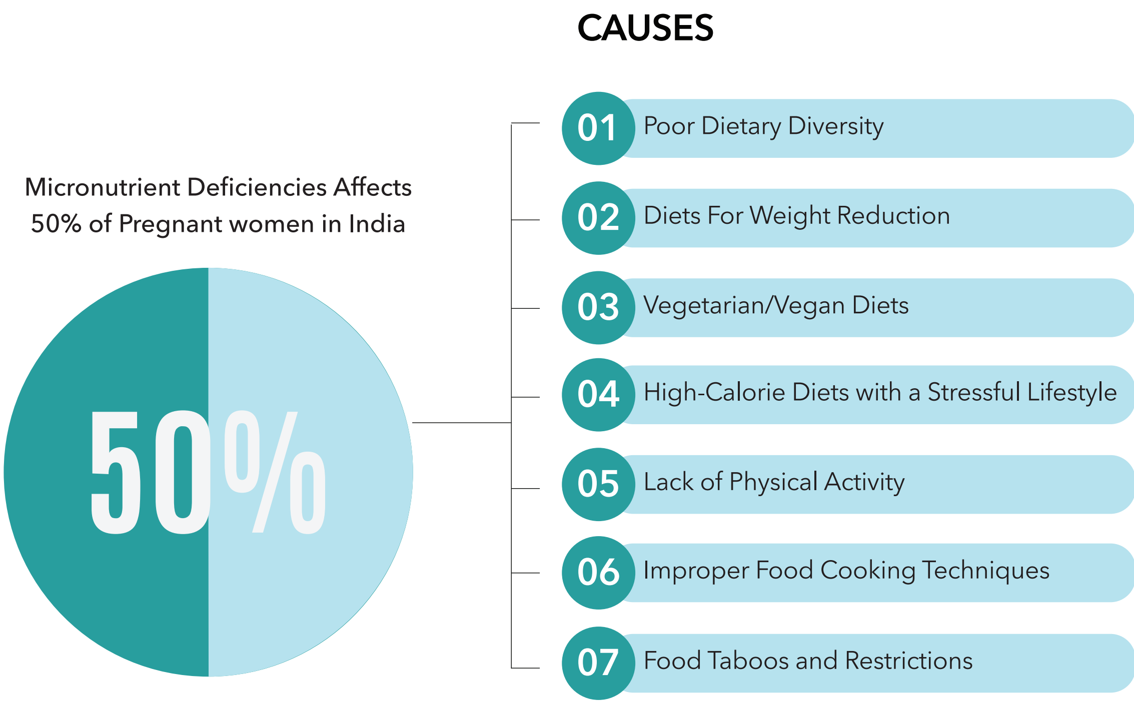


2.1 Introduction

Maternal nutrition during pregnancy is a critical determinant of health for both mother and child, shaping survival, growth, and development across the life course (1). Yet, many Indian women enter pregnancy in a nutritionally vulnerable state due to multiple reasons, such as being influenced by social and cultural contexts, limited access to adequate food due to their lower position within the marital household hierarchy, and low maternal awareness about adequate nutrition, which is a significant risk factor for overall undernutrition (2).

Approximately 80% of women are reported to have inadequate intake of calcium, thiamine, riboflavin, folate, vitamin B12, choline, and vitamin B6 in India (3).

Table 1: The table represents the prevalence of micronutrient deficiency in Indian pregnant women

Analyte	Global clinical cut-off	Prevalence of deficiency during pregnancy (%)
Vitamin D (ng/ml)	<12 ng/ml	63.5-74
Ferritin (ng/ml)	<15 ng/ml	67.7- 73.4
Vitamin B12 (pg/ml)	<200 pg/ml	49 - 51
Zinc (mcg/dl)	<66 µg/dl	73.5
Folate (ng/ml)	<4 ng/ml	26.3
Vitamin B6	<20 nmol/l	10.4
Vitamin B1	Whole-blood Thiamine Diphosphate (ThDp) <74 nmol/l	38.2
Copper	<80 mg/dl	2.7
Iodine	4.67 mIU/l	6.4
Vitamin A	<20 µg/dl	32.1

Despite national efforts primarily focused on iron and folic acid (IFA) supplementation, micronutrient deficiencies remain widespread. India's urban nutrition transition has produced a landscape where underweight, overweight, and micronutrient deficiencies coexist, each contributing to poor maternal and neonatal outcomes (4).

The lack of extensive, nationally representative data makes it difficult to quantify the exact burden, but small-scale studies highlight the seriousness of the problem. Recognition of this burden has driven recent recommendations by the World Health Organization (WHO) and the Indian Council of Medical Research (ICMR) to consider multiple micronutrient supplementation (MMN) during pregnancy (3).

Table 2: The table represents micronutrient deficiencies and their clinical consequences

Micronutrient	Clinical consequences of deficiency on maternal/fetal health
Iron	Increased maternal and fetal morbidity and mortality miscarriage decreased weight and fetal development
Folate	Neural tube defects miscarriage abruptio placentae prematurity
Vitamin B12	Abortion prematurity growth retardation neural tube defects cognitive impairment
Vitamin D	Gestational diabetes preeclampsia low birth weight long-term complications
Iodine	Alteration in the development of central nervous system mental retardation
Zinc	Delayed fetal growth and maturation prematurity
Copper	Abortion prematurity low weight

2.2 Urban Dietary Deficiencies

2.2.1 Micronutrient Deficiency Burden

Micronutrient deficiencies (MiNDs), also known as hidden hunger, affect over two billion people worldwide, with nearly half of them residing in India. Pregnant women in urban India, particularly in slum communities, have reported high rates of anemia (78.8-85%), iodine deficiency (22.9%), and vitamin A deficiency (4.8-19%) (5).

The current burden of hidden hunger in India is critical, driven by widespread deficiencies across several essential micronutrients. MiND affects more than 62% of urban and semi-urban adults, primarily due to poor dietary choices, nutritional inadequacies, and widespread anemia, resulting in multiple concurrent micronutrient deficiencies (6).

2.2.2 The 'Urban Advantage' – and Its Limits

According to data from the NFHS-4 (2015–2016), urban mothers from low socio-economic backgrounds in India face a significant burden of malnutrition in multiple forms.

Compared to the overall urban population, females from low socio-economic backgrounds had a higher prevalence of key nutritional deficiencies leading to short stature, thinness, and moderate to severe anemia as compared to females from upper socio-economic backgrounds, where obesity has been reported as a prevalent factor (7).

Some of the key comparative differences suggest that (7):

- Nearly one in five urban mothers is either thin or obese.
- Obesity among urban mothers increased 2.5 times between 2005–2006 and 2015–2016.
- Daily consumption of milk (and milk products), pulses or beans, eggs or meat, and dark green leafy vegetables by women of higher socio-economic background significantly reduced the risk of both short stature and thinness.
- Increased unhealthy food consumption, such as sweetened aerated drinks and fried food, has been linked to obesity.
- Anemia remained consistently prevalent across all wealth groups.

2.3 Changes in Maternal Dietary Landscape

2.3.1 Cereal Dominance, Low Diversity, and Rise of Processed Foods

Adequate dietary quantity and quality are well-established determinants of maternal nutritional status. The Global Burden of Disease Study highlighted poor diet as the leading risk factor for mortality worldwide, accounting for approximately 11 million deaths. Specifically, 3 million deaths were attributed to high sodium intake and another 3 million to low intake of whole grains, while low fruit consumption was responsible for 2 million deaths (8).

Women of Low- and Middle-Income Countries (LMICs) in reproductive age (WRA) consistently show inadequate dietary diversity. On average, women in these regions consume only 3.0 to 4.84 out of the recommended ten food groups. As a result, a significant proportion ranging from 42.3% to 90% fail to meet the critical minimum threshold of five food groups. This limited diversity contributes to widespread deficiencies in essential micronutrients, especially calcium, iron, zinc, vitamin A, thiamine, riboflavin, folate, and vitamin B12 (9).

Poor maternal diet during pregnancy has been strongly linked to adverse pregnancy outcomes, which can elevate the child's risk of developing cardiometabolic diseases later in life. Despite this well-documented evidence, maternal diets in low- and middle-income countries (LMICs) remain imbalanced, both in terms of macronutrients and micronutrients.

Urban diets are typically ultra-processed, low in nutrient diversity, and dominated by a few cereals like wheat and rice. All these factors are contributing to the lack of adequate amounts of essential macro and micronutrients, such as iron, zinc, vitamin B12, vitamin D, and iodine in pregnant women (10).

Maternal diets in India are shaped by a complex interplay of both supply- and demand-side factors. Some of the key challenges include (8):

- Financial limitations
- Limited access to nutrition services and counselling
- Cultural food restrictions and taboos during pregnancy
- Family influence
- Entrenched gender norms
- Insufficient maternal nutrition knowledge
- Increase in calorie-rich but nutritionally poor diet

Increase in income, urban growth, processes of globalization, and demographic changes have led to a reduction in the relative importance of cereals, while consumption of animal-based protein, processed and purchased foods has increased (11).

At the same time, the growing prevalence of sedentary lifestyles has become a pressing public health concern, particularly in developing nations such as India. Rapid urbanization and technological advancements have significantly altered daily routines, resulting in a decline in physical activity among adults. This shift has contributed to a rising burden of non-communicable diseases (NCDs) (12).

Case Study 1: Diet, Disease and Gestational Diabetes Mellitus (GDM)

Gestational diabetes mellitus (GDM) occurs when women without previous diabetes develop high blood sugar due to disrupted glucose metabolism during pregnancy. GDM can increase complications such as fetal oxygen deprivation, stillbirth, miscarriage, and various post-partum complications like vascular dysfunction or dyslipidemia (13). The prevalence of GDM in women residing in urban cities of India ranges from 15.2% to 17.8% (14).

A healthy, nutrient-rich diet represents a primary modifiable risk factor for GDM. Improving the diet can help stabilize blood glucose levels, minimize complications, and support postpartum recovery.

Various dietary approaches, including the Mediterranean Diet and the DASH Diet (Dietary Approaches to Stop Hypertension), have been inversely associated with GDM (15).

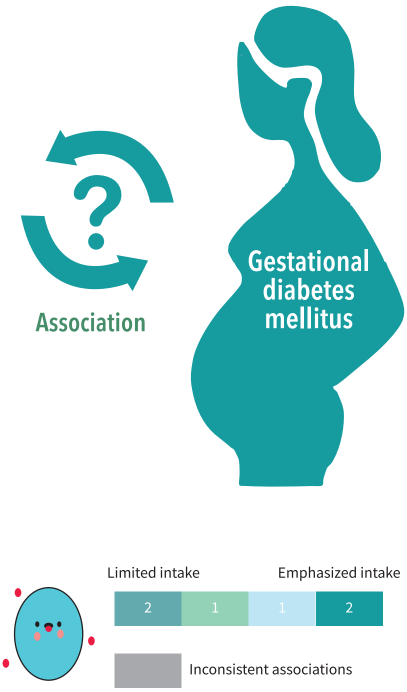
The reference diet, proposed by the EAT-Lancet committee in 2019, advocates a plentiful consumption of plant-based foods, including whole grains, fruits, vegetables, nuts, legumes, and unsaturated oils. A moderate intake of fish, poultry, and a reduced amount of added sugar, dairy products, and red meat was also recommended. The transition from a low-quality diet to the EAT-Lancet reference diet may reduce the global rates of diet-related diabetes in pregnant females (13).

***Conclusion**: Nutritional care during pregnancy in urban areas is even more complex due to drastic changes in people's lifestyles, food choices, and lack of physical activity. Healthy and nutritious food is not always affordable for everyone living in cities, but calorie-rich, fatty, and sugary food products are comparatively cheaper and often feel more satisfying.*

Nutrition through food or supplementation can provide a more comprehensive solution, offering mothers the support they need and babies the best chance to grow healthy. Evidence from the WHO and the ICMR now strongly supports the use of multiple micronutrient supplementation (MMS) as a superior approach to improving pregnancy health and long-term child development.

Figure 1: The figure represents the relationship between the EAT-Lancet reference diet components and gestational diabetes mellitus in pregnant women (13).

The EAT-Lancet reference diet components	Recommendation level	
Whole grains		
Tubers or starchy vegetables		
Fruits	Grapes	Melons
Vegetables		
Red meat		
Dairy foods	Full-fat dairy foods, cheese, and yogurt	Fat-free dairy foods
Fish		
Poultry		
Eggs		
Legumes	Soy products	Lentils
Nuts		
Added fats	Extra virgin olive oil	
Added sugars	Sugar-sweetened beverages	



2.3.2 Food Away from Home and Restaurant Dependence

The Urban Indian households spend more on processed foods and consume more food away from home than rural households. Most of these differences are attributed to varying socio-economic and demographic factors, including higher income, a busy lifestyle, and smaller urban household sizes (16).

A recent study reported the fastest rate of growth in the purchase of sweet-salty snacks and edible oil purchases. Also, Delhi has been reported as the highest consumer state for processed foods and beverages amongst all metropolitan cities of India (17).

The ease and luxury of ordering food from outside have increased the overall consumption of processed food with high sugar, salt, and poor-quality fat. This small change in habit is also one of the factors contributing to poor maternal diets in urban India.

2.3.3 Changed Agricultural Practices

Changes in agricultural practices are also one of the factors impacting the nutrient picture of urban India. Intensive farming, depletion of nutrients from farmland, increased pollution, and post-harvest processing can deplete the micronutrient content in plant-based food products. Moreover, the increased use of pesticides and chemical growth inducers also hampers the nutrient profile of a plant-based diet and poses a significant neurodevelopmental risk to the growing fetus (18).

2.3.4 Food Safety and Contamination Risks

Pregnant women are at high risk of developing food poisoning during pregnancy due to their immunomodulatory condition. Packaged, ready-to-eat, or outside food has a high risk of containing harmful microorganisms, such as *T. gondii or L. monocytogenes*, which can cause toxoplasmosis or listeriosis. Food-borne diseases can not only affect pregnant women but also cause miscarriage or stillbirth (19).

On the other hand, milk and dairy products can play a crucial role in achieving high nutrient density and bioavailability, due to their widespread availability and consumption. However, adulteration is also on the rise to meet the increasing demand. Consumption of adulterated milk products is linked to hormonal changes, digestive issues, and increased disease susceptibility in pregnant women (20).

2.3.5 Urban Lifestyle and Cooking Practices

One of the most crucial factors that leads to the upsurge of most diseases in urban areas is the unhealthy and sedentary lifestyle, with widespread unhealthy snacking habits, disordered eating patterns, and physiological stress that contributes to poor micronutrient status (21).

It is also noted that obese women from urban areas often follow poorly planned weight loss diets. These diets may lead to weight loss without proper nutritional guidance, but they can also raise the risk of malnutrition and deficiencies in essential nutrients. If these deficiencies are not addressed, they can negatively impact health outcomes (22).

2.3.6 Bioavailability Challenges

A nutrient-rich diet does not guarantee complete absorption of the available nutrients. The body's effective absorption and utilization of these nutrients can be significantly hindered by several factors, such as the presence of anti-nutrient compounds that naturally occur in many plant-based foods, including phytic acids, oxalates, tannins, and lectins.(23)

Anti-nutrients are naturally occurring compounds, predominantly found in plant-based foods, that interfere with the absorption or utilization of essential nutrients in the human body. These compounds may even damage specific vitamins. Their mechanisms often involve binding to vital micronutrients, forming insoluble complexes that prevent absorption, or inhibiting digestive enzymes critical for nutrient breakdown (24).

Table 2: The table represents common anti-nutrient compounds found in Indian diets and their impact:

	Anti-nutrient Compounds	Found in-	Interfere with Absorption of-
	Glucosinolates	Cruciferous vegetables like broccoli, Brussels sprouts, cabbage, and kale	Iodine
	Oxalates	Leafy greens, tea, beans, nuts, and beets	Calcium
	Lectins	Beans, peanuts, and whole grains	Calcium, iron, phosphorus, zinc
	Phytates/ Phytic acid	Whole grains, seeds, legumes, nuts, and seeds	Calcium, iron, magnesium, zinc
	Tannins	Tea, coffee, legumes (beans, lentils, peanuts) pomegranates, berries, raw nuts, chocolate, wine	Iron
	Saponins	Legumes (beans, lentils, peanuts), whole grains	Iron and zinc

Table 3: The table represents the list of enhancers of nutrient absorption

Enhancer	Mechanism of Action
Vitamin C (Ascorbic Acid)	Converts ferric iron (Fe^{3+}) to the more easily absorbed ferrous form (Fe^{2+}); counteracts the inhibitory effects of phytates, polyphenols, and oxalates.
Heme Iron & "Meat Factor"	Heme iron is inherently well-absorbed and not affected by inhibitors. The "meat factor" (peptides and amino acids) enhances non-heme iron absorption.
Traditional Indian Enhancers	Onions and garlic: Improve iron and zinc bioaccessibility. Amchur: Improves iron and zinc bioaccessibility. β-carotene: Enhances non-heme iron absorption by reducing iron and forming complexes to keep it soluble.
Organic & Food Acidulants	Organic acids (e.g., citric, malic) increase the solubility and uptake of iron and zinc from grains and pulses.
Magnesium Synergy	Interacts synergistically with other micronutrients (calcium, vitamin D, potassium, zinc, iron, vitamin B6) to support bone health, muscle relaxation, and enzyme activities.

Conclusion

Nutritional care during pregnancy in urban areas is even more complex due to drastic changes in people's lifestyles, food choices, and lack of physical activity. Healthy and nutritious food is not always affordable for everyone living in cities, but calorie-rich, fatty, and sugary food products are comparatively cheaper and often feel more satisfying.

Nutrition through food or supplementation can provide a more comprehensive solution, offering mothers the support they need and babies the best chance to grow healthy. Evidence from the WHO and the ICMR now strongly supports the use of multiple micronutrient supplementation (MMS) as a superior approach to improving pregnancy health and long-term child development.

Summary

1. The urban paradox: Cities offer better healthcare access, yet maternal diets remain poor, creating a dual burden of undernutrition and obesity.
2. Micronutrient deficiencies: Iron, folate, zinc, and vitamin A deficiencies persist in urban India, worsened by anti-nutrient compounds that reduce absorption.
3. Dietary transitions: Heavy reliance on cereals, processed foods, and calorie-dense diets, combined with sedentary lifestyles, increases pregnancy risks.
4. Cultural and social barriers: Food taboos, family pressures, financial constraints, and limited counselling undermine optimal maternal nutrition.
5. Food environment risks: Greater dependence on restaurant food, packaged products, and food adulteration further compromise nutritional adequacy.
6. Clinical implications: Urban ANC must integrate routine screening, personalised dietary counselling, and culturally sensitive advice into standard practice.
7. Strategic role of MMS: While counselling drives long-term change, prescribing multiple micronutrient supplements (MMS) gives obstetricians immediate, evidence-based control to reduce anaemia, low birth weight, and preterm birth.

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03

Maternal Malnutrition: Lasting Consequences Beyond Birth

Dr. Suchitra N Pandit & Dr. Parag Biniwale

Nutrition during pregnancy is not just a matter of meeting daily dietary requirements, it is a determinant of both immediate and lifelong health outcomes for mother and child. The impact of deficiencies extends far beyond delivery, influencing neonatal survival, childhood development, and even the risk of adult-onset diseases. For obstetricians in urban India, where women face a paradox of food abundance alongside nutritional gaps, understanding these consequences is essential for shaping effective antenatal care.

SHORT - TERM IMPLICATIONS

- Postpartum Hemorrhage
- Pre-eclampsia
- Fetal Growth Restriction
- Preterm Birth
- Gestational Diabetes
- Viral Infections
- Low Birth Weight

LONG - TERM IMPLICATIONS

- Cardiovascular Risks
- Hypertension
- Renal dysfunction
- Thyroid Disorders

Offspring

- Obesity
- Impaired brain functions
- Metabolic Disorders

Beneficial Key Nutrients

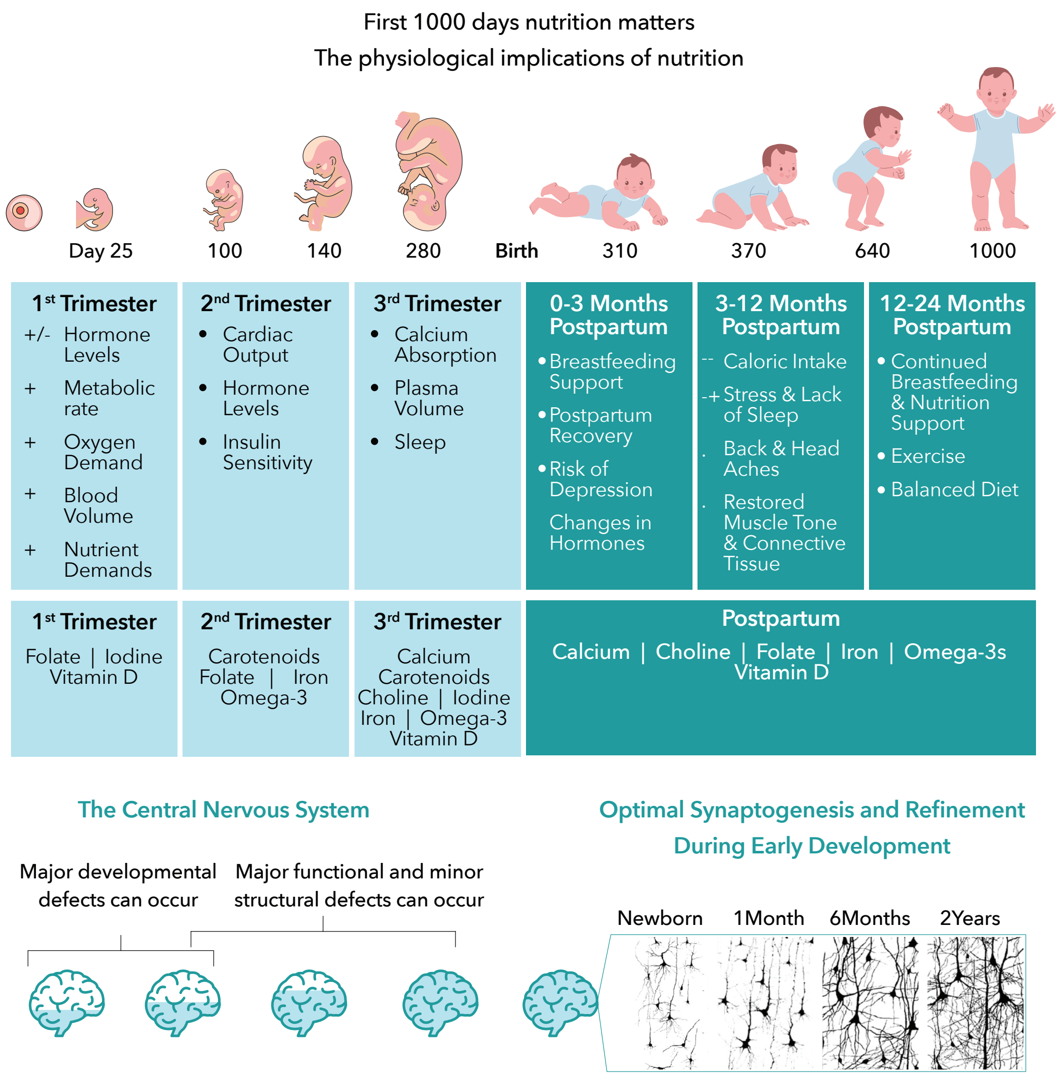
- Iron
- Calcium
- Vitamin D
- Folic Acid
- Iron Supplement
- Vitamin B12
- Zinc

3.1 Why Nutrition Matters?

Maternal nutrition is of critical importance throughout the reproductive period, including preconception, pregnancy, and helps the mother to create the best bodily reserves in anticipation of breastfeeding. Poor or inadequate maternal nutritional status can lead to poor health trajectories in the intrauterine environment. A stressed intrauterine environment can lead to an increased risk of chronic diseases in the offspring's lifetime (1).

Nutritional status throughout pregnancy not only impacts the growth of the foetus inside the womb but also determines the probable disease blueprint of the progeny for its later life. Abnormal foetal growth patterns such as low birthweight (LBW; <2500 g), small for gestational age (SGA), macrosomia (>4–4.5 kg), and large for gestational age (LGA) can occur due to poor maternal nutrition (2).

Figure 1: The figure depicts timeline of critical events during pregnancy and early development, and the role of nutrition (2).



3.2 Nutrients which Matter the Most

Optimal nutrient intake is critical for the well-being of both mother and baby. Nutrient deficiencies, even mild ones, can have detrimental effects on embryonic development that may compound over time, leaving a lasting impact on the infant's health for a lifetime. Nutrient deficiencies can similarly impact maternal health during this time, when a mother's ability to nurture, feed, and care for herself and her child is dependent on her health (2).

Traditionally, in India, the emphasis has been placed almost exclusively on iron and folic acid (IFA) supplementation. While these remain vital, focusing only on IFA overlooks the wider spectrum of nutrients that are equally critical for maternal and foetal health. A balanced diet with macronutrients, micronutrients, and vitamins is necessary for a healthy pregnancy. Some of the essential nutrients that are known to cause a lasting impact on maternal and child health are (2):

1) **B-Vitamins:** vitamins B6, B9 (folate), and B12 play a crucial role in early foetal development. Maternal vitamin B9 deficiency can result in neural tube defects, low birth weight, and impaired cognitive development. Vitamin B12 deficiency can lead to pre-term birth, congenital malformations, and an increased risk of first-trimester miscarriage. In mothers, vitamin B12 deficiency can cause mental slowness, memory problems, and numbness or tingling in the extremities (3). On the other hand, vitamin B6 deficiency can lead to neurodevelopmental issues in the foetus and anaemia, depression, and irritation in the mother(2).

2) **Calcium:** It is critical for foetal bone development as well as maintenance of the maternal skeleton and healthy smooth muscle contractions. Approximately 80% of the calcium in the foetal skeleton is transferred from the mother during the third trimester (2).

3) **Carotenoids:** They are antioxidants of our body that help our cells to protect against oxidative damage done to our cells and DNA; however, the prevalence of carotenoid deficiency, including from lutein and zeaxanthin, is unknown. Some studies have reported a strong association between high lutein and zeaxanthin concentration with reduced risk of pre-eclampsia and babies with Small for Gestational Age (SGA) (2).

4) **Choline:** Its intake during pregnancy is correlated with cognitive development in the foetus and newborn. Pregnant mothers with adequate choline status are shown to give birth to infants who have a significantly reduced risk of behavioural problems with a higher cognitive development score compared to women with poor choline status (2).

5) **Magnesium:** Its deficiency during pregnancy is associated with preeclampsia and pre-term delivery, poor vascular system growth in the first trimester of the foetus. This may result in Intra Uterine Growth Restriction (IUGR) and Low Birth Weight (LBW) in the newborn (2).

6) **Omega-3 Fatty Acids:** Docosahexaenoic acid (DHA) is the principal omega-3 found in mammalian tissues. It is known for optimal foetal brain and nervous system development with better visual function. Additionally, the continued intake of eicosapentaenoic acid (EPA) and DHA is also vital for the maintenance of the mother's cardiovascular health (2).

7) **Vitamin A:** The requirement for vitamin A for the foetus increases during the first and third trimester, and both the mother and child may be affected by deficiency. Maternal deficiency can result in night blindness accompanied by an increased risk of mortality. Foetal vitamin A deficiency increases the risk of preterm birth and mortality (2).

8) **Vitamin D:** Its deficiency increases the risk of placental insufficiency and pre-eclampsia, is associated with increased risk of bacterial vaginosis, and increases the risk of developing gestational type 2 diabetes (T2D) by increasing glucose intolerance (2).

9) **Trace Minerals**
    a. **Zinc:** Its deficiency slows the development of the placenta, which can delay organogenesis. It may also increase the risk of preterm labour, spontaneous abortion, and low birth weight (4).

b. **Copper:** It can affect early embryonic development pre- and post-implantation, by affecting the growth of connective and nervous tissue (4).

c. **Iron:** Maternal iron deficiency can result in serious consequences during pregnancy, including a smaller placental size and delayed organogenesis in the second trimester. Iron deficiency can impact foetal growth and can increase the risk of chronic foetal hypoxia. Low iron stores in the newborn can lead to poor birth outcomes, poor cognitive development, and cardiometabolic disease for the child's later life, and its demand increases by the third trimester (5).

d. **Iodine:** Maternal iodine deficiency can cause mental slowness and tiredness in the mother and can negatively impact nervous system growth during the first and second trimesters of foetal development. Severe maternal iodine deficiencies can cause significant foetal developmental delays and result in an infant born with cretinism (2).

3.3 Nutritional Deficiencies and Their Implications on Maternal and Infant Health

Maternal nutrition is of critical importance throughout the reproductive period, influencing not only the immediate course of pregnancy but also the lifelong health of both mother and child. In the short term, inadequate nutrition contributes to complications such as postpartum haemorrhage, pre-eclampsia, foetal growth restriction, gestational diabetes, preterm birth, low birth weight, and a higher susceptibility to infections. Over the longer term, the effects extend well beyond delivery—mothers may face increased risks of cardiovascular disease, hypertension, renal dysfunction, thyroid disorders, and bone weakness, while their children are more vulnerable to neurocognitive deficits, metabolic disorders, and obesity. Addressing these risks requires particular attention to key nutrients including iron, calcium, vitamin D, folic acid, vitamin B12, zinc, and other essential micronutrients, each of which plays a crucial role in preventing complications and supporting optimal outcomes across generations.

The following subsections explore these consequences in greater depth, beginning with the short-term effects on the mother and foetus, and progressing to the long-term implications that shape health across the life course.

3.3.1 Short-Term Implications

- **Postpartum haemorrhage:** It causes about 70,000 maternal deaths worldwide each year. Most deaths from postpartum haemorrhage are reported in low or middle-income countries (6).

  Multiple studies have demonstrated a strong association between prenatal anaemia and postpartum haemorrhage. Poor access to a healthy diet and untreated heavy menstrual bleeding, compounded by exposure to chronic infectious diseases such as HIV, malaria, tuberculosis, or intestinal parasites, are believed to be the leading causes of anaemia (7).

- **Pre-eclampsia:** Pre-eclampsia is a multisystem syndrome of pregnancy. It is one of the leading causes of maternal and perinatal morbidity and mortality. It complicates about 3%–5% of all pregnancies globally, causing approximately 42000 maternal deaths annually (8). The incidence of preeclampsia in India varies from 5% to 15% (9).

  Pre-eclampsia is defined as de novo hypertension presented after 20 weeks of gestation combined with proteinuria (>300 mg/day) or another maternal organ dysfunction. This can include renal insufficiency, liver involvement, neurological or haematological complications, uteroplacental dysfunction, or foetal growth restriction (9).

  It can be caused by multiple or combined nutritional deficiencies, such as vitamin C, D, B9 (folate), B12, E, calcium, magnesium, zinc, copper, selenium, and Omega-3 long-chain polyunsaturated fatty acids (PUFA)(10).

- **Gestational Diabetes Mellitus (GDM):** In some cases, it involves the discovery of a prediabetic condition, while in others, it represents the onset of diabetes. It is typically diagnosed at 24-28 weeks of gestation (11).

  Multiple reports are suggesting a strong association between vitamin D deficiency and gestational diabetes. Moreover, in neonates, vitamin D deficiency has been linked to an elevated risk of developing conditions such as type 1 diabetes mellitus (11).

It is suggested that an optimal vitamin D status through supplementation before conception and during pregnancy may reduce the risk of maternal and foetal complications and diseases in newborns and infants (11).

Vitamin D is also a hormone promoter involved in the metabolism of calcium in the body (12). Studies have also reported beneficial effects of co-supplementation of calcium with vitamin D on glycaemic control in pregnant women. It has also been reported to control fasting plasma glucose, plasma insulin, HOMA index, and LDL cholesterol, as well as a lower rate of caesarean section, macrosomia, hyperbilirubinemia, and hospitalization in newborns (13).

- **Low birth weight:** Birth weight predicts the health status of the mother and provides insight into the survival, development, and long-term health of the baby.

  Low birth weight (LBW) is defined as the first birth weight, which is less than 2500 g (5.5 pounds), resulting from birth before 37 completed weeks, or due to intrauterine growth restriction, or from both(14).

  LBW babies have 40 times more chances to die within the first 30 days of life than normal birth weight (NBW) babies. Poor maternal nutrition and lifestyle are the major causes of this condition. Studies suggest that the serum concentration of maternal vitamin C, E, and iron is linked to birth weight and length in the case of full-term deliveries (14).

  Studies have also demonstrated that a 1 µg/mL increase in the serum vitamin C level can lead to a 27.2 g increase in birth weight and 0.17 cm increase in birth length. Birth weight and length were found to be the highest when the levels of both vitamins C and E were high (15).

  Many studies also linked deficiency of folic acid, iodine, zinc, vitamins A and D, riboflavin, B6, and B12 with LBW. This highlights that a comprehensive approach to nutrition is crucial, and that a healthy diet with an emphasis on antioxidant nutrient balance is essential for pregnant women who are exposed to various oxidants through food, drinking water, or inhaled air (15).

- **Foetal growth restriction (FGR):** The primary risk factor for stillbirth is unrecognized foetal growth restriction, which is associated with intrauterine and neonatal deaths, and creates complications at later stages of the child's life or diseases occurring in adulthood (16).

  Foetal growth can be inhibited at any period during a pregnancy. The phenomenon that restricts foetal growth at early stages of pregnancy results in overall growth restriction, while at later stages, the development of only specific tissues is affected.

  The number of reports on the importance of vitamin D during pregnancy and pregnancy complicated by intrauterine growth restriction has been increasing. It was found that the human placenta contains elements involved in vitamin D signalling pathways, which regulate the expression and secretion of human chorionic gonadotropin and increase the production of steroids in the placenta. It is also vital in glucose, insulin, and calcium metabolism (17).

  A comparative study demonstrated a higher increase in foetal body weight in FGR-complicated pregnancies taking vitamin D supplementation at a dose of 2000 IU than in the group of women with pregnancies complicated by FGR taking vitamin D supplementation at a dose below 500 IU (16).

- **Preterm Birth (PTB):** Any birth before 37 weeks of completed gestation is defined as a preterm birth (18). Iron, folic acid, and calcium are reported as necessary supplements for pregnancy in general, and also have potential benefits for reducing the risk of PTB (19).

  In settings where there are low dietary or maternal zinc and vitamin B12 levels, low-to-moderate-certainty evidence suggests that zinc and vitamin B12 supplementation may reduce the risk of PTB. Recent evidence indicates that multiple micronutrient (MMN) (added to iron and folic acid) may slightly reduce the risk of PTB. The beneficial effects of omega-3 fatty acids are also reported for reducing PTB risk (19).

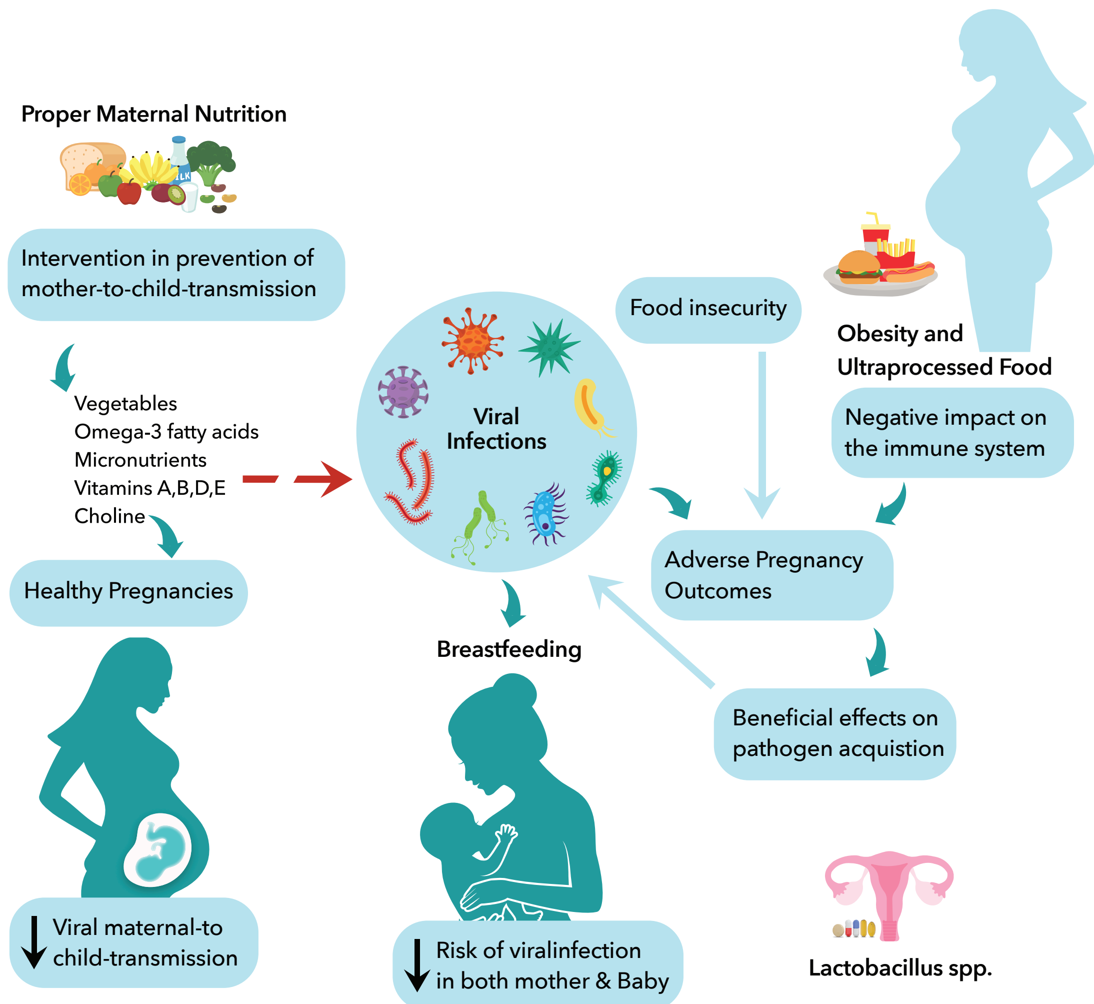
- **Infections:** Drastic adaptations of maternal physiology during gestation to accommodate the fetoplacental unit make this period prone to adverse maternal/foetal outcomes, including numerous alterations arising from viral infections.

Common infections during pregnancy that can be passed to newborns include toxoplasmosis, rubella, cytomegalovirus, and herpes simplex viruses. These are known as ToRCH infections. Other relevant viruses are enterovirus, parvovirus B19, hepatitis virus, varicella-zoster virus, human immunodeficiency virus, Zika virus, and Dengue virus. More recently, researchers have focused on the novel SARS-CoV-2. These viruses are important for current studies on maternal-fetal interactions in viral infections during pregnancy (20).

An adequate lifestyle with proper nutrition plans and feeding interventions can help in reducing the risk of virus-related gestational diseases and accompanying complications in later life.

Recent evidence demonstrated that a balanced diet with protein, omega-3 fatty acids, vitamin A, vitamin D, vitamin E, vitamin B1, vitamin B6, vitamin B12, vitamin C, iron, zinc, and selenium can improve multiple viral infections, including COVID-19 infection and its treatment outcomes. Moreover, MMN supplementation has been shown to decrease adverse pregnancy outcomes in pregnant women infected with HIV. Proper intake of omega-3 polyunsaturated fatty acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), is also found to reduce virus-related inflammation during pregnancy (20).

Figure 2: The figure depicts impact of maternal nutrition on viral infections during pregnancy



3.3.2 Long-Term Implications

- **Cardiovascular disease (CVD):** Women who experience adverse pregnancy outcomes (APOs) due to placental dysfunction or maternal vascular abnormalities (endothelial activation, inflammation, and vasospasm) are at increased risk for future cardiovascular disease (CVD) (21).
- **Hypertension:** APOs are associated with increased risk of development of hypertension.
- **Thyroid disorders and others:** Increased risk of maternal hypothyroidism and other thyroid disorders, bone health issues due to calcium deficiency, are some other long-term maternal health implications (22). Ventricular hypertrophy, vascular dysfunction, and renal dysfunction (caused by calcium, zinc, and vitamin D deficiency) (23).
- **Foetal long-term health:** Impaired brain development and neurocognitive deficits are particularly linked to iodine deficiency. Insulin resistance and metabolic disorders in offspring are linked to calcium deficiency (22).
- D**evelopmental Origins of Health and Disease (Barker hypothesis):** The rise in non-communicable chronic diseases (NCCDs) such as obesity, diabetes, hypertension, asthma, and neurodevelopmental disorders is not only linked to lifestyle in adulthood but also deeply rooted in early life exposures. The Barker hypothesis or Developmental Origins of Health and Disease (DOHaD) theory emphasizes that nutrition and environment during fetal life and infancy strongly influence long-term health (24).

  Key evidence comes from historical events like the Dutch Famine, where children exposed to severe undernutrition in utero showed higher risks of heart disease, diabetes, and other illnesses in adulthood. Modern studies have identified epigenetic mechanisms, chemical changes to DNA that regulate gene activity, as the biological link between early experiences and long-term health outcomes. These changes can persist for decades and may even be passed across generations (24).

  Alongside foetal nutrition, the gut microbiome plays a pivotal role. The infant gut is initially simple but develops rapidly into a diverse ecosystem shaped by delivery mode, breastfeeding, diet, and environment. A rich and balanced microbiome supports metabolism, immunity, brain development, and resistance against obesity and autoimmune diseases. Conversely, dysbiosis, loss of microbial diversity, especially in the first three years of life, heightens the risk of obesity, diabetes, allergies, and neuropsychiatric problems (25).

Conclusion

Poor maternal nutrition is not confined to the pregnancy period, it casts a long shadow over maternal health, foetal growth, neonatal survival, and the lifelong wellbeing of children and adults. From anaemia and pre-eclampsia to foetal growth restriction, prematurity, and later-life risks such as cardiovascular disease and obesity, the consequences are profound and intergenerational.

For clinicians, this reinforces the importance of recognising nutrition as a clinical determinant of maternal and child health. A holistic approach encompassing balanced diets, targeted nutrient intake, culturally sensitive counselling, and where appropriate, evidence-based supplementation must become part of routine antenatal care.

While micronutrient supplements, including MMS, have shown measurable benefits, they should be seen as complements rather than replacements to broader dietary improvements. The true opportunity lies in combining preventive nutrition strategies with clinical vigilance, thereby empowering women to enter motherhood with resilience and reducing the burden of preventable complications.

Summary

1. Maternal nutritional deficiencies have multi-generational consequences, spanning mothers, fetuses, neonates, children, and adults.
2. For mothers, they increase risks of anaemia, pre-eclampsia, obstructed labour, and mortality.
3. For fetuses, nutritional deficits contribute to intrauterine growth restriction, congenital anomalies, and stillbirths.
4. Neonatal outcomes include prematurity, low birth weight, and increased perinatal mortality.
5. Childhood and adolescence suffer through stunting, impaired cognition, and infection vulnerability.
6. Adult outcomes include greater risks of cardiovascular disease, diabetes, and obesity.
7. Routine antenatal care should integrate nutrition as a clinical priority—through balanced diets, counselling, and selective use of supplementation where indicated.

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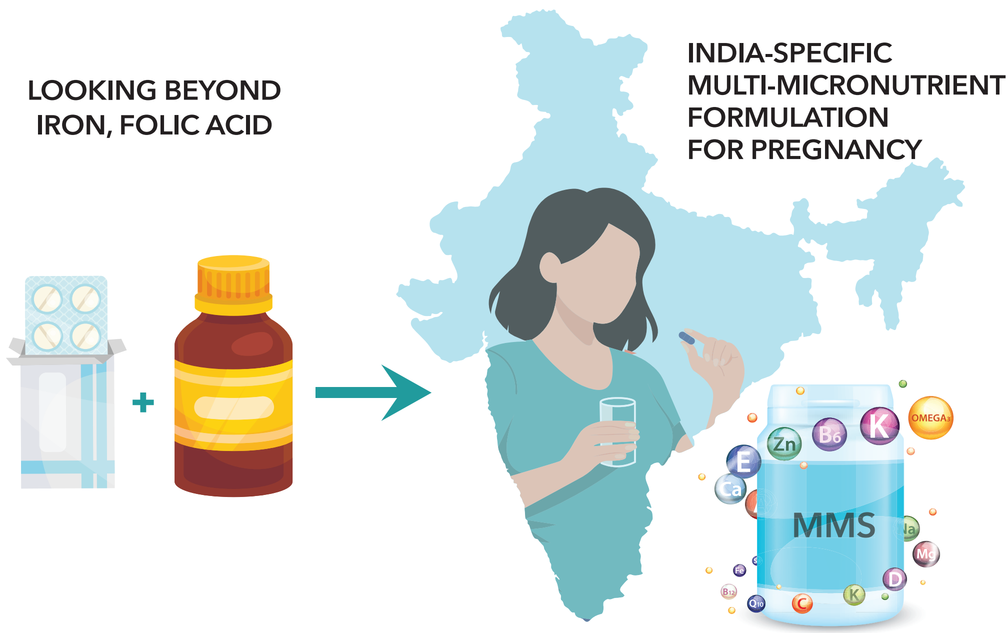
04

Advancing Antenatal Protocols: From Iron-Folic Acid to Multi-micronutrient Supplementation

Dr. Shailaja R. Bidri & Dr. Bharathi Rajshekar



4.1 Dietary Limitations and the Case for Multi-micronutrient Supplementation

Maternal nutrition lies at the heart of both immediate and long-term health outcomes for the mother and her child. A well-balanced diet, rich in both macro- and micronutrients, remains the cornerstone of antenatal care, shaping fetal growth, maternal wellbeing, and the future health trajectory of the next generation (1). Beyond food, healthy routines such as adequate rest, physical activity, and stress reduction practices like meditation also contribute significantly to positive pregnancy outcomes (1).

Yet, despite its central role, diet alone is often insufficient to meet the rising nutritional demands of pregnancy in today's context. Agricultural practices have altered food quality, urban lifestyles promote convenience foods, and cultural beliefs or behavioural patterns may restrict dietary diversity. As a result, even women who appear food secure may still suffer from "hidden hunger" that quietly undermine maternal resilience and fetal development.

For more than seven decades, iron–folic acid (IFA) supplementation has been the cornerstone of antenatal nutrition policy in India. Introduced in the 1970s, IFA addressed the visible crisis of maternal anaemia and neural tube defects at a time when maternal mortality was a central challenge. However, India today faces a paradox. While food and healthcare access have improved, NFHS-5 data show anaemia among pregnant women has actually risen to 52%, and the prevalence of low birth weight (LBW) remains stagnant at ~18% (2). Even urban women, who appear well-nourished, commonly present with deficiencies in vitamin B12, vitamin D, zinc, magnesium, and iodine reflecting the "thin-fat" phenotype of Indian women: normal body weight but high micronutrient insufficiency (3).

These realities demand a re-examination of our reliance on IFA alone and call for an expanded strategy: Multiple Micronutrient Supplementation (MMS) has been shown in large-scale international trials, including Cochrane reviews and pooled analyses, to reduce the risk of LBW, preterm birth, and small-for-gestational-age neonates, without increasing maternal or neonatal mortality (4-5). The Indian Council of Medical Research (ICMR) has now developed an India-specific MMS formulation (2023–24), tailored to local dietary gaps. This provides a historic opportunity for clinicians in India to advance protocols, combining the proven value of IFA with the broader benefits of MMS, and aligning antenatal care with global best practice (6).

4.2 The Inadequacy of Iron and Folic Acid (IFA): A Re-evaluation of Current Practice

WHO has long recommended universal IFA supplementation during pregnancy (30–60 mg iron + 0.4 mg folic acid for 6 months). India's National Anemia Control Program (launched in 1970) made IFA tablets a cornerstone of antenatal care (7-8).

Daily oral supplementation of a combination of iron and folic acid (IFA) is the most cost-effective intervention to reduce iron-deficiency anaemia and neural tube defects in pregnancy. Folic acid taken during preconception and early pregnancy can significantly lower the incidence of spina bifida and other neural tube defects. At the same time, iron supplementation addresses iron-deficiency anaemia to an extent (9).

The government has implemented various programs to address anemia in India (2). However, despite routine IFA interventions, the prevalence of anaemia has increased from about 50% (NFHS-4) to 52% (NFHS-5).

The reasons for this could be two-fold: a) lack of adherence; and b) lack of IFA alone to treat anemia and hidden hunger.

a) **Lack of Adherence:** The efficacy of these programs relies on the adherence of women to IFA supplementation. Due to low supplementation adherence, the efforts made by the government have fallen short, resulting in the prevalence of anemia being unacceptably high (2). According to the National Family Health Survey (NFHS)-5, only 26.0 % of pregnant women in India adhere to the recommended IFA supplementation (2).

   Primary reasons for noncompliance are many:

   - **Side Effects of IFA:** Some of the common side effects of IFA are bloating (30.8 %), constipation (23.9 %), and forgetfulness (73.0 %). Other side effects include dislike of taste (7.7%), headache (2.0%), and vomiting (1.2%) (10-11).

- **Misconceptions and personal barriers about IFA:** Some of the misconceptions related to IFA include that IFA tablets do not increase Hb levels, interfere with other tablets, might affect the baby, or make them tired and sluggish throughout the day (10-12). Some of the personal barriers include taking IFA only when feeling weak and stopping consumption when feeling better or worse, perceiving too many medications, job commitments, household chores, and not being interested (12).
- **Lack of counseling by healthcare workers on IFA supplementation and its benefits (93.5%):** Many women (58.7%) were reported to be unaware of the benefits of IFA. Even though 99% of women had institutional deliveries, 93.0% were unaware that IFA supplementation should continue for six weeks postpartum (10).
- **Healthcare System Deficiencies:** Healthcare providers sometimes fail to assess or record hemoglobin (Hb) levels in the Mother and Child Protection (MCP) Card for 95.5% of postnatal women, despite it being mandatory. Reasons for ineffective iron supplementation programs include inadequate supply to women, lack of follow-up for postnatal women, and insufficient training of health workers (10).

b) **Insufficiency of IFA alone to correct anemia & hidden hunger:** Hidden hunger is characterized by widespread deficiencies of a range of micronutrients, such as vitamins A, B2, B6, B12, folic acid, C, and minerals like iron, zinc, and calcium. IFA supplementation alone cannot curb hidden hunger because hidden hunger is a qualitative deficiency of multiple micronutrients, whereas IFA primarily addresses iron and folic acid deficiencies (13).

Vitamin B_{12} and folate are essential for proper DNA synthesis and the maturation of red blood cells. Additionally, nutrients like vitamin C, riboflavin, vitamin A, vitamin B_6, zinc, and copper play a key role. They support hemoglobin formation, improve iron absorption, and help maintain normal blood cell production. Due to this connection, anemia often occurs when there are multiple deficiencies. Identifying the nutritional gaps quickly and offering the right mix of supplements are important steps for both preventing and managing the condition. (14-16)

4.3 The WHO-UNIMMAP Study for Multiple Micronutrient Supplementation (MMN)

The United Nations International Multiple Micronutrient Antenatal Preparation (UNIMMAP) formula and the World Health Organization (WHO) have made significant statements regarding the usage and inclusion of Multiple Micronutrient Supplements (MMS).

Key features of MMS usage by UNIMMAP:

Target Population: The UNIMMAP formulation is primarily defined as an MMS for pregnant women. It aims to provide pregnant women and their offspring with a positive pregnancy and a healthy start to life in an efficacious, safe, and cost-effective manner. It is anticipated that most of the nearly 200 million pregnancies occurring annually in low- and middle-income countries could benefit from MMS use (17).

Composition: The UNIMMAP formulation contains 15 micronutrients at dosages that approximate the recommended dietary allowances for pregnancy. The UNIMMAP formulation was developed during a workshop of experts organized by the WHO, UNICEF, and the United Nations University in 1999, specifically to identify an MMS formula for efficacy clinical trials (17).

Table 1: The table represents recommended food / dietary / nutritional ingredients by UNIMMAP (17).

Nutrient	India-MMS	Rationale	UNIMMAP
Iron (mg)	40	1.5 RDA	30
Folate (ug)	500	1.5 RDA	360
Vitamin A (ug)	400	EAR	800
Vitamin C (mg)	65	EAR	70
Vitamin D (IU)	400	1.5 RDA@	200
Riboflavin (mg)	2.3	EAR	1.4
Niacin (mg)	11	EAR	18
Vitamin B-12 (ug)	4	1.5 RDA	2.6
Zinc (mg)	15	RDA	15
Iodine (ug)	160	EAR	150
Vitamin E (mg)	10	AI	10
Vitamin B-6 (mg)	1.9	EAR	1.9
Copper (mg)	1.7	AI	2
Selenium (ug)	40	AI	65

@1.5 RDA is 900 IU but 500 IU will be available from Calcium tablets; MMS: multiple micronutrient supplements; UNIMMAP: United Nations International Multi-micronutrient Antenatal Preparation; AI: Adequate Intake

Recent trial objective: UNIMMAP has recently started a trial in 2023 to assess the effectiveness of United Nations International Multiple Micronutrient Antenatal Preparation-Multiple Micronutrient Supplements (UNIMMAP-MMS) versus iron-folic acid (IFA) among women of reproductive age (WRA) in reducing anemia. The trial will provide evidence on the effect of UNIMMAP-MMS and IFA on Hb concentrations and anemia prevalence among anemic WRA (18).

The World Health Organization's stance on MMS usage: In 2021, the WHO officially added UNIMMAP-MMS to its essential medicine lists. As mentioned above, despite the MMS inclusion in the essential medicine list, the WHO recommended a rigorous study for its use in women of reproductive age (WRA), especially during pregnancy (18).

4.4 ICMR Special Report on Multi-micronutrient Supplementation (MMS)

An expert committee, comprising specialists in pharmacology, gynecology, paediatrics, and physiology, was constituted to examine the micronutrient status during pregnancy in India. The ICMR committee presented a special report to discuss the following key findings and recommendations (6):

Maternal anaemia and Feto-maternal Health: The primary objective of the report is to reduce maternal anaemia and enhance feto-maternal health, as anaemia is recognized as a major health problem that can lead to adverse pregnancy outcomes such as an increased risk of postpartum complications and neonatal and perinatal death (6).

Shift in Recommendation for MMS: The report highlights a significant change in the recommendation for MMS during pregnancy. Previously, in 2016, the WHO did not recommend, but it has since changed to "recommended in the context of rigorous research" in 2023. This shift underscores the growing recognition of MMS's potential benefits in reducing the risk of adverse pregnancy outcomes such as low birth weight, small for gestational age, stillbirth, and preterm birth, particularly among anaemic and underweight women (6).

Table 2: The table represents mean intakes of micronutrients from habitual diets in Indian pregnant women, NNMB urban survey 2016, and NNMB rural survey 2012 (6).

Table V. Mean intakes of micronutrients from habitual diets in Indian pregnant women NNMB urban survey 2016[46] and NNMB rural suvey 2012[47]

Micronutrients	Urban (1=326)		Rural (n=421)		Nutrient requirement		Gap (urban)		Gap (rural)	
	Median	IQR	Median	IQR	EAR	EDA	EAR - Median (Urban)	RDA - Median (Urban)	EAR - Median	RDA - Median
Iron, mg	11.3	8.6, 15	11	7.6, 16.4	21	27	9.7	15.7	10	16
Zinc, mg	7	5.5, 9.3	6.8	5.1, 8.9	12	14.5	5	7	5.2	7.7
Calcium, mg	319.8	201.9,484.3	334	177.6, 456.4	800	1000	480	680	466	666
Vitamin A, ug	105.9	48.9, 214.9	124	61.5, 511.6	406	900	300	794	282	776
Vitamin C, mg	47.3	25.2, 74.3	24.9	12.5, 47.9	65	80	18	33	40.1	55.1
Thiamin, mg (B1)	1	0.8, 1.3	1.1	0.8, 1.5	1.6	2	0.6	1	0.5	0.9
Riboflavin, mg (B2)	0.6	0.5, 0.8	0.7	0.5, 0.9	2.3	2.7	1.7	2.1	1.6	2
Niacin (B3), mg	8.6	6.8, 11	12.9	9, 16.4	14	16	5	7	1.1	3.1
Dietary folate, ug	167	127.235.3	108.6	72.7, 154.4	288	342	121	175	179.4	233

EAR: Estimated Average Requirement; RDA: Recommended Dietary Allowance; IQR: Inter-Quartile Range

Proposed doses of various micronutrients in the India-specific MMS: The nutrient requirements for pregnant women are defined using two key metrics: the Estimated Average Requirement (EAR) and the Recommended Dietary Allowance (RDA). The dosage of MMS should be decided based on the gap in the micronutrient deficiency. When a pregnant person shows a significant micronutrient deficiency (indicated by a biomarker), the MMS dose is increased by approximately 1.5 times the RDA levels. However, excessive consumption of daily nutrient intake should be avoided (6).

Table 3: The table represents India-specific MMS supplement composition (6)

Component	Chemical entity[a]	Amount
Vitamin A	Retinyl acetate	800 mcg RAE
Vitamin C	Ascorbic acid	70 mg
Vitamin D	Cholecalciferol	5 mcg (200 IU)
Vitamin E	Alpha tocopheryl succinate	10 mg α-TE
Vitamin B1	Thiamine mononitrate	1.4 mg
Vitamin B2	Riboflavin	1.4 mg
Vitamin B3	Niacinamide	18 mg NE
Vitamin B6	Pyridoxine HCl	1.9 mg
Folic acid	Folic acid	680 mcg DFE (400 mcg)
Vitamin B12	Cyanocobalamin	2.6 mcg
Iron	Ferrous fumarate	30 mg
Iodine	Potassium iodide	150 mcg
Zinc	Zinc oxide	15 mg
Selenium	Sodium selenite	65 mcg
Copper	Cupric oxide	2 mg

RAE: Retimal Activity Equipment; NE: Niacin Equivalent; α-TE: Alpha-tocopherol Equivalents

Need for a separate country-specific MMS formulation: The committee opposed a uniform acceptability and utility of a globally standardized MMS formulation due to the variations in gestational weight gain, dietary intake, nutrient deficiencies, and biochemical nutritional deficiency data in pregnant women from India (6).

The report clarifies that the formulation of MMS is for "potential research trials in India" and is "not an endorsement" for routine use yet. This indicates that the current recommendations are a step towards enabling further rigorous research to validate the efficacy and safety of an India-specific MMS (6).

4.5 A Case for Integrating MMS into Antenatal Care

The limitations of food-based approaches and IFA-only supplementation underscore the urgent need for broader strategies to address maternal malnutrition. International evidence consistently demonstrates that Multi-micronutrient Supplementation (MMS) improves a range of pregnancy outcomes without compromising safety. For obstetricians, MMS represents a natural progression of antenatal protocols building on the proven legacy of IFA while responding to the realities of hidden hunger and intergenerational risks. The following evidence highlights why MMS merits integration into antenatal care.

Key Evidence:

1. **Improved birth outcomes:** A 2020 pooled analysis found an average 12% reduction in low birth weight with MMS compared to IFA (19). Similarly, a Cochrane meta-analysis (2019) reported that MMS led to significant reductions in low birth weight, preterm births, and small-for-gestational-age infants (4).
2. **Reduction in maternal anaemia:** Studies show that supplementation with MMS, in addition to folic acid, reduces the risk of anaemia in the second and third trimesters. Early and frequent initiation of MMS was associated with a greater reduction in anaemia risk compared with FA-only supplementation (20).
3. **Safety profile:** Large-scale trials and pooled analyses have found no increase in maternal or neonatal mortality or morbidity with MMS compared to IFA. No serious adverse side effects have been documented to date, making MMS a safe addition to antenatal care (4).
4. **Cost-effectiveness and equity:** Evidence suggests that switching from IFA to MMS can be cost-effective, particularly when weighed against the long-term healthcare costs of prematurity and low birth weight. MMS has also been shown to have relatively favourable acceptability, feasibility, and equity outcomes in diverse populations (21).
5. **Targeted use in high-risk groups:** Policymakers and clinicians should consider MMS particularly in populations with high prevalence of nutritional deficiencies, where its benefits clearly outweigh any disadvantages. High-impact groups include adolescent mothers, women with low BMI, and those with multiple deficiencies (21).

4.6. Improving Pregnancy Outcomes: A Shift from Deficiency to Optimal Nutrition

The focus of antenatal nutrition is gradually shifting from merely addressing deficiencies to actively optimizing maternal and foetal health. Guidelines from the International Federation of Gynaecology and Obstetrics (FIGO) emphasize the importance of adequate nutrition across the preconception, pregnancy, and postpartum periods, highlighting the role of both balanced diets and supplementation for women with identified deficiencies or those at risk (22).

Globally, iron and folic acid (IFA) supplementation has remained the standard of care and continues to be endorsed by the World Health Organization (WHO). However, international evidence and clinical consensus are steadily moving towards Multiple Micronutrient Supplementation (MMS) as a more comprehensive strategy (21). This evolution reflects a recognition that diet alone, while foundational, is insufficient in the modern context, where nutritional quality rather than food quantity must be prioritized.

The long-standing reliance on IFA alone cannot fully combat the complex web of anaemia, hidden hunger, and other pregnancy-related risks. MMS has demonstrated the potential to not only reduce maternal anaemia but also improve outcomes such as low birth weight, preterm birth, and small-for-gestational-age infants.

For India, this shift carries particular urgency. With NFHS-5 data showing persistently high anaemia rates and stagnant low birth weight prevalence, a country-specific MMS formulation, already developed by the Indian Council of Medical Research (ICMR), represents a pragmatic next step. Integrating MMS into antenatal care protocols can help clinicians move beyond a deficiency-based model towards a proactive, optimization-focused approach that strengthens maternal resilience and secures long-term health benefits for the next generation.

Conclusion

The progress made with iron and folic acid supplementation since the 1970s cannot be understated—it transformed antenatal care and addressed a critical burden of maternal anaemia. However, the nutrition landscape in India has changed, and reliance on IFA alone is no longer sufficient. Hidden hunger, rising anaemia prevalence, and stagnant rates of low birth weight demand a more comprehensive response. Multiple Micronutrient Supplementation (MMS), developed to address broader deficiencies, offers a scientifically grounded and cost-effective strategy. It ensures that women enter pregnancy with stronger nutritional reserves and reduces risks across maternal and neonatal outcomes. For obstetricians and gynaecologists in India, the path forward is clear: advance beyond IFA-only models towards integrated antenatal protocols that combine balanced diets, dietary counselling, and MMS. This shift represents not a rejection of the past but an evolution—one that empowers clinicians to break the cycle of intergenerational malnutrition and improve outcomes for the next generation.

Summary

1. Food and diet remain the cornerstone of antenatal care but cannot meet rising nutritional demands alone.

2. IFA supplementation, though essential, addresses only part of the problem by focusing on anaemia and neural tube defects.

3. India faces a paradox: improved food access but persistently high anaemia (52%) and stagnant low birth weight (~18%).

4. Urban women often present with hidden hunger—deficiencies in B12, vitamin D, zinc, and iodine—despite normal weight.

5. MMS outperforms IFA in reducing low birth weight, preterm birth, and small-for-gestational-age neonates, with no safety concerns.

6. ICMR’s India-specific MMS formulation provides a historic opportunity to integrate broader supplementation into antenatal care.

7. Clinicians must move beyond IFA-only models and adopt holistic strategies that combine dietary counselling, balanced diets, and MMS.

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05

Trimester-Specific Nutrition: A Case for Precision MMS

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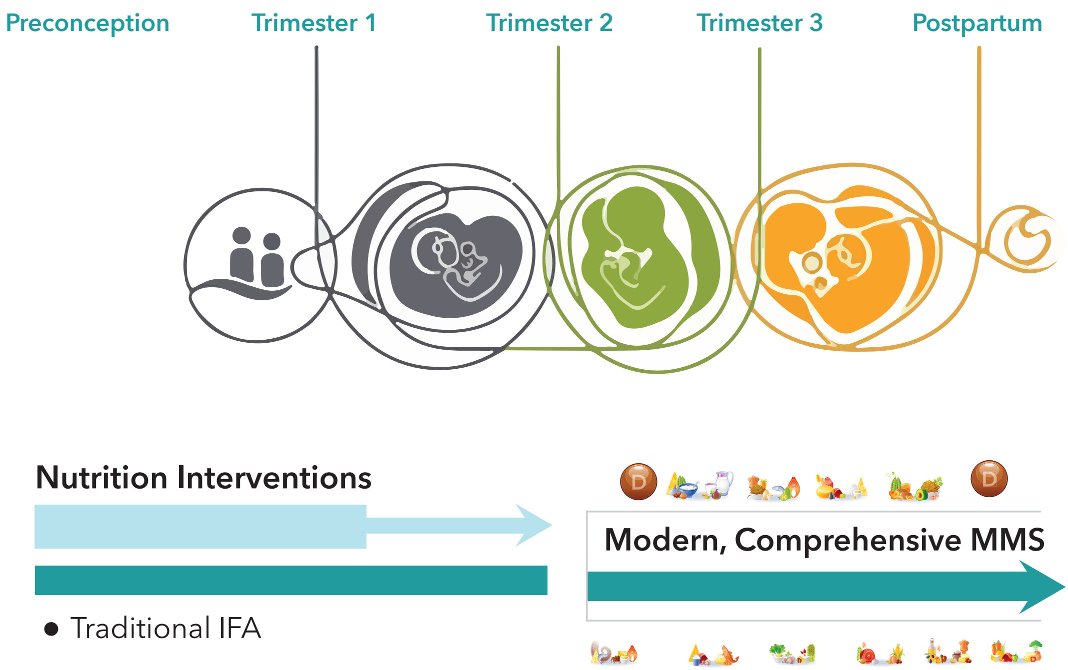

Maternal nutrition during pregnancy is a dynamic process that evolves across trimesters, with each stage presenting unique physiological demands for both the mother and the fetus. Understanding these trimester-specific needs is critical for optimizing outcomes. While a balanced diet remains the cornerstone, real-world challenges such as cultural practices, vegetarian diets, late antenatal registration, and food quality limitations mean that diet alone is insufficient.

For decades, iron and folic acid (IFA) supplementation has been the foundation of antenatal nutrition programs. However, the persistence of maternal anaemia, stagnant rates of low birth weight, and widespread deficiencies in vitamin B12, vitamin D, zinc, and iodine underscore that a broader approach is needed. This chapter examines trimester-specific nutritional needs and makes the case for advancing protocols from IFA alone towards multiple micronutrient supplementation (MMS), while recognizing the practical limitations of a one-size-fits-all approach (1).

5.1 Rationale for Trimester-Specific Micronutrient Supplementation

Several physiological changes happen during pre-conception, pregnancy, and the postpartum period. These changes affect both maternal physiology and fetal development. They need enough energy and proper nutrition. A healthy, nutritious diet and nutritional supplements can provide this support. A healthy diet can usually meet the increased dietary needs; supplementation is often recommended to support a healthy pregnancy and postpartum phase (2).

A single, fixed-dose supplementation approach, such as the traditional iron folic acid (IFA) tablets used in India for decades, cannot possibly meet these shifting needs. A trimester-specific strategy ensures that nutrients are provided when they are most critical, thereby improving both maternal health and fetal outcomes (3).

IFA has succeeded in reducing neural tube defects and anemia; however, it remains a blunt instrument against the broader burden of micronutrient deficiencies, including vitamin D insufficiency, zinc depletion, iodine gaps, and omega-3 fatty acid shortages, among others.

Supplements not only support nutritional deficiencies but also help reduce developmental issues arising from various deficiencies. Some of the most widely accepted interventions regarding supplementation during pregnancy include the intake of supplements such as folic acid for the prevention of congenital neural tube defects, iron for the prevention of maternal anemia and iron deficiency, and potassium iodide for addressing neurodevelopmental issues (4).

Additionally, some micronutrients have also been associated with pre-eclampsia, gestational diabetes mellitus, nausea, and vomiting in pregnancy. Due to the evidence supporting the benefits of multiple micronutrient supplementation in perinatal outcomes, the WHO and ICMR are now recommending its usage (5).

There is growing consensus that supplementation should be tailored to the health of the mother and the developing fetus, as nutrient requirements vary by trimester. Folate is necessary for the neural tube to close during the first trimester. As blood volume rises and skeletal growth quickens during the second trimester, iron and calcium become increasingly important.

Magnesium and vitamin K are essential during the third trimester as the body gets ready for delivery. A one-size-fits-all strategy cannot meet these evolving needs. The clinical challenge is to move beyond “IFA only” and employ a plan that addresses the different deficiencies observed in Indian women while customizing supplementation to the shifting conditions of each trimester.(6).

Table 1: The table represents summary of micronutrient supplementation during pregnancy and risks of deficiency and overload (5).

Micronutrient	Implications for deficiency	Supplementation policy	Risks of overload
Iron	Maternal IDA with increased risks of preterm delivery, LBW, stillbirth and reduced iron stores in the newborn	Universal supplementation according to the prevalence of anemia (60 mg/day for IDA prevalence of 40%) or Supplementation tailored to iron stores (see Table 1)	• Increased risk of hemoglobin concentrations at term higher than 130 g/l • Adverse pregnancy outcomes (e.g. LBW, maternal hypertensive disorders, thrombotic risk, gestational diabetes)
Folic acid	• NTD • Increased risks of LBW and non-communicable diseases in adulthood	Universal, 400-800 µg/day from two months before to three months after conception or 4-5 mg/d in case of high risk of NTD or folate deficiency Supplement continuation is recommended in association with iron throughout pregnancy for anemia prevention	• Delay in vitamin B12 deficiency diagnosis, masking megaloblastic anemia with neurologic consequences • Colorectal carcinogenesis
Calcium	• Impaired fetal skeletal development • Increased risk of maternal hypertensive disorders	1.5-2.0 g/day of elemental calcium starting from 20 weeks of gestation onwards in case of risk for deficiency or hypertensive disorders	Maternal side effects (e.g. gastrointestinal)
Iodine	Maternal and fetal/neonatal hypothyroidism, intellectual disability and long-term effects on neurocognitive development in the offspring	Recommended intake of 250 µg/day for pregnant and lactating women	Fetal goiter
Vitamin D	• Impaired fetal bone formation • Controversial associations with risks of preeclampsia, LBW, gestational diabetes, caesarean section and preterm birth	Universal supplementation 10 µg/day - 600 IU/day or Women at risk for deficiency	Controversial small increase in kidney stones
Selenium	Controversial associations with early pregnancy loss, preeclampsia, intrahepatic cholestasis	60 µg/day	Selenosis (tolerable upper intake level 400 µg/day)
Magnesium	Controversial associations with fetal growth restriction and preeclampsia	240 mg/day	Not reported
Vitamin A	Maternal anemia, night blindness, congenital malformations	Supplementation is only recommended to prevent night blindness in areas where vitamin A deficiency is a severe public health problem (10,000 IU/day, or 25,000 IU/week)	• Congenital malformations for intake higher than 10,000 IU daily • Maternal side effects

IDA: Iron Deficiency Anemia; NTD: Neural Tube Defects; LBW: Low Birth Weight

5.2 Optimizing Fertility: Preconception nutritional interventions

This "zero trimester" is when oocytes mature, sperm acquire competence, and the endometrium prepares for implantation. Nutritional status during this period not only enables conception but also programs the future health of the child through epigenetic marks on gametes and early embryos.

Changes in maternal biology: Folliculogenesis requires folate, zinc, and vitamin D. Endometrial receptivity is enhanced by adequate vitamin D and omega-3 fatty acids. Iron sufficiency prevents early placental compromise. Iodine stabilises maternal thyroid function, reducing risks of miscarriage and infertility (7).

Changes in fetal biology: Even before implantation, epigenetic modifications are already in effect. Parental deficiencies in folate, B12, zinc, or vitamin D can alter DNA methylation patterns in gametes, influencing placental efficiency, fetal organogenesis, and even long-term risks of obesity, diabetes, and hypertension (8).

Despite a high burden of malnutrition, the effectiveness of preconception nutrition remains poorly documented. Undernutrition among reproductive-age women, low birth weight (LBW), small for gestational age (SGA), and preterm birth are significant health burdens in India that interventions during pregnancy alone have not been able to resolve effectively.

5.2.1 Essential Micronutrients in the Preconception Period

1. **Folic Acid:** It is a B complex vitamin and is recognized as a major component of the preconception care of women in the reproductive age group. It is required for DNA synthesis and cell division. As per WHO recommendations, women trying to conceive should take a folic acid supplement from the time they plan a pregnancy till 12 weeks of gestation (9).
2. **Iron:** Iron deficiency in the preconception period can impair fertility, increase the risk of maternal anemia, and compromise early placental development (10).
3. **Calcium:** Adequate calcium intake before conception ensures proper calcium stores for early fetal development. It also reduces the risk of maternal bone demineralization during pregnancy and supports neuromuscular and vascular function, creating a healthier foundation for conception and subsequent pregnancy (11).
4. **Vitamin A:** It is essential for normal cell differentiation, oogenesis, and implantation. It supports the development of a healthy endometrium, improving the chances of conception. Adequate maternal stores ensure proper embryonic development immediately after conception.
5. **Vitamin D:** It plays a major role in human reproduction. It influences folliculogenesis, modulates endometrial receptivity, and regulates embryogenesis. It plays a vital role in trophoblast invasion. Vitamin D plays an essential role in embryonic and fetal skeletal development (12).
6. **Iodine:** Getting enough iodine before conception helps ensure proper thyroid function in mothers. This reduces the chances of infertility, early pregnancy loss, and subfertility. If a woman lacks iodine during the time around conception, it can harm the quality of her oocytes and affect fertilization. It might also negatively impact early fetal brain development, even before pregnancy is confirmed(13).
7. **Zinc:** Zinc is essential for several important biological processes that affect female germ cell development, fertility, and successful pregnancy. During folliculogenesis, maintaining adequate zinc levels within the oocyte is crucial. This helps keep the oocyte at meiotic arrest during prophase I. The regulation dependent on zinc ensures that the oocyte remains resting until it receives the signal to start maturing. This supports normal follicle development and reproductive ability(14).
8. **Omega-3 Fatty Acids:** Omega-3 fatty acids, especially DHA and EPA, are crucial during the preconception period. They support oocyte maturation, implantation, and early embryonic development. Omega-3s improve endometrial receptivity, modify inflammatory pathways, and boost blood flow to reproductive organs, which helps optimize fertility. They also help maintain hormonal balance and improve the quality of oocytes and sperm. This increases the chances of successful conception and positive pregnancy outcomes(15).

5.2.2 Positive Impacts of Preconception Nutrition and Supplementation

1. **Early Organogenesis and Nutritional Implications:** Rudimentary organ systems begin to form within the first five weeks of gestation, often before pregnancy is clinically recognized, and the majority of organ development is completed by 10 weeks. This narrow window highlights the importance of ensuring adequate maternal nutritional reserves even before conception, as deficiencies during this period may compromise organogenesis and long-term fetal health (16) .

2. **Epigenetic and Intergenerational Impacts:** The nutritional status of parents before conception significantly affects epigenetic changes in both sperm and egg cells. These changes have consequences for embryonic development and extend beyond it. They can impact the placenta functions, organ development, growth patterns, and long-term health outcomes. These effects may continue to impact future generations. Preconception supplementation helps this process by offering antioxidant and anti-inflammatory benefits. It also improves the mother's metabolic health and has a positive impact on fetal DNA methylation. This leads to healthier birth sizes and lowers the risk of chronic diseases later in life (17).

Targeted interventions initiated before conception have been shown to improve pregnancy and birth outcomes demonstrably. Randomized trials, such as the Mumbai Maternal Nutrition Project, indicate that starting dietary supplementation at least 3 months before conception can increase birth weight by an average of approximately 48 g and reduce the incidence of low birth weight (LBW) by around 24%, especially in women with a BMI of 18.6 or higher (18).

Systematic reviews across South Asia confirm that food supplementation initiated at least 90 days prior to conception improves birth size. In contrast, micronutrient-only approaches show mixed results (18).

A major randomized trial in Delhi found that combined preconception interventions, which include nutrition, health services, psychosocial care, and WaSH, significantly lower the risk of low birth weight and enhance linear growth for up to 24 months compared to standard care (19).

Limitations in Antenatal Care Services: Antenatal care typically begins after a pregnancy is confirmed, usually around 6 to 8 weeks of gestation. By this time, important events such as fertilization, implantation, and early organ development have already occurred. Since most women only start taking supplements after they find out they are pregnant, this method cannot prevent nutritional deficiencies that impact conception, early embryo development, or neural tube closure, which happens within the first 28 days.

According to the 2019-2021 National Family Health Survey, only 59.3% of women visit antenatal care facilities until the second trimester. This is often too late to improve fetal nutrition status (19). Nutrition interventions should ideally start before conception, using a "1000 days + preconception" approach (16).

5.3 The First Trimester: Foundations of Embryogenesis and Organogenesis

The first trimester is marked less by growth than by differentiation. By week 10, every central organ system has taken shape. The neural tube closes by day 28, and the heart is beating by week 6. These weeks are crucial, yet most antenatal visits typically begin only after these milestones have been reached.

Maternal changes: Many hormonal changes occur in the mother's body, including increased production of estrogens, progesterone, and prolactin, as well as the synthesis of specific placental hormones, such as human chorionic gonadotropin (hCG). Frequent nausea and vomiting are observed during the first trimester, correlating with the hCG peak (20). Plasma volume expands modestly.

Cardiovascular adjustments begin, renal plasma flow and GFR rise, and insulin sensitivity is still preserved. These adaptations make some nutrients more critical and others less efficiently absorbed. For a full-term pregnancy, the total daily calorie requirement is approximately 80,000 kcal, which translates to 300 kcal/day. In the first trimester, energy requirements are the same as those in a non-pregnant state, while they increase in the second and third trimesters. Energy requirements also vary with age, BMI, and activity level (21).

Fetal changes: The embryo undergoes rapid organogenesis: neural tube closure, cardiac development, and limb formation. Errors here are permanent.

5.3.1 Key Nutrients and Supplementation in the First Trimester

1. **Vitamin B9 (Folic Acid):** It is an essential nutrient that is required for DNA replication and as a substrate for a range of enzymatic reactions involved in amino acid synthesis and vitamin metabolism. Demands for folate increase during pregnancy because it is also required for the growth and development of the fetus. Studies reported that folic acid supplement use in the body increases by up to 93.1 % during the first trimester (21).

   The WHO recommends a daily folic acid supplement of 400 µg during this period. In cases of pregestational diabetes, a 5 mg daily dose is recommended. Folic acid (synthetic form) has better bioavailability than natural food folate (21).

2. **Vitamin B6 (Pyridoxine):** The WHO recommends taking vitamin B6 to relieve nausea in early pregnancy. Evidence suggests it likely reduces nausea symptoms, though it may have little to no effect on vomiting (21).

3. **Magnesium:** Magnesium requirements increase during pregnancy, and serum levels gradually decrease, though reaching their lowest values in the last trimester. Magnesium deficiency has been implicated in hypertensive disorders, GDM, preterm labor, and FGR (21).

4. **Zinc:** In the first trimester, zinc is vital for rapid cell multiplication, differentiation, and the initial development of fetal organs and the placenta. Its role in protein synthesis and cell division is essential for supporting the foundational growth of the embryo and fetus, including the early development of the nervous system and limbs (22).

5. **Vitamin D:** In the first trimester, vitamin D plays a vital role in the initial stages of pregnancy by supporting placental development and function, ensuring proper calcium absorption for maternal calcium homeostasis and fetal growth, and influencing immune regulation. Low levels of vitamin D in early pregnancy are linked to an increased risk of complications like preeclampsia, gestational diabetes, and preterm birth (23).

6. **Iodine:** In the first trimester, iodine is essential for thyroid hormone production, which is critical for the developing fetus's brain and nervous system development. Iodine requirements can increase up to 50% during pregnancy, partly due to maternal thyroid stimulation by hCG (24).

7. **Selenium:** Selenium is a trace element that plays a crucial role in antioxidative protection, protein synthesis, and immunomodulatory and anti-proliferative mechanisms. Recommended dosage of selenium increases to 60 mg/day during pregnancy (25).

   Observational studies reported associations between low selenium serum concentrations, early pregnancy loss, and pre-eclampsia, possibly due to reduced antioxidant protection of biological membranes and DNA, leading to implantation disorders and placental dysfunction. However, the results regarding the efficacy of supplementation in preventing these disorders are inconclusive (5).

8. **Omega-3 fatty acid:** First-trimester docosahexaenoic acid and eicosapentaenoic acid supplementation has been associated with significant increases in fetal growth, specifically greater estimated fetal abdominal circumference in the second and third trimesters of pregnancy (26).

   In cases where there is an increased risk of micronutrient deficiency, multivitamin supplementation can be a reasonable option, provided that dietary intake and nutritional status are properly evaluated to minimize the risk of overload.

5.4 The Second Trimester: Placental Expansion and Foetal Rapid Growth

By the second trimester, both the mother and fetus enter a phase of accelerated growth. The placenta enlarges, blood volume expands rapidly, and maternal appetite improves.

Maternal changes: Hepcidin is actively suppressed, dramatically improving iron absorption, which serves as nature's timing cue for supplementation. Calcium transfer begins to rise as skeletal ossification accelerates (27).
Fetal changes: Skeletal development intensifies, the fetal thyroid becomes functional, and the brain accumulates long-chain PUFAs during synaptogenesis.
Diet in the first trimester is more critical to the development and differentiation of various organs. In contrast, a balanced diet later in pregnancy is more important for overall fetal growth and brain development (28).

5.4.1 Key Nutrients and Supplementation in the Second Trimester

1. **Iron:** The iron requirements for pregnant women increase markedly (22–27 mg/day) due to the increased blood mass, fetal growth, and development of the placenta. Iron supplement use increases as pregnancy progresses, rising to 23.6% in the second trimester. The requirement is most significant in the last trimester, and it is essential to build up iron stores early (3). Additionally, Iron deficiency anemia can be diagnosed in the second trimester if the hemoglobin (Hb) level is less than 10.5 g/dL (3).

2. **Vitamin C:** During the second trimester, vitamin C plays a critical role in supporting maternal and fetal health. It functions as a potent antioxidant, protecting cells from oxidative stress, and is essential for collagen synthesis, which supports the development of fetal connective tissues, blood vessels, and the placenta. Additionally, vitamin C enhances the absorption of non-heme iron, which helps prevent maternal anemia and ensures adequate oxygen delivery to the growing fetus (3).

3. **Iodine:** Iodine requirements also increase approximately 50% during pregnancy, partly due to iodine transfer to the fetus for the synthesis of fetal thyroid hormones from the second trimester (3).

4. **Omega 3 Fatty acid:** DHA supplement use increases up to 34.9% during the second trimester. High accumulation of arachidonic acid (AA) and docosahexaenoic acid (DHA) in the fetal brain occurs from the sixth month of pregnancy. This period, which includes the later part of the second trimester, is critical as it is when the development of neuronal extensions, the establishment and stabilization of synapses, and myelination take place. Therefore, the dietary intake of polyunsaturated fatty acids (PUFAs), especially omega-3, is of obvious importance for brain development during pregnancy (3).

5. **Calcium:** Calcium supplement use increases significantly in the second trimester (76.3%) (24).

6. **Vitamins (excluding folic acid):** The use of vitamin supplements increases up to 40.6% which includes multi-vitamins and single vitamins like A, C, D, E (24).

   The second trimester is the time when overall nutritional demand increases compared to the first trimester. In addition to micronutrients, vitamin D, folic acid and calcium, the demand for iron, iodine, and essential fatty acids drastically increases (3).

5.5 The Third Trimester: Fetal Maturation and Maternal Reserves

The final trimester is about fortifying reserves. The fetus grows exponentially, laying down fat, bone, and iron stores for the newborn period. Meanwhile, the maternal body reaches its peak metabolic strain.

Maternal changes: Placental hormones induce insulin resistance, sometimes precipitating gestational diabetes. Lipid levels rise and calcium transfer to the fetus peaks, with ~30 g transferred by term. Bone turnover increases in the third trimester to meet the increased fetal calcium needs, with the calcium primarily sourced from previously stored maternal skeletal calcium. General musculoskeletal changes, such as exaggerated lordosis, joint laxity, and widening of sacroiliac joints and pubic symphysis, become more pronounced due to the growing fetus. Magnesium levels fall due to renal loss and hemodilution (22).

Fetal changes: The brain undergoes cortical expansion and myelination, while skeletal mineralization reaches its peak. Fetal iron stores are accumulated for the first six months of infancy.

Some of the essential metabolic changes that occur during the third trimester of pregnancy include maternal insulin resistance, an increase in total serum cholesterol and triglyceride levels, and an increase in calcium metabolism. Calorie demand also changes. In the second trimester, the recommended calorie intake is approximately 266 kcal/24 h, while in the third trimester, it can increase by up to 496 kcal/24 h (29).

The requirements of folic acid and vitamin B6 during pregnancy are increased by 50%. The need for vitamin A increases by up to 60%, while the need for vitamins C, niacin, vitamin B2, and vitamin B12 increases by up to 30%. However, the requirements of iron and iodine rise to 100% (30).

5.5.1 Key Nutrients and Supplementation in the Third Trimester

1. **Folic Acid:** Studies reported that the use of folic acid supplements significantly decreases after the first trimester, with rates dropping to 43.7% in the second trimester and 34.8% in the third trimester (24). However, in the third trimester, folic acid continues to support maternal and fetal health by contributing to rapid fetal growth, the formation of red blood cells, and the development of neural tissue. It helps maintain adequate maternal folate stores, reducing the risk of megaloblastic anemia and supporting efficient DNA synthesis. Adequate folate intake in late pregnancy also plays a role in placental function and fetal brain maturation, and may lower the risk of preterm birth (24).

2. **Iron:** The use of iron supplements peaks at 61.7% in the third trimester. This reflects the significant increase in iron requirements during mid-to-late pregnancy due to the expansion of plasma volume, red cell mass, and iron accumulation in the placenta (24).

3. **Calcium:** Calcium supplement use remains stable in the third trimester (80.4%) (24). The demand for additional calcium during pregnancy is well-established and has been discussed earlier in this chapter.

4. **Vitamins (excluding folic acid) and DHA:** The use of vitamin supplements (43.7%) and DHA (32.6%) remain stable in the third trimester (24).

5. **Vitamin K:** Vitamin K supplementation may help alleviate the deficiency of factor VII in megaloblastic anemia of pregnancy with thrombocytopenia. Maternal administration of vitamin K has been suggested to improve prothrombin and partial thromboplastin activities and reduce the incidence and severity of intraventricular haemorrhage (IVH) in infants (31).

Table 2: The table represents Recommended Dietary Allowances (RDA) for non-pregnant women and Estimated Average Requirements (EAR), RDA, and tolerable Upper Level (UL) for pregnant women.

Nutrient	RDA, Adult Non-Pregnant Women	EAR, Pregnancy	RDA, Pregnancy	UL, Pregnancy	Justifications
Vitamin A (µg/day)	700	550	770	3000	Regulation of genome expression and in cell differentiation
Vitamin D (µg/day)	15	10	15	100	Mineralization of the fetal skeleton and decreased risk of hypocalcemia accidents and symptomatic osteomalacia
Vitamin E (mg/day)	15	12	15	1000	-
Vitamin K (µg/day)	90	-	90	none	-
Vitamin B1 (mg/day)	1.1	1.2	1.4	none	-
Vitamin B2 (mg/day)	1.1	1.2	1.4	none	-
Vitamin B3 (mg/day)	14	14	18	35	-
Vitamin B6 (mg/day)	1.3	1.6	1.9	100	Relieve nausea in early pregnancy
Vitamin B9 (µg/day)	400	520	600	1000	Decreases the risk of spina bifida and other neural tube defects
Vitamin B12 (mg/day)	2.4	2.2	2.6	none	-
Vitamin C (mg/day)	75	70	85	2000	-
Calcium (mg/day)	1000	800	1000	2500	Mineralization of the fetal skeleton
Iodine (µg/day)	150	160	220	1100	Prevents pre-eclampsia
Iron (mg/day)	18	22	27	45	Maintenance of thyroid homeostasis
Magnesium (mg/day)	320	290	350	350	Decreases the risk of having a low birth weight or a premature baby
Phosphorus (mg/day)	700	580	700	3500	Involvement in the occurrence of hypertensive disorders, gestational diabetes mellitus, preterm labor, or intrauterine growth retardation
Selenium (µg/day)	55	49	60	400	-
Zinc (mg/day)	8	9.5	11	40	Involvement in cell division, protein synthesis and growth, nucleic acid metabolism

5.6 The *Fourth Trimester* or Postpartum Nutrition

The nutritional needs of women increase during breastfeeding to support these physiological changes and ensure the baby's normal development. Fat-soluble vitamins A, D, and K, and water-soluble vitamins C, B1, B6, B12, and folates are secreted in breast milk, and their content can be reduced if the mother is deficient. Fortunately, these deficiencies in breast milk can be addressed through maternal supplementation. Levels of calcium, phosphorus, and magnesium in breast milk are independent of the mother's serum levels and diet (3).

5.6.1 Nutrient Requirements During Lactation and Postpartum

1. **Calcium:** During the postpartum period, a significant amount of calcium is transferred to the neonate through nursing, accounting for approximately 210 mg/day. Fetal calcium needs are met through the extraction of calcium from maternal bone mass, increased intestinal absorption, or decreased renal excretion. To meet this increased skeletal stress, guidelines recommend 1000 mg/d of calcium for pregnant and lactating women who are 19 to 50 years old and 1300 mg/d for pregnant and lactating women who are <19 years old (31).
2. **Omega-3 Fatty Acids (EPA & DHA):** Newborn brain development is significantly impacted by omega-3 intake during breastfeeding. Maternal supplementation with essential fatty acids is necessary, and studies have shown delays in visual function development in infants fed milk substitutes low in ALA and devoid of DHA, which is linked to low blood DHA levels.

3. **Vitamin D:** A recent study suggests that maternal vitamin D3 supplementation with 6400 IU/day provides a safe and enough vitamin D in breast milk to meet infant needs, offering an alternative to infant supplementation.
4. **Vitamin A:** Vitamin A in milk has antioxidant properties that could improve the immune function of the infant. The recommended dietary intake of retinol for lactating women is 1300 mcg daily, compared to 770 mcg daily during pregnancy. Vitamin A deficiency is not uncommon, and maternal supplementation is necessary during lactation to meet the recommended daily intake of vitamin A (32).
5. **Vitamin B:** Vitamin B-12 plays a crucial role during lactation. Lactating women exhibit significantly higher total serum vitamin B-12 compared to non-pregnant. Infants need vitamin B12 to support brain development and produce healthy red blood cells. Infants who do not get enough vitamin B12 can become deficient. If left untreated, vitamin B12 deficiency in infants can lead to permanent brain damage (33).
6. **Iron:** A dose of 60 mg/day of iron is recommended for 3 months after postpartum to prevent maternal anemia. Micronutrient requirements during lactation and postpartum are listed in Table 3.

A personalized approach to nutritional counselling is vital, considering a woman's access to food, socioeconomic status, ethnicity, and cultural food choices (3).

While a balanced diet is the primary source of nutrients, supplementation can adapt to the needs of the fetus and prepare the body for breastfeeding. It can also correct common clinical signs of pregnancy. It is generally recommended that women continue to take a prenatal vitamin daily while breastfeeding (3).

Table 3: The table represents the micronutrient requirements for lactating women.

	Recommendations	Justifications for Breastfeeding
Calcium	1000 mg / day	Maintenance and production of breast milk
Magnesium	390 mg / day	Muscle relaxant Prevention of constipation
Zinc	19 mg / day	Participation in postpartum healing
Vitamin C	130 mg / day	Stimulation of immune functions
Vitamin D	10 µg / day = 400 IU [a] / day	Important contribution to obtain good quality milk
Vitamin A	10,000 IU / day or max 25,000 IU / week or unique intake 200,000 IU	Only in deficient populations, as soon as possible after childbirth, but not more than 8 weeks afterwards
Iron	60 mg / day	Prevention of maternal anemia
Vitamin B9	400 µg / day	For 3 months after postpartum
Omega-3	100 mg / day of DHA b during the 1st year of the newborn's life	Newborn brain development

5.7 Why Not "One Multivitamin Throughout"? A Case for Precision Nutrition

Nutritional needs increase significantly according to the growth and developmental needs of the fetus during all three trimesters. Nutritional requirements continue to be high during postpartum, particularly for breastfeeding women.

It may seem efficient to provide one fixed multivitamin throughout pregnancy. Yet physiology proves otherwise. Folate is urgently required for preconception and early pregnancy; iron is best tolerated and absorbed from the second trimester; calcium is most effective when introduced from mid-gestation; magnesium gains relevance later. A one-size formula risks under-supplying some stages and overdosing others.

Adherence is another challenge. Women given IFA and calcium separately often skip doses due to pill burden, especially when iron and calcium must be taken apart. Trimester-specific packs, which phase nutrients intelligently, reduce pill burden while aligning supplementation with the body's biological needs.

Obstetricians must now move beyond the iron–folic acid paradigm and embrace trimester-specific, multi-micronutrient strategies. This is how we prevent not only anemia and neural tube defects, but also low birthweight, preterm birth, preeclampsia, and the intergenerational inheritance of chronic disease.

Conclusion

Nutrition is not a supportive accessory to pregnancy care; it is a vital component of fetal medicine. The “1000 days + preconception” model reframes antenatal care as a continuum, beginning even before conception and extending through lactation.

Trimester-specific nutrition highlights that maternal and foetal needs evolve rapidly, demanding precision rather than uniformity. A single, fixed-dose supplement such as traditional IFA cannot address the spectrum of deficiencies—ranging from folate in early gestation to iron, calcium, magnesium, and vitamin K in later trimesters.

MMS offers a broader evidence-based solution, but in India its integration must respect clinical realities: pill burden and poor compliance, the need to withhold iron in the first trimester, the separation of iron and calcium, and the importance of nutrient cofactors. A blanket “multivitamin-for-all” strategy will not work; what is required is a tailored, India-specific approach such as the ICMR formulation that aligns supplementation with physiology.

For clinicians, the way forward is clear: combine balanced diets and counselling with trimester-sensitive, precision supplementation—using MMS as a foundation but adapting it intelligently. This is how we move beyond IFA alone, reduce intergenerational risks, and ensure that every pregnancy receives the right nutrients at the right time.

Summary

1. Nutrition in the preconception phase influences fertility, implantation, and foetal programming.
2. In the first trimester, folate is critical while iron is often withheld; balanced diets support organogenesis.
3. In the second trimester, iron and calcium are central as blood volume and skeletal growth increase.
4. The third trimester brings peak energy needs, with magnesium, vitamin K, and omega-3 fatty acids gaining importance.
5. Postpartum recovery and lactation require continued attention to iron, calcium, vitamin D, and omega-3 fatty acids.
6. IFA reduces anaemia and neural tube defects but does not address wider micronutrient deficiencies.
7. MMS has been shown globally to lower risks of low birth weight, preterm birth, and SGA infants.
8. In India, pill burden, compliance issues, and trimester-specific needs mean a generic multivitamin is not suitable.
9. Obstetricians must integrate diet, counselling, and trimester-tailored MMS to deliver optimal antenatal care.

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06

Micronutrients in Focus: From Absorption to Action

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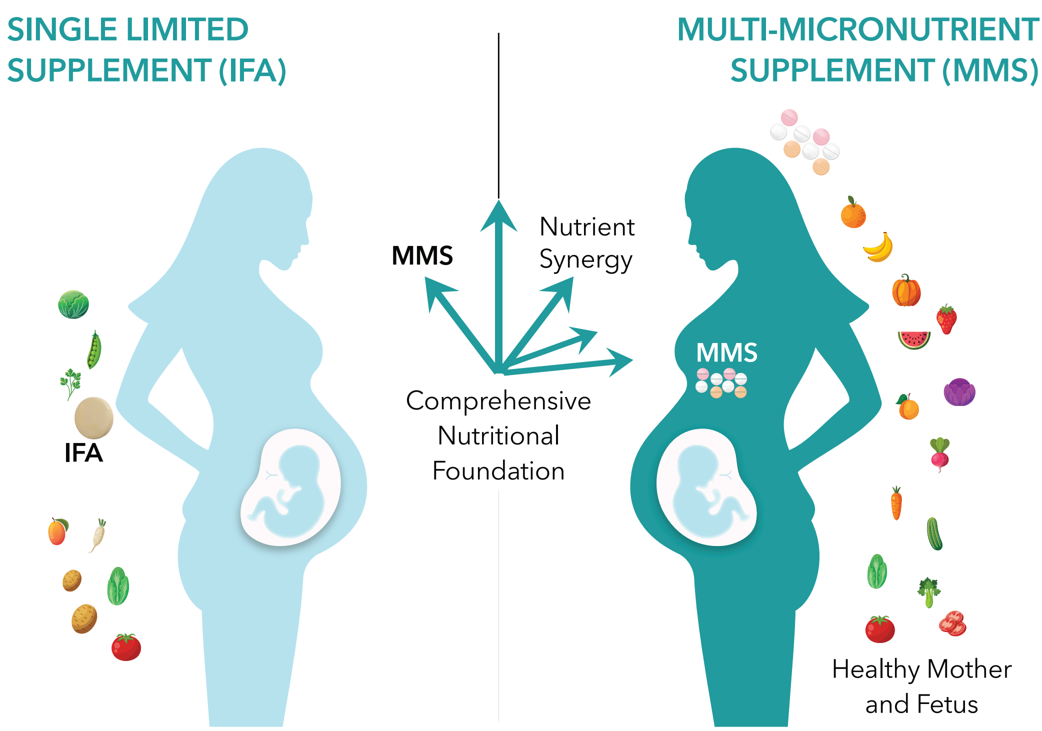


Pregnancy is a biological state of accelerated demand and limited reserve: the mother's tissues, the placenta and the developing fetus together create a metabolic environment where small shortfalls become clinically meaningful. International bodies and the evidence base emphasize "nutrition first" across preconception and pregnancy because what we give (or fail to give) in this window shapes outcomes across the life course (1-2).

For decades, clinical nutrition in obstetrics has revolved around addressing visible deficiencies: iron for anaemia, folic acid for neural tube defects, and calcium for bone health. These interventions remain lifesaving but represent a reductionist view of maternal nutrition.

Nutrients function in interconnected pathways, requiring co-factors for activation and absorption. When this interdependence is ignored, supplementation may deliver little benefit or even cause harm. For example, folic acid masks B12 deficiency, high-dose iron increases oxidative stress, and calcium without vitamin D fails to strengthen bone. The persistence of anaemia and micronutrient deficiencies in India despite long-standing IFA programs demonstrates the shortcomings of a single-nutrient approach.

Here we explore how micronutrients interact, how absorption is influenced by the microbiome and host physiology, and why timing and dosing determine outcomes. These lessons converge in the case for Multiple Micronutrient Supplementation (MMS), which provides balanced, low-dose combinations that reflect physiology and respect clinical realities.

6.1 Nutrient Synergy: Agonism and antagonism

Micronutrients rarely act alone. Their effectiveness often depends on the presence of complementary nutrients. Equally, antagonistic interactions can reduce absorption or blunt efficacy. Recognising these relationships helps clinicians prescribe supplements more effectively.

Nutrient synergy describes situations in which two or more nutrients — when present together produce a physiological effect greater than the sum of each acting alone. This is not an abstract biochemical idea; it is directly relevant at the bedside because interactions determine which supplements will change biomarkers and outcomes. Clinically useful examples include effects on absorption (one nutrient improving uptake of another), co-factor relationships within metabolic pathways, and mutual protection/restoration in antioxidant systems. That's not philosophy, it's how our transporters, co-enzymes, and signaling loops work. In clinic, this translates to pairing and timing nutrients, so mothers absorb more, and fetuses benefit earlier (3).

6.1.1 Mechanisms by which nutrients interact

- **Enhancement of absorption / bioavailability:** e.g., ascorbic acid (vitamin C) reduces non-heme iron and increases its intestinal uptake; the effect is dose-related and especially relevant for plant-based iron sources (4).
- **Mutual support within physiological pathways:** Folate and vitamin B_{12} are co-dependent within one-carbon metabolism for DNA synthesis and erythropoiesis; deficiency of one impairs the function of the other (5).
- **Regeneration and antioxidant recycling:** Fat- and water-soluble antioxidants (for example vitamin E and vitamin C) sustain each other to protect membranes and lipids (3).
- **Competition and antagonism:** Minerals may compete for transporters (excess calcium can blunt iron uptake; high phytate/fibre lowers non-heme iron and zinc uptake). Recognising antagonists is as important as knowing enhancers (6-7)

Table 1: The table represents examples of nutrient synergy benefits in clinical trials (3)

Synergistic ingredients	Outcome
Rhodiola + Magnesium + Green Tea + B-vitamins	Attenuated stress, heightened subjective and autonomic arousal, increased EEG theta activity
Vitamin B12, Folate, and Vitamin B6 C	Reduction in homocysteine; Slowing of brain matter loss progression
Omega-3 + Alpha Lipoic Acid S	Less decline in the Mini-Mental State Examination score and activities of daily living assessment
Folic Acid + Vitamin B12 S	Reductions in homocysteine
Coenzyme Q10 + Vitamin E S	Reduced low-density lipoprotein cholesterol (LDL-C), increased high-density lipoprotein cholesterol (HDL-C), reduced atherogenic coefficient
Omega-3 + Niacin S	Increased LDL apoE/apoB ratios and LDL apoA1/apoB ratios
Vitamin C + Vitamin E C	Protection against the acute effects of ozone pollution
Vitamin C + Vitamin E + Beta-carotene C	Improved FVC, FEV, and forced expiratory flow in hazardous environmental conditions
Synbiotic (probiotic + prebiotic) S	Greater quality-of-life improvements and a significant decrease in CRP levels
Synbiotic (probiotic + prebiotic) C	More effective in eradicating Helicobacter pylori when combined with a standard medication therapy
Zinc + Selenium S	Improved T3, free T4, and TSH levels
Vitamin D + Calcium + Leucine-enriched whey protein drink C	Suppression of parathyroid hormone, increased serum 25(OH)D, and accompanying small improvements in bone mineral density
Calcium + Vitamins D + Vitamin K S	Improved bone mineral density, circulating levels of biomarkers associated with bone health, and risks of fractures
Vitamin D + Calcium S	Reduced parathyroid hormone and increased calcium/creatinine ratio
Chlorella vulgaris + Vitamin E S	Attenuation of TNF-α levels in patients with NAFLD
Vitamin C + Zinc C	Symptom relief from the common cold
Vitamin C + Vitamin E S	Enhanced immune response

S, synergistic study design; C, combination stucy design; EEG, electroencephalogram; CRP, C-reactive protein; T3, triiodothyronine; 14, thyroxine: TSH, thyroid-stimulating hormone; IVP-a, tumor necrosis factor alpha; NAPLD, non-alcoholic fatty liver disease.

6.2 Why Single Nutrient Strategies Fall Short?

Obstetric practice has historically relied on single-nutrient prescriptions: iron for anaemia, folic acid for neural tube defects, calcium for bone health. While these were appropriate responses to immediate crises, they created a 'siloed' view of nutrition. The flaw is that supplementation without co-factors is often ineffective. Folate cannot be fully metabolised without B12, iron cannot be efficiently absorbed without vitamin C, and calcium is wasted without vitamin D. Furthermore, high-dose monotherapy increases risks: excess folic acid masks B12 deficiency, and large doses of iron cause oxidative stress and gastrointestinal upset. In contrast, low-dose combinations with co-factors enhance efficacy and reduce side effects. This principle forms the rationale for MMS, which moves beyond deficiency correction to precision supplementation.

6.2.1 Clinically important nutrient synergy in pregnancy

The nutrient synergy between various nutrients is crucial for ensuring optimal maternal health and supporting the healthy growth and long-term well-being of the offspring. Below I list the pairs I check for and counsel about in clinic, with the evidence clinicians need to know (8).

- **Vitamin C & Iron (non-heme) Synergy:** Non-heme iron from pulses, spinach, or fortified cereals is absorbed far better when taken with vitamin C–rich foods such as citrus, guava, or capsicum. When I prescribe oral iron, I advise my patients to take it with a glass of lemon water or alongside fruits, and to avoid tea or coffee at that time since tannins blunt absorption (3). Vitamin C converting insoluble ferric (Fe^3+) state to ferrous (Fe^2+) iron, which is more soluble and readily transported across the enterocyte. This mechanism explains why supplementation with iron tablets is often advised alongside vitamin C to optimize hematological response.
- **Folate and Vitamin B12 synergy:** Both are indispensable co-factors in one-carbon metabolism and DNA synthesis. Folate-rich foods and supplements are universally recommended in pregnancy, but without adequate B_{12}, which is typically found to be low in vegetarian populations, the folate provided cannot be utilized effectively. Clinically, this interdependence is seen in the "methyl-folate trap," where folate is metabolically trapped without B_{12}, leading to megaloblastic anemia. Combining folic acid or L-methylfolate supplementation with adequate B_{12} (dairy, eggs, or supplements in vegetarian women) ensures effective erythropoiesis and neural tube protection (5, 9).
- **Vitamin D, Calcium & phosphorus synergy:** Vitamin D, calcium, and phosphorus act synergistically. Vitamin D enhances intestinal absorption of calcium and phosphorus, while calcium and phosphorus together form hydroxyapatite for bone mineralization (10,11). This triad is essential in pregnancy, supporting fetal skeletal growth, maintaining maternal bone health, and preventing complications like rickets, hypocalcemia, and osteopenia. Supplementation of one without the others is suboptimal; combined support ensures maximum benefit. Clinicians should ensure both substrates and vitamin D sufficiency.
- **Zinc and Copper synergy:** The balance between copper and zinc shows that competition is just as important as collaboration. Both zinc and copper are necessary cofactors in different enzymatic and metabolic processes. These processes are vital for cell division, DNA synthesis, immune function, and antioxidant defense. These functions are particularly crucial during pregnancy to meet increased physiological needs (4). Their balance is essential. A change in the copper-to-zinc (Cu/Zn) ratio can cause problems. Excess copper can lead to zinc deficiency and the other way around. This imbalance has been linked to issues like preterm birth, anemia, and gestational disorders. Keeping the right ratio helps ensure healthy outcomes for both mothers and babies (5)..
- **Omega-3 fatty acids and Vitamin D synergy:** Emerging data highlight omega-3 fatty acids and vitamin D as complementary nutrients. Omega-3s (from fish, walnuts, or supplements) influence anti-inflammatory pathways and placental vascular function, while vitamin D modulates immune tolerance in pregnancy. Trials combining Omega-3s and vitamin D supplementation have suggested additive benefits, including improved respiratory health in offspring. For the clinician, this means counselling women to include oily fish or plant omega-3 sources along with ensuring adequate vitamin D status (14,15).
- **Vitamin A and Zinc synergy:** Both act as partners in micronutrient metabolism. Zinc is required for the synthesis of retinol-binding protein, which transports vitamin A in circulation. In deficiency states, even if vitamin A is consumed from carrots, pumpkin, or supplementation, impaired zinc status (from poor meat intake or high-phytate diets) may block its effective mobilization. This biochemical partnership has implications in immune protection and vision outcomes in pregnancy (16,17). In populations at risk of deficiency like India both must be considered by us.
- **Vitamin K and Calcium synergy:** Vitamin K is needed to γ-carboxylate osteocalcin and matrix Gla protein so that calcium is directed to bone and not to soft tissues; joint vitamin D + K biology is relevant when advising long-term bone and cardiovascular health (18).
- **B Vitamins (Vitamin B12, Folate, Vitamin B6):** Vitamin B-complex works as an interconnected network. Sufficient maternal supplementation does more than prevent anemia or NTDs. It also improves placental

function, fetal growth, neurodevelopment, and long-term health outcomes. The effects are synergistic. A deficiency in one vitamin can hinder the function of others, leading to worse outcomes. Including a complete B-complex in antenatal care is essential (19).

6.3 Bioavailability and Host Factors

The proportion of a nutrient absorbed and available for use depends on its form, the surrounding diet, and the individual's physiology. Bioavailability is the key reason why nutrient intake does not always equate to nutrient sufficiency.

The bioavailability of nutrients is highly variable and can be influenced by numerous factors, including physicochemical properties (20). A supplement's label dose is only half the story. In clinic its about:

- **Chemical form:** For example, L-5-MTHF (methyl folate) is the active folate form and bypasses MTHFR-dependent activation; it is 7 times more bioavailable than folic acid and should be preferred when metabolic activation is impaired (21).
  Heme iron is absorbed far more efficiently than non-heme iron; absorption is upregulated during iron deficiency (22)
- **Food matrix & anti-nutrients:** Phytates and polyphenols in whole foods can reduce mineral uptake; conversely, dietary fat improves carotenoid and fat-soluble vitamin absorption (23).
  For Example, Vitamin D requires dietary fat and bile salts for absorption; deficiency is therefore common among vegetarians (24)
- **Enhancers/inhibitors in the meal:** Tea/coffee, calcium and phytates, blunt iron absorption while vitamin C or fermented foods may enhance it. Practical counseling (timing of iron, avoidance of tea with meals) remains effective (23).
- **Host factors:** Genetic polymorphisms, gut inflammation, and individual variability alter bioavailability significantly. Consider testing and targeted replacement when standard therapy fails (25).

Table 2: The table represents examples of the enhancers and inhibiting factors (2)

Nutrient	Bioavailability (%)	Enhancing factors	Inhibiting factors
Vitamin A	15%	Dietary fat	
Vitamin B2	67%	Non-covalent binding to protein	Covalent binding
Vitamin B12	65%	Binding to transcobalamin or casein	Binding to haptocorrin
Vitamin K-2	Unknown	Dietary fat Fermentation products Long-chain menaquinones (MK7-9)	Medium-chain menaquinones (MK4)
Calcium	40%	Binding to casein and whey peptides Lactose amino acids Vitamin D (fortification)	Phosphorous Sulfur-containing proteins
Phosphorous	Unknown	Binding to casein and whey peptides Binding to phospholipids	Complexing with unbound calcium
Magnesium	24-75%	Binding to casein and whey peptides Lactose	High dosing
Zinc	25-30%	Mild acidic conditions Whey and casein peptides Low molecular ligands (amino acids organic acids)	
Iodine	90%	Inorganic unbound	

6.4 Microbiome, Probiotics, and Prebiotics

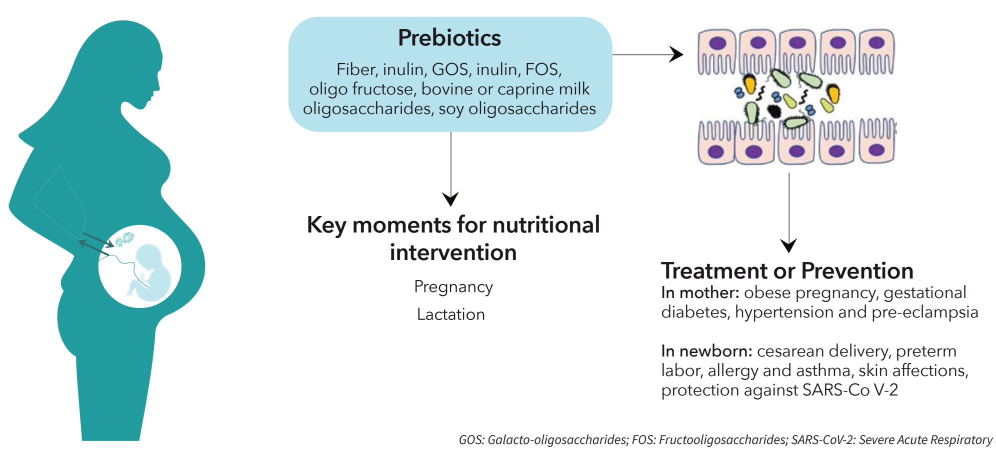
Pregnancy is not a "disease," but it is a state of major metabolic, immune, and microbial adaptation. The maternal gut microbiome undergoes changes across trimesters, which help modulate maternal energy harvest, systemic inflammation, and immune tolerance necessary for fetal growth (26).

Why this matters clinically: mounting evidence links maternal gut dysbiosis with common pregnancy complications like gestational diabetes, hypertensive disorders including pre-eclampsia, excessive gestational weight gain, and possibly preterm birth. Dysbiosis can amplify low-grade inflammation and alter metabolites that influence placental function and maternal metabolism. When you see metabolic derangement, think "microbiome" as one contributor among many (27).

Mechanistically, there are three clinically relevant pathways by which the microbiome and microbiome-directed therapies (prebiotics, probiotics) influence micronutrient absorption. Let's study the case of Iron absorption:

- **Microbiomes influence nutrient bioavailability:** fermentation of non-digestible carbohydrates into SCFAs alters gut pH and iron solubility, while probiotic strains like Lactiplantibacillus plantarum 299v enhance mucosal iron transport, reducing iron loss and improving ferritin in pregnancy cohorts. (28).
- **Microbiomes influence metabolism:** Microbiomes influence how inflammation affects sequestration and tolerance. Dysbiosis or high-dose iron can increase hepcidin and decrease availability, whereas adding prebiotics (e.g., GOS) or probiotics with oral iron enhances absorption, improves ferritin levels, and reduces side effects, offering a practical adjunct for women intolerant to ferrous salts (29).
- **Microbiomes support nutrient metabolism:** Lactoferrin, an iron-binding glycoprotein abundant in colostrum and available orally, shows superior tolerability and comparable or better improvements in hemoglobin and iron indices than ferrous sulfate in pregnancy trials. Lactoferrin is a dual modulator of iron homeostasis and maternal–fetal microbiome Health. Its benefits arise from modulating iron forms, reducing oxidative stress, and promoting a favorable gut microbiome, making it a practical alternative for women with GI intolerance to ferrous salts. The Food and Drug Administration (FDA) and the European Food Safety Authority (EFSA) have approved bovine milk-derived lactoferrin (BLTF) as Generally Recognized as Safe (GRAS) for use as a food additive and dietary supplement. In numerous clinical trials, native (10–20% iron-saturated) bovine lactoferrin (BLTF) was used orally at daily doses ranging from 25 mg to 250 mg per person (30).

Figure 1: The positive impacts of prebiotics in pregnancy and postpartum (1)



GOS: Galacto-oligosaccharides; FOS: Fructooligosaccharides; SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus 2

6.5 Timing, Repletion, and Interpregnancy Intervals

Replenishment of maternal stores is gradual. Iron, vitamin D, and bone calcium cannot be restored quickly, making pregnancy spacing vital.

- Iron takes months to replenish; close-spaced pregnancies increase anaemia risk.
- Vitamin D and calcium require sustained intake beyond pregnancy; discontinuation postpartum worsens maternal bone health.
- WHO recommends a minimum 24-month interval between pregnancies to allow recovery (31).

6.6 Integrating Lessons into MMS

The concepts of synergy, bioavailability, microbiome support, timing, and dosing converge in Multiple Micronutrient Supplementation (MMS). Unlike IFA, MMS provides a balanced mix of nutrients in lower doses, thereby mimicking physiological conditions. For India, practical considerations are crucial: iron may be withheld in the first trimester if it is poorly tolerated; calcium and iron must be administered separately; and higher therapeutic doses can be layered on top of MMS when deficiencies are diagnosed. MMS is best understood not as a replacement for diet, but as a baseline insurance policy for every pregnancy.

Conclusion

Clinical practice has long aimed at fixing visible deficiencies with specific supplements. While this is important, it misses the complex connections involved in micronutrient metabolism. Factors like synergy, antagonism, bioavailability, gut health, and dosing schedules affect the success of supplementation. Because of these complexities, using a limited number of supplements, such as IFA, is not enough. The greater effectiveness of Multi-micronutrient Supplementation (MMS) comes from its ability to provide a wide range of essential nutrients. This approach helps tackle hidden hunger and establishes a solid nutritional base. It is crucial for improving antenatal care from just correcting deficiencies to ensuring optimal health for both the mother and foetus.

Summary

1. Effective supplementation requires nutrient interdependence, with vitamin C enhancing iron absorption, folate requiring vitamin B12, and vitamin D enabling calcium–phosphorus utilisation.

2. Antagonistic interactions such as calcium blocking iron, phytates binding zinc and iron, and polyphenols reducing non-heme iron absorption demand careful scheduling and diet adjustments.

3. Bioavailability is influenced by nutrient form, diet, and host physiology; Indian diets rich in phytates and tea/coffee use contribute to persistent deficiencies despite supplementation.

4. The maternal microbiome modulates absorption, with probiotics, prebiotics, and lactoferrin improving mineral uptake and tolerance of supplements.

5. Nutrient repletion requires months, and short interpregnancy intervals intensify depletion; daily iron is more effective than intermittent regimens for correcting anaemia.

6. Multiple Micronutrient Supplementation (MMS) offers a balanced, co-factor–driven approach, integrating these principles into a comprehensive strategy adapted for Indian obstetric care.

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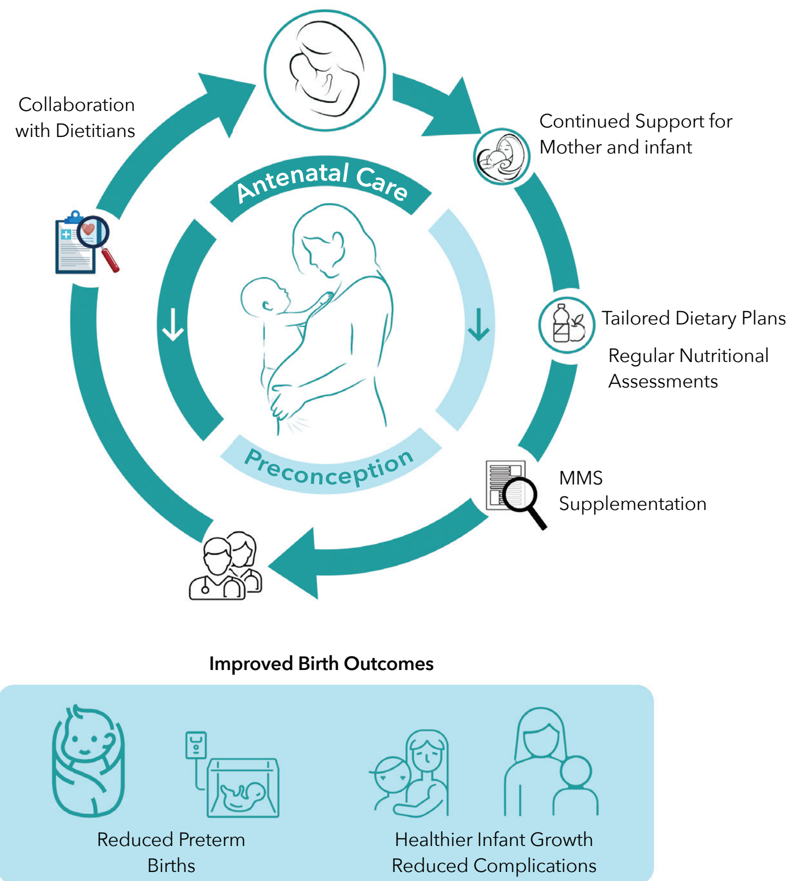
07

From Knowledge to Practice: Integrating Nutrition into Everyday Obstetrics

Dr. Vidya Thobbi & Dr. Hema Divakar

Nutrition-First Model of Obstetric Care



Nutrition is not a supportive accessory to antenatal care — it is its foundation. For decades, obstetric practice has focused on screening, managing complications, and supplementing with iron and folic acid (IFA). While these steps have saved countless lives, the persistence of anaemia, stagnant low birth weight, and widespread micronutrient deficiencies highlight that our work is not complete.

The future of obstetrics lies in transitioning from a reactive to a proactive model — where every antenatal consultation becomes an opportunity to strengthen maternal resilience and optimize fetal health. Let's evaluate a clinician's action framework: how to weave dietary counselling, screening, precision supplementation, and Multiple Micronutrient Supplementation (MMS) into routine practice.

7.1 Every ANC Visit: An Opportunity for Nutrition Counselling

Nutrition counselling is a cornerstone of high-quality antenatal care (ANC). It establishes a two-way dialogue between women and healthcare providers to identify nutritional problems, set achievable goals, and create tailored strategies (1). Counselling enhances awareness about balanced diets, correct supplement use, and healthy behaviours, including facility-based delivery and timely initiation of breastfeeding. Quality counselling on maternal micronutrient supplementation should be prioritized to reduce the risk of anaemia and its consequences. The World Health Organization (WHO) recommends nutrition counselling as part of regular antenatal care contacts to improve nutrition practices and health outcomes (1).

- Encouraging balanced diets with adequate macronutrients and micronutrients.
- Addressing food taboos and cultural practices that limit diversity.
- Reinforcing adherence to supplements despite nausea or side effects.
- Emphasizing physical activity, rest, and stress management (2).

7.2 Screening and Risk Stratification

Nutritional interventions are most effective when targeted. A two-minute screening at booking can identify women at risk:

- **FIGO Nutrition Checklist - Quick, validated, practical:** A validated, quick self-administered tool designed to identify dietary quality issues and nutritional risk in pre-pregnant and early pregnant women. It includes queries on food groups such as meat, dairy, fruits and vegetables, whole grains, and snacks. FIGO Nutrition Checklist is widely endorsed as practical across preconception, pregnancy, and postpartum settings (3).
- **Anthropometric Measures - Weight, Height, BMI, Mid-Upper Arm Circumference (MUAC):** These are simple, low-cost, reliable measures. Anthropometry is practical in assessing maternal nutrient reserves and predicting outcomes, such as low birth weight or foetal growth issues (4,5).

  Body Weight Gain Tracking: Monitoring gestational weight gain relative to BMI—e.g., <0.44 kg/week for underweight women indicates inadequate gain and malnutrition risk (6)
- **Dietary Assessment Tools:** 24-hour Recall, Food Frequency Questionnaires (FFQ), and Diet Quality Indices are standard methods to assess intake and diet balance. While detailed, they are time-intensive and require expertise (7).
- **Biochemical Markers (Recognized but not always captured by basic screening tools):** Although not always included in simple checklists, these remain critical to confirm specific deficiencies: Haemoglobin, Serum Albumin, Iron/Ferritin, Vitamin D, Folate, Vitamin B12, Calcium, Zinc, etc.

  Broader maternal nutrition guidelines and evidence support their assessment, though specific RCT-level citations were not retrieved in this search. Suspected individual micronutrient deficiencies (such as vitamin A, B, C, D, E, iron, and zinc) can be measured by performing specific tests (8).
- **Clinical Signs & History:** Signs like pallor, fatigue, weakness, hair/nail changes, dry skin, edema, bone/joint discomfort, oral lesions, headaches, poor sleep, low energy, and potential cognitive issues can indicate micronutrient or protein deficiency (9).

- **Obstetric History:** Short birth intervals, previous low birth weight or preterm births, poor gestational weight gain can point toward chronic or unresolved maternal malnutrition (10).
- **Accessing Socioeconomic & Lifestyle Factors:** Food insecurity, low household income, low maternal education, high physical workload, and cultural or religious dietary restrictions all contribute to risk (11). Urban areas show a nutrition transition, greater availability of energy-dense, processed foods, but lower affordability of fresh fruits, vegetables, and quality proteins (11).

7.3 Personalizing Supplementation

Personalized nutrition can be highly beneficial, as it offers a customized approach that is viewed as a promising future perspective for preventing and treating childhood and adult non-communicable diseases, starting from the earliest stages of foetal life (12).

The following principles should guide practice:

- **First trimester:** folate is critical; iron may be withheld if nausea is severe.
- **Second trimester:** iron and calcium supplementation are essential but must be administered separately.
- **Third trimester:** magnesium, DHA, and vitamin K gain importance for labour readiness and fetal neurodevelopment.
- **Postpartum:** continued supplementation with iron, calcium, vitamin D, and omega-3 supports maternal recovery and lactation (13).

7.4 Multi-micronutrient Supplementation (MMS)

For over 70 years, IFA has been the cornerstone of antenatal supplementation. It remains valuable, but it is insufficient in addressing the broader issue of hidden hunger.

Evidence:

- Cochrane 2019 and pooled analyses confirm MMS reduces low birth weight, preterm births, and small-for-gestational-age infants without increasing risks (14).
- Indian data highlight urban ‘thin-fat’ phenotype with deficiencies in vitamin B12, vitamin D, zinc, and iodine (15).
- ICMR has introduced an India-specific MMS formulation (2023–24), with iron (40 mg), folate (500 µg), vitamin B12, vitamin D, zinc, and other essential nutrients (16).

Clinical reality in India:

- Pill burden and poor compliance remain barriers.
- Iron is often avoided in the first trimester; iron and calcium cannot be co-administered.
- A generic multivitamin-for-all approach is not feasible.
- MMS must therefore be positioned as a baseline prophylaxis, layered with therapeutic doses of specific nutrients where deficiencies exist.

7.5 Building Collaborative Care

There is a strong need to enhance collaboration between dietitians and healthcare practitioners. Strengthening this collaboration could promote that nutrition becomes a recurring and standard topic in antenatal care (17).

- Collaboration with dietitians and nutritionists for high-risk patients.
- Training junior staff and nurses to reinforce counselling messages.
- Using digital tools (SMS reminders, apps) to improve adherence.
- Encouraging postpartum follow-up for sustained supplementation (18).

7.6 Policy and Practice Alignment: India must move beyond IFA-centric ANC

Evidence shows that antenatal multiple-micronutrient supplements (MMS, which include iron, folic acid, and additional vitamins/minerals) provide better protection against low birthweight, small-for-gestational-age births, and some preterm births compared with iron and folic acid (IFA) alone.

Short scientific rationale

- **Current problem:** Pregnant women in India frequently have multiple micronutrient shortfalls (not only iron/folate). These combined deficiencies impair foetal growth and raise the risk of low birthweight and related neonatal complications. Addressing only iron and folate leaves other common deficits uncorrected, limiting the impact on birth outcomes (19,20).
- **What MMS does differently:** MMS provides a balanced package of vitamins and minerals (iron + folic acid plus other essential micronutrients) in a single daily tablet. By addressing multiple common gaps, MMS targets several key biological pathways that support foetal growth, placental function, and maternal health — mechanisms that explain the observed improvements in birth weight and size-for-gestational age. (21, 22)
- **Evidence summary** Randomized trials and recent pooled analyses (including individual-participant data meta-analyses and systematic reviews) find that, compared with IFA, antenatal MMS reduces the risk of low birthweight and small-for-gestational-age births and probably reduces preterm birth in low- and middle-income settings. These analyses do not show convincing increased harm associated with MMS (20).

Therefore, Nutrition must be embedded as the foundation of maternal care

- **Preconception:** MMS should be initiated at this stage to correct latent deficiencies and optimize early organogenesis.
- **Pregnancy:** Trimester-specific MMS should be prescribed with dietary counselling at each ANC visit and involve dietitians for high-risk conditions.
- **Postpartum/lactation:** MMS should be continued for at least six months post-delivery to replenish stores and support lactation. This continuum addresses the difficulty of rapid dietary change during pregnancy by combining therapeutic control through MMS with sustainable habit formation through counselling.

WHO and FIGO endorse MMS in research or pilot contexts; ICMR has created a national MMS formula. FOGSI has urged wider integration. For India, the opportunity is clear: clinicians can lead where policy lags. By auditing outcomes and publishing data, private practitioners and teaching hospitals can accelerate national adoption.

Conclusion

Trimester-specific physiology, persistent deficiencies, and poor adherence make it clear: nutrition cannot be left to diet alone or to IFA tablets. MMS provides a stronger, evidence-based baseline — but it must be integrated with precision, respecting stage-specific needs, cofactor interactions, and patient realities.

As obstetricians, we stand at the threshold of a new era in antenatal care. Fifty years ago, IFA transformed maternal practice; today, MMS and precision nutrition offer us the same opportunity. Our responsibility is not only to treat but to reshape antenatal care into a proactive, life-affirming practice. By combining balanced diets, culturally sensitive counselling, and tailored supplementation, we can break the cycle of intergenerational malnutrition and ensure that every mother and child begins life with strength and resilience.

Summary

1. Nutrition is central to obstetric care, not an accessory.
2. Counselling at every visit helps overcome cultural and behavioural barriers.
3. Simple screening tools (FIGO checklist, BMI, MUAC, haemoglobin) can flag at-risk women early.
4. Supplementation must be personalised: folate in first trimester, iron + calcium in second, magnesium/DHA in third, continued support postpartum.
5. IFA alone is insufficient against hidden hunger and long-term risks.
6. MMS reduces low birth weight, preterm births, and SGA infants without safety concerns.
7. India requires trimester-tailored, compliance-friendly MMS, not generic multivitamins.
8. Collaboration with dietitians, nurses, and digital tools can improve outcomes.
9. Clinicians must lead adoption of MMS and precision nutrition, shaping the next generation of maternal health.

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Improving Birth Outcomes: Advancing Protocols from Iron, Folic Acid (IFA) to Multi-Micronutrient Supplementation (MMS)

India accounts for the largest number of pregnancies globally, yet also bears a disproportionate burden of preterm birth, low birth weight, gestational diabetes, and maternal anaemia. Despite decades of iron–folic acid (IFA) supplementation, more than half of pregnant women remain micronutrient deficient. In urban practice, a dual burden is increasingly evident — undernutrition existing alongside obesity and metabolic disease — fuelled by “hidden hunger” or micronutrient deficiencies even among women with adequate food access.

It is now clear that IFA alone is inadequate. Micronutrients act through synergy, bioavailability, microbiome interactions, and trimester-specific requirements; failure to address these dynamics limits effectiveness and perpetuates intergenerational risk. Evidence from global meta-analyses and India’s ICMR-adapted formulation confirms that Multi-micronutrient Supplementation (MMS) safely and cost-effectively reduces adverse pregnancy outcomes.

This book offers obstetricians a clinician-focused roadmap to embed a nutrition-first approach within antenatal care, advancing prescriptions from IFA to trimester-specific MMS protocols, and shifting practice from disease correction to a proactive strategy for optimising pregnancy outcomes.

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