REVIEW OF LITERATURE

The review of literature for the present study entitled 'Triple Burden of Malnutrition in Young Adult Women (18-21 years) and the Effect of Nutrition Interventions on their Nutritional Status and Nutritional Knowledge' is presented under the following headings.

2.1.Triple Burden of Malnutrition-An Overview

2.1.1.Meaning and Concepts

The "triple burden of malnutrition" refers to the simultaneous existence of three forms of malnutrition within populations, households, and individuals: under nutrition, over nutrition, and micronutrient deficiencies. The triple burden typically arises from common underlying factors such as poverty, limited access to nutritious foods, poor dietary choices, and the increased availability of cheap, unhealthy processed foods. This phenomenon is a global challenge affecting both low-income and high-income countries, leading to serious health consequences, including stunted growth, increased risk of non-communicable diseases, and overall poor health outcomes (Prentice, 2023).

Under nutrition includes conditions such as weight loss, as well as micronutrient deficiencies, often termed "hidden hunger". Over nutrition primarily manifests as overweight and obesity, which are increasingly prevalent among adolescents and young adults. Micronutrient deficiencies can occur even in individuals who are overweight or obese, highlighting the complexity of this issue. Addressing the triple burden of malnutrition requires coordinated efforts to improve food systems, enhance nutrition education, implement social protection measures, and regulate the marketing of unhealthy foods. The prevalence of micronutrient deficiencies, such as anaemia, is prevalent among young women, further complicating their health status. Factors such as maternal age, education level, and socio-economic status play critical roles in determining the likelihood of experiencing the triple burden. For example, women with lower educational attainment and those from poorer households are at a higher risk of facing these nutritional challenges (Chilot *et al.,* 2023).

Over nutrition among young adult women is an emerging public health issue, characterized by excessive caloric intake and insufficient physical activity, leading to

overweight and obesity. This demographic is particularly vulnerable due to lifestyle changes brought about by urbanization, globalization, and increased consumption of energy-dense, nutrient-poor foods. Studies indicate that young women aged 18-25 are increasingly experiencing the double burden of malnutrition, where both under nutrition and over nutrition coexist, significantly impacting their health and well-being. Factors contributing to over nutrition include sedentary lifestyles, unhealthy eating habits such as frequent snacking and high sugar consumption, and socio-economic influences that limit access to nutritious foods. The implications of over nutrition are severe, as it is linked to a higher risk of non-communicable diseases (NCDs) such as diabetes, hypertension, and cardiovascular diseases, which are becoming leading causes of morbidity and mortality in this population. Addressing over nutrition requires comprehensive strategies that promote healthy dietary practices and physical activity, particularly in low- and middle-income countries where the prevalence is rapidly increasing (Sserwanja *et al.,* 2021) (Darling *et al.,* 2020).

Limiting unhealthy meals, encouraging traditional options, and raising awareness through partnerships and media campaigns are the strategies used in India to address nutrition-related issues. To combat contamination risks, food quality standards enforcement is essential. Lowering the cost of nutrient-dense foods and promoting their consumption are necessary to balance under nutrition and obesity. Social safety nets are among the urgent steps that are required to lower the cost of nutrient-dense diets, especially for the impoverished in rural areas. The goal of this all-encompassing plan is to guarantee that food is widely available in India that is healthy and safe (Raghunathan *et al.,* 2021).

It is also worth highlighting that there are persistent gaps between geographic units within India. For example, states with relatively high income, such as Kerala, have experienced a major overweight and obesity burden while states such as Odisha, Uttar Pradesh, and Bihar face a higher burden of underweight and micronutrient deficiencies. Given the loss of life and loss in life expectancy resulting directly from malnutrition and indirectly from the associated increased frequency and intensity of disease, India must enhance its public health, nutrition, and agriculture policies. Relying on economic performance to improve social outcomes is insufficient. Moreover, India's public policies should not concentrate exclusively on reducing the proportion of the population that is underweight; halting the increase in overweight and obesity trends would be a huge benefit (Acosta, 2019).

Majunder (2021) revealed that the socioeconomic status (SES) is an essential measure to assess an individual's well-being. The socioeconomic condition is variably decided by the individual's health-related quality of life and physiological well-being. The SES is essential to maintain health, health-seeking behaviour, social class, and participation in socio-political and socio-cultural organizations. In the academic area of social science and humanities, SES has played a crucial role in correlating the relation between SES with other associated phenomena. Individual or family income, educational level, quality of life, and other related aspects are strongly related to a sustainable livelihood.

Mishra (2017) stated that despite significant efforts made by the Indian government to combat malnutrition, the fraction of the population that falls within the normal range on the nutrition scale has remained stable; about half of them have experienced under nutrition and over nutrition. Over time, under nutrition decreased, but this was partially offset by over nutrition. Household food insecurity and the degree of chronic food insecurity remain high since the national level did not trickle down. High rates of economic expansion haven't helped India's food security. Organisational, financial, and managerial improvements in this direction are necessary and feasible. Malnutrition has consequences beyond just physical decline; it also has an impact on victims' psychological well-being. To achieve the goal of a malnutrition-free India, the legislative, service, and educational approaches should be optimised.

2.1.2.Epidemiology and Prevalence of Triple Burden of Malnutrition

Mishra and Rampal (2020) observed that India's food insecurity status was dire even before the lockdown was enforced. India's hunger statistics are among the poorest in the world. India ranked 102 out of 117 countries in the 2019 Global Hunger Index. About 14.5 per cent (i.e., about 190 million) Indians are undernourished, and 51 per cent women of reproductive age (15– 49 years) were anaemic. In India, where social norms and lack of economic opportunities regard women as inferior beings, increased prevalence and intensity of food insecurity can have alarming impacts on nutritional status of women.

Malnutrition is primarily caused by a range of dietary, economic, social, and health-related factors. Dietary choices play a crucial role, as inadequate intake of essential nutrients—either due to insufficient overall food consumption or poor-quality diets—can lead to both under nutrition and over nutrition. Economic constraints, such as low income and limited access to nutritious food, further exacerbate the risk of malnutrition. Health

conditions, including chronic illnesses and mental health issues, can impair nutrient absorption and increase nutritional needs. Additionally, age-related factors, such as reduced appetite and the presence of multiple medical conditions in older adults, contribute to the prevalence of malnutrition. Social isolation and physical limitations can also hinder access to proper nutrition, making it essential to address these multifaceted causes comprehensively to improve nutritional health outcomes (Doley and Marian, 2022).

Narayan *et al.,* (2019) reported that the rates of malnutrition among women are disturbingly high, according to reports from the National Health and Family Survey, and WHO in India is high. The nutritional status of mothers, lactation practises, the education of women, and sanitation practises are among the factors causing malnutrition in the nation. These have a variety of effects on children, including as growth retardation, childhood sickness, and stunting. Although various government programmes are in place and India has theoretically reduced malnutrition during the past ten years, there is still a need for effective application of research-based knowledge to address under nutrition, particularly because it impedes the socio-economic growth of the nation.

A study by Meenakshi (2016) compiles recent data on the triple burden of malnutrition, which is now known to include under nutrition, over nutrition, and micronutrient deficiencies, using a variety of anthropometric, biochemical, and diet quality indicators. The data indicates that overweight is rapidly becoming a major public health issue, affecting both urban and rural areas; related non- communicable diseases are also rising. The majority of under nutrition indicators have improved over time, but their magnitudes are still significant. Anaemia is a recurring issue, with a high and stable prevalence. When it comes to food, quality seems to have a stronger correlation with malnutrition than quantity. Micronutrient intakes have not increased, despite some increases in diet quality. A diet high in vegetables, dairy products, and meat has become more and more difficult for the impoverished to maintain because their costs (per unit calorie) have increased more quickly than those of grains.

Debnath *et al.,* (2019) confirmed that adolescents with poor physical growth patterns will exhibit multifaceted detrimental physical and social conditions that delay puberty onset, impair labour capacity, and negatively impact reproductive outcomes when they become adults. The body continues to mature with a rise in height even in late adolescence. The solution to such dire circumstances is an adequate supply of nutrition in the form of a balanced meal high in nutrients (like iron).

The paper by Madzorera and Fawzi (2020) pointed out that on Malnutrition in Women, Malnutrition results from imbalance between the needs of the body's requirement for nutrients and the intake of nutrients. In India, gender inequality in nutrition is present from infancy to adulthood. Women never reach their full growth potential due to nutritional deprivation. Malnutrition in women is related to poverty, lack of development, lack of awareness and illiteracy. The study mentions percentage wise malnourished females as 25.2 per cent as compared to males (20.2 per cent). A wide variety of development actions are needed to improve the food security and nutrition of women.

In India, the main risk factor for the prevalence of disease is still malnutrition. The fact that India has set high goals to lower malnutrition through National Nutrition Mission (NNM) is positive. According to the trends up until 2017, in order to meet the Indian 2022 and worldwide 2030 targets, much higher rates of improvement will be required for all malnutrition indicators in the majority of states. Subnational evaluations could be helpful for other middle-class and low-income nations (Swaminathan *et al.,* 2019).

Research from developing nations shows that there is a mixed association between socioeconomic class (SES) and place of residence with overweight/obesity. The percentage of overweight and obese people in India is now rising quickly, particularly among adult women. The inter-state situation of overweight and obesity varies greatly due to the stark socioeconomic variation that exists throughout India's states. However, promoting availability to fruits, grains, vegetables, and pulses as well as enforcing taxes and regulations on unhealthy diets may encourage people to adopt a healthy eating habit (Sengupta *et al.,* 2015).

Women and children continue to suffer from changes in food security, which makes it harder for them to deal with daily risk. The negative effects of natural catastrophes and climate change continue to disproportionately affect women and children. Measures are followed; however women and children are frequently the unrecorded victims, perpetuating the idea that they are the victims who go unnoticed (Cutter, 2017).

NFHS-5 indicates a reduction in under nutrition among women, with the percentage of women aged 15-49 years with a Body Mass Index (BMI) below normal decreasing from 22.9 per cent in NFHS-4 to 18.7 per cent in NFHS-5. However, the survey also reveals that 41.3 per cent of women are now classified as overweight or obese, reflecting a growing trend of over nutrition alongside under nutrition (Modi, 2023).

Study of Kumar *et al.,* (2021) is important in highlighting the risk factors for TBM among mother-child pairs in India. Triple Burden of Malnutrition was 14 per cent substantially less common among moms who were 30 years or older at the time of their first child's birth compared to mothers who were 19 years or younger. Various studies have noted a positive association between increasing women's age and the rise in obesity (Kumar *et al.,* 2021).

Study of Patel *et al.,* (2020) made an effort to investigate how mother-child pairings in India coexist with the double burden of malnutrition (DBM). Compared to Nepal's surrounding nations, India has a lower overall double burden of malnutrition among mother-child couples as well as Bangladesh. The mother's age at her first birth is another significant maternal factor that has a high positive correlation with DBM. The findings indicated that when a mother's age at her first birth increases, her likelihood of developing DBM lowers. The idea that a mother's nutritional awareness increases with age and that this reduces the incidence of double malnutrition is a well-explained concept.

In a study conducted by Menon *et al.,* (2015) the percentage of women who were deficient in zinc, vitamin B12, vitamin A (VAD), folate, anaemia, and vitamin B12 was 66 per cent, 52 per cent, 34 per cent, 4 per cent, and 2 per cent of the total. Less than 10 per cent of participants exhibited low levels of folate and retinol in their serum. Only 14 (11 per cent) of the women in total did not have any nutritional deficiencies. These women had multiple micronutrient deficiencies.

It has been discovered that a mother's varied diet, protects her children from low birth weight (LBW). Anaemia and underweight conditions were linked to a higher chance of having LBW offspring. The incidence of LBW new-borns was greater (20.4 per cent) in women with low dietary diversity compared to those with medium (17.5 per cent) or high (15.8 per cent) dietary diversity. In addition, LBW children were more likely to be born to underweight (21.3 per cent) and anaemic (17.8 per cent) women than to other women (Zaveri *et al.,* 2020).

Maternal nutrition plays a crucial role in the long-term health of children, influencing their growth, cognitive development, and overall well-being. Adequate maternal nutrition before, during, and after pregnancy is essential for foetal growth and infant health. Poor maternal nutrition can lead to complications such as foetal growth restriction, low birth weight, and increased risk of neonatal death, establishing a cycle of

under nutrition that can persist throughout the child's life. Children born to malnourished mothers are at a higher risk of stunting, which adversely affects brain development, sensory and cognitive functions, and learning capacity. This can result in poor school performance and, later in life, reduced earning potential and increased susceptibility to chronic diseases such as diabetes, hypertension, and obesity. Furthermore, maternal micronutrient deficiencies, particularly in iron and folate, can exacerbate these risks, highlighting the need for targeted nutritional interventions to improve maternal health and, consequently, child health outcomes (Swaminathan *et al.,* 2019).

In the study by Kumar *et al.,* (2021) stated that most significant correlates of the triple burden of malnutrition (TBM) among mother-child pairs in India were the mother's age, her educational attainment, the baby's birth size, the caesarean section delivery method, the household's wealth, and the mother's place of residence. Furthermore, a higher chance of TBM was observed in women with a secondary education level and surprisingly, this probability broke down for moms with a higher educational level. Mother-child couples with rich wealth status also had an increased likelihood of having TBM.

Malnutrition among women has significant long-term consequences that affect their health and the well-being of future generations. Physiologically, malnutrition can lead to impaired growth, increased risk of chronic diseases, and weakened immune systems, making women more susceptible to infections and complications during childbirth. Socially and economically, malnutrition perpetuates cycles of poverty, as malnourished women often face reduced productivity and increased healthcare costs, while their children are more likely to experience similar health issues, creating intergenerational challenges. Addressing women's malnutrition is crucial for improving health outcomes and fostering economic growth, as healthy women are better equipped to fulfil their roles in society and support their families (Serbesa *et al.,* 2019) (Vir and Malik, 2015).

A high prevalence of under nutrition was observed among adults, the proportion being higher among women than men. Women are generally more vulnerable, particularly in tribal areas of the country, mainly due to socio-cultural practices. Lack of food diversity is an important issue, particularly in developing countries where diets consist mainly of starchy staples, with less access to nutrient-rich food. The locations in this study in India had cereal-based diets. The basis for emphasizing dietary diversity in developing countries is mainly due to nutrition deficiency and the importance of increasing food and food group variety to ensure nutrient adequacy (Nithya and Bhavani, 2018).

A study by Luhar *et al.,* (2020) stated that between 2010 and 2040, the percentage of Indian individuals aged 20 to 69 who are overweight will more than quadruple, while the percentage who are obese will triple. By 2040, the prevalence of overweight and obesity will be 30.5 per cent and 9.5 per cent among males, and 27.4 per cent and 13.9 per cent among women.

In India, the prevalence of obesity is 40.3 per cent. The south had the most zonal variances, at 46.51 per cent, while the east had the lowest, at 32.96 per cent. Women were more likely than men to be obese (41.88 per cent vs. 38.67 per cent), to live in metropolitan areas (44.17 per cent vs. 36.08 per cent), greater levels of education (44.6 per cent college vs. 38 per cent uneducated) and lower levels of physical activity (43.71 per cent inactive vs. 32.56 per cent vigorously active) were associated with greater rates of obesity. All regions of India have extremely high rates of obesity. Obesity rates rise with age, and they are higher in women and people who live in cities. The highest rates of obesity are found in older, sedentary, college-educated metropolitan men and women. The two biggest factors that contribute to obesity are ageing and physical activity (Venkatrao *et al.,* 2020).

A study was carried out on 5,82,320 Indian women, aged 18 to 49, with a median age of 31 years and an interquartile range of 16 years. In total, 36.3 per cent of the women were overweight or had class I or class II obesity (body mass index (BMI) ≥23.0 kg/m2), while 20.1 per cent of the women were underweight (BMI <18.5 kg/m2). According to adjusted multinomial logistic regression, underweight was associated with younger age, lower wealth status, lower education, not eating fruits and vegetables every day, membership in a scheduled tribe, and tobacco use. Overweight or obesity was associated with older age, higher wealth, higher education, belonging to a different backward class or other, living in an urban area, eating fruits and vegetables every day, having heart disease, hypertension, and high or very high blood glucose levels. Tobacco usage and scheduled caste membership were inversely correlated with being overweight or obese (Pengpid and Peltzer, 2019).

The study stated that 30.4 per cent (n = 152) of the population had Iron deficiency anaemia (IDA) overall; 54 per cent of those with IDA were female (n = 82) and 46 per cent were male (n = 70). Students between the ages of 20 and 22 had a higher prevalence of anaemia (59.2 per cent) than did students between the ages of 17 and 19 (25.0 per cent) and 23 and 25 (15.8 per cent). When compared to irregular breakfast consumption, statistical analysis revealed that regular breakfast consumption had a substantial ($p < 0.001$)

preventive effect on the development of IDA. While coffee and cola consumption had an insignificant impact ($p = 0.585$; $p = 0.513$) on IDA, infrequent consumption of vegetables and fruits, meat, fish, and chicken, tea drinking, low household income and smoking showed a significant role ($p < 0.001$) in causing IDA. According to this study, the majority of college students—especially women—have IDA, which might worsen due to poor diet, unhealthy lifestyle choices, and ignorance. Our findings imply that IDA can be avoided by educating students on a good diet, a better lifestyle, and the negative effects of IDA (Al-Alimi *et al.,* 2018).

WHO recommends that, to reduce the level of Iron deficiency anaemia (IDA), India should strengthen its strategy along three pillars – food-based strategies (dietary diversification and food fortification), food supplementation and improvement of health services. Among these three, food fortification together with dietary diversification is deemed a more sustainable alternative, but better implementation strategies are required to increase uptake. Between 2005–2006 and 2015–2016, IDA in India decreased by only 3.5 percentage points (from 56.5 per cent in 2005–2006 to 53.0 per cent in 2015–2016) for women aged 15–49 years. However, during the same period, of 27 states compared, IDA increased in eight: Delhi, Haryana, Himachal Pradesh, Kerala, Meghalaya, Tamil Nadu, Punjab and Uttar Pradesh; furthermore, some of these (e.g. Kerala) are states that rank among the highest on the state Human Development Index but had failed to contain the burden of IDA (Rai *et al.,* 2018).

A large percentage of women were found to have nutritional deficiencies or low levels of ferritin or haemoglobin. Folate deficiency was found in 56.8 per cent women, vitamin B12 deficiency in 44.4per cent, low serum ferritin in 46.2per cent and low haemoglobin levels in 28.4 per cent of women. About one-half women were found to be underweight. Women with folate deficiency had roughly two times higher prevalence of vitamin B12 deficiency (Singh *et al.,* 2017).

Calcium deficiency, also known as hypocalcemia, can manifest through a variety of symptoms that highlight its impact on overall health. Common signs include muscle cramps and spasms, particularly in the hands, feet, and face, as well as numbness and tingling sensations in the extremities and around the mouth. Fatigue, weakness, and light-headedness are prevalent, often accompanied by brain fog and changes in mood. Dental issues, such as increased susceptibility to decay and periodontal disease, can arise due to a lack of calcium. Long-term deficiency can lead to low bone density and increased fracture

risk, while severe cases may result in seizures, arrhythmias, and other serious complications. If these symptoms are present, it is advisable to consult a healthcare provider for assessment and potential treatment options to address the underlying calcium deficiency (Bromage *et al.,* 2016).

Osteoporosis and bone loss can be effectively prevented and treated by increasing calcium intake, particularly through diet. After adolescence, when bone growth is greatest, women's bone strength essentially stays constant until they are between 30 and 40 years old. Bone loss usually happens at a rate of 0.5 per cent to 1 per cent annually beyond the age of 40. If less calcium is taken from the diet than is advised, there is increased bone loss. By taking supplements of calcium, women over 40 can minimise their loss of bone. According to some research, consuming calcium for 30 years following menopause may boost bone strength by 10 per cent and lower the likelihood of bone breaking by 50 per cent overall (Niharika *et al.,* 2020).

2.1.3. Types of Triple Burden of Malnutrition

2.1.3.1. Under nutrition

Underweight in young adult women is a significant health concern, defined by a body mass index (BMI) of less than 18.5. This condition can arise from various factors, including inadequate dietary intake, underlying health issues, and lifestyle choices. Young women who are underweight face numerous health risks, including hormonal imbalances that can lead to irregular menstrual cycles or amenorrhea, which can affect fertility. Additionally, being underweight is associated with a higher risk of developing osteoporosis later in life due to decreased bone mineral density, particularly if the underweight condition persists over time. Studies indicate that underweight women are also more susceptible to malnutrition, anaemia, and mental health issues such as depression, which can further complicate their overall health status. Addressing underweight requires a comprehensive approach that includes nutritional education, medical evaluation, and support to achieve a healthy weight, thereby reducing the associated health risks and improving quality of life for young women (Tatsumi *et al.,* 2016).

The main causes of underweight in young adult women are multifaceted, encompassing dietary, health, and psychological factors. Poor eating habits, including inadequate caloric intake and a lack of essential nutrients, are primary contributors. Health issues such as hyperthyroidism, diabetes, gastrointestinal disorders (like Crohn's disease or

celiac disease), and chronic illnesses (such as cancer or COPD) can also lead to weight loss or difficulty gaining weight. Additionally, mental health conditions, including eating disorders like anorexia nervosa and bulimia, significantly impact body weight, often resulting in severe under nutrition. Lifestyle factors, such as excessive exercise or high physical activity levels without adequate caloric compensation, further exacerbate the risk of being underweight. Stress and anxiety can diminish appetite, contributing to underweight status as well. Understanding these causes is crucial for developing effective interventions to support healthy weight management in this population (Lim and Park, 2018).

The most vulnerable members of society bear the brunt of the health hazards, particularly women and children. Lack of energy and protein affects women and children more than males. These negative health impacts are sometimes exacerbated by micronutrient deficiencies, specifically in iodine, iron, zinc, and vitamin A. Women eat less when there is a food shortage because they usually eat last, and making sure everyone else has eaten first. This leads to malnutrition. They often consume too few calories each day to keep up with their intense physical workload. Furthermore, having children often puts additional metabolic demands on them. The majority of women in impoverished nations suffer from chronic malnutrition, which is made worse by pregnancy and frequently dates back to infancy. Pregnant women who are undernourished are more likely to give birth to babies that are underweight (Ngoma and Mayimbo, 2017).

In a study by Siddiqui and Donato (2017), reported that young ladies in rural areas are a particularly vulnerable subpopulation, according to our research. Since economic growth by itself is unlikely to lessen India's malnutrition burden, policymakers must address the larger social variables that lead to greater rates of underweight prevalence in particular demographic segments.

Eating disorders, particularly anorexia nervosa and bulimia nervosa, are a significant contributor to underweight in young adult women. These mental health conditions are characterized by an intense fear of gaining weight and a distorted body image, leading to severely restricted food intake and unhealthy weight loss behaviors. Individuals with anorexia nervosa severely limit the amount of food they eat, often consuming very few calories per day. This caloric deprivation leads to rapid weight loss and an underweight BMI. Bulimia nervosa involves cycles of binge eating followed by purging through vomiting, laxative abuse, or excessive exercise. While bulimic individuals may not appear

underweight, the combination of binge/purge cycles and potential laxative abuse can contribute to electrolyte imbalances and malnutrition (Sharan and Sundar, 2015).

A study by Ahmed *et al.,* (2020) stated that compared to women of reproductive age who held a formal job, the prevalence of underweight was greater among unemployed women (14.5 per cent). Women living in affluent households were more likely to be overweight (23.9 per cent) than individuals (11.5 per cent) who lived in low-income homes. Compared to women of reproductive age who had no education (4.9 per cent), those who completed secondary or higher education had a greater prevalence of obesity (13.1 per cent). Compared to women of reproductive age without employment, those with informal employment had a lower likelihood of being underweight. Compared to unmarried women, married women had a lower likelihood of being underweight.

Long-term health consequences of being underweight in young adult women can be severe and multifaceted, affecting various aspects of physical and mental health. One significant risk is osteoporosis, as underweight individuals often have lower bone mineral density (BMD), increasing the likelihood of fractures and bone-related issues later in life. Studies indicate that women who remain underweight into adulthood are at a particularly high risk for developing osteopenia and osteoporosis, which can lead to brittle bones and fractures as they age (Tatsumi *et al.,* 2016).

Additionally, underweight women may experience menstrual irregularities, including amenorrhea (the absence of menstruation), which can complicate reproductive health and lead to difficulties with fertility. This is often linked to hormonal imbalances caused by insufficient body fat, which is crucial for regulating menstrual cycles (Wells *et al.,* 2020).

Moreover, being underweight can result in malnutrition, leading to deficiencies in essential vitamins and minerals, which can cause conditions such as anaemia, characterized by fatigue and weakness due to insufficient red blood cells. The immune system may also be compromised, making underweight individuals more susceptible to infections and illnesses due to a lack of nutrients necessary for maintaining immune function (Amarya *et al.,* 2015).

2.1.3.2.Over nutrition

Young women aged 18-25 are experiencing a "double burden of malnutrition", where both under nutrition and over nutrition coexist. Factors contributing to over nutrition

include sedentary lifestyles, consumption of energy-dense, nutrient-poor foods, and limited access to healthy food options (Dutta, 2024).

The main causes of over nutrition in young adult women are multifaceted and often interrelated, stemming from lifestyle, socio-economic, and environmental factors. One significant contributor is increased caloric intake, particularly from energy-dense, nutrient-poor foods, which are often more accessible and marketed aggressively. This dietary pattern is frequently accompanied by sedentary lifestyles, as many young women engage in less physical activity due to work, study commitments, or leisure activities that promote inactivity, such as screen time (Sserwanja *et al.,* 2021).

Several socioeconomic factors significantly contribute to over nutrition in young adult women. Women from higher wealth quintiles are more likely to experience overweight and obesity, as increased financial resources often lead to greater access to energy-dense, processed foods. Additionally, marital status plays a role, with married women typically exhibiting higher rates of overweight and obesity, potentially due to changes in dietary habits and physical activity levels. Regional disparities also exist; for instance, women in certain regions may face different food environments and cultural influences that affect their nutrition. Education can have a dual effect; while higher educational attainment is generally associated with better health awareness, it can also correlate with increased purchasing power for unhealthy foods. Furthermore, women in sedentary occupations are at greater risk of over nutrition due to reduced physical activity levels. Collectively, these socioeconomic factors highlight the complex interplay between economic status, lifestyle choices, and health outcomes in young adult women (Sewale and Zewudie, 2022)

Maternal complications such as hypertensive disorders of pregnancy, preeclampsia, gestational diabetes mellitus, caesarean sections, and postpartum haemorrhage were significantly more common among obese mothers compared to non-obese mothers. Additionally, there was a statistically significant increase in the risk of foetal and perinatal complications in obese mothers as compared to non-obese mothers. These complications included large for gestational age, hyper -bilirubinaemia, miscarriages and preterm new-borns (Kutchi *et al.,* 2020).

A study by Wells *et al.,* (2018) has taken into consideration variables like wealth level, rural/urban location, offspring sex, and maternal age, this study has detailed secular

trends in the C-section rate in India and evaluated if this might be associated to maternal short stature and overweight/obesity. The study found that the risk of C-section was higher in short women than in women of normal stature, that the risk of C-section was higher in overweight and obese women, and that the risk of C-section in overweight or obese women was further increased if the woman was also short.

2.1.3.3.Micro nutrient deficiencies

Micronutrients are often considered as "magic bullets'. Magic bullets refer to single interventions, expected to have a dramatic effect, and often in practice circumventing or displacing more locally appropriate and sustainable activities. The term "magic bullets," originally coined by Paul Ehrlich to describe targeted therapies for diseases, has been applied to micronutrients and dietary supplements, which are often touted as solutions for various health issues. While micronutrients like vitamins and minerals are essential for metabolic functions and overall health, their effectiveness as standalone remedies is complex and often overstated. Dietary supplements can help individuals meet nutritional needs but should not replace a balanced diet or be seen as guaranteed cures for conditions like malnutrition or chronic diseases. Ultimately, while they play a valuable role in health management, they should be viewed as part of a holistic approach rather than as panaceas. (Mason and Margetts, 2017).

Micronutrient deficiencies have an impact on health, which leads to low productivity and a vicious cycle of malnutrition, underdevelopment, and poverty. Micronutrients are essential for the healthy growth and development of the human body. Micronutrient deficiencies impact almost 25per cent of the world's population and are considered a public health concern. Over the years, India has implemented numerous projects aimed at enhancing the country's nutritional status and overall health. Nevertheless, a significant proportion of the population continues to suffer from micronutrient deficiencies. Nearly 50–60per cent of preschool-aged children and women suffer from anaemia, the most prevalent type of micronutrient deficiency, but iodine- and vitamin A-deficiency disorders (IDD) have improved over time (Gonmei and Toteja, 2018).

Vitamin B12 deficiency is more common in strict vegetarians. Half to two thirds of the target population (women and children) are still anaemic in many areas around the world.

Periconceptional folate and vitamins are shown to reduce birth defects like neural tube defects and congenital heart disease, especially in those with micronutrient deficiencies (Elizabeth, 2019).

Iron plays an important role in early foetal brain development, and other micronutrients, such as vitamin B6, B12, Folic Acid, and zinc, are influential. Folic Acid, vitamin B12, and zinc participate in brain DNA and RNA synthesis, which begins early in gestation. Vitamin B12 has also been shown to affect myelination, which begins during gestation and may affect cognitive functioning. As women may not realize they are pregnant during the first 1–2 months, optimal nutrition prior to pregnancy is critical (Young and Ramakrishnan, 2020).

Nutritional anaemia caused due to the deficient of essential nutrient in body. Anaemia is mostly gender specific as it mostly affects women. Also it has determinant effect on younger children. It can be cured by eating healthy nutrient rich food. Improvement in the food habit can prevent the occurrence of anaemia. There is an urgent need for government program for spreading awareness among people of rural and urban area and supplementation of iron fortified foods to women (Bhadra and Deb, 2022).

The study by Tijerina-Sáenz *et al.,* (2015) demonstrated a favourable correlation between serum ferritin and body fat percentage in young, healthy, normal-weight and obese women who had comparable food intake and menstrual cycle duration. Study reported that plasma ferritin levels were greater in overweight and obese adolescents compared to their normal-weight counterparts, suggesting a direct relationship between obesity and elevated ferritin levels. This trend was further supported by findings that linked serum ferritin to visceral fat area and subcutaneous fat area, indicating that higher ferritin concentrations may serve as a marker for systemic fat content and insulin resistance.

Calcium is essential for women's health, providing numerous benefits throughout various life stages. It plays a critical role in building and maintaining strong bones, with about 99per cent of the body's calcium stored in bone tissue. Adequate calcium intake helps prevent osteoporosis, particularly important as women age and experience hormonal changes, especially during menopause when bone density declines. Calcium also supports muscle function, nerve transmission, and blood clotting. During pregnancy and lactation, calcium is vital for fetal development and maternal health, with increased requirements to support both the mother and baby. Additionally, sufficient calcium intake has been linked

to lower risks of hypertensive disorders during pregnancy and may contribute to better cardiovascular health. To meet daily calcium needs, women should incorporate a variety of calcium-rich foods into their diets, including dairy products, leafy greens, fortified foods, and certain fish (Cashman, 2022).

An estimated 1.5 million fractures occur yearly due to osteoporosis, with most occurring in the hip, vertebrae, wrist, pelvis, and ribs. The Centers for Disease Control and Prevention reports that 4.2 per cent of men and 18.8 per cent of women ≥ 50 years of age have osteoporosis of the femoral neck or lumbar spine, as defined by BMD measurements. In 2013, approximately 50 million Indians were estimated to have osteopenia or osteoporosis. Prevalence of osteoporosis among Indian women >25 years of age was reported as 8–62 per cent. Projections on incidence of hip fractures in India indicated that by 2050, there would be a 2.39-fold increase in the total number of hip fractures compared with 2018 (Shlisky *et al.,* 2022).

Calcium deficiency in women can arise from several factors, including inadequate dietary intake of calcium-rich foods like dairy products and leafy greens, particularly during critical life stages such as menopause. Hormonal changes, especially the decline in estrogen levels during menopause, accelerate bone loss and increase deficiency risk. Medical conditions like gastrointestinal disorders, kidney disease, and hyperparathyroidism can impair calcium absorption or increase loss. Additionally, vitamin D deficiency hinders calcium absorption, while certain medications, such as corticosteroids and anticonvulsants, can disrupt calcium metabolism. Lifestyle factors like high caffeine or alcohol consumption further negatively affect calcium balance. Addressing these issues through dietary changes, supplementation, and medical management is crucial for preventing calcium deficiency and its associated health risks, including osteoporosis and cardiovascular problems (Beto, 2015).

Folic acid supplementation is crucial for women with folic acid deficiencies, particularly for those who are pregnant or planning to conceive. Folic acid, the synthetic form of vitamin B9, plays a vital role in DNA synthesis, red blood cell production, and the prevention of neural tube defects (NTDs) such as spina bifida during early fetal development. Women are advised to take 400 micrograms (mcg) of folic acid daily, increasing to 600 mcg during pregnancy and 500 mcg while breastfeeding. Despite its importance, many women remain unaware of the recommended dosages and benefits of folic acid, with studies indicating that a significant percentage do not supplement

adequately. Foods rich in folate, such as leafy greens, legumes, and fortified cereals, should be included in the diet alongside supplements to ensure optimal intake. Addressing these deficiencies through proper supplementation can lead to improved maternal and foetal health outcomes (Chitayat *et al.,* 2016).

Folic acid, or vitamin B9, is crucial for women's health, particularly during pregnancy, as it significantly reduces the risk of neural tube defects (NTDs) such as spina bifida. Adequate folic acid intake is essential for proper cell growth and development, especially in the early stages of pregnancy when the neural tube forms. Research indicates that taking a daily supplement of 400 micrograms of folic acid before conception and during the first trimester can prevent up to 70per cent of NTD cases, including spina bifida (Yingngam, 2024).

Folic acid deficiency in women can result from several factors, including inadequate dietary intake of folate-rich foods like leafy greens and fortified cereals. Excessive alcohol consumption can impair absorption and increase excretion of folate. Medical conditions such as gastrointestinal disorders (e.g., celiac disease) and certain cancers may hinder absorption, while some medications, particularly those for seizures or cancer treatments, can disrupt folate metabolism. Genetic mutations affecting folate metabolism also contribute to deficiency risk. Additionally, the increased demand for folic acid during pregnancy heightens the risk of deficiency if intake is not sufficient. Addressing these factors through dietary changes, supplementation, and medical management is essential for preventing deficiencies and associated health risks (Cawley *et al.,* 2016).

Ten per cent of women have folate levels below 7.0 ng/mL according to NFHS 5 and show additional signs of malnutrition. Prior to the delivery of vitamin supplements, it is advised that patients with GI issues, chronic kidney disease, and sepsis undergo routine testing for serum folate levels. Even in patients with BMIs over 25, malnutrition should be assessed if serum folate levels are less than 7.0 ng/mL. Supplementing with folate should only be started after ruling out a concurrent vitamin B12 deficiency (Kozman *et al.,* 2020).

2.2.Methods for assessing the nutritional status

2.2.1. Anthropometry Measurement

Anthropometric measurements are essential for assessing the nutritional status and health of young adult women. Key measurements include height, weight, and body mass index (BMI), which help determine whether an individual is underweight, normal weight,

overweight, or obese. For instance, a height of less than 145 cm is commonly used as a cutoff for short stature in women, while BMI values below 18.5 kg/m² indicate underweight status. Studies have shown that maintaining a healthy weight during young adulthood is crucial for preventing long-term health issues, such as osteoporosis, as being underweight can lead to low bone mineral density. Additionally, anthropometric data can inform public health policies and interventions aimed at improving women's health outcomes (Branco *et al.,* 2018).

Anthropometric measurements are vital in studying malnutrition among women, as they provide objective data on body composition and nutritional status. These measurements, including body mass index (BMI), mid-upper arm circumference (MUAC), and skinfold thickness, help identify under nutrition, obesity, and overall health risks. They are particularly useful because they are inexpensive, non-invasive, and can be conducted in various settings, making them accessible for large-scale assessments. Accurate anthropometric data can reveal trends in nutritional deficiencies and inform public health interventions aimed at improving women's health outcomes. Overall, incorporating anthropometric assessments in malnutrition studies is essential for developing effective strategies to address nutritional issues in women (Phadke *et al.,* 2020).

Several methods are used to examine Body Mass Index (BMI) and assess the nutritional status of individuals, particularly young adult women. The standard calculation involves dividing weight in kilograms by height in meters squared, providing a quick estimate of body fat and categorizing individuals into underweight, normal weight, overweight, or obese classifications. To enhance the assessment, waist circumference and waist-to-hip ratio measurements are often included, as they help identify abdominal obesity, a significant risk factor for various health conditions. Additionally, alternative methods such as skinfold measurements using calipers, hydrostatic weighing (underwater weighing), and bioelectrical impedance analysis (BIA) can provide more accurate assessments of body composition, distinguishing between fat and lean mass. While BMI is a widely used screening tool, it has limitations, such as not accounting for muscle mass or fat distribution, making it beneficial to combine BMI with other assessment methods for a more comprehensive evaluation of an individual's health status (Khanna *et al.,* 2022).

Waist-to-hip ratio (WHR) is an important anthropometric measurement for assessing body fat distribution and potential health risks in young adult women. WHR is calculated by dividing the waist circumference by the hip circumference, providing insight

into fat distribution patterns. A WHR of 0.85 or lower is considered healthy for women, while a ratio above this threshold indicates an increased risk of obesity-related diseases, such as type 2 diabetes and cardiovascular conditions. Measuring waist circumference involves placing a measuring tape around the waist at the level of the iliac crests, while hip circumference is measured at the widest part of the hips. WHR is particularly useful as it highlights the risks associated with abdominal obesity, which is more strongly linked to health complications than overall body weight. While WHR is a simple and cost-effective screening tool, it should be used alongside other measurements, such as body mass index (BMI) and body fat percentage, for a comprehensive assessment of health status in young adult women. Maintaining a healthy WHR through balanced nutrition and regular physical activity is crucial for reducing health risks associated with over nutrition and promoting overall well-being (Kibria *et al.,* 2019).

Waist circumference (WC) is a crucial health metric, particularly for women, as it serves as an indicator of abdominal obesity and associated health risks. Studies have shown that women with a waist circumference greater than 35 inches (88 cm) face significantly increased risks for chronic conditions such as hypertension, type 2 diabetes, and cardiovascular diseases, even if their Body Mass Index (BMI) falls within normal ranges. This relationship underscores the importance of measuring WC alongside BMI, as abdominal fat is a more direct predictor of health risks than overall body weight. Research indicates that high WC is linked to an increased prevalence of metabolic syndrome and other health issues (Darsini *et al.,* 2020).

Hip circumference is often overlooked in health surveys primarily due to the increasing focus on waist circumference as a straightforward measure of obesity-related health risks. While waist circumference is recognized for its association with visceral fat and related health conditions, hip circumference has been shown to independently predict health outcomes, particularly in women. Research indicates that larger hip circumference is inversely related to the risk of cardiovascular diseases and diabetes, suggesting that neglecting this measurement may lead to an incomplete assessment of an individual's health status. Therefore, incorporating both waist and hip circumference measurements into health surveys is essential for a comprehensive understanding of obesity-related risks and better health promotion strategies (Cameron *et al.,* 2015).

According to the current study, between 1975 and 2012, the prevalence of Chronic Energy Deficiency (CED) decreased from 52per cent to 34per cent, whereas the prevalence of

overweight and obesity grew from 7per cent to 24per cent. Kerala had the lowest incidence of CED, while Gujarat, Uttar Pradesh, West Bengal, and Orissa had the highest rates. However, compared to Madhya Pradesh and Orissa, Kerala has a greater prevalence of overweight and obesity. Additionally, even though nutrient intakes have increased over time, it was found that the median intakes of all nutrients—aside from fat, thiamin, niacin, and vitamin C—were below the recommended amounts. Micronutrients below the RDA included calcium, iron, vitamin A, and vitamin C (Meshram *et al.,* 2016).

2.2.2. Biochemical Estimation

Biochemical estimation plays a vital role in women's health by providing critical insights into various physiological and pathological conditions. This process involves measuring specific biochemical markers in blood and urine, which can help diagnose diseases, monitor health status, and evaluate the effectiveness of treatments. Routine biochemical tests, such as measuring serum levels of vitamins, minerals, and proteins like albumin and prealbumin, can reveal underlying issues that may not be apparent through clinical assessment alone. These tests are particularly important for detecting deficiencies in essential nutrients, such as vitamin B12 and folate, which are vital for red blood cell production and overall health. Additionally, biochemical markers can help assess the impact of malnutrition on bodily functions and guide appropriate interventions. For women, biochemical tests can reveal important information about metabolic functions, hormonal levels, and organ health, particularly concerning conditions like diabetes, liver disease, and cardiovascular issues. Accurate interpretation of these tests is crucial for effective clinical decision-making, ensuring that women receive appropriate and timely medical care tailored to their unique health need (Wang *et al.,* 2022).

A blood test to detect folic acid deficiency measures the levels of folate, a vital B vitamin, in the bloodstream. This test is particularly important for women, especially those who are pregnant or planning to become pregnant, as adequate folic acid is crucial for preventing neural tube defects in developing foetus. The test typically requires a blood sample, which is analysed for folate concentration, with normal levels ranging from 2.7 to 17.0 nanograms per milliliter. Low levels may indicate dietary deficiencies, malabsorption issues, or other health conditions, necessitating dietary changes or supplementation to ensure adequate folic acid intake for overall health and proper foetal development (Ilhan, 2022).

During the late teens and early 20s, women reach their peak bone mass. Adequate calcium intake and absorption is crucial during this time to maximize bone density and reduce the risk of osteoporosis later in life. Young women are at higher risk for eating disorders like anorexia nervosa, which can severely restrict calcium intake. Many young women are lactose intolerant, limiting their intake of dairy products which are a major dietary source of calcium. A blood test can detect deficiencies and guide treatment to prevent bone loss and other complications (Matikainen *et al.,* 2021)

In a study conducted by Al Hassan (2015), venous blood samples were taken from successive female students at Taibah University's medical centre in order to evaluate iron deficiency and iron deficiency anaemia; those who were already receiving iron supplements for iron-deficiency anaemia were not included in this sample. A total of 117 students, or 64per cent, were found to be anaemic. In total, 45per cent, 49per cent, and 6per cent of people had mild (10–11 g/dL), moderate (7–10 g/dL), or severe (Hb <7 g/dL) anaemia. Among the anaemic students, 1.6per cent had macrocytic variety and 81per cent displayed microcytic. The findings of this study call for larger-scale, evidence-based surveys to confirm these conclusions and eventually pave the way for the creation of structured educational and dietary initiatives aimed at preserving and enhancing the health of the country. The increased frequency of iron deficiency anaemia in the current study may be linked to the food and lifestyle choices made by female students. It is advised that female students always have breakfast because it is crucial for both their mental and physical health.

2.2.3.Clinical Examination

Signs and symptoms of malnutrition in young adult women can manifest in various physical and psychological ways. Physically, individuals may exhibit noticeable weight loss, a thin or wasted appearance, brittle hair and nails, and pale skin or conjunctiva. Other signs include swollen or bleeding gums, muscle weakness, and edema in the extremities. Symptoms can also encompass fatigue, irritability, and cognitive difficulties, such as poor concentration. Additionally, young women may experience amenorrhea (absence of menstrual periods) or irregular menstrual cycles due to insufficient nutrient intake. These manifestations highlight the importance of monitoring nutritional status to prevent long-term health complications related to malnutrition (Craven *et al.,* 2018).

Micronutrient deficiencies in women can lead to a range of signs and symptoms that significantly impact overall health. Common deficiencies include iron, vitamin D, vitamin

B12, and folate, each presenting unique symptoms. For instance, iron deficiency often results in anemia, characterized by fatigue, weakness, and pale skin. Vitamin D deficiency can lead to bone pain and muscle weakness, while a lack of vitamin B12 may cause neurological symptoms such as numbness, memory issues, and fatigue. Folate deficiency is associated with symptoms like irritability, diarrhoea, and in severe cases, megaloblastic anemia. Recognizing these signs early is crucial for effective intervention and prevention of long-term health complications related to micronutrient deficiencies in women (Ritchie and Roser, 2024).

Increase in morbidity, mortality, hospital length of stay, readmission rates, healthcare cost and reduced quality of life is an indicator of poor nutrition status and is associated with adverse clinical outcomes (Hummell and Cummings, 2022). Therefore, a thorough nutrition assessment needs to include a number of components, such as: assessing the clinical diagnoses and history of the patient; examining the patient physically for signs of malnutrition (such as oedema or specific nutrient deficiencies) and/or clinical indicators of inflammation (such as fever, hypothermia, or tachycardia) (Tang *et al.,* 2020).

Individuals who are deficient in Vitamin B12 may exhibit vague symptoms like lethargy, weariness, stunted growth, and agitation. Rapid cell development in the hematologic and intestinal systems is typically linked to vitamin B12 deficiency. Additionally, there can be neurologic abnormalities. In patients who have had a long-term shortage in vitamin B12, the signs and symptoms may not go away even while the neurologic findings progress slowly (Sayar *et al.,* 2020).

2.2.4.Dietary Survey

Dietary intake is challenging to measure, and there isn't a single instrument that works well in every situation. Instead, each approach has advantages and disadvantages that should be considered when choosing the instrument to be used. Even with the intriguing advancements and the application of cutting-edge technology to nutritional evaluation techniques, some of the same problems persist. Because of this, research teams still advise combining various approaches, with the 24 hr dietary recall being the most exhaustive, complete, and comprehensive tool available at this time (Castell *et al.,* 2015).

Several studies have demonstrated that the food frequency questionnaire is not as accurate in providing dietary intake data for energy, protein, potassium, and salt as short-term dietary assessment tools such the 24hr dietary recall and in some cases, the food record.

The expense of interviewer administration for the 24hr dietary recall and the cost of coding for the food record have been the main obstacles to the use of these short-term approaches in large-scale investigations. Food frequency questionnaires did not always produce as accurate results as 24hr dietary recalls did for the study (Thompson *et al.,* 2015).

The study by Shaikh *et al.,* (2017) reveals the alarming need to change for lifestyle and eating patterns. With the exception of fruit juices (12 per cent) and snacks (11 per cent), the analysis revealed good concordance (50–65 per cent) for the food groups dairy, tea and coffee, red meat, sugar, soda and energy drinks, unhealthy global foods, eggs, fried snacks, grains, fried traditional foods, breads, processed foods, fruit juices, vegetables, snacks, and sweets and desserts; and fair concordance (30–49 per cent) for the food groups fruits and pulses and nuts,

In terms of vegetable consumption, adults from Bhutan reported consuming 3.8 servings per day, the highest value being recorded by Indians, who consumed 0.9 servings per day. The World Health Organisation recommends consuming twice as much fruit and vegetables as the inhabitants of practically all South Asian countries. Therefore, it is imperative that prompt measures be taken to increase the consumption of fruits and vegetables throughout the area (Jayawardena *et al.,* 2020).

2.3. Effect of Nutrition Interventions-Nutrition Education and Dietary Supplementation on nutritional knowledge and nutritional status of Triple Burden of Malnutrition

Nutrition education empowers individuals to make informed food choices that enhance their physical and mental health. By understanding the nutritional content of foods, people can select options that prevent chronic diseases such as obesity, diabetes, and heart disease. In many developing regions, a lack of knowledge about nutrition contributes to malnutrition. Education programs can help raise awareness about dietary needs and the importance of balanced diets, which is essential for improving public health outcomes (Kumar *et al.,* 2024).

Effective interventions to prevent malnutrition in women include a combination of nutritional support, education, and healthcare improvements. Key strategies involve providing multiple micronutrient rich food supplementation during pregnancy, which has been shown to enhance maternal and infant health outcomes by reducing the risks of low birth weight and maternal mortality. Community-based food programs that offer ready-to-

use therapeutic foods can address acute malnutrition in vulnerable populations. Furthermore, integrating nutrition education into health services empowers women to make informed dietary choices, while addressing underlying health issues through improved healthcare access is essential for long-term prevention of malnutrition. These interventions, as outlined in various studies and reports, highlight the importance of a comprehensive approach to tackle malnutrition effectively in women, particularly in low- and middle-income countries (Shenoy *et al.,* 2023).

Nutrition education helps young women understand the specific dietary requirements that align with their health goals. Studies have shown that tailored interventions can lead to increased nutritional knowledge, which is crucial for making informed food choices. For example, nutrition education sessions have demonstrated significant improvements in knowledge among young female athletes, leading to better dietary habits and energy availability (Tektunalı Akman *et al.,* 2024).

Nutrition education uses information on individual characteristics to develop targeted nutritional advice, products, or services to assist people to achieve a lasting dietary change in behaviour that is beneficial for health. A tailored nutritional approach is always beneficial in addressing the nutritional need of any individual. This personalisation may be based on biological evidence of differential responses to foods/nutrients dependent on genotypic or phenotypic characteristics, and/or based on current behaviour, preferences, barriers and objectives. Tailored nutrition is equally applicable to patients and to healthy people who may or may not have enhanced genetic susceptibilities to specific diseases. Personalised nutrition approach can be applied in two broad areas: firstly, for the dietary management of people with specific diseases or who need special nutritional support—for example, in pregnancy or old age, and, secondly, for the development of more effective interventions for improving public health. It has traditionally focused on maximising the benefits and reducing the adverse effects of dietary changes for the individual (Ordovas *et al.,* 2018).

A study by Wendt *et al.,* (2015) stated that overall, 37 per cent of women received any Iron and Folic acid (IFA) during their last pregnancy. Of those, 24 per cent consumed IFA for 90 or more days. The results of this analysis demonstrate that individual is significantly associated with IFA receipt and consumption in this context. Interventions which go beyond the individual and household level to target facility and community level

factors will be critical in addressing issues of both IFA adequate consumption. Proper nutrition education is crucial for proper food consumption and supplementation in women.

A study by Daphnee *et al.,* (2018) stated that when compared to the standard prescription, an individualized protocol to diagnose, stratify the severity of malnutrition early, and follow up by customized nutrition planning help individuals to achieve nutritional targets more effectively. In spite of individuals' diversity in nutritional habits and reluctance to accept change, it is clear that a qualified and dedicated transplant nutrition team can successfully implement perioperative nutrition protocol to achieve better nutritional targets and clinical outcomes.

A study carried out in a peri urban village of Chandigarh showed most women had poor knowledge about anaemia despite of the fact that all women had been beneficiaries of anaemia prophylaxis programme. Those women who were exposed to nutritional education were much better at identifying causes and preventive measures of anaemia. It has been shown in the study that despite having knowledge, women do not pay particular attention to their diet and hardly change their eating habits. A study carried out in India to see the effect of education on knowledge, attitude and practice of women showed that 93 per cent of the educated women were in favour of including iron rich foods in their diet as compared to 67 per cent in the group with no education. Education has a pivotal role in reducing micronutrient deficiencies and research has shown that maternal education can increase iron intake and ultimately rectify iron deficiency. In developing countries under nutrition can be attributed to various socio-economic reasons and poor awareness of basic nutritional requirements. A study carried to estimate the burden of anaemia in Jat women revealed that daily intake of fruits, vegetables, milk and milk products was below the recommended level in both the rural as well as urban women. The main reasons for discontinuing the supplements. A statistical report of WHO has shown the despite iron supplementation, anaemia has remained a significant nutritional problem among women in developing world and one of the reasons include gastro intestinal side effects (Ali *et al.,* 2020) .

Adequate iron intake is crucial for women's health. However, adequate nutrition may not be possible in many developing countries. Iron supplementation should be considered early in these cases. There is an increasing need for public health strategies to educate the population as to the need for a healthy diet and iron supplementation before conception, or at least at the beginning of the pregnancy. Integrating this information into educational curricula, pre-marital counselling, and prenatal care is needed. Mothers should

receive appropriate nutritional advice and supplementation at their first point of contact with healthcare professionals (Abu-Ouf and Jan, 2015).

A study was conducted in folic acid supplementation in pregnant women.82 per cent had knowledge of FA supplementation and 89per cent received Folic acid (FA) supplementation. 51 per cent followed national recommendations. We found a statistically significant correlation between higher educational level and knowledge about FA supplementation, actual supplementation of FA and FA supplementation in accordance with national recommendations. Family, friends, general practitioner and the internet were the main information sources. It is recommend that interventions comprise information channels already commonly used by pregnant women, especially family, friends, general practitioners and the internet. Nutritional awareness is the key for a healthy life (Zheng *et al.,* 2020).

A study by Bower *et al.,* (2017) stated that with nutrition education, 62.3 per cent of women were aware of the correct message of the association between folate and spina bifida before they became pregnant, 11.1 per cent became aware during pregnancy and 26.7 per cent were unaware of the association before or during pregnancy. 28.5 per cent reported taking 200µg or more of folic acid in supplements periconceptionally, and 56.6 per cent were estimated to be consuming over 100µg folic acid daily from fortified foods in the 6 months prior to pregnancy. We found that better educated women and women who engaged in other health-promoting behaviours (not smoking, taking exercise, planning pregnancy) were more likely to know about the preventive effect of folate and to have taken periconceptional folic acid supplementation.

The increasing pool of evidence supporting the health-promoting effects of folic acid suggests the possibility of its future role in the prevention and the treatment of diseases. Folic acid is used as a supplement in most cases but is increasingly being used as medication especially in tri¬als as an anti-cancer medication. Although the effect of folic acid supplementation during the pre-conception pe¬riod to reduce the incidence of neural tube defects (NTDs) is well established, its effect on other diseases yielded many contradictory results. Therefore, research into its effect on these diseases warrant further investigations (Liew, 2016).

Promoting dietary intake of certain food items (grams or pulses, grains, and greens), and cooking in iron pots, have had limited effect, mostly because of reduced bioavailability.

Haem iron (found in meat, fish, and poultry) is superior to non-haem iron (found in vegetables). In countries like India iron folic acid (IFA) supplementation programs have begun addressing adolescents, pregnant and lactating mothers, infants, and children in recent years. Poor motivation and compliance, however, mean that the program has yet to show any success in India. The latest survey reports show a significant burden of malnutrition and multiple deficiencies (Gawande *et al.,* 2021).

Women of childbearing age should supplement with folic acid as early as possible, ensuring coverage of the critical window for foetal heart development to prevent coronary heart disease (CHDs). Additional studies, especially clinical trials, will be necessary to evaluate the appropriate folic acid supplementation in any form (eg. food or supplements) to prevent CHDs and to determine the role of pre-conceptional Folic Acid containing multivitamin use on CHDs (Qu *et al.,* 2020).

In countries choosing mandatory fortification with folic acid, careful assessment of beneficial as well as potential negative health effects is of prime importance. In countries deciding against mandatory fortification, promotion and funding of research on additional effective means to improve folic acid supplementation in the form of food use is essential. At present, there exist only a few new strategies, which are not yet part of comprehensive folic acid campaigns worldwide. Thus, not only careful monitoring and research in relation to safety issues of folic acid fortification is required. Equal emphasis should be laid on the research and assessment of new creative public health strategies to improve folic acid supplementation in the prevention of neural tube defects (Obeid *et al.,* 2016).

Iron-rich foods including red meat, pig, chicken, and seafood, as well as beans, dark green leafy vegetables, dried fruits, and peas, can help prevent anaemia. Vitamin C-rich foods, such as broccoli, tomatoes, oranges, and lemons, improve the absorption of iron. Eating a nutritious diet rich in nutrients can help treat it. Anaemia can be avoided by changing one's eating habits. Government awareness campaigns in rural and urban areas are desperately needed, as is the provision of iron-fortified diets to women (Bhadra and Deb, 2020).

In a study by Panchal *et al.,* (2022), a total of 77 women (mean age 24 years) were divided into four groups for a 12-week intervention study. The groups included blood-based crisp bread (35 mg iron, 27 mg of which was haem Fe, iron supplementation (35 mg of non-haem iron/day) [Fe35], iron supplementation (60 mg of non-haem iron/day) [Fe60], and

controls (iron-free tablets). While no change was seen in the control group, body iron levels rose significantly in the crisp bread group by a median of 2.7 mg/kg, the Fe35 group by 2.7 mg/kg and the Fe60 group by 4.1 mg/kg. In comparison to the two iron-supplemented groups, there was no statistically significant difference in the rise in iron status between the crisp bread groups. The iron status of women who are of reproductive age can be effectively improved using dietary-based treatment that contains haem iron and has minimal negative effects.

Anaemia Mukt Bharat 6 X 6 X 6 Strategy was designed at the NITI Aayog, which is the prime public policy think tank of the Government of India. It aims to reduce the prevalence of IDA by 3per cent per year for the age group of 15–49 years individuals. The 6 X 6 X 6 strategy to combat IDA uses six beneficiaries, six interventions, and six institutional mechanisms. In adults, IDA impairs memory capacity, attention span, and cognitive development, resulting in up to 30per cent of impairment in physical work performance. Maternal death is three times higher in women with IDA than without this condition. In developing countries, the rapid growth of the population without adequate socioeconomic protection leads to disparities in nutrition. Consequently, more than half of women 15–49-yearold (53 per cent) are anaemic (Kumar *et al.,* 2022).

Diversification of diet is the first-rank approach for the prevention of iron deficiency as it can be easily implemented and accepted. Dietary diversification involves creating balance recipes to meet the iron requirements. Notwithstanding, consumption of diversified or balanced foods is limited by the economic, social, and cultural environments. For example, intake of more haem iron from animal foods could significantly reduce the risk of anaemia. At the same time, consuming excess animal food could trigger hypertension, type 2 diabetes, chronic diseases, and gastrointestinal cancers. Therefore, special attention needs to be paid to iron supplementation. Care must be taken while incorporating these iron-rich ingredients in food products to avoid side effects, such as weakening the bone metabolism and probability of infection that can be resulted due to excess iron intake. Oral administration of iron supplement is a cost-effective intervention to reduce iron deficiency (Chen *et al.,* 2019).

The current study is an effort to find the relationship between dietary interventions over consumption of supplements of iron. The study was to assess the improvement in the performance of females after dietary modification. There seems to be evidence that dietary

iron interventions may assist in maintaining iron status in females, especially during intensive physical activity and competition regimens (Alaunyte *et al.,* 2015).

2.4.Nutritional significance and health benefits of the formulated Dietary Supplements

2.4.1.Sprouts Tikki

Chickpeas are an easy means to help consumers meet the recommended RDA of legumes per week. Chickpea per day provides approximately 2 cups of legumes per week and ~25 grams of dietary fiber—a shortfall nutrient in the diets of many adults and children. Consuming Chickpeas may help prevent or offset the development and progression of several chronic diseases (CVD, type-2 diabetes, etc.) and promote healthier functional outcomes (e.g., weight management). Consuming Chickpeas in moderation may have additional benefits beyond improving nutrient profiles of meals (e.g., delaying gastric emptying and slowing carbohydrate absorption) (Wallace *et al.,* 2016).

The present study suggest that soaking at room temperature for 22 hours followed by steaming for 1 hour is the best method for retaining polyphenolic contents of Chickpea. Sprouted Chickpeas with increased phenolic content have shown inhibitory potential against key enzymes, namely, α-glucosidase and α-amylase associated with type 2 diabetes, suggesting that novel health-promoting factors may be generated during seed metabolism. Considering these anti-diabetic effects, Chickpeas may be considered as a chief and risk-free source of energy for diabetic individuals. High dietary fiber intake has several attributes such as longer eating times because of the lower energy density of high-fiber foods, delayed gastric emptying, which consequently sends earlier signs of fullness, earlier satiety due to the feeling of gastric and intestinal bulking, reduced absorption of nutrients, and effects of short-chain fatty acids on hunger and satiety. As outcomes, the legume-based diet was the only dietary approach inducing a significant reduction in body weight, systolic blood pressure measurements, total cholesterol, low-density lipoprotein (LDL), and high-density lipoprotein (HDL) concentrations. Addition of 10per cent (w/w) Chickpeas to the high-fat diet reduced the weight gain from 6 months to the end of the experiment. In addition, Chickpea treatment resulted in a 45per cent decrease in the serum TAG, a 23per cent decrease in LDL, a 35 per cent rise in HDL, and a 30per cent reduction in LDL/HDL compared to the high fat diet fed group. Therefore, a Chickpea-based diet may be considered as a healthy food for the management of obesity (Gupta *et al.,* 2017).

Sprouting was found as an effective method in retaining folate than the thermal processing method in almost all the pulses and legumes. Vitamin C content of Chickpea increased from 0mg/100g in raw beans to 20-30 mg/100 g after germination (Hall *et al.,* 2017).

Bioavailability of Chickpea protein in the human body is higher as compared to other pulses. Chickpea protein hydrolysates have antioxidant and Angiotensin-Converting Enzyme-I (ACE-I) inhibitory properties. α- Galacto oligosaccharides present in Chickpea act as prebiotic because they are indigestible and are fermented by the colonic bacteria resulting in the formation of short-chain fatty acids (SCFAs) that are reported to have potential health benefits. Although Chickpea contains only 2.70–6.50per cent fat, it is an important source of unsaturated fatty acids, mainly linoleic and oleic acid. Isoflavones and carotenoids are the major bioactive compounds present in Chickpea. Chickpea has potential health benefits such as prevention of cardiovascular disease, hypo-cholesterolemic, anti-diabetic, anti-cancerous, and anti-inflammatory activity. Processing of Chickpea before consumption results in the elimination of anti-nutritional factors. Germination, roasting, and extrusion results in an increase in in-vitro starch and protein digestibility (Kaur and Prasad, 2021).

Microwave cooking has also been studied to enhance nutritional quality, reduce the concentration of anti-nutritional factors, increase protein digestibility, and reduce cooking times. In comparison to boiling and autoclaving, microwave exhibits a smaller loss in minerals for pulse transformation processes. Microwave treatment reduces cooking time and increases the lipid/protein ratio of the Chickpea product (Divekar *et al.,* 2017).

The contents of daidzein and genistein in Chickpeas are comparable to the concentrations reported in soybeans, which suggests that this legume seed may potentially substitute soybeans as a source of isoflavone aglycones. In contrast, due to their lower lipid content, Chickpea seems to offer a better option in weight management and prevention of type 2 diabetes (de Camergo *et al.,* 2019).

Chickpea is a more and more appreciated and more widely analysed plant. The chemical composition of Chickpea flour is different significantly from the composition of wheat flour. Chickpea flour has increased health properties, with little impact on the texture of food products manufactured from it. A small addition of this flour can significantly lower the content of carbohydrates and fat and increases the amount of protein, fiber, and mineral

substances in food products. Chickpea and its protein may limit the formation of acrylamide in cookies and other foodstuff —based on flour wheat. Adding of Chickpeas to food can be used after removal of anti-nutritional compounds using heat treatments that improve the nutritional value of Chickpeas (Rachwa-Rosiak *et al.,* 2015).

2.4.2.Nutriball

According to the Indian Food Composition Tables (IFCT), bajra (pearl millet) contains approximately 6.42 mg of iron per 100 grams. This makes it a significant source of iron, which is especially beneficial for women who are at a higher risk of iron deficiency anaemia due to menstrual blood loss and increased nutritional demands during pregnancy. Bajra's high iron content, combined with its other nutrients, such as fiber and essential amino acids, makes it an excellent food choice for improving overall nutritional status and addressing micronutrient deficiencies in women (Vijayakumar et.al, 2024).

Bajra, also known as pearl millet, is a nutritious grain that offers various health benefits. It is rich in fiber, which aids in digestion and helps maintain a healthy weight. Bajra is also a good source of essential nutrients, including protein, iron, magnesium, and B vitamins, making it beneficial for overall health. In addition to its nutritional profile, bajra is gluten-free, making it an excellent choice for individuals with gluten intolerance or celiac disease. It has a low glycemic index, which helps regulate blood sugar levels, making it suitable for diabetics. Bajra can be consumed in various forms, such as flour for making rotis, porridge, or snacks like puffed bajra balls, which are popular for their crunchy texture and nutty flavor. These snacks provide a convenient way to incorporate bajra into the diet, offering a healthy alternative to processed snacks. Bajra can be consumed in various forms, such as flour for making rotis, porridge, or snacks like puffed bajra balls (Gore *et al.,* 2020).

According to the Indian Food Composition Tables (IFCT), horsegram contains 6.8 mg of iron per 100g. It is considered one of the richest plant sources of iron, along with other pulses like green gram, black gram, and chickpeas. The iron in horsegram is in the non-haem form, which is not absorbed as easily as haem iron from animal sources. However, consuming horsegram with foods rich in vitamin C can enhance iron absorption (Agnihotri, and Rana, 2021).

Jaggery is recognized as a significant source of iron, making it beneficial for improving haemoglobin levels and combating iron deficiency anaemia. Regular consumption of jaggery can help prevent iron deficiency anaemia, which is characterized

by fatigue, weakness, and pale skin due to insufficient haemoglobin levels. The iron content in jaggery contributes to better oxygen delivery to tissues, which can enhance energy levels (Rao and Singh, 2022).

2.4.3.Ragi Brownie

According to the Indian Food Composition Tables (IFCT), ragi (finger millet) contains approximately 344 mg of calcium per 100 grams. This positions ragi as one of the highest calcium-rich cereals available, making it a significant dietary source of this essential mineral, especially for those who may not consume dairy products (Patel *et al.,* 2016).

Calcium is an essential mineral that plays a vital role in numerous bodily functions, particularly in maintaining bone and dental health. It is crucial for the development, strength, and maintenance of bones and teeth, helping to prevent conditions like osteoporosis and rickets. Beyond skeletal health, calcium is involved in regulating muscle contractions, including the heartbeat, and is necessary for normal blood clotting and nerve transmission. Adequate calcium intake is also linked to cardiovascular health, as it helps maintain proper heart function and may assist in lowering blood pressure. Additionally, calcium can play a role in reducing the risk of preeclampsia during pregnancy and may improve cholesterol levels. To ensure optimal calcium absorption, it is important to pair calcium intake with adequate vitamin D levels. A deficiency in calcium can lead to various health issues, highlighting the importance of obtaining sufficient amounts through diet or supplements when necessary (Reid *et al.,* 2015).

Finger millet (Ragi) contains roughly 5-8 per cent protein, 65-75 per cent carbohydrates, 15-20 per cent dietary fibre, and 2.5–3.5 per cent minerals. It is typically used as a whole meal in traditional food preparations like roti, muddle, and ambali (thin porridge). Regular consumption of whole grain cereals and their products has been linked to a lower risk of diabetes mellitus, gastrointestinal disorders, and cardiovascular diseases. Because millets are whole grains, important nutrients like dietary fibre, minerals, phenolics, and vitamins are concentrated in the outer layer of the grain or the seed coat (Dayakar Rao *et al.,* 2017).

Ragi provides approximately 7 grams of protein per 100 grams, making it a valuable protein source, especially for vegetarians and vegans. The high calcium content supports strong bones and teeth, reducing the risk of bone-related disease. Ragi has a low glycemic index, which helps in stabilizing blood sugar levels and may reduce the risk of diabetes.

Ragi acts as a natural relaxant, helping to alleviate anxiety and improve sleep quality (Jagati *et al.,* 2021).

The study's findings by Jamale *et al.,* (2022) suggest that making nutri cookies with ragi in place of refined wheat flour and whole wheat flour in a ratio of 40:30:30 was a more palatable option. We may conclude that by successfully incorporating 30per cent of each of ragi and whole wheat flour into refined wheat flour, cookies with acceptable sensory qualities can be produced. Since ragi and whole wheat flour are excellent sources of calcium and iron, using them enhanced the cookies' calcium and iron content considerably. Therefore, including ragi in cookies will enhance the consumer's nutritional status.

In India and other countries, finger millet (Ragi) is regarded as a vital, fundamental source of healthful food supplements. After examining the functional and nutritional properties, it was discovered that finger millet has higher mineral, antioxidant, and fatty acid content than other cereals. These elements are critical to a diet rich in nutrients and necessary for sustaining good health. As a nutritional supplement, it may benefit those living in rural areas who are malnourished due to an energy-protein shortage. Finger millet comes in a variety of processed, value-added forms with improved activity, no gluten, and a balanced protein level. Finger millet comes in a variety of processed, value-added forms with improved activity, no gluten, and a balanced protein level. Given the unique way that finger millet is consumed, it calls for a particular design and marketing strategy to encourage the use of finger millet as a vital dietary supplement in our daily lives (Jagati *et al.,* 2021).