CHAPTER- I:

INTRODUCTION

1.1. OVERVIEW

Worldwide observations have established the fact that inadequate diet and poor nutritional condition can hamper overall growth of a child and severe irreversible physical and cognitive damage can occur during childhood (Akhter 2016; de Onis and Branca 2016). Child undernutrition has long-term negative influence on all areas of life including health, education and productivity of an individual as well as of a community. Moreover, prevalence of child undernutrition seriously affect the human capital and economy of a country because poor nutritional conditions are strongly associated with faltered growth pattern, delayed mental/cognitive development and depleted intellectual capacity of individuals (Zere and McIntyre 2003; Shrimpton et al. 2011; Dessie et al.2019). Those children who suffer from undernutrition (e.g., stunting) in children may also suffer from overweight-obesity, insulin resistance and chronic non-communicable diseases during adulthood due to over-accumulation of adipose tissue in the body (Judith 2011). Childhood undernutrition has been observed to be interlinked with maternal nutritional status as suggested by several research studies. Malnutrition is associated with both undernutrition and overnutrition causes great amount of human suffering (both physical and emotional) which is also a violation of the child's human rights (Smith and Haddad 2000). Maternal nutrition and health conditions significantly influence the nutritional status and health of children as observed in several research studies. Maternal malnutrition is a prevalent factor for morbidity and mortality in children of the developing countries. Several studies also have observed the prevalence of undernutrition as well as overweight and obesity simultaneously among women/mothers in one population. The contributing factors for maternal malnutrition include inadequate food intake, poor nutrient supply through diets, frequent infections, short inter pregnancy intervals, number of child birth, occupation and husbands occupation etc. The results of poor maternal nutritional status are low weight gain during pregnancy, low birth weight (LBW) of baby and

high infant mortality as well as maternal morbidity and mortality (WHO 1995; Ramachandran 2014).

The quality of nutrient consumption and the body's ability to utilize them for its metabolic needs are important factors in an individual's nutritional status. In developing countries like India high prevalence of undernutrition is considered as a major public health problem (Nandy et al. 2005; Ramachandran 2007, 2014; Mondal and Sen 2010a,b; Khambalia et al. 2012; Islam et al. 2014; Bhargava et al. 2015; Corsi et al. 2015; Tigga et al. 2015a,b; Akhter 2016; Debnath and Bhattacharjee 2016;Madrid and Traisci-Marandola 2016; Asim and Nawaz 2018; Debnath et al. 2018a,b,c,d; Huda et al. 2018; Sharma and Mondal 2018, 2020). Child undernutrition plays a major role in physical growth attainment, premature mortality and morbidity of millions of children in the developing countries like India (Nandy et al. 2005; Ahmed et al. 2012; Madrid and Traisci-Marandola 2016; Asim and Nawaz 2018; Debnath et al. 2018a,b,c,d; Huda et al. 2018; Sharma and Mondal 2018, 2020; Sen et al. 2020). Undernourished children who survive to adulthood suffer from poor cognitive growth and adverse health related diseases (Black et al. 2008). Even if it does not cause death, it accounts for several vulnerable infections, diseases and blighting the quality of lives millions of children (Nandy and Miranda 2008; Black et al. 2013; Ramachandran 2014; Smith and Haddad 2015). Prevalence of undernutrition is estimated to be the largest contributor to global burden of disease, effecting millions of children (i.e., morbidity) in the developing countries and causing heavy health expenditures in developing countries (Black et al. 2003; Lenoir-Wijnkoop et al. 2013; Sen et al. 2020). Gender discriminations and gender related nutritional trends are also observed in South Asia where girls are more likely to be undernourished than boys (UNICEF 2007, 2013). The prevalence of undernutrition was estimated to be the cause of 45.0 % of all deaths among children <5 years (Black et al. 2013). India contributes 38.0 % of the global burden of stunting (low height-for-age) (nearly 62 million children) (UNICEF

2013). In India with the large population size, widespread poverty and significant economic and social disparities, majority of individuals are underprivileged and undernourished (Ramachandran 2007; Antony and Laxmaiah 2008; Varadharajan et al. 2013; Debnath et al. 2019). Maternal and child undernutrition account for almost 11% of the total global burden of disease (Black et al. 2008). Maternal nutritional status has significant impact on the children as the WHO estimated in 1998 that between half and two-thirds of deaths among children less than five years of age in developing countries can be attributed to undernutrition (Son and Menchavez 2008). India is the largest country in the region is also home to the largest number of undernourished children in the world (Khor 2008; Ramachandran 2014; Corsi et al. 2015; Smith and Haddad 2015; Aguayo et al. 2016; Ali et al. 2016; Dhok and Thakre 2016; Saxton et al. 2016; Mandal et al. 2017; Patil et al. 2017; Debnath et al. 2018a,b,c,d; Sharma and Mondal 2018).

Health status of individuals and populations are determined by assessing nutritional status and body composition of people (Peter et al. 2015; Shidfar et al. 2016; Alamgir et al. 2018). Determination of nutritional status and body composition of individuals/populations has immense application in human biology, biological anthropology, public health and primary health care (Park 2009; BDA 2012). Body composition studies are particularly important to understand the amount of fat content (i.e., fat mass) and non-fat (i.e., fat-free mass) content in human body. Such data is useful in assessing the nutritional deficiencies and excesses of body adiposity. Useful insight on health risks like, on heart disease, diabetes, cancer and minimal energy stores, poor cardiovascular function, starvation, prone to illness, low hormonal levels, weak muscles, osteoporosis and other related morbidity can be obtained from such investigations (Howley and Franks 2007; Zhao et al. 2008; Speakman and Westerterp 2013; Kalyani et al. 2014; Falsarella et al. 2015; Preto et al. 2017; Boseet al. 2019).

Studies have observed some socio-economic and demographic factors play significant roles in the nutritional status. Such variables include family size, number of siblings, residence, family income, education, clean water supply, hygienic sanitary facility, age, sex, birth intervals and mother's age at childbirth (Zere and McIntyre 2003; Hien and Kam 2008; Mondal and Sen 2010a; Mondal et al. 2015; Tigga et al. 2015a,b; Debnath et al. 2018c; Sen et al. 2020).

Anthropometry is the universally applicable, inexpensive, non-invasive and easy to handle technique available to researchers for the assessment of nutritional status and body composition of the human body (WHO 1995; Gibson 2005; Lee and Neiman 2005; Hall et al. 2007). The body mass index (BMI=weight/height, kg/m^2) is a derived proxy anthropometric index to assess the under- or overnutrition in children and adults (WHO 1995, 2007; Wells 2007). The most commonly utilised anthropometric measures of nutritional assessment are height-for-age (stunting), weight-for-height (wasting), weight-for-age (underweight) and BMI-for-age (thinness)among children (WHO 1995; 2007; Hall et al. 2007). The interpretation of these nutritional indices is based on Z-score classification and children found to be below −2 Z-score of any nutritional indices is considered to be undernourished (WHO 1995, 2007). These anthropometric measures reflects distinct biological processes but poses major methodological limitation in assessment of actual magnitude of undernutrition in population level (Svedberg 2000; Nandy et al. 2005; Nandy and Svedberg 2012; Sen and Mondal 2013; Savanur and Ghugre 2015).The coexistence of maternal overnutrition (overweight and obesity) is an emerging phenomenon present mostly in developing countries which are undergoing the epidemiological and nutritional transition (Popkin et al. 1996; Garret and Ruel 2003; Barquera et al. 2007).

Several researchers have studied nutritional transitions in different countries and have observed unique features in terms of prevalence of undernutrition and overnutrition across

populations (Adair and Popkin 2005; Popkin 2006). Recent trends showed that populations tend to shift from undernutrition to overnutrition due to the change in dietary and demographic patterns associated with socio-economic status change (Popkin 1998, 2001; Doak et al. 2000; Barquera et al. 2007). Epidemiological studies have observed that body mass index (BMI) is an adequate surrogate anthropometric measure of adiposity (Horlick 2001; Weber et al. 2012; Little et al. 2016; Verma et al. 2016; Debnath et al. 2019).

Assessments of child and maternal nutritional status are important because they contribute to the negative health consequences in human populations. Adult obesity and child stunting are critical health conditions as they contribute to the burden of non-communicable diseases such as cardiovascular disease, type-2 diabetes, osteoarthritis and certain types of cancer among adults (Lee et al. 2008, 2010; Debnath et al. 2019) with stunting contributing to the poor cognitive development, poor attainment of linear growth and poor overall growth among children (Berkman et al. 2002; Sawaya et al. 2003). The dual burden households of undernutrition and overnutrition demand particular attention. Some recent studies indicate that undernutrition and overnutrition can co-exist not only in the same population, but in the same household (Doak et al. 2000a,b, 2002; Garrett and Ruel 2005).

The coexistence of undernutrition and overweight-obesity among the members of a same household raises questions about its cause. According to some researches one of the possibilities is that the economic development and urbanization declines the severe poverty improving household income levels and food availability. In one hand some household members remain undernourished due to the deficiencies of essential nutrients and on the other handsome of them become overweight from excess energy and nutrient intake. A somewhat different possibility as proposed by researchers is that at higher levels of economic development the physical energy is sufficient for both adults and children, but low intake of micronutrients leads to undernourishment in children and overweight-obesity among adults.

1.2. NUTRITION SITUATION IN INDIA

Inspite of the high economic growth of India is unable to ensure food security of the entire population. According to Ramachandran (2014), food security of people depends on three major factors:

1. Food Availability— in a sustainable manner throughout the year.
2. Food Accessibility— the economic ability or purchasing power.
3. Food Absorption— the ability to absorb micronutrients which are essential for superior nutrition which depends on the availability of other supportive measures like supply of clean drinking water, access to sanitation facilities, hygienic environment.

There are existing endemic pockets of hunger, mainly in the tribal areas, less developed rural areas and among the unemployed and homeless migrants living in large cities (Ramachandran, 2014). The most poverty affected areas in India are rural Odisha, West Bengal, Kerala, Assam and Bihar and it usually peaks in late summer or the monsoons when household food grain supplies are exhausted and both on-farm and off farm employment is unavailable (Ramachandran 2004). According to the National Census data of 2011, as many as 8.6 million people are facing chronic hunger (Census 2011). In rural and underdeveloped regions of the country, men, women and children continue to exhibit unacceptably high rates of undernutrition (Ramachandran 2014). Among children this undernutrition is observed in terms of underweight, stunting, wasting and thinness. Malnutrition among mothers are also prevalent in the country and has been assessed by several research studies (Radhakrishna and Ravi 2004; Abdullah 2015).

Although economic growth in India has been taking place for a long time but the improvement of nutrition situation is not directly proportional to economic growth and a large proportion of children and adolescents in India is remaining undernourished which gives rise to undernourished adults. The United Nations Children's Fund (UNICEF) has estimated that

one in every three malnourished children observed globally lives in India and 47% of children under age three are underweight, 46% are stunted and 16% are wasted in the country (UNICEF 2013). Even though India is becoming the world's third largest economy (Dre`ze and Sen 2013), but its child and infant mortality rates rank among the worst 50 nations (Lozano et al. 2011). The country has one of the highest rates of child malnutrition in the world which is almost double of sub-Saharan Africa and five times that of China. Nearly annually 50.0% of the 2.5 million child deaths occur in India and this can be attributed directly or indirectly to malnutrition (Klasen 2008). While a major portion of Indian children is suffering from undernutrition, there is an increasing trend in the prevalence of overweight and obesity among them (Gupta et al. 2012). In the lower income groups underweight remains a major concern, overweight and obesity rates among children are increasing mainly among the higher socio-economic groups (Ranjani et al. 2016). It has been observed that the issue of malnutrition in the country appears to be a concentrated phenomenon and a relatively small number of states, districts and villages account for a large share of the malnutrition burden. Only five states and 50.0% of villages account for about 80% of the malnutrition burden (Gragnolati et al. 2006).

1.3. METHODS OF ASSESSING NUTRITIONAL STATUS OF HUMANS

1.3.1. Anthropometry

Anthropometry has been widely and successfully applied to the assessment of health and nutritional risk. It is a useful technique to assess nutritional status and body composition of an individual or population (WHO 1995, 2007; Hamieda and Billot 2002;Lee and Neiman 2005; Hall et al. 2007). The most commonly utilized measurements are as follows:

a) Height/length

b) Weight

c) Mid-upper arm circumference (MUAC)

d) Head circumference

f) Waist circumference

g) Hip circumference

h) Skin fold thicknesses

As the present study is based on anthropometric measurements, this section is discussed in details subsequently.

1.3.2. Biochemical Methods

The underlying principle of this method is that any changes in the quantity and composition of the diet is reflected by variations in the concentrations of nutrients or their associated compounds in different body tissues and fluids along with the appearance or disappearance of metabolites. Haemoglobin estimation is the most important test to interpret the overall state of nutrition. This indicates prevalence of anaemia and deficiencies in proteins and trace elements. Stool examination is utilized to test for the presence of ova and/or intestinal parasites. Urine examination can be used for albumin and sugar tests. Vitamins promote other metabolic reactions in the body that produce energy (Campbell 2017; Saltveit 2019). This in turn leads to better maintenance of cells and tissues, along with promoting growth and development. Hence, a determination of the levels of these vitamins of different body tissues (biomarkers) can help to ascertain deficiencies. The important vitamins needed by the body are vitamins A, B, C, D, E, and K.

Vitamin A deficiency is indicated by plasma ß-carotene levels and fasting plasma amino acid pattern, which in turn indicate a deficiency of plasma retinol. Deficiency in vitamin B1 (thiamine) is determined by thiamine levels in urine. The long term result is an impaired red cell transketolase enzyme function. The biomarker for riboflavin or vitamin B2 deficiency is urinary riboflavin and the function of the enzyme red cell gluthione reductase is impaired. The biomarker for the determination of vitamin B6 deficiency is urinary 4-pyridoxic acid, indicating plasma pyridoxal 5' phosphate dysfunction. Deficiency in vitamin B12 is indicated

in plasma holotranscobalamin II levels which in turn show a deficiency in the function of the enzymes plasma vitamin B12 and plasma methyl malonate. Analysis of plasma and urinary ascorbate levels is associated with a deficiency in vitamin C. There is a cell depletion of leucocyte ascorbate in the long term. Vitamin D deficiency is documented by the analysis of 25-hydroxy-vitamin D in the plasma. The deficiency results in the improper function of the enzyme plasma alkaline phosphatase. The ratio of plasma tocopherol to cholesterol + triglyceride is the biomarker to determine deficiency in vitamin E status. Vitamin K deficiency is determined by the plasma analysis of phyllo Quinone. This deficiency results in the impairment in the function of plasma prothrombin. Proteins are responsible for maintaining fluid balance, blood clotting, cell growth and repair, and immunity. Proteins also provide fuel for the body and glucose for the synthesis of sugar. Diets low in energy and proteins lead to a situation known as protein-energy malnutrition (PEM) and kwashiorkor. Analysis of urinary nitrogen indicates reduced intake of proteins. The principal advantages of the biochemical method are that it is precise, accurate, reliable and extremely useful in assessing in detecting early cases of malnutrition before the appearance of the clinical signs. The biochemical measurements usually reflect the immediate past intake of nutrients or the changes produced by a long-standing deficient intake of a nutrient.

1.3.3. Clinical Examination

Clinical examination is a simple, yet objective method to assess nutritional status. The signs and symptoms can be in the skin, mouth, gums, nails, lips, eyes and hair of the subjects under study. The 1963 WHO Expert Committee on Medical Assessment of Nutritional Status provided a classification of the physical signs that can be utilized for nutritional assessment. This classification was subsequently updated in the World Health Organization Monograph Series No. 53 entitled "The Assessment of the Nutritional Status of the Community" published in the year 1966. The WHO classification is very helpful when a rapid nutritional screening

of a population is required within a stipulated time frame and also for specific research studies that needs to evaluate certain signs and symptoms. Physical signs and symptoms need to be recorded in a precise manner. The signs of malnutrition can be multiple. An experienced observer should possess the inherent capability of going for a more precise assessment of the body, after the initial findings based on a single sign. He/she also has to take into account the physical environment of the subject, along with the cultural features that can contribute to malnutrition. The age of the subject also plays an important role as the signs of a particular deficiency. The two aspects that are vital for proper and objective diagnosis are the reliability of the signs of symptoms and the experience of the investigator.

For convenience, the signs and symptoms are being classified into two categories. The categories are

a) Physical signs and general appearance

b) Internal signs

The physical signs and symptoms need to be recorded as accurately and possible. This can only be attained by the nutritionist/health worker by constant practice. The age of the individual under study is also related to the signs and their interpretation. Any physical finding that is indicative of malnutrition should be a clue that needs to be pursued more precisely. The physical signs and symptoms are strongly related to the ethnic features of the population under study. In a diverse country such as India, this is even more evident. The main advantages of this method are that it is inexpensive, rapid, reliable and easy to perform in any situation. It is also non-invasive and do not require the collection, transportation and analysis of any biologically active material. No specialized laboratory is required as such.

The main disadvantages of this method is that it is often not possible to detect early cases of malnutrition and that some of the clinical signs may not be specific to a particular nutrient deficiency and often one sign is an indicator of two or more such deficiencies. Moreover, the

prevalence of the different clinical signs of malnutrition is quite low. There also can be differences in the assessment of the clinical signs by different observers (inter-observer error). The physical signs and symptoms can also vary over time periods.

1.3.4. Dietary Intake

Dietary surveys are extensively used in the areas of nutritional epidemiology, clinical assessment, population surveillance and experimental research.

a) Twenty-four hour recall

b) Weighed intake

c) Food frequency questionnaire

d) Food diary

e) Dietary history

a) Twenty-four hour recall method

All the food items that were consumed during the last 24 hours are recorded ("24-hour recall method"). This method is utilized in large-scale nutritional surveys. The subject is usually asked to recall and describe in as much detail as possible his/her food intake during the last 24-hours either through an interview or by a questionnaire.

The most widely preferred subject for this method is the housewife. The investigator asks her to recall the kind and amount of the food used, the preparations actually made and distributed to the family members. Standard measuring containers such as cups, glasses, saucers and spoons are used to help the subject in recalling the information. To get proper information, the investigator may use several stages in which each data obtained are checked and verified, and each recall may therefore take almost 45 minutes.

The main advantages of this method are that it is inexpensive, quick, easy and relies on short-term memory.

b) Weighed intake method

The main difference between the 24-hour recall method and the weighed intake method is that in the case of the latter, the investigator remains actually present when the subject is eating and the food amounts are weighed before serving, during serving and subsequently the left-over (food not consumed). The differences between them give the amount of food actually consumed by the individual.

c) Food frequency questionnaire (FFQ)

The FFQ method tries to obtain long-term dietary habits. The individuals generally complete the FFQ themselves. The detailed instructions are sent by post along with the questionnaires. However, in the developing countries such as India, it is advisable for the investigator to fill up the questionnaire after interviewing the subjects. In the FFQ method the individual is asked about how often specific food item are consumed. The responses of the subjects are standardized as the subjects just need to tick mark on the responses. The frequency is generally calculated as per week/fortnight/month. The list of food items should not generally exceed 150 items. Up to 10 categories ranging from never to six times per day are the usual format. The FFQ method has been used in large epidemiological studies to assess food patterns associated with inadequate intake of nutrients and descriptive information of the food and diet.

The FFQ check list has two main parts, namely, a list of different food items and the frequency of consumption of these food items.

d) Food diary

The subject is required to keep a record in written form (diary) and photographs of all the food and beverages consumed over a certain period of time. This method is generally utilized when interviewing all the members regarding their dietary intakes is not possible due to some practical constraints. A time period of one week can be used in the diary to estimate the dietary intake. The subjects are initially tutored to describe and weigh/estimate the amount

food immediately prior to eating and subsequently to record left overs, if any. Standardized bowls and utensils are given to them prior to writing the diary. Even though the subject burden appears to be the highest while using this method, the food diary method has been effectively used in a number of large prospective epidemiological studies and for validating the results obtained from other methods of dietary assessment.

e) Dietary history

Dietary history records the dietary practices of the respondents over a prolonged period of time. The investigator obtains a retrospective estimate of the food intake using this method. The time duration covered is 3 months to one year. The information is recorded either through interviews and/or questionnaires addressed to the subject. This method is not used in large scale epidemiological surveys.

1.3.5. Vital and Health Statistics

Analysis of the mortality and morbidity data, along with the infant mortality rate, second year child mortality rate, rate of low birth weight and the life expectancy can also identify the at-risk groups with regards to nutritional status. The data of morbidity in the clinical settings or community health and morbidity surveys particularly those in relation to the protein energy malnutrition (PEM) and vitamin deficiencies are valuable in providing additional information with regards to the nutritional status of populations.

1.3.6. Ecological Studies

Malnutrition can be the end result of many interacting ecological factors. In many nutritional surveys it becomes necessary to collect the ecological information of the given community in order to make a complete nutritional assessment. A study of the ecological factors comprises of food balance sheets, socio-economic factors, health and educational services and finally conditioning influences.

1.4. REVIEW OF PUBLISHED LITERATURE

1.4.1. Studies done on Body Composition and Nutritional Status Assessment among Non-Indian Populations

Several studies have been done on the assessment of body composition and percent of body fat (PBF) by measuring skin-fold thickness (Slaughter et al. 1988; Rolland-Cachera 1993; Deurenberg et al. 1998; Gibson 2005; Wells 2007; Sen and Mondal 2013; Debnath et al. 2018a). Studies have been done on body composition assessment using recently developed advanced methods includes DXA, BIA among children and adolescents. Studies on whole body bone mineral content, FFM and FM have been done by Boot et al. (1997) among the Dutch children and adolescents; Bolanowski and Nilsson (2001), Eisenko¨lbl et al. (2001), Kontogianni et al. (2005) also used DXA for studying body composition among children and adolescents. Sala et al. (2007) reported that body composition among Canadian children and adolescents. A study was done by Wickramasinghe (2011) to assess the body composition among Sri Lankan children. Some studies have also been published using the indices like FM, FFM, FMI and FFMI on the issue of body composition among children among both non-Indian children (Musaiger and Gregory 2000; Nakao and Komiya 2003; Freedman et al. 2005; Gu¨ltekin et al. 2005; Ghosh et al. 2009; Leonard et al. 2010; Weber et al. 2012; Giri et al. 2017a; Debnath et al. 2018a). Several non-Indian studies have been done on the body composition assessment of children using Dual-energy x-ray absorptiometry (DXA) (Goran et al. 1996; Huang et al. 2003; McDonald et al. 2007; Hoffman et al. 2012; Kuzawa et al. 2012; Xiong et al. 2012; De Moraes et al. 2013; Tanvig et al. 2014; Marra et al. 2019; Alburquerque-Sendín et al. 2020).

Yanovski et al. (2011) conducted a study on body composition among children and adolescents of United States. Pereira et al. (2014) studied body composition using PBF as an indicator among female adolescents of Brazil. Weber et al. (2013) also studied body composition using body fat and BMI among children and adolescents. Stanfield et al. (2012)

reported another study among the mother and baby in London. Kim et al. (2013) reported body composition using body fat among Korean children. A study on body fat using DXA is reported by Ackerman et al. (2011). Studies using DXA were also reported by Wells et al. (2010) and Bauer et al. (2012) .

A number of studies have been done on the assessment of body composition and percent of body fat (PBF) by measuring skin-fold thickness (eg., Gibson 2005; Kontogianni et al. 2005; Wells 2006; Basu et al. 2010; Xiong et al. 2012; Weber et al. 2013). Studies have also been done using indices like fat mass, fat free mass and fat mass index to estimate body composition among children (Freedman et al. 2005; Gu¨ltekin et al. 2005; Sala et al. 2007; Wickramasinghe 2011). Several non-Indian studies have been done on the body composition assessment of children using bio-electrical impedance methods (Ackerman et al. 2011; Yanovski et al. 2011; Kuzawa et al. 2012; Tanvig et al. 2014; Wendel et al. 2016). A number of studies have been done world-wide on the measurements of nutritional status among under-five years age. Some studies in this respect are by Kosti and Panagiotakos (2006), Cole et al. (2007), Edris (2007), Tienboon and Wangpakapattanawong (2007), Amsalu and Tigabu (2008), Mashal et al. (2008), Bomela (2009), de Onis et al. (2010), Emina et al. (2011), Kamiya (2011), Abubakar and van de Vijver (2012), Abuya et al. (2012), Massad et al. (2012), Mugo (2012), Nketiah-Amponsah et al. (2012), Sufiyan et al. (2012), Ghazi et al. (2013), Akorede and Abiola (2013), Bhandari and Chhetri (2013), Flax (2013), Islam et al. (2013), Owoaje et al. (2014), Aheto (2015), Chirande et al. (2015), Iannotti et al. (2015), Aguayo et al. (2016), Ahmed et al. (2016), Devkota et al. (2016), Rachmi et al. (2016), Rakotomanana et al. (2016), Valente et al. (2016) and Karra et al. (2017).

Studies on maternal body composition and nutritional status have been published. Some recent studies on the field are by Lewycka et al. (2013), Keino et al. (2014) and Tebekaw et al. (2014). There are also studies on maternal nutritional status and its association with the

child nutrition and socio-economic factors (Black et al. 2008; Davidson et al. 2008; Lartey 2008; Victora et al. 2008; Oken 2009; Padilha et al. 2009a,b; Lampl et al. 2010; Limwattananon et al. 2010; Peiris and Wijesinghe 2011; Khan and Khan 2012; Målqvist et al. 2012). Studies on assessment of maternal nutritional status include those of Drehmer et al. (2010), Young et al. (2012), Haileslassie et al. (2013), Li et al. (2013), Ma˚lqvist et al. (2013), Felisbino-Mendes et al. (2014), Hambidge et al. (2014), Jayawardena (2014), Restrepo-Mesa et al. (2014), Abrha et al. (2016), Bhandari et al. (2016), Gyenes et al. (2016), Mohsena et al. (2016), Veena et al. (2016), Jomaa et al. (2017) and Tanwi et al. (2019).

A number of studies have been done world-wide on the measurements of growth among various populations. One of the earliest significant studies in this regard is that of Partington and Roberts (1969) on height and weight of Indian and Eskimo school children. Other notable studies include those of Johnston et al. (1973) on height, weight and their growth velocities in Guatemalan private school children, that of Hartaman et al. (1973) on height of school children in Bandung that of Shephard and Rode (1995) on the growth patterns of Canadian Inuit children that of Merola et al. (1998) on height, weight, height velocity of primary school children in Italy and that of Kamal et al. (2004) on height, weight, height velocity of Qatari preschool children.

Studies have also been initiated on establishment of growth reference values such as that among Belgian children of 3-18 years of age (Hauspie et al. 1993). Sutphen (1985) discussed the common anthropometric techniques and emphasizes the inference of nutritional status from such measurements. Many of the studies on human growth were initiated in the early part of the 20th century and most of them were long-term. As a background for the International Growth Reference for Children and Adolescents, 21 long-term longitudinal studies of physical growth were reviewed by Himes (2006). Seidell et al. (2006) opined in another review that normative data are necessary to create a reference that indicates optimal

development of weight in relation to height and age, particularly in the face of the unfolding obesity epidemic in many developed and developing countries around the world. Ideally, a reference would be based on longitudinal data in populations with little underweight, overweight and obesity. Cole et al. (2000) have reported reference population for assessing the prevalence of overweight and obesity among children and adolescent. Childhood overweight and obesity is worldwide trend. A number of studies have reported the prevalence of overweight and obesity among children from different populations (Kosti and Panagiotakos 2006; de Onis et al. 2010; Evans et al. 2010).

In a recent study, a high prevalence of malnutrition among Karen children has been observed by Tienboon and Wangpakapattanawong (2007) involving anthropometric measurements. Sex differences in different anthropometric measurements were also studied. In a study done in Libya, it was reported that there was a marked difference in anthropometric measurements between boys and girls at the age of 14 years (Shamssain 1989). In another significant study, Huque and Hussain (1991) showed that it was possible to detect of low birth-weight among new born babies by anthropometric measurements. Ben Salem et al. (2006) evaluated weight-for-age, height-for-age and weight-for-height in infants in Tunisia and compared them with the National Centre of Health Statistics (NCHS) reference. Secular trends in various anthropometric measures have also been studied (Ayatollahi et al. 2006; Matton et al. 2007).

1.4.2. Studies done on Body Composition and Nutritional Status Assessment among Indian Populations

Anthropometry is the single universally applicable, inexpensive and non-invasive technique available to researchers for the assessment of the size and proportion of the human body, physical growth pattern and nutritional status (WHO 1995, 2007; Lee and Neiman 2005; Hall et al. 2007). It is considered to be very useful tool in the assessment of growth and

nutrition of individuals (Lee and Neiman 2005). The technique of anthropometry has been successfully utilized by different researchers to assess and document the growth and nutritional status of various populations. Several research studies have reported that prevalence of undernutrition is considered to be the one of the major public health concerns among children (George et al. 2000; Rajaram et al. 2003; Rao et al. 2004; Nandy et al. 2005; Som et al. 2006, 2007; Bose et a. 2007a; Mondal and Sen 2010a,b; Sen and Mondal 2012; Singh and Mondal 2013; Mondal 2014; Islam et al. 2014; Sharma and Mondal 2014; Mondal et al. 2015; Sharrma and Mondal 2018; Debnath et al. 2018a,b,c).

A sizeable number of these studies have been done on pre-school children (Khongsdier 2001; Som et al. 2006; Mondal and Sen 2010a,b; Sen and Mondal 2012; Tigga et al. 2015a,b; Singh et al. 2016; Debnath et al. 2017a; Debnath et al. 2018a,b,c; Kramsapi et al. 2018; Sharma and Mondal 2018). The anthropometric parameters (e.g., mid-upper arm circumference (MUAC), head circumference (HC), height-for-age, weight-for-height, weight-for-age) that are used are widely to assess physical growth and nutritional status of children (WHO 1995; Nandy et al. 2005; Bose et al. 2007; Mondal and Sen 2010a,b; Debnath et al. 2018; Sharma and Mondal 2018, 2020). Extensive studies have also been done in assessment of nutritional status using anthropometry among children, particularly in the age group below 12 years using conventional anthropometric measurements and indices (e.g., stunting, underweight and wasting) (e.g., Rao et al. 2005; Rajaram et al. 2003; Som et al. 2006, 2007; Mittal and Srivastava 2006; Bose et al. 2007a; Mitra et al. 2007a,b; Bisai et al. 2008a; Chowdhury et al. 2008; Mondal and Sen 2010a,b; Bisai and Mallick 2011; Sen and Mondal 2012; Mondal et al. 2015; Debnath et al. 2018a,b,c).

The inadequate/poor physical growth attainment in weight and height were also reported in other tribal and non-tribal children and adolescents in India (Reddy and Rao 1995, 2000; Mitra et al. 2002; Rao et al. 2006; Medhi et al. 2007; Mondal and Terangpi 2014; Singh

and Mondal 2014; Roy et al. 2016; Mondal et al. 2017; Sharma and Mondal 2018) compared to the recommended international growth references (e.g., WHO and CDC) (Frisancho 1990; Kuczmarski et al. 2002; WHO 2007). The population/ethnic specific physical growth and nutritional studies were also assessed using anthropometric measurements (e.g., height and weight) among Indian children and Indian adolescents (ICMR 1972). Here, the studies on Bengali boys of West Bengal (Dasgupta and Das 1997), Assamese Muslim of Kamrup, Assam (Begum and Choudhury 1999), Sugalis tribal adolescents of Andhra Pradesh(Reddy and Rao 2000), Kamar tribal of Chhattisgarh (Mitra et al. 2002), School children of Assam (Medhi et al. 2006), Khasi adolescents Meghalaya (Khongsdier and Mukherjee 2003), Tribal adolescents of Assam (Medhi et al. 2007), Santal tribe of Orissa (Chowdhury et al. 2008), Shabar tribe of Orissa (Chakrabarty and Bharati 2008, 2010), Bengali adolescents (Banerjee et al. 2009), SonowalKachari tribe of Assam (Singh and Mondal 2014), Indian adolescents (Khadilkar et al. 2015), Rajbanshi (Roy et al. 2016), Karbi adolescents (Mondal and Terangpi 2014; Sharma and Mondal 2018, 2020) are mentionable.

Several studies have been done using upper arm composition which includes the indices of upper arm muscle area (UMA), total upper arm area (TUA), upper arm fat area (UFA), arm fat index (AFI), upper arm fat area estimate (UFE) and upper arm muscle area estimate (UME) to assess body composition of children and adults. Several studies during the last decade have established the usefulness of upper arm composition in the assessment of body composition among them (e.g. Bolzan et al. 1999; Chowdhury and Ghosh 2009; Sen et al. 2011a; Senbanjo et al. 2014; Singh and Mondal 2014; Sen et al. 2015; Debnath et al. 2017b), although not adopted for routine assessment of body composition and nutritional status. Several studies have been conducted among children using UMA and UFA as reliable indicator of body composition and nutritional status (e.g., Erfan et al. 2003; Chowdhury and

Ghosh 2009; Çiçek et al. 2009; Basu et al. 2010; Sen et al. 2011, 2015; Sikdar 2012a,b; Singh and Mondal 2014; Debnath et al. 2017b).

There are a number of Indian studies available on FMI, FFMI (Bhat et al. 2005; Bose et al. 2008; Khongsdier 2005; Rao et al. 2012; Bose et al. 2006; Verma et al. 2016) and MUAC (Bose et al. 2007; Bose et al. 2006; Bisai et al. 2009; Chakraborty et al. 2009; Das et al. 2012a; Mallick and Roy 2019). Studies on West Bengal have also been reported (Ghosh et al. 2001; Das and Bose 2006; Bisai et al. 2008; Datta Banik 2011; Das et al. 2012a; Das and Bose 2012; Sen and Mondal 2013; Kuiti and Bose 2015; Pratiharp et al. 2016; Bose et al. 2019; Mallick and Roy 2019).

Composite Index of Anthropometric failures (CIAF) is more useful over the conventional anthropometric indices (i.e., stunting, underweight and wasting) in assessing the overall magnitude of undernutrition and identifying children with multiple anthropometric failures (Nandy et al. 2005; Nandy and Miranda 2008; Nandy and Svedberg 2012; Sen and Mondal 2012; Dasgupta et al. 2014; Savanur and Ghugre 2015; Goswami 2016; Kramsapi et al. 2018; Sen et al. 2020). The CIAF comprises typical anthropometric indicators and their combination into seven categories and proposes an additional measure to study malnutrition as an alternative to the evaluation of stunting, wasting and underweight as the separate measure (Nandy et al. 2005; Nandy and Svedberg 2012; Sen and Mondal 2012). Several researchers have reported that conventional anthropometric indices could not provide the overall prevalence of undernutrition as the researcher had to 'choose' a certain category of anthropometric failure when assessing nutritional status among preschool children (Nandy et al. 2005; Seetharaman et al. 2007; Berger et al. 2008; Nandy and Miranda 2008; Nandy and Svedberg 2012; Kramsapi et al. 2018). Several research studies have reported the overall magnitude of undernutrition status using CIAF among Indian preschool children and children residing in both rural and urban population (Nandy et al. 2007; Seetharaman et al. 2007; Das

and Bose 2009; Sen and Mondal 2012; Dasgupta et al. 2014; Savanur and Ghugre 2015; Dhok and Thakre 2016; Goswami 2016; Gupta et al. 2017; Kramsapi et al. 2018; Sen et al., 2020).

A significant number of contributions have observed that the prevalence of chronic energy deficiency (CED) is the important nutritional issue among Indian adults (e.g., Khongsdier 2001, 2005; Gautam et al. 2006; Bose et al. 2006; Subramanian and Smith 2006; Bharati et al. 2007; Subramanian et al. 2007; Sengupta 2014). In a very significant study involving 81,712 rural women from 26 states and 6 zones, Bharati et al. (2007) reported that 31.20% of them were suffering from CED. Here, the studies among the Oraon (Mittal and Srivastava 2006) and Santal (Bose et al. 2006) may be also mentioned. Using body mass index (BMI) and mid upper arm circumference (MUAC), Bose et al. (2006c) reported a high prevalence of undernutrition among adult Santals of Odisha (26.20% males and 33.70% females).

The current nutritional trends have shown that the prevalence of overweight and obesity has increased among Indian populations residing in the urban areas of the country (Subramanian and Smith 2006; Subramanian et al. 2007; Mungreiphy and Kapoor 2010; Sen et al. 2013; Sengupta et al. 2014; Rengma et al. 2016; Tigga et al. 2018). Studies on waist-circumference (WC) (Ghosh and Bandypadhyay 2007; Chakraborty and Bose 2009; Singh et al. 2014; Banik et al. 2016; Ghosh and Bose 2018), waist-to-height ratio (WHtR) (DeNino et al. 2001; Despres and Lemieux 2006; Abdelaal et al. 2017) and human physical variation in body dimension (Dewangan et al. 2005; Singh et al. 2014; Banik et al. 2016; Ghosh and Bose 2018) has also been published.

1.4.3. Socio-Economic and Demographic Factors Affecting Physical Growth and Nutritional Status among Children

Socio-economic and demographic factors are considered to be the major contributors to the prevalence of undernutrition, mortality and morbidity among children around the world

(Jafari et al. 2010; Zsakai and Bodzsar 2014; Tigga et al. 2015; Choy et al. 2017; Galgamuwa et al. 2017; Wang et al. 2017; Debnath et al. 2018c). Zsakai and Badzsar (2014) have observed a significant relationship between physical growth and socio-economic status among children. Studies have reported poor feeding practices (Lindsay et al. 2012), low household income and illiteracy, improper care during childhood triggers the prevalence of undernutrition among the children and decreases the cognitive abilities and makes them less productive (WHO 1995; Black et al. 2013; Mondal et al. 2015; Tigga et al. 2015; Wang et al. 2017). Specific nutritional deficiencies in terms of protective foods (i.e., micronutrient deficiency such as vitamin-A, zinc deficiency and iron deficiency) caused due to inadequate intake of food can be attributed to the greater prevalence of undernutrition and morbidities among children (Alaofe 2017; Chengezi and Lindberg 2017). The existence of low socio-economic status, poor environmental, unhygienic conditions and unavailability or inaccessibility of the healthcare degrades health status of women and often makes them prone to deliver an undernourished child (Alaofe et al. 2017). The relationship between nutritional status (e.g., undernutrition) and dental eruption chronology has been evaluated by many studies (Barbería et al. 1988; Psoter et al. 2008; Must et al. 2012; Heinrich-Weltzien et al. 2013; Juliana et al. 2017).

Several socio-economic, demographic and lifestyle determinant have shown significant effects on the prevalence of undernutrition (e.g., stunting or thinness) and that poverty highly affects the linear growth mechanism than body weight of the children (Black et al. 2008; Janevic et al. 2010; Agostoni and Fattore 2013; Meshram et al. 2016). A number of studies have showed that poor children tend to be at higher risk of being undernourished and having restricted growth. Therefore, economic inequality remains an independent determinant for childhood undernutrition (Zere and McIntyre 2003; Janevic et al. 2010; Meshram et al. 2016; Roy et al. 2016). These determinants include poor socio-economic status, poverty, income, hygiene and adverse environments (e.g., rural), including low income

(Choudhury et al. 2000; Mahgoub et al. 2006; Tigga et al. 2015a,b; Roy et al. 2016). Physical growth attainment, health status and nutritional benefits from economic growth tend to be concentrated only among the economically advantaged groups (Vardharajan et al. 2013; Mushtaq et al. 2011; Meshram et al. 2015). Moreover, the developing countries remain vulnerable to food insecurity, poor access to health services, undernutrition (e.g., stinting) and increased morbidity and mortality (Zere and McIntyre 2003; Nandy et al. 2005; Nandy et al. 2008; Smith and Haddad 2015; Akseer et al. 2017; Dondi et al. 2020). The major factors affecting the prevalence of undernutrition in the developing countries are poor socio-economic and environmental conditions, ethnic, socio-economic and demographic disparities (Mahgoub et al. 2006; Ramachandran 2007, 2014; Antony and Laxmaiah 2008; Mondal and Sen 2010; Ahmed et al. 2012; Varadharajan et al. 2013; Tigga et al. 2015; Huda et al. 2017; Debnath et al. 2018c, 2019). The consequences of such undernourishment are poor growth associated with greater risk of morbidity and mortality from infectious diseases, adverse long-term consequences of delayed linear growth (e.g., stunting) (Black et al. 2013; Ramachandran 2014; Smith and Haddad 2015). Most of the studies documenting nutritional status in India have observed that girls were more affected by undernutrition than boys (Bose et al. 2007; Mondal and Sen 2010; Sen and Mondal 2012; Tigga et al. 2015; Pal and Bose 2017; Sinha et al. 2017; Debnath et al. 2018c,d; Seshadri and Ramakrishna 2018; Sharma and Mondal 2018). Several researchers have also reported existence of sharp sex/gender disparities, with rural girls were more likely to be severely undernourished than rural boys (Choudhury et al. 2000; Mondal and Sen 2010; Bhargava et al. 2015; Pal and Bose 2017; Sinha et al. 2017; Debnath et al. 2018; Seshadri and Ramakrishna 2018).

1.4.4. Studies done in Biological Anthropology among Different Populations of North-Eastern India and North Bengal

Northeast India is comprised of eight states, namely Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. The region has international boundaries with China, Bhutan, Myanmar and Bangladesh. This region of India is the most interior and inaccessible part of the country as a result of mountainous terrain and poor communication means. Noteworthy studies have been reported in the field of nutrition assessment among communities of Northeast India. The high prevalence undernutrition is considered to be a serious problem among adult populations of Northeast India. Several studies have reported that chronic energy deficiency (CED) is widely prevalent and causing various form mortality and morbidity among individuals. Khongsdeir (2001) using data from 12 populations of Northeast India reported that the prevalence CED of was significantly lower in tribal than Hinduized and caste populations. The prevalence of CED was also found to be 21.43% among Dibongiya Deoris of Assam (Gogoi and Sengupta 2002) and 35.00% among male War Khasi individuals (Khongsdier 2002). When the population specific prevalence of undernutrition (e.g., CED) was taken into consideration the data shows a lower prevalence among tribal populations such as Boro Kachari (11.22%), Mech Kachari (6.00%) and Pnar Khasi (14.28%) than the tribes like Lalung (34.69%) and Mishing/Miri (34.00%). The prevalence of CED was found to be higher in the Hinduized Mongoloid groups like Ahom (52.00%), Koch (50.00%) and Rajbanshi (42.00%) (Khongsdier 2001). Khongsdier et al. (2005) further reported excess chronic energy deficiency (CED) was observed among male adolescents in the context of patrilineal and matrilineal societies in Northeast India. Other significant contributions in the field of nutritional assessment and growth studies among children and adolescents are also available among diverse ethnic populations of Northeast India (e.g., Devi et al. 1997; Sharma and Bora 1998; Begum and Choudhury 1999; Khongsdier and Mukherjee 2003a,b; Agrahar-Murugkar 2005; Som et al. 2006; Medhi et al. 2007; Basu et al. 2010; Sil et al. 2011; Islam et al. 2014; Mondal and Terangpi 2014; Sharma and Mondal

2014; Singh and Mondal 2014; Mondal et al. 2015; Sharma and Mondal 2018, 2020). Recent studies of Basu et al. (2010) and Singh and Mondal (2014) have reported that upper arm composition and nutritional status among Khasi adolescent and Sonowal Kachari children remained nutritionally deficient with gender specific muscle and fat proportion, respectively. Recent trends suggested that the prevalence of overweight and obesity also apparent among the adult individuals of Northeast India (Mungreiphy and Kapoor 2010; Rengma et al. 2015).

Several research studies were also conducted on different anthropological and health related issues of non-communicable diseases (Misra et al. 2014), malnutrition (Sikdar 2012), healing practices and folk medicine (Shankar et al. 2012), Obesity (Rengma et al. 2015) and ABO and PTC sensitivity (Das et al. 1985a,b) among the Mishing tribal population and among Muslims of Northeast India. Significant contributions have been made in the field of nutritional assessment and growth studies in the different population of North-east India (Devi et al. 1997; Sharma and Bora 1998; Khongsdier and Mukherjee 2003; Agrahar-Murugkar 2005; Medhi et al. 2006; Som et al. 2007; Bharati et al. 2008; Sharma and Mondal 2014; Singh and Mondal 2014; Mondal et al. 2016; Rengam et al. 2017; Kransapi et al. 2018). Medhi et al. (2007) reported the very high prevalence of stunting (47.40% boys; 51.90% girls) and thinness (59.50% boys; 41.30% girls) among the adolescent working in the tea gardens of Dibrugarh district of Assam. Basu et al. (2010) reported the in upper arm composition and nutritional status among Khasi adolescent children remain nutritionally deficient with gender dimorphic muscle and fat proportion. Sil et al. (2011), reported the prevalence stunting (23.70%), thinness (23.70%) among the rural tribal children in Tripura. Some studies have been initiated in the field of Hbopathies among populations of North Bengal (e.g., Bhattacharyya et al. 2013; Goswami et al. 2014; Ghosh et al. 2015). Some other studies on nutritional status and body composition among children have been done in North Bengal are that of Debnath et al. (2017a, 2018a,b,c,).

1.4.5. Studies on Muslim in North Bengal, West Bengal and India

Population specific studies among the Indian Muslims are rare in the field of nutritional status and body composition. In the field of body composition two significant studies were reported from North Bengal using the upper arm composition and FM and FFM among the Bengalee Muslim children by Sen et al. (2011) and Sen and Mondal (2012), respectively. Studies have assessed nutritional status among the Muslim children and women simultaneously with other Indian populations or religious groups. One population specific study among the Muslim adolescents of Deganga, North 24 Parganas has been reported by Khatun et al. (2017).

In West Bengal studies on the assessment of nutritional status includes that among school going Muslim adolescent girls in a semi urbon area of West Bengal (31.36%) (Pramanik et al. 2014), among Muslim adolescent school girls (16.00%) (Sarkar et al. 2015), among adolescent girls in a slum area of Kolkata that includes 30.28% of Muslims (Pal and Pal 2017). Some of the other studies in West Bengal which have included Muslims in the study population are by Pal (1999) and Bisai et al. (2010). Several studies have been done by Debnath et al. (2017, 2018a,b,c,d, 2019) who included Bengali Muslim children. Sen et al. (2020) have reported a study on Composite Index of Anthropometric failure (CIAF) which included Bengali Muslim children.

A population specific study among Muslim women in Assam has been done by Haloi and Limbu (2013). Indian studies which have included Muslims as the study population include that of adult males of different social groups (includes 13.15% Muslims) in Odisha and Bihar (Chakrabarty et al. 2008), under five children (Muslim 13.90%) of rural area of Western Maharashtra (Avachat et al. 2011), young children in Mumbai slums (Muslims 43.00%) (Das et al. 2012), adolescents in northern Karnataka (Rajaretnam and Hallad 2012), school going children (6-9 years) (includes 5% of Muslims) in rural area of Bhopal district,

Madhya Pradesh (Murugkar et al. 2013), urban slum children (Muslim 24.20%) (Lohia and Udipi 2014), children aged 1-6 years in rural Lucknow, Uttar Pradesh (Muslims 29.50%) (Prasot et al. 2014), rural adolescents of 10-19 years age (includes 61.34% Muslims) in Bareilly, Uttar Pradesh (Singh et al. 2014), school children (includes 29.00% Muslims) in Sullia town, South India (Amruth et al. 2015), adults in urban slums of Delhi (Muslim 49.80%) (Singh et al. 2015), adolescents in rural school of Unokoti District of Tripura (Uddin et al. 2015), women (includes 15.50% Muslims) in a rural population of North Karnataka (Mastiholi et al. 2018), women of reproductive age in India (Al Kibria 2019), school children (includes 11.60% Muslims) in Udupi, Karnataka (Gautam and Jeong 2019), elderly adults in Patna (Kumari 2019) and adolescent girls aged 10-19 years (includes 26.67% Muslims) in urban slums of Agra in Uttar Pradesh (Kumar and Mishra 2019).

Some of the other studies which included Muslims were that among Indian women (Bharati et al. 2008), children (Bose 2011; Griffiths et al. 2002; Imai et al. 2014; Viramgami et al. 2014; Puttaraju and Uma 2015; Joe et al. 2019; Pakrashi and Saha 2020), among adults (Dutta et al. 2019), Indian Muslims in general (Ismail and Mustaquim 2013) and females of reproductive age group of Azamgarh district, Uttar Pradesh (Mishra et al. 2011). Studies on assessing the low birth weight situation in India (Muslims 13.10%) (Chakraborty and Anderson 2011) and prevalence of anemia in Muslim (92.3%) and non-Muslim pregnant women of western Rajasthan (Bansal et al. 2013) are also mentionable. Paul and Mondal (2020) have reported the prevalence morbidity and mortality among Indian children which included 16.80% of Muslims in the study population.

1.5. The Insidious Impact of Maternal Malnutrition on the Health of Child health and Community Health

Maternal health has an important link with the health of the individual, family and society (Gill et al. 2007; Delisle 2008). Mothers/Women's nutritional status impacts all these

levels of society in present and future generations and their health and well-being is connected with their own socio-economic and lifestyle status, their education, occupation and on the power to make decisions. Maternal health affects women's survival as well as the health and survival of their children and future generations (Smith et al. 2003; Delisle 2008). Women's good health and better nutritional status can be directly reflected in better nutrition and health of their children (Smith et al. 2003; Delisle 2008). Maternal undernutrition is associated with CED status of mother, fetal growth restriction, low-birth weight for gestational age and child birth with a high risk of undernourishment among those who survive (Delisle 2008). The nutritional status of children is adversely influenced by the health and nutritional conditions of the mother. There are various Problems caused by poor maternal health and nutritional conditions.

The prevalence of LBW (Low Birth Weight) which is a significant public health concern in the developing countries including India (Sen et al. 2011; Shastri et al. 2014; Mondal et al. 2018; Dey et al. 2019; Laopaiboon et al. 2019). Significant interaction between the allocation group and maternal pre-pregnant BMI has been reported by Potdar et al. (2014). The factors associated with LBW among new-born babies in an urban slum community in Bhopal has been reported by Choudhary et al. (2013) where the mean birthweight of new-borns was 2.57± 0.36 kg and 105 (36.2%) new-borns had a birthweight lesser than 2500 gm. Some of the other studies on risk factors for LBW and pregnant women are those by Bharati et al. (2011), Negandhi et al. (2014). Study on the variability in survival of very LBW neonates in hospitals of India has been done by Chawla et al. (2015). Studies have observed the relationship between neonatal, peri-natal mortality and maternal nutritional status in Indian states (Bamji et al. 2008; Kumar et al. 2014; Siddalingappa et al. 2014). Sethuraman et al. (2006) has observed that malnutrition continues to affect 46% of children under five years of age and 47% in rural women in South India. According to the study done by Udipi et al. (2000)

maternal nutrition is very important for the course and outcome of pregnancy. In another study Kulkarni et al. (2011) observed regional body composition changes during lactation in Indian women from the low-income group and have assessed relationship to the growth of their infants. It has also been observed in several studies that when maternal income is higher than that of men's income then it is directly reflected among their children (Smith et al. 2005; Delisle 2008). Studies have pointed out the relationship of gender inequality and deprivation among and the health expenses of these for the whole population (Osmani and Sen 2003; Subramanium and Smith 2006; Delisle 2008). Some adverse consequences of women's poor health and nutrition harm the entire population because the offspring are affected as children and as well as future adults. Although women's physiological processes (that is, their childbearing and hormone functions) require an excess of essential fat i.e., the "sex-specific fat" but overnourishment among mothers (i.e., overweight-obesity) can also give birth to children who become malnourished (e.g., stunted) on later age as suggested by several studies on obesogenic environment. The presence of maternal overweight-obesity also exposes the child to increased risk of gestational diabetes and macrosomia (ESHRE Capri workshop group 2006). Moreover, the female off-springs of malnourished mothers are at higher risk of becoming stunted and undernourished women themselves and also to have low-birth weight babies, thereby perpetuating the vicious cycle of undernourishment (Delisle 2008). Socio-economic inequalities denote the degree of prevalence of malnutrition in population and the forms differ between more and less socially and economically advantaged groups (Van de Poel et al. 2008; Mazariegos 2019). The National Family Health Survey-3 2005–2006 data showed that combined prevalence of overweight and obesity 12.6% among women aged 15–49 years and the NNMB 2005–2006 data showed that in rural areas the combined prevalence was 10.9% among adult women aged 18–60 years (Wang et al. 2009). On the other hand the prevalence of child undernutrition is persistently high in India (Khor 2008; Ali et al. 2016;

Dhok and Thakre 2016; Saxton et al. 2016; Mandal 2017; Patil et al. 2017; Debnath et al. 2018a,b,c). Although causes of child undernutrition and maternal overnutrition are different but the both of them can coexist. Several studies (e.g., Doak et al. 2005; Garrett and Ruel 2005; Dieffenbach and Stein 2012; Doak et al. 2016; Jayalakshmi and Kannan 2019), have observed such a coexistence. Chronic undernutrition such as stunting among children and maternal undernutrition in terms of CED are serious health issues in poor income and developing countries. Moreover, the nutrition transition, lifestyle changes and economic disparities in these countries are contributing towards the occurrence of overweight and obesity in population. But occurrence of childhood stunting and maternal obesity present in the same households is more serious issue than occurrence of undernutrition and overnutrition separately in different households. Therefore, the occurrence and contribution of the obesogenic environment needs special attention.

Several socio-economic and demographic indicators e.g., maternal age, maternal age at menarche, family size, family type, earning head, monthly income, monthly expenditure, toilet use and fathers occupation have been observed to be significantly associated with the obesogenic environment.

1.6. STATEMENT OF THE PROBLEM

Childhood malnutrition is the underlying cause of death in an estimated 35% of all deaths among children, under the age of five years. More than two million children die each year as a result of undernutrition before the age of five years and iron-deficiency anaemia is estimated to contribute to a significant number of maternal deaths every year in low- and middle-income countries (WHO-UNICEF 2014). India has the highest occurrence of child undernutrition in the world and it has been estimated that more than half of the Indian children remain undernourished (Ahmed et al. 2012). It has also been reported that the country has more than 47 million stunted children and that nearly 20% of children are born with LBW

(Bharati et al. 2011; Kader and Perera 2014). The effect of undernutrition among Indian children and mothers are high. High rates of infant mortality, under-five mortality and maternal mortality are observed in India, which are higher than those of some of the developing countries of South-East Asia. There is also a scarcity of the scientific studies on maternal and child nutritional status in the selected area. Undernutrition was identified to be the principal underlying cause of mortality among children and the WHO has estimated that, in the year 2012, a total of 6.60 million deaths occurred among children aged under-five years (WHO 2014). The relationship between maternal and child undernutrition is affected by biological consequences during child birth and lactation. Poor nutritional condition among children and mothers perpetuates generation after generation in human population. Therefore, it is very important to assess the nutritional status of such children and their mothers. Interventions by improving maternal nutritional status could have a significant role in the prevention of childhood malnutrition. Keeping the above-issues in mind, the present study aims to assess the nutritional status of children (1-5 years) and their mother.

1.7. OBJECTIVES OF THE PRESENT STUDY

Assessment of nutritional status and body composition of individuals is recognized as the most significant indicator of health and wellbeing status of an individual or population. The ultimate objective of nutritional assessment studies is to improve the quality of human health and life conditions by implementing various nutritional intervention programmes.

The objectives of the present study are as follows:

1. To assess the nutritional status of the children (1-5 years) and mothers of the Bengali Muslim population of Darjeeling district, West Bengal using conventional anthropometric measures.
2. To ascertain the effect of maternal body composition and nutritional status on the child nutritional status.

3. To find out the association and effect of certain socio-economic, demographic and lifestyle variables on child and maternal nutritional status.
4. To compare the child and maternal nutritional status of the Bengali Muslim population with the available studies done on different Indian and non-Indian population.

1.8. RESEARCH QUESTIONS OF THE PRESENT STUDY

It is evident from the above discussion that nutritional status and body composition is generally influenced by several biological, physical, socio-economic, demographic and lifestyle determinant factors. It is considered to be one of major factor affecting the physical growth, delay in developmental processes and increases the mortality and morbidity conditions. As established by several research studies, women suffering from chronic energy deficiency (CED) (e.g., undernutrition) and poor body composition will continue the vicious cycle of undernutrition and such issues have the direct influence on the reproductive outcome and the prevalence of undernutrition among children in the population. Therefore, the present study is proposed on the basis of the following research questions:

1. What is the present condition of body composition and nutritional status of of the Bengali Muslim children and mothers?
2. What is the extent of prevalence of malnutrition among the Bengali Muslim children and mothers?
3. How maternal nutritional status is affecting the nutritional status of children?
4. Does socio-economic, demographic and lifestyle conditions have any effect on the child and maternal nutritional status?

1.9. SIGNIFICANCE OF THE PRESENT RESEARCH STUDY

The poor physical growth attainment and undernutrition are considered to be major causes of ill-health conditions among nutritionally vulnerable segments (e.g., children) of the population. Children are the worst affected individuals due to their rapid physical growth and

development. Maternal nutritional status has important effect on child health, growth and development. In the field and clinical investigations, anthropometric measurements and indices (e.g., stunting, underweight, wasting or thinness) play major roles in the assessment of the physical growth pattern and development, body composition and nutritional status of an individual/ populations, mainly because the technique is widely utilized, easy-to-use, non-invasive and inexpensive in nature. Due to its immense population size, socio-economic disparities, demographic composition, illiteracy and inadequate access to health facilities the Indian populations are undernourished and underprivileged. The overall health and nutritional scenario are found to be similar in the populations of North-east, India. The present study will provide insight to understand the possible mechanism and interaction of the determinant factors (e.g., poverty, illiteracy, occupation, low socio-economic conditions, unavailability of clean drinking water, inadequate food intake, inadequate dietary knowledge and unavailability of health-care facilities) with physical growth and nutritional status (e.g., undernutrition) among children residing in rural environments. The findings of the present research study will help to identify the ethnic/population variations of physical growth and nutrition status. The outcomes of the present study may be helpful to the Government and other public health organizations to formulate the suitable health intervention strategies for the overall improvement of the physical growth pattern and nutritional status of the under study population. Further, the data of the present study will be helpful for comparison of physical growth pattern, body composition and nutritional status (e.g., undernutrition) with other populations of India, as well as with national and international data. The results will also evaluate the efficacy of ongoing the nutritional intervention programme or need of any appropriate public health strategies to ameliorate the nutritional conditions of the population concern.