Gestational Maternal Undernutrition: Implications on Fetal Development, Cardiovascular Diseases and Prevention by Complementary and Alternative medicine

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SUMMARY

There are reported links between sub-optimal maternal nutrition and compromised fetal development and growth leading to higher cardiovascular disease (CVD) incidence in adolescence and later stages of life. CVDs are a major cause of disease and death in mankind and are an impediment to sustainable human development, globally. Recent reports suggest that about 17.9 million human deaths are caused by CVDs, annually (WHO, 2022). Among the various CVDs, the most prevalent one is coronary artery disease (CAD). The CAD resulted in about 9 million deaths and affected 110 million people, in 2015 (WHO, 2022). The health of a woman and her generations depends upon nutritional status, during pregnancy and lactation. The risks of progressing insulin resistance, high blood pressure, and type-2 diabetes mellitus in later stages of life were likely greater in babies born with low birth weights than those born with normal weights and not exposed to maternal malnutrition. Complementary alternative medicine (CAM) often includes the use of dietary supplements, such as specific vitamins and minerals, to support the nutritional needs of both the mother and the developing fetus. Herbal sources of iron, such as nettle (*Urtica dioica*) and yellow dock (*Rumex crispus*), have been historically used to address anemia and improve iron status. A positive impact of Moringa oleifera supplementation has been demonstrated on maternal nutritional status and birth outcomes. Galactagogue herbs like fenugreek (*Trigonella foenum-graecum*) and fennel (*Foeniculum vulgare*) have been traditionally used to enhance milk production and support breastfeeding mothers.

INTRODUCTION

This chapter has been written to give a good insight into the global incidence of maternal and child undernutrition, maternal under-nutritional effects on fetal development and CVD incidence, the link between CVDs and IMT, association of Intrauterine Growth Restriction (IUGR) and CVDs, during pregnancy and optimal nutritional provisions during pregnancy to avoid adverse effects of maternal undernutrition for improvement of overall health and wellbeing.

IMPACT OF GESTATIONAL MATERNAL UNDERNUTRITION ON FETAL DEVELOPMENT

"It is on the condition of the health of the mother that the condition of the health of the child depends", Hippocrates stated. This is one of the very early reported references to the concept that placental life has an effect on adult life. But the full concept came into being as we know it in the 1930s, during this era substandard living conditions in infancy were linked to premature death, later. Further studies were carried out which linked these substandard living conditions in early life to several cardiac disorders later in life when the living conditions were better this gave a hint that development in early life and the environment was rather important for the well-being of the individual, in 1977 (Hanson, 2015).

Approximately one-half of the world's total population is affected by maternal and child undernutrition (Ahmed et al., 2012). Maternal and child undernutrition causes 3·5 million deaths annually, 11% of worldwide disability-adjusted life-years (DALYs), and more than one-third of the disease burden

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in children (less than 5 years of age). Optimum and balanced maternal nutrition is indispensable for proper fetal development and growth (Barker & Clark 1997). Nutritional factors and proteins present in milk promote fetal growth in pregnant women (Borazjani et al., 2013). Ignorance, poverty, food insecurity, infectious diseases, lack of proper feeding practices for infants and young children, and poor sanitation and hygiene lead to the prevailing high levels of child and maternal undernutrition in developing nations. Maternal undernutrition is highly prevalent in the resource-poor countries of southeast Asia, sub-Saharan Africa, and south-central Asia. Its prevalence in South Asia ranges from 10 to 40% (Ahmed et al., 2012; Jouanne et al., 2021).

Pakistan being a developing country, about 12.5% population (28 million) faced undernourishment, in 2021 (FAO, 2021). In Pakistan, both lactating and pregnant women suffer from a higher prevalence of malnutrition (16.1%) than their non-pregnant peers (12.5%). It is understood that undernutrition reduces a nation’s economic progress by at least 8% resulting in poorer cognition, direct productivity losses, and reduced schooling. The enormity of children and maternal undernutrition in Pakistan is so much so that about one crore children in Pakistan face stunting, largely due to maternal undernutrition (UNICEF, 2022). To cope with this grave situation, in 2014, the World Bank committed 47.95 million US dollars to improve the nutritional status of lactating and pregnant women. A similar situation is prevalent for women and children in many developing countries (World Bank, 2014).

Maternal undernutrition has been proven to have a profound effect on fetal growth, with body weight and many key organs. It has been reported previously that during the first two weeks of pregnancy, the provision of a 5% protein diet only (undernutrition) led to a reduction in brain weight, size, and cortical thickness of the brain (Gressens et al., 1997). A severe gestational maternal protein restriction in rats caused a reduced number of glomeruli and hypertension in both male and female newborns, this hypertension is salt-sensitive and worsens with age, but is approximately equivalent in males and females (Woods et al., 2004)

Chronic energy deficit or maternal undernutrition means having a body mass index (BMI) below 18.5. If the females are under-nourished females at the time of conception, then during pregnancy (when there are additional demands due to the growing fetus), they are unlikely to improve their nutritional status. They are more likely to fail to gain sufficient weight during pregnancy and are at a higher risk of mortality than well-nourished and healthy women (Smith et al., 2003).

IUGR predisposes developing fetuses to reduced organ and body weights. Most information about the long-term and short-term effects of IUGR has come from animal models. In recent years, many animal models of placental insufficiency and/or poor maternal nutrition have been developed to investigate the causes and effects of IUGR. Both maternal dietary manipulations and surgical interventions have been employed for these studies. A number of animal species have been studied for IUGR effects, including rodents, rabbits sheep, and primates (Louey et al., 2000; Mitchell et al., 2004; Jonker et al., 2018).

Maternal nutrition during pregnancy is a vital predictor of fetal growth, gestation consequences, and, ultimately, mature health. The normal placental role enables the flow of nutrients from the mother to the fetus, which is essential for a healthy fetus development. Fetal growth is slowed in the presence of maternal malnutrition, which affects placental development and function. Organ development can also be affected by this condition's impact on the inbuilt gene expression or endocrine system.

Intrauterine undernutrition, such as feeding a hypocaloric or low-protein diet during gestation, induces IUGR which is manifested in low birth weights (Kominiarek & Rajan 2016). Furthermore, a limited supply of nutrients limits fetal growth and development and delays the binucleation of cardiomyocytes (Wang et al., 2011).

Gestational maternal undernutrition in sheep and rabbits led to decreased maternal weight gain. A 50% decreased feed intake in sheep (Welsh Mountain ewes), during the early 28 days of gestation, led to a massive decrease in maternal weight gain of under-nourished pregnant ewes as compared to the control group (Cleal et al., 2007). In rabbits (days 7-19 and 20-27 of pregnancy), fed 50% of maintenance energy requirements, maternal weight slightly decreased (140-145 g) when compared with the initial weight (Symeon et al., 2015).

In New Zealand white IUGR fetal rabbits' body weight was significantly lower (31.38 ± 10.15g) than control fetuses (49.15 ± 7.51 g). Thoracic diameter values were reported for well-fed born kits (2.37± 0.03 cm) and underfed kits (2.15± 0.03 cm) in New Zealand white rabbits. On the 21st day of pregnancy, the fetal values were 1.34± 0.04 and 1.32± 0.03, respectively, for well-fed and underfed rabbits. At day 21st of pregnancy, the biparietal diameter has been reported in the control group (1.02± 0.02cm) and underfed group (1.0± 0.02 cm) and for well-fed newborn kits (2.26± 0.02 cm) and underfed kits [2.03± 0.02 cm (Garcia-Canadilla et al., 2019)].

In rabbits, the crown-rump length, at birth, values have been reported in the control group (10.75 ± 0.14 cm) and underfed group [10.21± 0.12 cm (López-Tello et al., 2015)]. Another study has reported fetal values at day 14 as 12.008±0.216 mm, and at day 20 as 34.576±0.279 mm (Ghazi and Al-Jebori, 2014).

In sheep, slaughtered at day 78 of gestation, well-fed fetuses had a crown-rump length of 23.55 ± 0.50 cm, while nutrient–restricted were 21.56 ± 0.61 (Vonnahme et al., 2003). In cows, subjected to feed restriction in mid to late gestation, during the last month of gestation, the crown-rump length values were 78.2 ± 2.4 cm for hi-diet fetuses and 75.9 ± 3.8 for low-diet fetuses (Paradis et al., 2017). In mini-lop rabbits, ultrasonographic studies have reported abdominal circumference values at day 16 and 21 of gestation as 20.2 ± 0.5 and 34.8 ± 0.7 mm respectively (Mazandarani et al., 2021).

According to the World Health Organization, a birth weight below 2.5 kg can result from preterm birth, inappropriate growth in utero, or their combination. This is independent of gestational age and ethnic groups/ populations (Zohdi et al., 2015). There is a consistent link between low birth weight (LBW) and increased risk of adult hypertension. The global prevalence of LBW is 15.5%, which amounts to about 20.6 million births with LBW, annually. Out of these 96.5% are born in low-income, developing countries. India alone contributes forty percent of the world’s total LBW population, with about one-third of all newborns weighing 2.5 kg at birth (Ahmed et al., 2012).

In sheep fetuses, the orbital diameter was found higher in feed-restricted fetuses at 45, 90, and 135 days (5.7, 18.4, 26.1 mm) than in control group fetuses at these days (5.1. 17.4, 23.9, 29.8 mm). However, the orbital diameter was higher in the control group (29.8mm at birth) than in feed restricted group (Pillai et al., 2017). However, the extra energy required during pregnancy and lactation (5 and 8%, respectively) only presents a small percentage of household total food energy needs. However, due to the persistent food insecurity in the households, even these small chunks of extra food energy may not be available to pregnant or lactating females (Kominiarek & Rajan 2016).

Not only maternal undernutrition but the intrauterine over-nutrition, results in fetal macrosomia (being much larger than normal) and subsequent offspring obesity which increases the CVD risk. This overnutrition can result from feeding a hypercaloric or high-fat diet during pregnancy, which causes obesity in mothers (Moreno-Fernandez et al., 2020). Maternal protein restriction caused a loss in bone area and density in late adult offspring, but not bone mineral density. These findings in elderly rats were like those seen in human epidemiological research. Furthermore, maternal protein restriction is linked to alterations in the emergence of the epiphyseal growth plate in children during late adulthood.

Maternal undernutrition and IUGR are associated with low birth weight (LBW), which leads to an increased risk of kidney disease due to lower nephron development resulting in hyperfiltration and the subsequent loss of nephrons. The size of kidneys is widely used as a substitute for the number of nephrons (Lillås et al., 2021). However, small kidney size in pre-term babies not leading to kidney dysfunction still predisposes individuals to long-term kidney dysfunction risk (Liefke et al., 2022).

GESTATIONAL MATERNAL UNDERNUTRITION AND CARDIOVASCULAR DISEASES (CVDS)

CVDs are a major cause of mortalities in humans and an impediment to sustainable human development, globally. Recent reports suggest that about 17.9 million human deaths are caused by cardiovascular diseases (CVDs) annually (WHO, 2022). CVDs have a high incidence rate in animals too. In dogs, heart diseases affect approximately 10-15% of all dogs (Macpete, 2021). CVDs include ischemic stroke, atrial fibrillation, hemorrhagic and other stroke, peripheral arterial disease (PAD), cardiomyopathy and myocarditis, aortic aneurysm, rheumatic heart disease (RHD), endocarditis, hypertensive heart disease, and other CVD conditions.

Among the various CVDs, coronary artery disease (CAD), also known as coronary heart disease (CHD) atherosclerotic heart disease, or ischemic heart disease is the most prevalent one. CAD resulted in about 9 million deaths and affected 110 million people in 2015. Thus, globally, it is the most common cause of human deaths, causing 15.6% of all deaths. CAD involves a waxy substance (plaque) build-up in the coronary arteries and arterioles, leading to decreased blood flow to the cardiac muscles. Due narrowing of the vascular lumen, the coronary vessels are unable to supply the optimum volume of oxygen-rich blood to the heart tissues, which may lead to death (WHO, 2022). One of the best available tools for CVD control is the prediction of CVD risk (Yang et al., 2020). Previous literature suggests that intima and media thicknesses (IMT) in carotid and aortic arteries can help predict the risk of CVDs in human subjects (Kume et al., 2005; Kokubo et al., 2018).

Previous reports suggest that increased peripheral vascular resistance is attributed to increased blood pressure. It involves small arteries (150-300 µm luminal diameter), and larger arterioles (50-150 µm luminal diameter). These small arteries and arterioles are the most important sites in the arterial network which undergo changes leading to an increased peripheral vascular resistance, embodied by hypertension (Schiffrin, 1992). Highly variable luminal diameters have been reported in the cerebral (87 µm), mesenteric (178-222 µm), and femoral (167 µm) resistance arteries of rats with elevated blood pressures. In the rats with normal blood pressure, luminal diameters of femoral, mesenteric, and cerebral arteries have been recorded as 199, 194- 265, and 102 µm, respectively (Ledingham & Ashton 2005; Souza-Smith et al., 2011).

Epidemiological studies suggest associations between impaired fetal growth and sub-optimal maternal nutrition leading to a high prevalence of CVDs in adolescence and later life stages. This supports the concept regarding the fetal origins of many diseases commonly known as the developmental origin of health and disease (DoHAD). This states that an individual's long and short-term health is affected by exposure to certain environmental factors during specific periods of growth and development (Osrin & Anthony 2000; Miller et al., 2016; Mandy & Nyirenda 2018). This theory states that lifestyle-related diseases have their origins at the time of fertilization, embryonic, fetal, and neonatal stages by the association of genes and environmental factors like nutrition, environmental or chemical stress, etc. (Arima & Fukuoka 2020).

Balanced and sufficient intrauterine nutrition, coupled with ample oxygen to the developing fetus(es), is vital for normal cardiovascular physiology and cardiac development in the offspring. These provisions equip them to cope with the stressors that enhance the onset of CVDs during later stages in life (Govindsamy et al., 2018). The Dutch famine (1944-45) created the tragic circumstances to examine the effects of prenatal (maternal) undernutrition on human health, during later stages of life. The persons exposed to famine conditions in early gestation showed increased stress-induced rise in blood pressure, during later stages of life (de Rooij et al., 2016). The elevated blood pressure reactions were reflected in their response to everyday stressors and thus led to an increased deterioration of the cardiovascular components (De Rooij et al., 2021).

The fetal adaptations to the stress factors set both the fetuses and future offspring, at an increased risk of CVDs. Before the onset of a significant metabolic or cardiovascular disease in adulthood, subclinical evidence of cardiovascular dysfunction is already there during fetal and early neonatal life. This supports the notion of fetal and perinatal programming (Malhotra et al., 2019). An increased prevalence of hypertension, cardiovascular illness, and non-insulin-dependent diabetic mellitus in adult life has been linked to disrupted intrauterine development. Reduced prenatal nutrition availability is thought to disrupt fetal development while also altering or programming the form and function of the developing cardiovascular system, predisposing the person to adult hypertension and cardiovascular illness.

CVDS and IMT

Studies have shown that arterial IMT, during initial life phases, can help predict the CVD risk of in later life stages. In high-risk Japanese populations, carotid IMT was found to be a confirmed independent predictor of cardiovascular incidents, including unstable angina, myocardial infarction, hemorrhagic or ischemic stroke, or surgical intervention for coronary or peripheral artery diseases. However, these studies were conducted on the aorta and carotid arteries during postnatal life, while implicating results for atherosclerosis in the coronary arteries (Kume et al., 2005; Hong, 2010; Kasliwal et al., 2014).

So far, there is a scarcity of literature about the intima-media thickness (IMT) of coronary vessels in different species. We have previously reported that maternal undernutrition adversely affects the IMT of coronary arterioles (these are branches of the coronary arteries) in sheep fetuses, collected at the 140th day of pregnancy (Rehan et al., 2014). In rabbit fetuses and neonates, the gestational age and maternal undernutrition resulted in significantly different coronary values as compared to the well-nourished female rabbits. The highest mean coronary IMT (46.14±1.50 um) was found in under-nourished (UN) neonates and the lowest (9.96±1.34 um) in well-nourished (WN) fetuses (2nd week) of pregnancy. The lowest mean coronary vascular perimeter (122.7±46.60um) was observed in UN fetuses at 2nd week of development and the highest (458.1±46.63 um) in UN neonates. The mean coronary vascular diameter was lowest (39.06±12.84 um) in WN fetuses at 2nd week of pregnancy and highest (146.27±14.84 um) in WN neonates. These values suggested that maternal undernutrition decreased fetal heart dimensions and weight, fetal and maternal body weights, increased coronary vascular IMT, and decreased coronary luminal and vascular diameters (Rehan et al., 2023).

Intrauterine growth restriction (IUGR) and CVDS

IUGR is a fetal condition that influences up to ten percent of all pregnancies and is associated with cardiovascular structural and functional remodeling which persists postnatally. IUGR fetuses have shown increased coronary luminal diameter when compared with controls. An increased blood flow to myocardial tissues has been reported in IUGR fetuses (Garcia-Canadilla et al., 2019). Gender-based studies have shown that in response to fetal insults, females are less prone to the development of adult disease, while males are more sensitive, although the opinions are divided. The sex hormones may be responsible for modulating the activity of regulatory systems, leading to lower vascular dysfunction and hypertension in women than men (Grigore et al., 2008; Radulescu et al., 2013).

It has been reported that at the 30th day of pregnancy, in New Zealand white rabbits, IUGR fetuses had less spherical hearts than the control subjects. IUGR fetuses had increased left ventricular wall thickness as compared to the control group. This suggests that IUGR fetuses had hypertrophic hearts (6.88 ± 0.54 vs 5.19 ± 0.75 mm). Also, the IUGR hearts were clearly smaller than the control hearts, also showing dilated coronary arteries. Lengths of IUGR fetal hearts (7.08 ± 0.73mm) were smaller than controls (8.49 ± 0.53mm) and the basal diameter was slightly higher in IUGR hearts (6.59 ± 0.25mm) than controls [6.49 ± 0.17mm (Garcia-Canadilla et al., 2019)]. Ultrasonographic measurements of fetal hearts described fetal length values as 2.1- 2.8mm on the 15^{th} day, 4- 4.9mm on the 21^{st} day, and 10.3- 13.7mm on the 29^{th} day of pregnancy. The width of the fetal heart at the 15^{th}, $21^{st,}$ and 29^{th} gestational days in rabbit fetuses, was reported as 1.7-2.6mm, 3.5-5mm, and 8.4-10.3mm, respectively (Chavatte-Palmer et al., 2008).

In England, the incidence of death from coronary artery disease was the highest in the males with the lowest birth weights, born between 1911 and 1930, compared to normal birth weight individuals; this was independent of lifestyle factors (Barker et al., 1989). While, an increased birth weight led to a decreased blood pressure during adulthood (Zohdi et al., 2015). During pregnancy, the maternal diet has a pivotal role in the development of the fetus/es, affecting the fetus's productivity and health. Maternal malnutrition is a major reason for low birth weight, and it has a significant impact on the fetus's short-term morbidity. The newborn's heart, brain, spinal cord, liver, muscles, and gonads are all affected by maternal malnutrition (Belkacemi et al., 2010).

Growth retardation is cumulative when undernutrition occurs at a consistent intensity across multiple generations. Intergenerational dietary studies allow us to investigate unique adaptation mechanisms and, as a result, human population evolution. Although the results of these experiments cannot be directly applied to people, they do help us better understand the unfavorable secular tendency in human populations (Cesani et al., 2014). Humans and animals were both impacted by maternal malnutrition, which resulted in low birth weight. The risks of progressing insulin resistance, high blood pressure, and type 2 diabetes mellitus in later stages of life were likely greater in babies born with low birth weights than those born with normal weights and not exposed to maternal malnutrition.

Maternal undernutrition had a significant influence on fetal growth. Four groups were investigated, two of which were controls, and the groups were divided gender-wise; samples were obtained at various intervals of maternal undernutrition. This study looked at the consequences of maternal malnutrition on both genders at different ages. During early life development in both males and females, maternal malnutrition did not affect the heart of the fetuses; nevertheless, cardiac oxidative stress was a parameter that may be present during many degenerative alterations in the heart. Due to hypertension exposure, the male heart deteriorates earlier than the female heart in later life.

In fetal life, in both fetal growth-restricted (FGR) animals and human cohorts, the altered vascular tone sets up the path for the developmental programming of future hypertension. The major blood vessels, such as the carotid arteries and aorta showed an increased stiffness and wall thickness in FGR animals and humans. These vascular changes persist into adulthood, more obvious in the peripheral vascular beds than in the central vascular bed (Bhunu et al., 2021).

Vascular compensation has been observed in FGR offspring. The remodeling of the arterial wall, elastin, and collagen contents adds to altered vascular mechanics. Guinea pig and rodent studies have shown that an interruption of mid-gestation fetal growth is associated with a crucial phase of elastin production within vasculature, thereby, attenuating elastin deposition so that collagen is increased, and elastin is reduced. Since collagen is a hundred times stiffer than elastin, this remodeling greatly impacts the vascular mechanics. Consequently, vascular stiffness is highly increased. In the growth-restricted offspring, these altered vessel biomechanics are mostly noted in the lower body arteries. In adolescent rodents, the aorta (despite being normotensive) is not only stiffer but has an increased fibrotic tendency, too. These studies suggest that prolonged hypoxia and adaptive hemodynamic redistribution lead to vascular remodeling, in response to changes in flow and pressure, rather than hormone or metabolic alterations (Malhotra et al., 2019).

Prevention of maternal undernutrition during pregnancy

The nutritional requirements of females are increased during gestation and lactation. In the coming lines literature about nutritional requirements during pregnancy has been discussed in brief in humans, cows, sheep, and rabbits. The health of a woman and her generations depends upon her nutritional status, during pregnancy and lactation. During pregnancy, the nutritional requirements are considerably different from those of non-pregnant ladies. The nutritional requirements of women are increased during pregnancy and lactation to support all the changes occurring in the body, to prepare the body for birth for lactation, and to ensure the optimal development and growth of the fetus/baby. The metabolic and cellular activities in a woman (mineralization, oxygen transport, cell differentiation, proliferation, hemoglobin production, etc.) need an optimal intake of omega-3 fatty acids and micronutrients (i.e., minerals and vitamins). The intestinal absorption capacity of iron, during pregnancy, is increased from 10- 40% at the end of pregnancy (Jouanne et al., 2021). To maintain a healthy pregnancy appropriate and timely vitamin and mineral supplementation, a balanced diet, and regular exercise are needed. During pregnancy, about 300 calories in extra are needed each day, in addition to an elevated requirement for macro and micronutrients (Hopkins, 2019).

In mature cows, progressing from mid to late gestation, a 16 percent increase in total digestible nutrients and a 20 percent increase in crude protein is needed to match with increasing fetal growth. When a cow calves, the requirement for additional nutrients is magnified so as to produce milk for a calf (Dahlen & Crawford 2016). The additional nutritional requirements of pregnancy begin at the 70th day of pregnancy, thus this point is the beginning of fetal needs for nutrients (Sguizzato et al., 2020).

In sheep, the ewes' nutritional requirements increase greatly during the final 6 weeks of pregnancy because 70% of fetal growth occurs in this span. Ewes underfed during late pregnancy produce lambs with decreased brown fat reserves, used specifically for insulation against Hypothermia. The crude protein requirement for a 70 kg ewe in the last month of gestation is about 214g/day (Dempsey, 2019). Nutritional requirements are different for females carrying singleton lambs than having twins. The energy requirements for an ewe with a single lamb increased about 50% above her maintenance requirements, while energy requirements for an ewe carrying twins increased up to 75%. Hence, during the last month of gestation, ewes should consume 10.5 to 11.5% crude protein, 59 to 65% total digestible nutrients (TDN), and approximately 3.5 to 4.5 lbs. dry matter (Barkley, 2022). As feeding levels decrease at each stage of gestation (due to reduced room in the abdominopelvic regions), the apparent digestibility of carbon and nitrogen is increased. At days 40- 130 of gestation, the daily net maintenance energy requirements ranged from 295.80-, 323.59 kJ kg–1 $BW^{0.75}$ (metabolic body weight) with a partial efficiency of metabolizable energy utilization of 0.664 and 0.620, respectively. The daily net maintenance protein requirements were 1.99- 2.99 g/ Kg $BW^{0.75}$ at days 40- 130 of gestation, respectively (Zhang et al., 2018). In commercial farming expecting a lamb crop of 130%–180%, ewes should be fed a diet with 11.3% crude protein and 65% total digestible nutrients (Filly, 2018).

In nulliparous rabbits does, fed different levels of protein, weight gain at term ranged from 652- 850g (Saidj et al., 2019). Lactating does, when they are concurrently pregnant, need higher dietary protein. These extremely high requirements result in a negative protein balance and the body reserves are mobilized to fulfill these requirements. So, a higher protein level of 17 to 18% is required in the diet of pregnant, lactating rabbits does (Blas & Wiseman 2020).

THE COMPLEMENTARY ALTERNATIVE MEDICINE (CAM) INTERVENTIONS TO MITIGATE THE EFFECTS OF UNDERNUTRITION ON MATERNAL AND FETAL HEALTH

CAM encompasses a diverse range of therapies and practices that go beyond conventional medical approaches, offering potential benefits for both maternal and fetal well-being. The role of CAM in fetal health is a subject of growing interest and research. This has been discussed in brief below

Dietary supplements

CAM often includes the use of dietary supplements, such as specific vitamins and minerals, to support the nutritional needs of both the mother and the developing fetus. Adequate nutrition is crucial for fetal development, and CAM approaches aim to ensure proper nutrient intake (Leung & Kaplan 2009). Insufficient intake of key nutrients such as folic acid, iron, iodine, vitamin D, and omega-3 fatty acids is associated with an increased risk of neural tube defects, low birth weight, developmental delays, and impaired cognitive function in offspring. Common prenatal supplements, such as folic acid, iron, calcium, vitamin D, and omega-3 fatty acids, aim to support maternal health, bridge nutritional gaps and positively influence fetal development (De-Regil et al., 2015; Peña-Rosas et al., 2015).

During the early stages of pregnancy, folic acid is crucial for neural tube development. Its deficiency leads to an increased risk of neural tube defects. Folic acid supplementation before conception and during the first trimester significantly reduces neural tube defects (CDC, 2022; De-Regil et al., 2015). Iodine is essential for the synthesis of thyroid hormones, critical for fetal brain development. Maternal Iodine deficiency during pregnancy can result in cognitive impairments in the offspring. Iodine supplementation, especially in regions with low dietary iodine, is crucial to prevent iodine deficiency disorders and support healthy fetal neurodevelopment (Pearce et al., 2016).

Vitamin D supplementation is recommended, especially for women with limited sun exposure, to ensure adequate vitamin D levels for both maternal and fetal well-being. Supplementing pregnant women only with vitamin D reduces the risk of gestational diabetes, pre-eclampsia, severe postpartum hemorrhage, and low birth weight (Palacios et al., 2019). Omega-3 fatty acids, particularly docosahexaenoic acid (DHA), are essential for fetal brain and visual development. Prenatal supplementation with omega-3 fatty acids has been associated with improved cognitive outcomes in children. Ensuring an adequate intake of these essential fatty acids is crucial for supporting optimal neurodevelopment in the fetus (DiNicolantonio & O'Keefe 2020).

Despite the widely available (potential) benefits of these herbal, vitamin, and mineral supplements, adherence to supplement regimens, potential interactions, and the variability of individual nutritional needs underscore the importance of personalized care. Additionally, the quality of supplements, appropriate dosages, and potential side effects should be carefully considered.

Herbal remedies

Some CAM practices incorporate herbal remedies to supplement nutritional needs. However, caution is necessary, as not all herbs (ginger, iron-rich herbs, echinacea, and cranberry) are safe during pregnancy. Consultation with a healthcare provider experienced in CAM is essential to ensure safety and efficacy (Nordeng et al., 2011). Many traditional healing systems, such as Ayurveda, Traditional Chinese Medicine (TCM), and Indigenous medicinal practices, incorporate herbs to address nutritional deficiencies and promote overall well-being during pregnancy (Kavita Mule & Nikita Dasarwar 2021).

Ginger has been traditionally used to alleviate nausea and vomiting during pregnancy. Studies suggest that ginger may be effective in reducing symptoms of morning sickness without adverse effects on fetal development (Lete & Allué 2016). In the pregnant mice, maternal supplementation with curcumin induced a potent antioxidant response in LP-fed; specifically, curcumin (i) increased Nfr2 mRNA expression, GSH-Px activity, and the blood sinusoids area; (ii) reduced apoptosis in the placenta, thereby, leading to increased placental efficiency, reduced malondialdehyde (MDA) content; and (iii) elevated the expression of the antioxidant genes CAT, SOD1 and SOD2 and protein expression of Nrf2 and eme oxygenase-1(HO-1) in the liver. On the whole, curcumin supplementation during pregnancy reverted tissue damage and contrasted with the decrease in fetal weight induced by a low protein diet. Curcumin improved birth weight, inflammation, and oxidative damage also in fetal growth restriction (FGR) newborn rats. The FGR rats (at six weeks age for six weeks) supplemented with 400 mg/kg curcumin displayed the reduced activity of AST, ALT, and MDA enzymes, reduced levels of the inflammatory cytokines TNF-α, IL-1β, and IL-6, and increased Gpx and GSH activity in serum. Antioxidant defense in the liver improved significantly as well (Filardi et al., 2020).

Certain herbs complement maternal nutrition, for instance, Moringa oleifera, known as the "drumstick tree," is a traditional remedy in many cultures and is recognized for its high nutritional content, including vitamins, minerals, and antioxidants (Stohs & Hartman 2015). A positive impact of Moringa oleifera supplementation has been demonstrated on maternal nutritional status and birth outcomes (Derbo & Debelew 2023). Maternal undernutrition is often linked to increased stress levels, impacting both physical and mental well-being. Adaptogenic herbs, such as Ashwagandha (*Withania somnifera*) and Rhodiola (*Rhodiola rosea*), have been traditionally used to modulate the body's stress response (Panossian & Wikman 2009). Herbal sources of iron, such as nettle (*Urtica dioica*) and yellow dock (*Rumex crispus*), have been historically used to address anemia and improve iron status (Hoffman, 2003). Maternal undernutrition can impact lactation and breastfeeding. Galactagogue herbs like fenugreek (*Trigonella foenum-graecum*) and fennel (*Foeniculum vulgare*) have been traditionally used to enhance milk production and support breastfeeding mothers (Wani & Kumar 2018). These herbs may be valuable in addressing nutritional needs during the postpartum period.

CAM may include the use of herbal teas, such as ginger or peppermint tea, to alleviate nausea and vomiting during pregnancy. These natural remedies have been found to be effective and are considered safe when used in moderation. CAM practitioners often provide dietary guidance and lifestyle modifications tailored to the individual needs of pregnant women experiencing undernutrition. This may include recommendations for nutrient-dense foods, meal planning, and lifestyle changes to optimize nutritional intake (Holst et al., 2009). Incorporating traditional dietary practices from various cultures into CAM interventions acknowledges the diversity of nutritional sources and habits, offering personalized approaches to address gestational undernutrition.

CONCLUSION

CAM interventions offer a multifaceted approach to addressing maternal undernutrition, drawing on historical practices and contemporary scientific research. Integrating nutrient-rich herbs, adaptogens, anti-inflammatory herbs, and galactagogues into maternal care may contribute to improving nutritional status, reducing stress, and supporting overall maternal and fetal well-being. However, caution is warranted, and the incorporation of herbal interventions should be guided by scientific evidence, safety considerations, and cultural sensitivity.

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