CHAPTER-I:

INTRODUCTION

INTRODUCTION

1.1. INTRODUCTORY NOTES

Food contains various substances that are required for normal growth and development. These substances ("*nutrients*") comprise of proteins, carbohydrates, fats, vitamins and minerals. The amount of each nutrient required by an individual depends upon his/her age and physiological status. Adult individuals need nutrients for maintaining constant body weight and ensuring proper body functions. Infants and growing children require more nutrients not only for the maintenance of body function but also for their growth and development. A balanced diet and proper nutrition are two very important issues in the promotion and maintenance of good health throughout life. Their role as deterrents of malnutrition and Non-Communicable Diseases (NCDs) is well established and this occupies a prominent position in nutritional assessment. Nutritional status is now recognized to be a prime indicator of the overall health of a population or an individual. The World Health Organization (WHO) goes on to state that the ultimate objective of nutritional assessment is the overall improvement of the quality of human health (Beghin *et al.*, 1988). The prevalence of under-nutrition is now a major public health concern in many of the developing countries. The assessment of nutritional status thus has a potential role to play in formulating developmental nutritional intervention strategies of the concerned populations. Nutritional status is reflected in a variety of metabolic processes that provide the basis for the number of methods for its assessment.

Hunger and malnutrition remain two of the most important issues facing the majority of worlds' poor and under-privileged populations. Nearly 30.00% of the populations are currently suffering from malnutrition. Over 2000 million people world-wide are currently suffering from iron deficiency. Nearly 250 million children under 5 years of age suffer from iron deficiency, which remains the single-most cause of childhood under-nutrition.

Approximately 60% of the 10.9 million deaths each year among children aged less than 5 years of age in the developing world are associated with malnutrition. Malnourished children suffer from longer and more severe illnesses (Black *et al.*, 1984; Sepulveda *et al.*, 1988) and have a higher risk of mortality and morbidity (Pelletier, 1994, 1998; Schroeder and Brown, 1994) as compared to well nourished ones. Malnutrition can also lead to delayed motor development (Pollitt *et al.*, 1994) and lower cognitive function and school performance (Pollitt, 1990) among children. Adult individuals who were malnourished as children exhibit impaired physical work capacity (Haas *et al.*, 1995) and lower reproductive performance (WHO, 1995; Martorel *et al.*, 1996). Malnutrition can also have negative effects on the children of the affected individuals (Ramakrishnan *et al.*, 1999).

Nutrition is the single most important component of preventive health care in a country and individual nutritional levels are closely related to health and disease. The nature of the diet is associated with diseases such as cancer, heart disease, diabetes, hypertension, arteriosclerosis, and liver cirrhosis. An optimum and sufficient nutrition level is the level of intake that promotes the highest level of health. However, an excess caloric intake leads to obesity, whereas a deficit results in depletion of essential nutrients. These alterations can lead to biochemical changes and eventually to clinical signs and symptoms. Nutrition requirements are influenced by many factors such as gender, age, physical activity, physiological status, drugs and alcohol intake. The ability of the human individual to respond to stresses like high altitude, heat, trauma, surgery, and infection are also strongly associated with nutritional status. However, as individuals grapple with ever-increasing sedentary life styles and less physically demanding jobs, the caloric requirements are reduced. This has made nutritionally sound food choices more difficult.

It is a well known fact that contemporary India is composed of a sizeable number of ethnic and indigenous elements having enormous amounts of ethnic and genetic diversity

(Beiteille, 1998; Majumder, 1998; Indian Genome Variation Consortium 2008). The country has one of the highest burdens of under-nutrition in the world and is beginning to experience the emerging problem of overweight and obesity (Visscher and Seidell, 2001; Mendez *et al.*, 2005; Vas *et al.*, 2005). Although, a rapid overall development has occurred in India during the last two decades in the field of public health (Griffiths and Bentley, 2001), the country shows disappointing results in the context of nutritional assessment as more than half of the world's undernourished population lives here (Krishnaswami, 2000). During the last twenty five years, a large database has been accumulated on the diet and nutritional status of rural populations belonging to different states of India. The National Nutrition Monitoring Bureau (NNMB) and the National Institute of Nutrition (NIN) have carried out extensive diet and nutrition surveys in twelve states where the diets were found to be inadequate and/or deficient in most of the nutrients (Vijayaraghavan and Rao, 1998). The reasons behind this inadequacy and/or deficiency were attributed to extreme poverty, low socio-economic status (low SES), poor living conditions and inadequate dietary intake (Ramachandran, 2007; Antony and Laxmaiah, 2008; Mahal and Karan, 2008). Lack of diversity in diets is another particularly severe problem encountered among the poor populations, where diets are based predominantly cereal based and often included little or no animal products and only seasonal fruits and vegetables (Gopalan *et al.*, 2003). It has also been observed by Rao (2001) that the nutritional scenario in India is passing through a transitional phase where the vast majority of the adult populations are suffering from Chronic Energy Deficiency (CED) and NCDs such as diabetes, hypertension and coronary heart disease. Lower maternal nutritional status, high prevalence of low birth weight (LBW), high morbidity and mortality in children are some of the other major nutritional manifestations associated with lower SES among Indian populations (Ramachandran, 2007).

1.2. DEFINITIONS OF THE TERMS "NUTRITION", "UNDER-NUTRITION" AND "MALNUTRITION"

The terms '*nutrition*', '*under-nutrition*' and '*malnutrition*' have been conceptualized and defined in many ways. The Webster's dictionary defines '*nutrition*' as "the series of processes by which an organism takes in and assimilates food for promoting growth and replacing worn and injuries tissue" (Webster's New Universal Unabridged Dictionary, 1983). The term '*undernourished*' has been defined as "to provide with less than the least amount of food needed for health and growth". This dictionary also includes the term '*under-nutrition*' which has been defined as "deficient bodily nutrition due to inadequate food intake or faulty assimilation". The 6th World Food Survey Report published by the Food and Agriculture Organization (FAO) defines '*under-nutrition*' as a state of dietary energy deficiency whereby an individual is unable to maintain good health (in the sense of being free from avoidable morbidity, risk for premature mortality and so on) or the desire level of physical activity" (FAO, 1996). Although this definition considers energy as the primary nutrients of interest, it is suggested that the optimal state of "good health" be considered as a point of reference. The Webster's dictionary has also defined 'malnutrition' as "faulty or inadequate nutrition, undernourishment resulting from insufficient food, improper diet etc" (Webster's New Universal Unabridged Dictionary, 1983).

In the literature, the terms '*under-nutrition*' and '*malnutrition*' have often been used interchangeably, traditionally in reference to the situation when an individual has an inadequate intake (or utilization) of protein and energy (or total calories). Presently, these terms are still widely used in a generic sense to refer Protein-Energy Malnutrition (PEM) or Protein-Caloric Malnutrition (PCM). However, with the gradual recognition of the critical role of micronutrients in maintaining good health and survival, the concepts of under-nutrition and malnutrition needed to be expanded.

The term '*micronutrient malnutrition*' is now commonly used to describe under-nutrition. It refers to the situation where individuals have an inadequate intake, absorption or utilization of one or more of the micronutrients. In recent years, research projects and intervention programmes especially in developing countries have focused on micronutrients such as vitamin-A, iron, iodine and zinc. Each micronutrient has multiple functions in the human body and an inadequate intake, absorption, or utilization of any one of them may result in a variety of adverse health consequences. Deficiencies in vitamin-A, iron deficiency, iodine and zinc, along with PEM represent different forms of under-nutrition that again contribute to the global burden of mortality and morbidity.

1.3. THE NUTRITIONAL TRANSITION IN INDIA

In the global context, a number of countries are witnessing demographic and nutritional transitions. The term '*nutritional transition*' is used to depict the shift in disease patterns towards nutrition related NCDs. This shift is associated with changes in behaviour, lifestyle, diet, physical activity, smoking and alcohol consumption (Amuna and Zotor, 2008). The rapidity of such nutritional transitions is clearly visible in the emerging developing nations of Asia (Kosulwat, 2002; Lipoeto *et al.*, 2004). There is also an evidence of such a rapid nutritional transition amplifying the burden of chronic diseases and obesity in India (Shetty, 2002). Time trends in childhood obesity has already predicted an escalating burden of obesity related issues in the near future in this country. A number of other countries have also reported significant levels of malnutrition and child mortality together with rising prevalence of obesity and NCDs. This double burden is a result of an interaction between various factors where social inequality merits more attention than others. Social inequality has also emerged as a major factor in differential mortality in both the developed and developing countries.

The background to Indian's nutritional transition can be traced back to the rapid economic and demographic transformations that had taken place. During the last 30 years, there has been a sustained rise in average living standards. The gross domestic product per capita rose by 23%. Poverty continued to decline at an annual rate of 0.88% during the period from 1983 to 1994 and at a slightly lower rate of 0.77% from 1993 to 1905. Life expectancy has also steadily risen from 54 years to 69 years while the Crude Birth Rate (CBR) has fallen from 34 to 22 from 1980 to 2008. Rapid economic growth has been also been accompanied by rising urbanization. During the last two decades of the 20th Century, the share of the urban population rose from 23.00% to 28.00%. By the year 2030, it is estimated to rise to 41.00%. This momentum in growth has been strongly influenced and accelerated by a wide ranging domestic and external liberalization of the Indian economy set in the 1990s. A key feature of this economic transformation has been the change reflected in the nature of the diet. There has been a perceptual shift from inferior to nutritionally sound superior foods and a substitution of the traditional staples by primary food products that are more prevalent in the western diets. These shifts were subsequently reflected in higher consumptions of proteins, sugars, fats and vegetables.

However, India still remains one of the poorest countries in the world with a population of over one billion and a fertility rate well above the replacement level (World Bank, 2000). With more than half of the world's undernourished individuals living in this country (Krishnaswami, 2000), the improvements in nutritional status of these individuals have not been quite impressive (Griffiths and Bentley, 2001). Measham and Chatterjee (1999) suggested that one of the key causes of malnutrition among the individuals in this country was the lack of access to sufficient food and resources. Nutrition research in India has mainly focused on the problem of under-nutrition, particularly among women and children. A study conducted by the National Family Health Survey 1998-1999 (NFHS-2)

showed that a significant proportion of Indian women were affected with under-nutrition and anaemia. Moreover, the health status of women in this country reflected gender discrimination from birth (Sharma, 1995; Murthy, 1996; Measham and Chatterjee, 1999), along with inadequate distribution of health resources (Ganatra and Hirve, 1994; Sharma, 1995; Choi and Lee, 2006; Singh, 2012) and early and frequent reproductive cycling and infections (Coyaji, 1991; Sarin, 1992; Ghosh, 1995; Koblinsky, 1995; Rajaram *et al.*, 1995; Brabin *et al.*, 1998).

It is now an established fact that India is in the midst of rapid socio-economic, demographic, nutritional and health transitions. While the country is yet to overcome poverty, under-nutrition and the incidence of communicable diseases, it is increasingly facing problems related to affluence as a result of industrialization, urbanization and economic betterment. Over the last two decades, over-nutrition and obesity have emerged as major public health issues. There has also been a progressive increase in the prevalence of diabetes and cardiovascular diseases especially in the urban areas. Their magnitude varied between states, between urban and rural areas and between different socio-economic groups. The NNMB and the India Nutrition Profile (INP) surveys (NNMB, 1979-2002; INP, 1995-96) observed that the prevalence of under-nutrition was lower among urban adults than rural adults. Prevalence of over-nutrition was higher in the urban areas, while over the last three decades there has been a progressive decline in under-nutrition and some increase in over-nutrition in both the urban and rural areas. Data from the NFHS (1998-99) showed the prevalence of under-nutrition in urban areas to be 50% of that in rural areas of India. The data also suggested that the prevalence of under-nutrition continued to be higher among poorer women while over-nutrition and obesity were emerging as major problems among wealthier women. As a result, it has been opined that the country should gear up for the

detection and management of this dual burden (Subramanian and Smith, 2006; Subramanian *et al.*, 2007).

The NNMB surveys were the only surveys that provided data on time trends in intra-family distribution of food and dietary intake and nutritional status of all age groups over the last three decades among different populations. The amount of food consumed was compared with the Recommended Dietary Allowance (RDA) as drawn up by the Indian Council of Medical Research (ICMR) in 1989 (Gopalan *et al.*, 1993). It was observed that over the last three decades, there has been some decline in cereal consumption in both the urban and rural areas. Over the same period there has been a steady decline in the consumption of pulses, which remains a major source of protein in Indian diets. The consumption of vegetables and fruits continued to be very low. In the rural areas there were no significant increases in per-capita consumption of fats, oils, sugar and jaggery. It has been further suggested that the dietary intake has not undergone any major shift towards increases in the consumption of processed food and energy intake.

The country is now facing a dual burden of high communicable and rising NCDs (World Bank, 1993). A progressive decline in poverty ratio and a steep increase in per capita income have been suggested to be the main reasons. Economic improvement inevitably results in improved purchasing power and that can lead to increases in energy intake from fats, sugar, refined carbohydrates, and reduction in energy intake from complex carbohydrates and reduction in dietary fiber. Simultaneously there has been a reduction in physical activity and perhaps an increase in work-related stress because of changes in occupation. The increase in the proportion of body fat as measured by the body mass index (BMI) and the prevalence of abdominal obesity is higher among Indians (Ramachandran, 2004; Ramachandran *et al.*, 2004). The prevalence of over-nutrition and abdominal obesity are closely associated with increased risks of hypertension and diabetes among Indians adults

(Yagnik, 1998; Gupta *et al.*, 2003; Gupta 2004; Bhargava *et al.*, 2004; Deshmukh *et al.* 2006a; Gupta *et al.* 2007; Gupta *et al.*, 2008). A review of the studies suggested a steady increase in the number of NCDs in the country and that this increase is most marked in the urban areas.

Nearly one-third of all Indian infants weigh less than 2.5 kg at birth. Incidence of LBW appears to be the highest among low-income groups (Prema, 1989). With an increase in survivability of LBW neonates, there are growing concerns about the relationship between LBW and poor growth during childhood and adolescence as well as the increased risk of chronic degenerative diseases in later life. A sizable number of studies are available from India on the prevalence of LBW and its associated factors (Rajanikumari *et al.*, 1986; Bhargava *et al.*, 1991; Kinare *et al.*, 2000; Rao *et al.*, 2001; Dwarkanath *et al.*, 2007).

The prevalence of anaemia and iron deficiency is widespread among Indian populations, especially among women and children. Anaemia remains to be major cause of maternal mortality accounting for over 20.00% of all maternal deaths. The nationally representative data from the NFHS (1998-1999) on anaemia among women described the magnitude of this problem. More than a third of all Indian women had a BMI <18.50 kg/m^2, thereby reflecting CED and micronutrient deficiency. The prevalence of anaemia among them was 52%, whereas 15% of them were classified as moderately anaemic and 2% as severely anaemic. A recent study has also suggested that nearly 50% of all young Indian women were anaemic (Thankachan *et al.*, 2007). The preponderance of malnutrition in terms of micronutrient deficiency appears to be the primary factor responsible for the high prevalence of anaemia and iron deficiency. It has been reported by Singh (2004) that over two-thirds of all Indian children exhibited clinical evidences of iron deficiency and also that deficiencies of trace minerals such as iodine and zinc were quite common. As a result, India

became the first developing country to take up a National Nutritional Anaemia Prophylaxis Programme (NNAP) to prevent anaemia among pregnant women and children.

1.4. METHODS OF NUTRITION STATUS ASSESSMENT IN HUMANS

The nutritional status of an individual is the result of many interrelated factors such as his/her physical health (WHO, 1978). The objectives of nutritional assessments are twofold:

a) To obtained precise information on the prevalence and the geographic distribution of under- and over-nutrition status of a given population.

b) To identify the at-risk group within the population who are in need of nutritional assistance.

The objectives have been aptly reviewed by Hetzel (1985) who also observed that the main thrust of nutritional assessment studies was to develop health care facilities that met the needs defined by the assessment, including evaluation and effectiveness of subsequent programmes. The assessment of nutritional status of an individual or a population involves various techniques. Proper evaluation demands a multi-dimensional approach, covering all the different strategies. Jelliffe (1966) in his excellent monograph "*The Assessment of the Nutritional Status of the Community*" has proposed six methods for the assessment of nutritional status. In general, the WHO has classified the available methods of assessing nutritional status into two categories:

a) Direct methods (e.g., anthropometry and biochemical techniques)

b) Indirect methods (e.g., vital statistics)

1.4.1. ANTHROPOMETRY

Anthropometry is a non-invasive and an inexpensive technique that has been widely used to assess the size and proportion of the human body. It is a useful technique to assess nutritional status and body composition of an individual or a population (Jelliffe, 1966; WHO, 1966; Hamieda and Billot, 2002).

The measurements of height, weight, skinfold thicknesses and arm circumference are valuable indicators of nutritional status. The additional measurements include head circumference and chest circumference. The measurements of Mid-Upper Arm Circumference (MUAC) (James *et al.*, 1994; de Onis *et al.*, 1997) and Waist Circumference (WC) (WHO, 2000) are also useful in the assessment of under- and over-nutrition respectively. Skinfold measurement such as Biceps Skin Fold (BSF), Triceps Skin Fold (TSF), Sub-scapular Skin Fold (SSF) and Supra-iliac Skin Fold (SISF) are also frequently used to estimate subcutaneous adiposity and thus nutritional status (Weiner and Lourie, 1981; Gibson, 1990; Lee and Neiman, 2005). Percent of Body Fat (PBF), upper arm composition in terms of Upper Arm Muscle Area (UMA), Upper Arm Fat Area (UFA) and TSF-for-age can are also used for the assessment of nutritional status.

A number of indices are calculated from the anthropometric measurements. The commonly used ones are stunting (low height-for-age), underweight (low weight-for- age), wasting (low weight-for-height), thinness (low BMI-for-age), MUAC-for-age and MUAC-for-height. These indices are expressed in terms of Z-scores or percentiles. The WHO recommends a comparison of these indices with an international reference population to determine under-nutrition (Dibley *et al.*, 1987). The justification for use of a reference population is the empirical finding that well-nourished children of all populations follow very similar growth patterns (Habicht *et al.*, 1974).

The BMI is a surrogate anthropometric indicator of overall adiposity (both overweight and obesity) and is an established indicator for adult nutritional assessment (Weiner and Lourie, 1981; Gibson, 1990; Lee and Nieman, 2005; WHO, 1995). Such assessments using BMI is very suitable in the field situations (James *et al.*, 1988; Ferro-Luzzi *et al.*, 1992; Ferro-Luzzi and James, 1996). The use of BMI, together with WC, Waist-Hip

Ratio (WHR), Waist-Height Ratio (WHtR), and Conicity Index (CI) have been found to be quite useful for the differentiation of overweight and obesity among adult individuals.

1.4.2. Biochemical assessment

The underlying principle of this method is that any changes in the quantity and composition of the diet and nutrients are 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. Such estimations of the concentration levels reflect the nutritional status of the individuals. The most important laboratory tests include haemoglobin estimation and stool and urine tests. With the increasing knowledge of the metabolic functions of vitamins and minerals, assessment of nutritional status by clinical signs has given way to more precise biochemical tests which may be applied to measure individual nutrient concentration in fluids and biomarkers (*e.g.*, whole blood, serum and head hair). The tests can also include the determination of metabolites in urine (*e.g.*, urinary iodine) or estimation of enzymes to document malnutrition in the pre-clinical stages. The biochemical tests also include estimation of vitamins and essential trace element concentrations.

1.4.3. Clinical examination

The 1963 WHO Expert Committee on Medical Assessment of Nutritional Status provided a classification of the physical signs that can be utilized for nutritional assessments. This classification was subsequently updated in the WHO Monograph Series No. 53 entitled "*The Assessment of the Nutritional Status of the Community*" (Jelliffe, 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.

1.4.4. DIETARY INTAKE

Methods of dietary intake at the individual or the population level utilize various procedures to estimate food, energy and nutrient intakes. Direct assessment of food consumption involves a dietary survey which may be conducted either at the household or the individual level. Such a survey provides information about the dietary intake patterns of specific foods consumed and estimated nutrient intakes. The dietary assessment methods are useful to evaluate the nutrient intake for research or large scale surveillances and in clinical assessment. This method has also assumed prime importance as nutritionists now recognize the major role that nutrition plays in the prevalence of obesity, heart diseases and diabetes (together termed as "*etiology of common chronic diseases*"). Accurate and reliable methods for assessing dietary intake of a free living population are desirable to answer important questions regarding associations between the processes involved in the etiologic of disease (Beaton *et al.*, 1983). Dietary investigations are carried out using a number of methods. These methods are the 24-hour recall (24-HR) method, weighted intake method, food frequency questionnaire (FFQ), food diary, dietary history and oral questionnaire method (Gibson, 1990; Lee and Nieman, 2005).

The most widely used method for field of dietary intake is the 24-HR method (Beaton *et al.*, 1983; Baranowski *et al.*, 1991; Egger *et al.*, 1991; Nicklas *et al.*, 1995; Olinto *et al.*, 1995). In the developed countries, the FFQ have been also utilized for identifying dietary risk factors associated with chronic diseases like coronary artery disease and various forms of cancers (Graham *et al.*, 1967; Bjelke, 1975; Date *et al.*, 1996; Shu *et al.*, 2004).

Bingham *et al.* (1994) compared the FFQ and the 24-HR methods and observed that these methods were closely associated with diet and there was no significant different between the in average food and nutrient intake. A validation study conducted by Beer-Borst and Amada (1995) on self-administered 24-HR questionnaires among 3,653 individuals

concluded that the self-administered 24-HR questionnaire was a valid method for estimating the median and mean dietary intakes of such large groups of individuals. The feasibility and relative validity of the 24-HR method was also tested on 60 pregnant women in rural southern Malawi by Ferguson *et al.* (1995). Relative validity was assessed by comparing the intakes from two 24-HRs with those assessed by using two weighed records (reference method) conducted on the same two days. The average intakes obtained by the two methods were in good agreement with each other, thus confirming that the 24-HR method could be used to determine average intakes. Schatzkin *et al.* (2003) in their comparison of the FFQ and 24-HR methods also observed the utility of these methods for detecting protein and energy intake statuses.

SES plays a major role in the dietary intake the dietary intake of individuals and population groups. A number of studies was undertaken to understand the effects of SES on the dietary intake of populations (Egger *et al.*, 1991; Ivanovic, 1992; Bialostosky *et al.*, 2002; Barquera *et al.*, 2003; Capdevila *et al.*, 2003; Borges-Yañez *et al.*, 2004; Vitolo *et al.*, 2006; Manios *et al.*, 200 9; Montenegro-Bethancourt *et al.*, 2009). Using the 24-HR method, Egger *et al.* (1991) showed that children belonging to a lower SES had a lower fat intake, a lower contribution of fat to the energy intake and a higher contribution of carbohydrates to the energy intake as compared to children belonging to a higher SES. Barquera *et al.* (2003) reported that socioeconomic status reflected an increasing availability of inexpensive calorie-dense foods in marginal groups, and total energy, cholesterol, saturated and total fat were consumed in greater quantities by women from higher SES of the urban areas. Similar results were also reported on the consumption pattern and SES among Spanish adult individuals (Capdevila *et al.*, 2003). Studies have also reported that certain demographical and socio-economic factors influenced the dietary habits of individuals (Manios *et al.*, 2009; Velasco *et al.*, 2009).

1.4.5 VITAL STATISTICS

An analysis of the mortality and morbidity data, along with 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 on 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.

1.4.6. ECOLOGICAL STUDIES

Malnutrition is 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 comprised food balance sheets, a number of socio-economic factors, health and educational services and finally conditioning influences.

1.5. REVIEW OF THE PUBLISHED LITERATURE

As the scope of the present study is limited to nutritional assessment using the methods of anthropometry and dietary intake, a review of the studies done in these two aspects are being detailed below.

1.5.1. NON-INDIAN STUDIES DONE ON NUTRITIONAL ASSESSMENT USING ANTHROPOMETRY

Anthropometry is a useful technique to assess nutritional status and body composition of an individual or population (Jelliffe, 1966; Rao *et al.*, 1976; Gorstein *et al.*, 1994). This technique has been successfully utilized by various researchers to document nutritional status of different human populations. The studies of Rolland Cachera, (1989), Rolland Cachera *et al.* (1991), Pelletier *et al.* (1991, 1994, 1998), Dittwyler (1992), Ferro-Luzzi *et al.* (1992) Strickland and Ulijaszek (1993), Giay and Khoi (1994), Aiken (1995), Alemu and Lindbjorn (1995), Rotimi *et al.* (1995), Ferro-Luzzi and James (1996), Martorel *et al.* (1996), Higgins

and Alderman (1997), Zerihun *et al.* (1997), Smolej-Narančić (1999), Teller and Yimar (2000), Kuczmarski *et al.* (2000), Bloom *et al.* (2001), Chilima and Ismail (2001), Bakr *et al.* (2002), Schutz *et al.* (2002), Nubé and van den Boom (2003), Kyle *et al.* (2003), Zohoori *et al.* (2003), Zverev and Chisi (2004), Pichard *et al.* (2004), Nikolic *et al.* (2005), Tur *et al.* (2005), Barker *et al.* (2006), Sánchez-García *et al.* (2007), Shafique *et al.* (2007), Huxley *et al.* (2008) and Nubé (2009) may be cited here.

The BMI is a useful indicator in assessing the health condition of a community. It is also now an established anthropometric indicator used for the assessment of adult nutritional status (Weiner and Lourie, 1981; James *et al.*, 1988, 1994; Gibson, 1990; Ferro-Luzzi *et al.*, 1990, 1992; Naidu and Rao, 1994; Shetty and James, 1994; Bailey and Ferro-Luzzi, 1995; WHO, 1995; Ferro-Luzzi and James, 1996; Lee and Nieman, 2005). The FAO and the International Dietary Energy Consultative Group (IDECG) have suggested that BMI should also be used to define adult CED (Weisell, 2002). Studies have recognized that BMI was a good indicator for the understanding of under-nutrition in terms of CED among different populations (Ferro-Luzzi *et al.*, 1990, 1992; Gibson, 1990; WHO 1995; Ferro-Luzzi and James, 1996; Lee and Nieman, 2005). Several studies have also investigated the relationship between SES, BMI and CED among different ethnic populations (Deurenberg *et al.*, 1991; Pryer, 1993; Shetty and James, 1994; Delpeuch *et al.*, 1994; Ahmed *et al.*, 1998; Nubé *et al.*, 1998; Khongsdier, 2001, 2002, 2005; Pryer *et al.*, 2003; Clausen *et al.*, 2006; Monteiro *et al.*, 2007; Shannon *et al.*, 2008). Studies have also focused on the association of percent body fat with BMI (Deurenberg-Yap *et al.*, 2000; Shah *et al.*, 2005; Kolt *et al.*, 2007). Studies have also evaluated the relationship between BMI and mortality (Costa, 1993; Allison *et al.*, 1997; Calle *et al.*, 1999; Khongsdier, 2002, 2005). A study conducted in the developing countries has observed that women with a BMI less than 18.50 kg/m^2 showed a progressive increase in

mortality rate and an increased risk of illness (Rotimi *et al.*, 1999) and associated health problems during pregnancy and lactation (Allen *et al.*, 1994; Prentice *et al.*, 1994).

An understanding of distribution and redistribution of fat is necessary in order to assess obesity and under-nutrition within a population. The BMI, together with different adiposity indicators such as WHR, CI and WHtR has been observed to be very useful for the differentiation of over-nutrition (overweight and obesity) among adults. The WHR provides an indication of the predominance of fat storage in the abdominal region (regional adiposity). Furthermore, WC can also be useful to assess nutritional status (*e.g.*, overweight and obesity) of adults and children (WHO, 2000). The skinfold measurements have been the most frequently used for the estimation of subcutaneous adiposity. The measurement of BSF, TSF, SSF and SISF gives the adiposity measures and reflects the nutritional status (Siri, 1956; Durnin and Womersely, 1974; Frisancho, 1974, 1981, 1989; Gibson, 1990; VanItallie *et al.*, 1990; Eckhardt *et al.*, 2003).

The MUAC is another simple anthropometric measurement that has been extensively used to determine the nutritional status of adult individuals, particularly from different ethnic population in the developing countries (Bern and Nathanail, 1995; Collins, 1996; Ferro-Luzzi and James, 1996; Gartner *et al.*, 2001; Khadivzadeh, 2002; Zverev and Chisi, 2004; Bose *et al.*, 2007a; Bisai and Bose, 2009; Lemma and Shetty, 2009; Chakraborty *et al.*, 2009; Chakraborty *et al.*, 2011). James *et al.* (1994) after an extensive study in eight countries (Mali, India, Senegal, Zimbabwe, Somalia, Ethiopia, Papua New Guinea and China) suggested that MUAC could be used for a simple screening of adult nutritional status. It has also been opined that BMI in combination with MUAC can provide a much better assessment of CED (Ferro-Luzzi *et al.*, 1992; James *et al.*, 1994; Bern and Nathanail, 1995; Ferro-Luzzi and James, 1996; Ahmed *et al.*, 1998; Dorlencourt *et al.* 2000; Gartner *et al.*, 2001; Suzana *et al.*, 2002; Nair *et al.*, 2006). It has been noted that since MUAC is a simpler

measure than BMI and require a minimum of equipment, it can predict morbidity and mortality as accurately as deficits in weight (Breind *et al.*, 1989). It could be used both in emergency situation where semi-skilled monitors are available. It can thus, be used as a substitute for BMI when rapid screening of an adult population is required as a prelude to targeting intervention for the undernourished (James *et al.*, 1994).

1.5.2. Indian Studies done in the assessment of nutritional status using anthropometry

The basic causes of under-nutrition in the developing countries such as India are related to poverty, poor hygienic conditions and little access to preventive health care (WHO, 1990). In these developing countries, anthropometry remains the most practical technique for the assessment of nutritional status of individuals or populations (Khongsdier, 2001, 2002, 2005). Several studies have been undertaken to assess the nutritional status of individuals belonging to different ethnic Indian populations using anthropometry. Most of the studies have assessed nutritional status using the conventional anthropometric indices of stunting (height-for-age), underweight (weight-for-age) and wasting (weight-for-height) and comparing them with the reference data of National Centre of Health Statistics (WHO/NCHS, 1983; WHO, 1995).

1.5.2.1. Studies done on pre-school children using anthropometry

India shows the highest occurrence of childhood under-nutrition in the world (Bamji, 2003). It has been estimated that more than half of the country's children are undernourished (Measham and Chatterjee, 1999). The prevalence of under-nutrition among Indian children is far higher than the countries with similar levels of economic development (Gragnolati *et al.*, 2005). A number of studies have been undertaken to assess and document the prevalence of under-nutrition among Indian pre-school children utilizing the conventional anthropometric indices. The studies of Upadhyay *et al.* (1992), Rajasree and Soman (1994),

Pal (1999), Yadav *et al.* (1999), George *et al.* (2000), Rao *et al.* (2000, 2004), Awasthi *et al.* (2003), Rajaram *et al.* (2003), Shaikh *et al.* (2003), Bishno *et al.* (2004), Kumari (2005), Kaur *et al.* (2005), Pooni *et al.* (2006), Rao *et al.* (2006b), Sharma *et al.* (2006), Singh *et al.* (2006), Som *et al.* (2006, 2007), Bose *et al.* (2007a, 2008a), Bharati *et al.* (2008, 2009), Das and Bose (2009a), Dutta *et al.* (2009) and Bisai and Mallick (2011) may be cited here. Due to the high prevalence of under-nutrition among pre-school children, the Government of India started the Integrated Child Development Scheme (ICDS) aimed for early detection and prompt and effective treatment of under-nutrition among them. However, studies have reported a high level of under-nutrition among these children. Here the studies of Bose *et al.* (2007a), Mandal *et al.* (2008) and Biswas *et al.* (2009) are mentionable.

Very recently, studies have reported the prevalence of under-nutrition among pre-school children in India utilizing the Composite Index of Anthropometric Failure (CIAF). In this connection, the studies of Nandy *et al.* (2005), Seetharaman *et al.* (2007), Biswas *et al.* (2009), Das and Bose (2009b), Deshmukh *et al.* (2009), Mandal and Bose (2009), Mukhopadhyay *et al.* (2009) and Mukhopadhyay and Biswas (2011) are mentionable.

1.5.2.2. Studies done on children aged more than 5 years using anthropometry

In India, extensive studies have been undertaken to assess the prevalence of under-nutrition status among Indian children in the ages of 5-12 years. Using the conventional indices, a large number of studies have reported high prevalence of under-nutrition among them. Here the studies of Chhabra *et al.* (1996); Kumar *et al.* (1996), Vazir *et al.* (1998), Yadav and Singh (1999), Brahmbhatt *et al.* (2001), Choudhary (2001), Mitra *et al.* (2002; 2007), Elizabeth and Muraleedharan (2003), Vashisht *et al.* (2005), Bhanderi and Choudhary (2006), Mittal and Srivastava (2006), Medhi *et al.* (2006), Bisai *et al.* (2008), Bose *et al.* (2008a), Chowdhury *et al.* (2008), Chakrabarty and Bharati (2010a), Mondal and Sen, (2010a), Banik and Chatterjee (2010) and Gupta *et al.* (2011) may be cited. Very recently,

studies have used the CIAF to report the prevalence of under-nutrition among children aged more than 5 years (Sen *et al.*, 2011a; Sen and Mondal, 2012).

Kishor (1993) and Gopaldas and Gujral (1995) have reported that in almost all Indian populations, boys have a better access to food and basic amenities than girls and that there was a pronounced preference for the male child. Numerous studies have further reported discriminations in diet and basic amenities against the girl child and that the girls were engaged in many different strenuous household chores thereby affecting their nutritional status (Ghosh, 1990; Devendra, 1995; Borooah, 2004). Several studies have also documented the fact that girls were more affected by under-nutrition than boys (Singh *et al.*, 1996; Yadav and Singh, 1999; Vashisht *et al.*, 2005; Bose *et al.*, 2007a; Mondal and Sen, 2010a, b; Sen *et al.*, 2011a, b; Sen and Mondal, 2012).

The body build of a child can be very accurately assessed using BMI (Bhalla, 2002). Mitra *et al.* (2002) carried out a cross sectional growth study on the Kamar, a primitive tribe of Chhattisgarh using this index. They compared the data with that of other Indian tribes and the ICMR all India data, and concluded that poor SES of this primitive tribe may be one of the reasons for the poor growth pattern of the children.

Very recently, the use of low-BMI-for-age or thinness has been introduced by Cole *et al.* (2007) to assess child nutritional status. Studies have subsequently been conducted to document the prevalence of under-nutrition using thinness among Indian children. Here the studies of Bose and Bisai (2008a), Mandal *et al.* (2008), Chakraborty and Bose (2009), Ghosh and Bandyopadhyay (2009), Mondal and Sen (2010c) and Sil *et al.* (2011) may be cited.

1.5.2.3. STUDIES DONE ON ADOLESCENTS USING ANTHROPOMETRY

The adolescent period is a very important phase in the life span of an individual. It is defined as the period of transition between childhood and adulthood and is characterized by

an exceptionally rapid rate of growth (Tanner, 1978). In India, the adolescents comprise a nutritionally vulnerable segment of the Indian population. Most of the adolescents belonging to the lower socio-economic groups are reported to be affected by under-nutrition. Several studies have been undertaken to document the prevalence of under-nutrition using stunting (low-height-for-age) and thinness (low-BMI-for-age). A significant number of studies have reported the prevalence of under-nutrition among Indian adolescents. They include those of Anand *et al.* (1999), Bose and Mukhopadhyay (2004), Das and Biswas (2005), Khongsdier *et al.* (2005), Bose and Bisai (2008b), Banerjee *et al.* (2009), Prashant and Shaw (2009), Banik and Chatterjee (2010), Bisai *et al.* (2011) and Shivaramakrishna *et al.* (2011).

The studies of Deshmukh *et al.* (2006b), Das *et al.* (2007) and Medhi *et al.* (2007) have reported that a significant proportion of the adolescent population exhibited a high prevalence of under-nutrition. Utilizing data from the NNMB, Venkaiah *et al.* (2002) reported that 39% of the rural adolescents were stunted. Malhotra and Passi (2007) reported the prevalence of stunting to be 29.7% among rural adolescent girls from North India. Anand *et al.* (1999) reported the prevalence of stunting to be 37.2% among adolescent girls and 41% among adolescent boys, with an overall prevalence of 38.5%. Recently, Mondal and Sen (2010c) has reported that a high prevalence of stunting (46.6%) among rural adolescent boys and girls from North Bengal. Very recently, Maiti *et al.* (2011) have reported the prevalence of stunting to be 34.2% among adolescents from Paschim Medinipur district of West Bengal.

A number of studies have reported a high prevalence of thinness utilizing BMI-for-age (Anand *et al.*, 1999; de Onis *et al.*, 2001; Venkaiah *et al.*, 2002; Deshmukh *et al.*, 2006b; Malhotra and Passi, 2007; Medhi *et al.*, 2007; Mondal and Sen, 2010c). It is now a generally accepted fact that there existed a high prevalence of thinness among Indian communities and that more than 50.00% of the adolescents were affected (de Onis *et al.*, 2001; Deshmukh *et al.*, 2006b). Venkaiah *et al.* (2002) reported that the prevalence of thinness to be higher

among boys (53.10%) than girls (39.50%). Rao *et al.* (2006a) utilizing the NNMB data from 9 Indian states, reported the prevalence of thinness among tribal adolescent to be 63% among boys and 42% among girls. They also obtained a significant association between under-nutrition and different socio-economic parameters (family type, size of land holding and occupation). Low prevalence thinness among adolescent girls (30.6%) has also been reported from North India (Malhotra and Passi, 2007). In a very recent study, Maiti *et al.* (2011) reported the overall extent of thinness to be as high as 37.7% among adolescents of Paschim Medinipur district of West Bengal.

1.5.2.4. STUDIES DONE ON ADULT INDIVIDUALS USING ANTHROPOMETRY

There have been a sizeable number of contributions in the issue of adult nutritional among different populations of India. Here the studies of Visweswara Rao *et al.* (1990, 1992, 1995), Durandhar and Kulkarni, (1992), Ferro-Luzzi *et al.* (1992), Gopinath *et al.* (1994), Reddy (1998), Yadav *et al.* (1999), Mehta and Shringarpure (2000), Zargar *et al.* (2000), Dudeja *et al.* (2001), Khongsdier (2001, 2002, 2005), Gogoi and Sengupta (2002), Shukla *et al.* 2002, Sahani (2003), Snehalatha *et al.* (2003), Bose and Chakraborty (2005), Arlappa *et al.* (2005), Khongsdier *et al.* (2005), Venkatramana *et al.* (2005), Adak *et al.* (2006), Ghosh and Bharati (2006), Bhardwaj *et al.* (2006), Bose *et al.* (2006a, b, c), Gautam *et al.* (2006), Subramanian and Smith (2006), Bose *et al.* (2007 a, b, 2008 a, b, 2009), Banik (2007), Banik *et al.* (2007, 2009), Bharati *et al.* (2007, 2009), Subramanian and Smith (2006), Subramanian *et al.* (2007), Chakrabarty *et al.* (2008, 2009), Bisai and Bose (2009), Sarkar *et al.* (2009) Chakrabarty and Bharati (2010b) and Masoodi *et al.* (2010) are mentionable.

It has been suggested that most of the adult individuals from India were affected by different grades of undernourishment or CED (James *et al.*, 1999). It was reported that a high proportion of them (49%) suffer from different grades of CED (Naidu and Rao, 1994). In a significant study among the War Khasi of rural Meghalaya, Khongsdier (2002) reported that

35% of them were suffering from CED. In another important study involving 81,712 rural women from 26 states and 6 zones, Bharati *et al.*, (2007) reported that 31.2% of them were suffering from CED.

A number of studies have been done using BMI as an indicator of nutritional status and socio-economic conditions (Shetty and James, 1994; Khongsdier, 2002; Subramanian and Smith, 2006; Subramanian *et al.*, 2007). Recently, a review of the studies done in the field of nutritional assessment using BMI in India has been published (Mondal and Sen, 2009). A review of the studies done using MUAC in India has also been recently published (Sen *et al.*, 2010a). The BMI along with WC, HC and WHR have also been used to assess body composition and regional adiposity in many studies (Misra *et al.*, 2001; Bose *et al.*, 2005; Das and Bose, 2006; Misra *et al.*, 2003). Association between body fat densities, disease risk factors with BMI among different populations of India have also been reported (Zaadstra *et al.*, 1993; Singh *et al.*, 2000; Misra *et al.*, 2001, 2003, 2004; Bose *et al.*, 2003; Ghosh and Das Chaudhuri, 2005; Ghosh *et al.*, 2004, 2006; Ghosh, 2006; Ghosh and Bandyopadhyay, 2007).

There have been a number of studies in the assessment of nutritional status among individuals belonging to different Indian tribal populations. Using BMI, the recent studies of Bose *et al.* (2006a) among the Santal, Mittal and Srivastava (2006) among the Oraon, Bose *et al.* (2006b) among the Savar and Chakrabarty and Bharati (2010b) also among the Savar have documented a high prevalence of under-nutrition. Arlappa *et al.*, (2005) conducted a study among the tribal elderly population from 9 provincial states of India and reported that females were more affected than males (65.4% versus 61.8%). Bose *et al.* (2006a) reported a high prevalence of under-nutrition among adult Santal individuals (males: 26.2%; females: 33.7%).

A large scale study was conducted adult males belonging to 38 different populations and comprising of 5 major social groups that included scheduled tribe, scheduled caste, other backward caste, general caste and Muslim populations from central India by Adak *et al.* (2006). It was observed that the prevalence of under-nutrition was the lowest among the general castes (43.1%) as compared to the scheduled castes (60.3%), the scheduled tribes (51.5%), other backward castes (51.7%) and the Muslims (47.5%).The higher level of nutritional status among the general caste was corroborated by their higher social and economic status.

Gautam *et al.* (2006) utilized anthropometric data collected by the Anthropological Survey of India to assess the nutritional status using BMI of 31 populations residing in 38 districts of central India They reported a higher level of nutritional status among the populations of the non-backward districts. However, they opined the need for further intensive investigations in these populations, as because BMI being a measure of CED, the severity of CED and morbidity, mortality and health status need to be studied.

A recent study was conducted by Chakrabarty *et al.* (2008) on body composition and nutritional status among adult individuals belonging to the major social groups of the states of Odisha and Bihar. The results indicate that in Odisha, individuals belonging to the scheduled tribes have lower mean values of BMI and cormic index as compared to those of the other groups, whereas in Bihar, schedule caste individuals had lowest mean values of BMI. The scheduled castes and tribes of Bihar showed the highest prevalence of CED (64.71% and 57.45% respectively). The results further suggested that Muslims were more affected with CED (52.62%), but the overall prevalence of CED was lower in Odisha (49.11%) than in Bihar (54.62%).

1.6.1. NON-INDIAN STUDIES DONE ON NUTRITIONAL STATUS UTILIZING DIETARY METHODS

Extensive studies have been undertaken using dietary methods to depict under-nutrition in different populations (Fogarty and Nolan, 1992; Heitmann and Lissner, 1996; Gharbi *et al.*, 1998; Mennen *et al.*, 2000; Banjong *et al.*, 2003; Corrêa Leite *et al.*, 2003; Wu *et al.*, 2005; Esmaillzadeh *et al.*, 2008). Studies have also highlighted the dietary intake and food-related behaviour among different populations (Hatloy *et al.*, 1998; Onyango *et al.*, 1998; Trudeau *et al.*, 1998; Tarini *et al.*, 1999; Gray-Donald *et al.*, 2000; Mennen *et al.*, 2000; Mennen *et al.*, 2001; Starkey *et al.*, 2001; Capps *et al.*, 2002; Neuhouser *et al.*, 2004; Roos *et al.*, 2004; Alves and Boog, 2007).

A number of studies have been conducted in this aspect among pre-school children aged less than 5 years (Baranowski *et al.*, 1991; Davies, 1997; Omar, 2000; Weker *et al.*, 2000; Chen *et al.*, 2002; Navia *et al.*, 2003; Cooke *et al.*, 2004; Faber, 2005; Manu and Khetarpaul, 2006; Manios *et al.*, 2009; Frackiewicz *et al.*, 2011; Jennings *et al.*, 2011). Studies have also been done among children more than 5 years of age and adolescent (Egger *et al.*, 1991; Royo-Bordonada *et al.*, 2003; Adams *et al.*, 2005; Heath and Panaretto, 2005; Blum *et al.*, 2005; Al Sabbah et *al.*, 2007; Martin *et al.*, 2008; Abudayya et *al.*, 2009; Kollataj *et al.*, 2011; Shiu *et al.*, 2012). Studies have also been conducted among adult by Taylor *et al.* (1992), Adachi and Hino (2005), Wang *et al.* (2008) and elderly individuals by Fogarty and Nolan (1992), Posner *et al.* (1994), Maruapula and Chapman-Novakofski (2006), Johnson *et al.* (2008) and Risonar *et al.* (2009).

Studies have also pointed out the specific dietary and nutrient intake patterns with respect to urban and rural individuals by Fogarty and Nolan (1992), Taylor *et al.* (1992), Posner *et al.* (1994), Barquera *et al.* (2003), Tooze *et al.* (2007), Wang *et al.* (2008) and Manios *et al.* (2009). Most of these studies have shown the mean consumption of different food and nutrients to be higher among urban individuals as compared to rural individuals.

Deficiencies in vitamin-D, vitamin-A, vitamin-E and thiamine are a serious problem in the developing countries (Christian *et al.*, 1998, 2000; Krishna *et al.*, 1999; Andiran *et al.*, 2002; Pehlivan *et al.*, 2003; Maghbooli *et al.*, 2007; Khatib and Elmadfa, 2009; Lips, 2010; Dror and Allen, 2011). Studies have also indicated that a majority of the elderly individuals were suffering from vitamin deficiencies (Charlton *et al.*, 1997; Huang *et al.*, 2001; Martins *et al.*, 2002; Watanabe *et al.*, 2004; Chen *et al.*, 2005; Hinds *et al.*, 2011). It has been reported by Asobayire *et al.* (2001) that the prevalence of iron deficiency was 41%-63% among women and children and 13% among males from Africa. Zinc deficiency has also been observed to be widespread in the developing countries particularly among children and pregnant females (Ferguson *et al.*, 1993; Huddle *et al.*, 1998).

1.6.2. INDIAN STUDIES DONE ON NUTRITIONAL STATUS UTILIZING DIETARY METHODS

The inadequacy in diet is one of the key causes of under-nutrition among Indian populations. The vulnerable groups are children, adolescents, pregnant mothers and the elderly (Singh, 2002; Arlappa *et al.*, 2005, 2011; Rao *et al.*, 2006a, 2010; Malhotra and Passi, 2007; Mitra *et al.*, 2007; Harinarayan *et al.*, 2008; Laxmaiah *et al.*, 2012). These inadequacies are believed to be due to poor living conditions and inadequate intake of dietary micronutrients (Thankachan *et al.*, 2007). A number of studies have been conducted in the field of nutritional status assessment and dietary intake among individuals belonging to different Indian populations. Here the studies of Venkatachalam *et al.* (1962), Jyothi *et al.* (1963), Gill *et al.* (1968), Rao and Gopalan (1969), Bamji (1970), Swaminathan *et al.* (1973), Narayanan *et al.* (1974), Purohit and Sharma (1975), Vijayalakshmi and Devaki (1976), Rajalakshmi and Ramakrishnan (1978), Vijayadurgamba and Geervani (1979), Pushpamma *et al.* (1982), Vijayaraghavan and Rao (1998), Mittal and Srivastava (2006), Yajnik *et al.* (2006), Harinarayan *et al.* (2007) and Puri *et al.* (2008) may be mentioned.

1.6.2.1. INDIAN STUDIES DONE ON NUTRITIONAL STATUS UTILIZING DIETARY METHODS AMONG CHILDREN AND ADOLESCENTS

A number of studies have been conducted to assess the food, nutrition and dietary habits of the children (Sidhu *et al.*, 1993; Begum, 1994; Rao *et al.*, 1994; Khader, 1996; Jood *et al.*, 2000; Singh *et al.*, 2006; Kulsum *et al.*, 2009) and adolescents (Choudhary *et al.*, 2003; Rao *et al.*, 2006a; Malhotra and Passi, 2007; Gupta *et al.*, 2010; Sanwalka *et al.*, 2010) belonging to different Indian populations. Joshi *et al.* (1989) have reported the nutritional status among pre-school children from Hyderabad using dietary methods. The association of SES with dietary intake showed that dietary inadequacy was significantly higher among children belonging to a lower SES than a higher SES (Qamra *et al.*, 1990). Khader (1996) has reported dietary intake and nutrient adequacy status of rural pre-school children from Andhra Pradesh. The food intake and nutrient distribution patterns among Rajput children of Rajasthan were studied by Saxena and Ulijaszek (1998). A study was also been conducted on children belonging to different tribal populations of Maharashtra by Singh (2002).

Utilizing the NNMB (1998-1999) data recorded from tribal adolescent girls of 9 states in India, Rao *et al.* (2006a) reported that food and nutrient intake was grossly inadequate. The mean intake of the foodstuffs, especially the income elastic foods such as pulses, milk and milk products, oils and fats and sugar and jaggery were lower than the RDA of the ICMR (2000). Choudhary *et al.* (2003) reported the energy expenditure and energy balance among rural adolescents girls in Varanasi utilizing the 24-HR oral questionnaire method. They observed that the average energy intake of 1609.42 ± 528.87 kcal/day was less than their mean energy expenditure of 1896.19 kcal/day. The energy expenditure was also significantly influenced by age, caste and family type.

A recent study by Malhotra and Passi (2007) assessed the diet quality and nutritional status of beneficiaries of the Adolescent Girl Scheme, a national programme targeted

towards the nutritional/health needs of adolescents. They reported that the girls followed a two-meal pattern and their diets were monotonous and cereal-based. Nearly half of them (49.3%) were observed to have an energy intake less than 75% of the RDA. A substantial proportion of them had inadequate nutrient intake with respect to most of the food groups and nutrients, especially iron (84.7%), folic acid (79.4), vitamin-A (73.2%), milk and milk products (47%), pulses (36%), green leafy vegetables (GLVs) (26%), other vegetables (34%) and fruits (3%) as compared to the suggested levels of the RDA.

1.6.2.2. INDIAN STUDIES DONE ON NUTRITIONAL STATUS UTILIZING DIETARY METHODS AMONG ADULTS

A large amount of scientific literature is present on the assessment of dietary intake using the 24-HR method from adult individuals belonging to different populations of India (Chaturvedi *et al.*, 1994; Mehta and Shringarpure; 2000; Choudhary *et al.*, 2003; Goyal and Grewal, 2004; Harinarayan *et al.*, 2004; Arlappa *et al.* 2005; Mittal and Srivastava, 2006; Gupta *et al.*, 2010; Bowen *et al.*, 2011; Radhika *et al.*, 2011; Venkaiah *et al.*, 2011).

Murty and Reddy (1994) observed that 30% of women from a slum exhibited dietary inadequacies. A study on pregnant women reported a high incidence of dietary zinc deficiency (Pathak *et al.*, 2003). Low dietary intake in terms of energy, protein, iron, and vitamin-C was also reported from Khasi women (Agrahar-Murugkar and Pal, 2004). Insufficient amount of dietary intake and prevalence of under-nutrition has also been reported from elderly tribal individuals (Arlappa *et al.* 2005). The inadequate nutrient intakes with respect to most of the micronutrients, especially iron (84.7%), folic acid (79.4%) and vitamin-A (73.2%) have been reported from north India (Malhotra and Passi, 2007). Gautam *et al.* (2008) in their study among rural pregnant women have reported the dietary allowance to be less than the RDA.

The consumption patterns of food and nutrients are diverse in nature in India. These vary from region to region and population to population. Several researchers have studied these diverse food habits. Mital and Gopaldas (1985) reported the food habits of adult females from Gujarat. Kaur (1987) reported the dietary patterns of adult female individuals belonging to low and medium socio-economic groups from Punjab. Hira (1993) has observed nutrient adequacy among rural adult males also from Punjab. The dietary habits and food consumption related to nutritional status have been reported from adults in Madhya Pradesh (Dubey and Koley, 1995). Studies have also been undertaken to document the food habits and dietary patterns among expectant mothers of different states (Gupta, 1998; Sahoo and Panda, 2005). Recently, a study has been conducted to understand the food consumption patterns and nutritional status among rural females from Odisha (Rout, 2009).

A number of studies have been conducted to assess the food habits, dietary and nutrients intakes of adult individuals belonging to different ethnic populations of India (Banerjee and Sinha, 2001; Sharma and Dwivedi, 2005; Mohanty *et al.*, 2007; Koshal *et al.*, 2008; Chakma *et al.*, 2009). Rajyalakshmi and Geervani (1992) reported the food habits along with nutritional status and related morbidity of 4 tribal populations of south India. A dietary evaluation study has been done among the Dimasa of North Cachar hills by Khongsdier and Basu (1998). Reddy and Reddy (2000) has reported the bio-ecological aspects of food and nutrition and its change among 5 tribal ethnic populations of Tamil Nadu. Bera (2004) has reported a higher consumption of food, nutrients and nutritional status among the Tibetan women in India. Periodical data from the NNMB and NFHS have indicated that there are clear differences in diet between urban and rural areas within a specified region. The existence of a diverse dietary profile in India is closely linked to the religion, ethnicity and geographical regions. These make assessments about national dietary profile difficult. The problem is further compounded by the methodological issues related to

dietary assessments. An extensively review on the methodological issues has been published by Vas *et al.* (2005).

1.7. STUDIES DONE IN BIOLOGICAL ANTHROPOLOGY AMONG THE DIFFERENT POPULATIONS OF NORTH BENGAL

Popularly called North Bengal, the northern part of West Bengal and comprises the 6 districts of Malda, Uttar Dinajpur, Dakshin Dinajpur, Darjeeling, Cooch Behar and Jalpaiguri. A number of indigenous populations such as the Rajbanshi, the Lepcha, the Rabha and the Toto are found in this area. A thorough search of the existing scientific literature on various aspects of biological anthropology among different populations of North Bengal was done using "Pubmed". This is an on-line database developed by the National Center for Biotechnology Information (NCBI) at the National Library of Medicine (NLM), United States of America. It consists of indexed citations and abstracts pertaining to medical, nursing, dental, veterinary, health care, nutrition and pre-clinical science journals. As of 15th January 2012, PubMed has over 21.47 million records going back to 1966, selectively to the year 1865, and very selectively to 1809. About 500,000 new records are added each year to this database.

One of the earliest studies in the field of biological anthropology among the populations of North Bengal was that of Sarkar (1969) who observed variations in certain dermatoglyphic variables among some caste and tribal populations of Jalpaiguri district. Later on, dermatoglyphic studies were done among the Oraon and the Munda who had migrated to North Bengal (Sarkar, 1971) and the Meche (Sarkar and Biswas, 1972) of Jalpaiguri district. Notable studies have also been conducted on the dermatoglyphics patterns among the Rajbanshi by Sen and Mondal (2008) and Sen *et al.* (2011c).

Studies have also been undertaken in the areas of blood genetic markers (Saha *et al.*, 1988), mitochondrial-DNA (Chakrabarti *et al.*, 2002) and HLA (Debnath and Chaudhuri,

2006). In their study on blood genetic markers, Bajpai and Bajpai (1990) concluded that although the overall intergroup heterogeneity was not significant for the Rabha and the Meche, the Toto showed a difference from the local population and differed slightly from the Meche and the Rabha. There exists just a single study on the age at menarche among the Rajbanshi (Chakravarty, 1994). There is, however, a very significant contribution on the Rajbanshi in the form of a book. It is authored by Sanyal (1965) and entitled '*Rajbanshi of North Bengal*'. Sen and Ghosh (2008) and Sen *et al.* (2011d) reported the estimation of stature and sex utilizing the foot dimensions of the Rajbanshi individuals of North Bengal respectively. Limited number of studies has reported the health status and practices among different indigenous population of North Bengal. Here the study of Bagchi (2003) among the Meche can be cited.

1.7.1. Studies done in the area of nutritional assessment among the different populations of North Bengal

Studies on the assessment of nutritional status among the different populations of North Bengal are relatively scarce in the existing literature. Mittal and Srivastava (2006) in their study among the Oraon, observed the incidence of under-nutrition to be 54.00% and 40.00% respectively. Banik *et al.* (2007) reported a high incidence of under-nutrition (36.40%) among the Dhimal. Recently, Banik *et al.* (2009) conducted a cross-sectional study among the Dhimal, the Meche and the Rajbanshi and reported high incidences of under-nutrition and CED (Dhimal: 37.45%; Meche: 13.20%; Rajbanshi: 23.56%). Mondal and Sen (2010a) reported very high prevalence of under-nutrition from children belonging to the the Rajbanshi, tribal and the Bengalee Muslim populations. They observed the overall incidences of stunting, underweight and wasting to be higher among children belonging to the tribal (41.67%, 50.85% and 23.46%) followed by those of the Bengalee Muslim (33.7%, 43.8% and 26.61%) followed by those of the Rajbanshi (35.85%, 37.4% and 13.6%) populations.

The prevalence of thinness (low BMI-for-age) was also observed to be higher among children of this region (Mondal and Sen, 2010b). A high prevalence of under-nutrition has been also reported utilizing the conventional anthropometric indices and CIAF among Muslim children of North Bengal (Sen *et al.*, 2011c). In another study, Mondal and Sen, (2010c) observed that the adolescents exhibited a high prevalence of stunting (low height-for-age: 46.6%) and thinness (low BMI-for-age: 42.4%). The incidence of LBW was also found to be high among the populations of North Bengal and this has been observed to be closely associated with maternal nutritional status (Sen *et al.*, 2010b).

Using the recently developed CIAF along with the conventional indices, Mukhopadhyay *et al.* (2009) and Sen *et al.* (2011c) reported a very high prevalence of under-nutrition among children of North Bengal. In a very significant study, Sen and Mondal (2012) have documented the socio-economic and demographic factors affecting the CIAF, using children from North Bengal as the subjects of study.

There have been some very recent studies dealing with the development of new methodologies involved in assessing nutritional status of individuals and populations. Dutta Banik (2011) has tried to assess the nutritional status among Dhimal individuals using arm span as a proxy measure of under-nutrition. Sen *et al.* (2011b) have tried to assess under-nutrition among children using upper arm composition.

1.8. STATEMENT OF THE PROBLEM

The knowledge of the nutritional status of a population is necessary to have a comprehensive idea about the development process. This is primarily because under-nutrition is one of the major health problems in the developing countries. Hence, the assessment of the nutritional status of a population becomes a prime objective.

From the foregoing paragraphs, it is apparent that the nutritional status of Indian populations is observed to be very poor. There is an existence of high prevalence of under-

nutrition in all segments of the populations. Given the above facts, a comprehensive approach on the assessment of nutritional status using anthropometry and dietary assessment is proposed to be taken up in the present study. There has been hardly any such comprehensive study done earlier to document the nutritional status of an ethnic population of North Bengal using these two parameters. So the present study also bears importance from the methodological point of view. The present study also focuses on the socio-economic and demographic variables that can affect nutritional status.

1.9. OBJECTIVES OF THE PRESENT STUDY

The main objectives of a nutritional assessment study is to obtain precise information on the prevalence of under-nutrition in a given community and identification of the individuals who comprise the "at risk group", i.e., those who need of the nutritional assistances. Therefore, the present study was done keeping the following objectives in mind:

1. To assess the nutritional status of adult individuals aged 20 years to 49 years and belonging to an ethnic population of North Bengal using anthropometric measurements, standard anthropometric indices and internationally accepted cut-off points.
2. To compare the overall prevalence of under-nutrition among these individuals with the available international and national data.
3. To find out the association between different indicators of nutritional status with the different socio-economic, demographic and lifestyle variables.
4. To evaluate dietary intake of different foodstuffs, essential nutrients, vitamins and minerals using quantitative 24-HR method.
5. To compare the dietary consumptions of the different foodstuffs and nutrients of the individuals under study with the RDA as suggested for the Indian population.

6. To compare the dietary intakes of the individuals with the available dietary data of different populations of Indian.
7. To document the factors affecting energy, protein inadequacy and PEM status with different socio-economic, demographic and lifestyle variables.