Chapter 1

INTRODUCTION

1.1 OVERVIEW

Nutrition is not just confined to biochemical or physiological processes involved in the intake and utilization of food substances by living organisms, including ingestion, digestion, absorption and metabolism of food, as it is usually defined (Norgan, 2002). Nutrition may be interpreted in a broader sense and be affected by a variety of psychological, sociological and economic function (Williams, 1999). This reflects the involvements of psychology, anthropology, sociology and economy in nutrition, diet and food policy planning. The definitions are not comprehensive if they are not willing to incorporate social welfare aspects of nutrition research which is firmly established. It is rightly pointed out nutrition science will be effective to address the relevant challenges and opportunities of the twenty-first century only as an integrated biological, social and environmental science.

Such an integrated approach is the mainstay of epidemiology, public health and biological anthropology when dealing with nutrition. In the broader sense science of nutrition is driving towards two major directions. First is more reductionist in its approach as it moves from biochemistry, physiology to gene and genomics. The other one is more toward the social and economic aspects of nutrition. This aspect of nutrition science is described more vividly by Kazarinoff and Habicht (1991) where on one side of spectrum lies molecular genetics, molecular biology, biochemistry, physiological chemistry, cell biology, analytical chemistry via psychology, physiology, pathology, immunology, clinical sciences reaches to epidemiology, sociology, anthropology, economics, policy sciences, demography and education on the other end of the spectrum. Hence, nutrition science is much wider in its research span as new technology and new societal change created new possibilities and demands (Pelletier et al., 2013). If one holds on the view that nutritional science is an integration of biological, social and environmental science than it will be easier to apply the findings of nutrition science to humanity and to deal with rising challenges.

The view of anthropology on nutrition is more comparative and evolutionary. Biological anthropologists are interested in the nutrition of contemporary populations, historic and pre-historic populations, and the *hominins* of evolutionary past (Dufour and Piperata, 2018). So, the three thematic areas of the biological anthropologist are

i) diet in the evolution of genus *Homo*,
ii) diet and nutrition in the transition from hunting and gathering to agriculture, and
iii) diet and nutrition in the current era of globalization.

The present study falls under the third thematic area of biological anthropology. The emergence of more or less discrete sub-discipline of nutritional anthropology dated back to 1970s when several review were published with more emphasis on social-cultural anthropology (Strickland and Tuffrey, 1997). Nutritional anthropology has been defined as 'the study of the interrelationship between diet and culture and their mutual influence upon one another' (Freedman, 1976). In this sense, nutritional anthropology revolves around the theories of socio-cultural anthropology to solve various problems of humanity related to diet and health. Subsequent efforts have been made to give it a more interdisciplinary approach with inputs from biological anthropology, public health and epidemiology (Haas & Pelletier, 1989, Unger et al., 2006). Indeed, a large depository of work generated using anthropometry to document nutritional character of the population around the world can be considered as a part of nutritional anthropology (Dorjee and Sen, 2016). The incorporation of nutritional anthropometry is well justified in the light of five direct methods put forth by D.B. Jelliffe in the year 1966 for the assessment of nutritional status. These are anthropometric measurement, biochemical assessment, clinical examination, dietary survey and vital statistics (Jelliffe, 1966).

Anthropometry remains unique to biological anthropology and has been continuously used to assess nutritional status of populations around the world. Nutritional status is the extent to which nutrients are available to meet metabolic needs, which is usually measured based on the various indices available. Nutritional status further infers that availability of various nutrients to individual and population, which has prognostic value for the related morbidity and mortality. Nutritional status is now recognized to be a prime indicator of the overall health of a population or an individual. The ultimate objective of nutritional assessment studies is related to the overall improvement of the quality of human health (Beghin et al., 1988).

Among five methods given by Jelliffe (1966) anthropometry is the mainstay of the present study. Since anthropometry is the technique employed in the present study a brief account of its development and facets are discussed.

1.1.1 ANTHROPOMETRY

Anthropometry is the science of human body measurements. The actual origin of anthropometry lies in arts not in science or medicine, artists working on to produce life like images were confronted with the right proportions and accuracies for which they devices scales and instruments. The artists involved in the pursuit of right proportions were influenced by the Pythagorean philosophy where man was made on the image of God and God was considered most immanent in number, proportion and harmony. So the artists were in rigorous search of that simple, linear and harmonic number of proportion. In this regard Vitruvius rule of human proportion can be considered as the first known contribution followed by Leon Battista Alberti (1404-1472) who is credited as the first person to devise an instrument to measure people. Another important contributor in this line of progress was a German physician, Johann Sigismund Elsholtz (1623-1688) who coined the term “Anthropometry” and also constructed the first anthropometric rod. Introduction of the meter in 1795 was another landmark development in this regard before which there was lots of variation in the scales used. This was a major difficulty faced by those involved in the pursuits of proportion and harmony (Tanner, 1981). During the 1740s the study of growth of the fetus and the young child were seriously pursue by Buffon. Probably he was the first to measure the human fetus, yet, procedures for taking measurements are unknown. Buffon influenced his friend, Montbeillard, to undertake the first growth study from birth to maturity.

The first longitudinal growth study from birth to maturity conducted by Montbeillard was on his son from 1759-1777, which is available on record. Minimum information on how measurements were recorded can be inferred from his publication (Tanner, 1981). Another intentional study conducted in this regard was records of boys’ height of a famous institute, The Carlschule, which can be found in the Stuttgart City Archives. This is the second source of longitudinal growth studies (Tanner, 1981). Another study discussed by Tanner (1981) in this regard is a set of boys’ data on height of the Marine Society of the United Kingdom. This is how search of harmony and proportions paved the way for the development of anthropometry during seventeen century and shaped the understanding of human growth.

It was Villerme who first conducted the anthropometric measurement with the purpose of human welfare. This Frenchman is considered as the chief founder of public health and public concern in France. As a surgical assistant in the Napoleonic wars, he became aware of misery of war and famine and postwar effects on manual laborers and prisoners. In 1829 Villerme published his classical analysis of the effect of poverty on the height of French recruits. Immediately after this, Quetelet conducted a first cross-sectional population survey of children, which actually comprises of two surveys first of height only and second of height and weight. This trend and tradition was continued later through the measurements in schools and infant welfare clinics and the London County Council Surveys of 1905 to 1965, to the modern British growth standards and the National Surveys of Health and Growth of 1970s. This activity is term as auxological epidemiology, the use of growth data to search out, and later to define, sub-optimal conditions of health (Tanner, 1981). Flourishing practice of human body measurement progressing through proportion and beauty to understanding growth and finally to human welfare is still a most widely use technique in the field of growth study and nutritional anthropometry.

Selection of conscripts and slaves is another area of the practice of anthropometry. This was mainly driven by then prevailing idea of human resource. In the nineteenth century, anthropometry was used in the creation and validation of racial typologies. This idea was challenged and overturned in the second half of the twentieth century with empirical testing of evolutionary and ecological mechanisms for human biological variation. Important insights were from Boas (1912) in his understanding of plastic opposed to typological of human morphology (Tanner, 1981; Ulijaszek and Komlos, 2010). After the recognization of human physical plasticity by Boaz (1912), it was used in the Human Adaptability section of the International

Biological Programme (HAIBP) studies as an explanatory framework for human adaptation. In fact, HAIBP studies strengthened anthropometric practice and standardized various parameters, which is still used in the field of nutritional anthropometry as a standard protocol (Ulijaszek and Komlos, 2010). Pioneering anthropometric approachs to body composition was made by the Czeck anthropologist Jindrich Matiegka and details were published in the American Journal of Physical Anthropology in the year 1921 (Brozek, 1961; Brozek and Prokopec, 2001).

The present study deals with nutrition anthropometry. Anthropometry is the single most universally applicable, inexpensive and non-invasive method available to assess the size, proportions, and composition of the human body (Sen et al., 2011; Sen and Mondal, 2012). Growth in children and body dimensions at all ages reflect the overall health and welfare of individuals and populations (Radhakrishna, 2012). Anthropometry is also utilized to predict performance, health and survival (WHO, 1995; Ahmad et al., 2006; Singh and Mehta, 2009). Recent research and understanding have demonstrated the relevance of anthropometry throughout life, not only for individual assessments but also for reflecting the health status and socio-economic circumstances of population groups (Gorstein and Akre, 1988; Steckel, 1995; WHO, 1995; Komlos and Snowdon, 2005).

Anthropometric measurements have advantage over other methods like clinical signs of malnutrition, biochemical indicators, and physical activity as indicators of nutritional status. Among these, anthropometric measurements should be preferred since body measurements are highly sensitive to even minor levels of malnutrition whereas biochemical and clinical indicators are useful only when the level of malnutrition is extreme (de Onis, 2000; Radhakrishna, 2012). Recent research has expanded the applications of anthropometry to include predicting who will benefit from interventions, indentifying social and economic inequity and evaluating responses to interventions (WHO, 1995; Bogin and Keep, 1999; Komlos and Baur, 2004).

Understanding nutritional status of vulnerable section of population like children, women and elderly are important (Gorstein and Akre, 1988; Sen et al., 2010a; Sen et al., 2011; Sen and Mondal, 2012; Sen and Mondal, 2013). However, idea about the health and nutritional status of adult men and women are also equally important as they form the backbone of the society. The demands of physical activity and productivity at work and role of breadwinner in the family is significant for economic growth of any country (Strickland and Tuffrey, 1997). Healthy children are better able to learn, and healthy adults are better able to contribute socially and economically (WHO, 2013). Nutritional status assessed using anthropometric characteristics of adults may serve as early guide to households and communities at nutritional risk.

1.2 LITERATURE REVIEW

The present study is solely concerned with anthropometric characteristics which signify the nutritional situation of the population under study. It further seeks to understand the associations of various socio-economic, demographic and life-style related factors on the anthropometric characteristics under study.

The major portion of literature search relevant to the field of the study has been conducted using “PubMed”. It is a free online database with over 27 million citations for biomedical literature from MEDLINE including life science journals, and online books relating to the fields of biomedicine and health, covering portions of the life sciences, behavioral sciences, chemical sciences, and bioengineering. This web base resource is developed and maintained by the National Center for Biotechnology Information (NCBI), at the U.S. National Library of Medicine (NLM), located at the National Institutes of Health (NIH) (https://www.ncbi.nlm.nih.gov/pubmed). Google and Google Scholar were also utilized to some extent. Literatures were also obtained through personal communication with some authors.

1.2.1 STUDIES DONE ON THE ASSESSMENT OF NUTRITIONAL STATUS AMONG CHILDREN

Nutrition forms the foundation for normal human health and development. The process of malnutrition often starts in utero, and the first 1000 days of a child's life between a women's pregnancy and child's 2nd birthday are considered important for the normal growth and cognitive development. Girls and women remain vulnerable throughout the life cycle. Undernutrition like stunting and underweight among female children if continued through adult life also increases the chances of her children being born malnourished (Gillespie and Flores, 2000; Collins et al., 2003; Mason et al., 2014). Studies have reported the incidence of low birth weight (weight < 2500 kg at birth) among economically deprived section of societies (Collins et al., 2003, 2015; Sen et al., 2010b; Verropoulou and Basten, 2014; Esimai and Ojofeitimi, 2014; Gong et al., 2015). The prevalence of low birth weight is high in Asia than anywhere else and programs for its elimination should focus on intra-uterine growth retardation, prenatal care and maternal nutrition (Muthayya et al., 2009; Mason et al., 2014). Hence the studies of Tofail et al. (2012), Chiang Mai Low Birth Weight Study Group (2012), Wang et al. (2014), Shakya et al. (2015), Chang et al. (2014) are mentionable. Studies have also suggested the impact of low birth weight on adolescent and adult anthropometry (Harada et al., 2012, 2013). Breastfeeding and weaning practices during infancy are also important correlates of malnutrition among under 5-year old children with significance bearing on adult life. Any deviation during this period is irreversible (Zhou et al., 2012; Engebretsen et al., 2014; Roba et al., 2016).

Approximately 200 million children are unable to attain their full development potential because of stunting and micronutrient deficiencies (WHO, 2013; Christian et al., 2016). 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 (Schroeder and Brown, 1994) as compared to well nourished ones. The developmental delays like cognitive and motor development were found to be associated with preterm and low birth weight babies (Dewey et al., 1999,2011; de Kieviet et al., 2009; Oliveira et al., 2011;). Stunting and wasting were also reported to cause such developmental delays (Crookston et al., 2011a,b; Sudfeld, 2015a, 2015b; Christian et al., 2016).

The commonly used anthropometric measurements among children and adolescents are stunting (low height-for-age), underweight (low weight-for- age) and wasting (low weight-for-height) which were considered to be associated with specific biological process of growth failure (WHO, 1995, 2007; Rogol and Hayden, 2014). Studies have reported prevalence of stunting, wasting and underweight from many developing countries of the world (Casale et al., 2014; Darteh et al., 2014; Gaurav et al., 2014; Neufeld and Osendarp, 2014; Motbainor et al., 2015; Hasan et al., 2015; Olofin et al., 2013; Jiang et al., 2015; Semali et al., 2015; Chirande et al., 2015; Demirchyan et al., 2016; Kinyoki et al., 2016). These studies reported the prevalence of undernutrition among children from birth to 60 months of age. Studies have also utilized MUAC-for-age and MUAC-for-height (de Onis et al., 1997) for assessment of nutritional status.

All of the above conventional indices of nutritional status are expressed in terms of Z-scores or percentiles. The WHO recommends a comparison of these indices with an international reference population to determine undernutrition (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).

Studies have highlighted the rising prevalence of undenutrition among Indian children (Measham and Chatterjee, 1999; Bamji, 2003; Bishno et al., 2004: Dolla et al., 2005). According to a recent review prevalence of undernutrition among under-five year aged children was high (under-weight: 39-75%; stunting: 15.4-74%; wasting: 10.6-42.3%) (Sahu et al., 2015). Studies have also highlighted associations of poverty, poor hygiene, illiteracy and lesser investment in public services with high prevalence of undernutrition in India, inspite of the country's economic growth (Sen et al., 2010b; Sahu et al., 2015; Vijayaraghavan, 2016; Singh et al., 2017). Studies have shown the association of BMI with dental caries among children (Aluckal et al., 2016; Kumar et al., 2017). A large number of studies have used the conventional measures of low height-for-age, low weight-for- age, and low weight-for-height to assess the undernutrition among children below 5 years of age (Nandy et al., 2005; Bose et al., 2007; Mondal and Sen, 2010a; Sen and Mondal, 2012; Som et al., 2006; Sen et al., 2011).

Thinness based on BMI-for-age as proposed Cole et al. (2000, 2007) is considered to be more efficient in the sense it helps to interpret BMI of children and adolescents in line with adult BMI, which also facilitates direct comparison of different grade of thinness. The cut-off points were derived based on multicentre data from four developed countries (United States, Great Britain, Hong Kong, Netherlands) and one developing country (Brazil) from 2-18 years old individuals. Studies have successfully utilized these cut-offs to report the magnitude of thinness among Indian children (Medhi et al., 2006, 2007; Mishra and Mishra, 2007; Bose and Bisai 2008; Biswas et al., 2009; Chakraborty and Bose, 2009; Mandal et al., 2009; Bisai et al., 2010; Bisai and Manna, 2010; Mondal and Sen, 2010a; Das and Bose, 2011; Dorjee, 2015; Tigga et al., 2015).

Some studies were undertaken on the body composition of children were Bose et al. (2005), Sen and Mondal (2013). Studies on low birth weight infants were also reported from the country (Hirve and Ganatra, 1994; Basai et al., 2007; Sen et al., 2010b). Low birth weight related developmental delay among children was observed by Adde et al. (2016) and Mukhopadhyay et al. (2016). The associations of low birth weight with maternal nutritional status, body composition and socio-economic variables were also observed (Hirve and Ganatra, 1994; Basai et al., 2007; Sen et al., 2010b). Studies have also shown the positive impact of community base intervention on nutritional status of tribal and non-tribal children (Prasad et al., 2018; Devara and Deshmukh 2017; Jayalakshmi and Jissa, 2017).

1.2.2 STUDIES DONE ON THE ASSESSMENT OF NUTRITIONAL STATUS AMONG ADOLESCENTS

Adolescence is a transition phase between child and adult which is accompanied by various changes in an individual’s body towards adulthood still retaining some childhood characters. Adolescence begins with pubescence, the development of secondary sexual characteristics, and continues until morphological and physiological changes near adult status (WHO, 1995). The WHO has defined individuals aged between 10-19 years as adolescents.

During this period of life individuals may suffer from substances abuse, sexually transmitted diseases, pregnancy, and accidental and intentional injuries, which could be the result of various ongoing psychosocial, morphological and biological changes. In the same phase of life growth acceleration is experienced by adolescents, known as adolescents growth spurt. In the same phase of life individual may exposed to obesity inducing environment, which make them susceptible to chronic diseases like cardiovascular diseases (CVDs), diabetes, and cancer etc in later life.

The behaviours identified by the Minnesota Adolescent Health Survey and other studies among adolescents include high prevalence rates of inadequate intake of fruits, vegetables, and dairy products; unhealthy weight-control practices; and overweight status (Neumark-Sztainer et al., 1996, 1998). A significant review by Kurz et al. (1996) conducted on nutritional status of adolescent boys and girls of Benin, Cameroon, Ecuador, India, Jamaica, Mexico, Nepal, Guatemala, and the Philippines reported high anemia and slow growth. The study further highlighted sex difference in BMI-related weight gain. Similarly, Shahabuddin et al. (2000) reported high prevalence of stunting and anaemia among rural adolescents of Bangladesh. Studies from Bangladesh, also reported correlates (poor personal hygiene, lack knowledge about nutrition and socio economic status and education) of stunting and thinness among adolescents girls along with prevalence of stunting and thinness (Rah et al., 2009; Alam et al., 2010).

Wasting along with micronutrients deficiency was reported to be higher among children aged above 12 years compared to children below 12 years of age (Sarraf et al., 2005). Undernutritions including thinness, iron, and zinc deficiencies were reported in school children and adolescent of Dakar, Senegal, West Africa (Fiorentino et al., 2013). A study from Mizan district of Ethiopia reported high prevalence of underweight and stunting among adolescent girls with significant rural-urban difference in stunting (Berheto et al., 2005). Another study reported prevalence of stunting among children, and overweight and obesity among adolescents in rural South Africa (Kimani-Murage et al., 2010).

Adolescence is a phase of rapid growth and development during which physical, physiological and behavioural changes takes place. Adolescents constitute more than 1.2 billion worldwide, and nearly 21% of Indian population (Census of India, 2011). Thinness, stunting and overweight were reported among adolescents Bengali boys by de Onis et al. (2001). The study further emphasized on the need of population specific reference data. The BMI of Khasi adolescents were compared with Indian and non-Indian populations and efforts were also made for ethnic specific references (Basu et al., 2013). Many other studies have reported stunting and thinness among the adolescents of India (Anand et al., 1999; Venkaiah et al., 2002; Das and Biswas, 2005; Deshmukh et al., 2006; Das et al., 2007; Malhotra and Passi, 2007; Medhi et al., 2007; Mondal and Sen, 2010c; Sil et al., 2011; Mondal and Terangpi, 2014; Roy et al., 2016).

A significant study observed declined stunting (11.2% to 4.9%) and thinness (50.5% to 22%), and increased overweight (4.7% to 17.2%) among adolescents of Kolkata. The factors strongly related with positive changes in anthropometric traits were maternal education and family expenditure (Dasgupta et al., 2008). Secular trend was observed among children, adolescents, and young adults of Kolkata along with influence of socio-economic status (SES) (Dasgupta, 2015). Increasing prevalence of overweight and obesity were observed among adolescents of affluent sections of Indian society (Faizi et al., 2017). High prevalence of obesity and central obesity were observed among the adolescents and young adult students (Pengpid and Peltzer, 2014). The Calcutta Childhood Obesity Study have shown the influence of family income on the study population, thinking of obesity, thinking of taking too much fast and junk foods, breakfast skipping, extra salt consumption, and spending time with computers on their BMI (Ghosh, 2014). Goyal et al. (2011) showed the association of BMI with socio-economic status. The rising prevalence of overweight and obesity were also shown among children and adolescents of Kashmir (Ganie et al., 2017). Another study from West Bengal reported rising BMI and PBF among adolescents (Chatterjee et al., 2006).

A study examined blood pressure levels, adiposity and growth of adolescent boys from high and low social classes of Indian society (Rao and Apte, 2009). A strong association of elevated blood pressure with neck circumference and BMI was reported among urban and rural adolescents of Tamil Nadu (Goel et al., 2016; Rajagopalan and Balaji, 2017). Body fat distribution was observed to be associated with hypertension in West Bengal (Ghosh and Bandyopadhyay, 2013). The association of BMI with dental caries among children and adolescents were also documented (Subramaniam and Singh, 2011; Kottayi et al., 2016). Mid Upper-Arm Circumference (MUAC) were also put forth as alternative measure of overweight and obesity among adolescents (Jaiswal et al., 2017).

Upper-arm anthropometry was used to assess body composition among children and adolescents of Assam, Meghalaya and West Bengal (Chowdhury and Ghosh, 2009; Basu et al., 2010; Sen et al., 2011; Jaswant and Nitish, 2014). Upper-arm composition utilizes MUAC and tricep skinfold measurement and is a good alternative measures of nutrition reserved in the body. Studies have also focused on body fat distribution and body composition among adolescents (Chowdhury and Ghosh, 2013; Dasgupta, 2015; Garg et al., 2016). Studies have also utilized BMI-for-age to assess the nutritional status of adolescents (Kulkarni et al., 2014; Deshmukh et al., 2006).

The prevalence of thinness and cardio-metabolic risk among adolescents of Delhi was observed (Garg et al., 2013). Rural-urban comparison of anthropometry and menarcheal status were reported among adolescence girls of Rajasthan (Choudhary et al., 2016). Association of nutritional status with menarcheal age and per capita income was also observed among young adults (Ghosh et al., 2009). The effects of nutritional programs and prevalence of stunting among south Indian tribal adolescents was documented by Thomas et al. (2013). Studies of body fat pattern and body composition were also under taken among adolescents (Mukhopadhyay et al., 2005a, 2005b; Chowdhury et al., 2008).

1.2.3 STUDIES DONE ON THE ASSESSMENT OF NUTRITIONAL STATUS AMONG ADULTS

The double burden of malnutrition is now one of the leading global causes of death and disability (Shafique, 2007; Winichagoon, 2013). Obesity among men has increased from 3.2% to 10.8% and among women it has increased from 6.4% to 14.9% from 1975 to 2014 (NCD-RisC, 2016). At the same time underweight remains a major problem for developing countries including India with a meager reduction from 13.8% to 8.8% in men and 14.6% to 9.7% in women from 1975 to 2014 (NCD-RisC, 2016). Obesity has increased among the population of developed countries and urban population of some developing countries. High prevalence of underweight is reported from the south Asia (men: 23.4% and women: 24.0%) followed by central and east Africa (men: 15% and women: 12%) (NCD-RisC, 2016). The rapid increase of obesity and slow decrease of undernutrition is a challenge for policy maker. Nutritional assessments have a potential role to play in formulating developmental and nutritional intervention strategies.

1.2.3.1 Undernutrition

Height and weight are the two frequently used anthropometric measurements to assess undernutrition. The body mass index (BMI) is the measure of weight relative to the height. This was first formulated by Adolphe Quetelet in the year 1832, hence also known as Quetelet index. The index is based on the concept that “the weight increases as the square of the height”. Keys (1972) compared and validated the available different indices of relative weight and confirmed the validity of Ouetelet index, terming it as Body Mass Index. The BMI is generally considered to be good indicator of both the nutritional status and socio-economic condition of the population (Ferro-Luzzi et al., 1992; Shetty and James, 1994). It has been extensively used as an indicator of undernutrition (Weiner and Lourie, 1981; James et al., 1988, 1994; WHO, 1995; Lee and Nieman, 2005).

Undernutrition can be defined in terms of chronic energy deficiency (CED). The BMI is recommended to define adult CED by the International Dietary Energy Consultative Group in the year 1992 (Norgan, 1994; Bailey and Ferro-Luzzi, 1995;

Weisell, 2002). The CED is defined as a "steady state" where an individual is in energy balance, i.e. the energy intake equals the energy expenditure, despite low body weight and low energy stores (FAO, assessed on 3-11-2016). This has been considered as adaptive with some cost, which is reduction in total energy expenditure which in turn results in lower body size and less physical activity (Khongsdier, 2005; Kurpad et al., 2005). The BMI <18.5 kg/m^2 is considered as CED which is further graded into three category such as Grade I (mild), Grade II (moderate) and Grade III (severe).

CED is caused by inadequate intake of energy accompanied by high level of physical activities and infections (Shetty and James, 1994; Shetty et al., 1994) and is associated with reduced work capacity (Pryer 1993; Durnin 1994), performance and productivity (Kennedy and Garcia, 1994). It is likely to be associated with morbidity or other physiological and functional impairments (Chakaborty et al., 2006). Supplementation during CED may lead to rapid fat accumulation in the body. This factor raises the risk of susceptibility to various deleterious consequences (Kurpad et al., 2005).

There is now clear evidence suggesting that individuals exhibiting low BMI have more sickness, a lower work capacity, limited social activity, and a low income (Rotimi et al., 1999; Bose et al., 2007; Sen et al., 2010b; Hanrahan et al., 2010). Mothers with low BMI have a greater proportion of low birth weight babies compared with those who are normal (Allen et al., 1994; Hirve and Ganatra, 1994; James 1994; Prentice et al., 1994; Karim and Mascie-Taylor, 1997; Rotimi et al., 1999; Sen et al., 2010b).

Other factors responsible for CED are low SES, education, age and gender (Khongsdier, 2002; Bharati et al., 2007). Poor sanitation and infectious diseases can also lead individuals to undernutrition (Sahn and Younger, 2009; Chantler et al., 2016 and Janmohamed et al., 2016). Studies reporting the prevalence of undernutrition using BMI from developing countries includes that of James et al. (1988), Immink (1992), Ferro-Luzzi et al. (1992), Pryer (1993), Giay and Khoi et al. (1994), Berdasco (1994), Ismail et al. (1995), Ahmed et al. (1998), Lim and Chee (1998), Rotimi et al. (1999), Winkvist et al. (2000), Nyaruhucha et al. (2001), Nube et al. (2003), Faruque et al. (2006), Azmi et al. (2009), Pei (2013), Huong et al. (2014), Asiimwe et al. (2015) and El Kishawi et al. (2016).

The Mid-Upper Arm Circumference (MUAC) is another widely used anthropometric indicator of undernutrition (James et al., 1994; Ferro-Luzzi and James, 1996). A change in MUAC tends to parallel changes in muscle mass and is a useful indicator of protein-energy starvation (Harries et al., 1984). Thus, changes in the arm circumference reflect the increase or decrease of tissue “reserves” of energy and protein (WHO, 1995). MUAC has two main advantages such as its portability and universal applicability (Sen et al., 2010a). This make MUAC better suited for emergency intervention like in famine and post conflict situations and in bed ridden patient. The combine use of BMI with MUAC can provide a better assessment of CED (Ahmed et al., 1998; Dorlencourt et al., 2000; Gartner et al., 2001; Basai and Bose, 2009; Ghosh and Bose, 2015), and recently, the target group for intervention was observed to be reduced when only BMI were used to define CED (Bisai and Bose, 2008; Ghosh and Bose, 2015).

Studies have shown the relationship between low MUAC of mother and risk for low birth weight (Assefa et al., 2012; Sebayang et al., 2012; Ramlal et al., 2012; Ververs et al., 2013; Chen et al., 2014; Hambidge et al., 2018). Studies from Vietnam, Bangladesh, India have provided cut-offs for MUAC among adults men and women (Rodrigues et al., 1994; Nguyen et al., 2014; Sultana et al., 2015). Lower MUAC was observed to be associated with higher risk of mortality among adults (Irena et al., 2013, de Hollander et al., 2013; Chen et al., 2014; Asiimwe et al., 2015; Kamiya, 2016). Similarly studies have shown the influence of SES on MUAC (Baqui et al., 1994; Suzana et al., 2002; Assefa et al., 2012; Sengupta and Sahoo, 2014). Other study conducted using MUAC among adults of developing countries has successfully shown the prevalence of undernutrition (Ahmed et al., 1998; Bose et al., 2006a; Bisai and Bose, 2009; Das and Bose, 2012; Briton et al., 2016; Tang et al., 2013; 2017).

1.2.3.2 Overweight and obesity

Studies have reported the prevalence of overweight/obesity along with undernutrition from the developing countries of the world (Shafique et al., 2007; Chhabra and Chhabra, 2007; Romaguera et al., 2008; Tuan et al., 2008; Sola et al., 2011; Gunaid 2011; Hoque et al., 2015). It has also been reported that countries in transition to westernized lifestyles are experiencing substantial increase in its prevalence. The primary environmental determinants of obesity are high calorie intake and low levels of physical activity (Poston and Foreyt, 1999; Harnack et al., 1999; Ismail et al., 2002; Partonen 2014; Rathnakaye 2014; Sartorius et al., 2015; Trivedi et al., 2015). Such prevalence of overweight/obesity makes a population highly susceptible to diseases like type 2 diabetes mellitus, cardiovascular diseases, hypertension and cancer (Freedman et al., 2010; Kee et al., 2011; Malaza, 2012; Zhao et al., 2013). This is evident from the rising premature deaths (the death under the age of 70) worldwide due to Non-Communicable Diseases (NCDs). An estimated 52% of such premature deaths were due to NCDs in the year 2012. Over three quarters of those premature deaths were caused by CVD, cancer, diabetes and chronic respiratory disease (CRD). In terms of mortality the leading NCD is CVD which claimed 17.5 million lives in 2012 which includes 7.4 million due to coronary heart disease and 6.7 million to stroke. The CVD is followed by cancer (8.2 million, with 4.3 million under age 70), and then CRD (4.0 million) and diabetes (1.5 million). Diabetes is also a risk factor for CVD, with about 10% of cardiovascular deaths caused by higher-than-optimal blood glucose level (World Health Statistics, 2016).

The World Health Organisation has defined Body mass Index (BMI) above 25 kg/m^2 as overweight and above 30 kg/m^2 as obese (WHO, 1995). It is a well accepted benchmark definition of obesity. BMI above 30 kg/m^2 usually identifies risk of ill health and metabolic syndrome. The available WHO criteria are based on the association of BMI with morbidity and mortality. These studies were mostly conducted among the European population (WHO, 1998). Similarly, association of BMI with morbidity and mortality were reported from the different population of the world (Costa, 1993; Allison et al., 1997; Calle et al., 1999; Khongsdier, 2002, 2005; Janssen, 2007; Lee, 2010; Aekplakorn et al., 2011; Aoki et al., 2014; Padwal et al., 2016).

However, obesity is by definition a condition of excess fat, not excess weight. Sport persons, athletes and fitness freak may have high weight without being fatty and their BMI usually range high (Deurenberg et al., 2002). In other word their BMI is high due to excess lean mass not fat mass. In fact BMI is a measure of general obesity and used as surrogate for body fat among adults. Thus BMI is a simple tool to screen an overweight or obese status which cannot differentiate between fat and lean body mass, especially in people with a BMI of <30kg/m^2 (Bastein et al., 2014; Lavie et al., 2009; Weig et al., 2016). Hence, BMI should be always interpreted in combination with diseases, smoking, blood pressure, serum lipids, glucose intolerance and types of fat distribution not in isolation (WHO, 1995). This is also corroborated in a recent study (Hung et al., 2017). Studies have shown high correlation between BMI and percentage body fat (Zhao et al., 2013; Gupta and Kapoor, 2014; Banik et al., 2016). Recent research reported strong correlation of BMI with BF % estimated by bioelectrical impedance among adults (Ranasinghe et al., 2013; Heo et al., 2012; Kupusinac et al., 2014; Limpawattana et al., 2014; Shaikh et al., 2016). High body fat percentage at lower BMI is usually observed to be risk factor for CVD among Asians (Deurenberg and Deurenberg-Yap, 2001; Oliveros et al., 2014). Such a low BMI and high body fat percentage were also reported among Australian aboriginals (Norgan, 1994, 1995; Piers et al., 2003). Beside, ethnic differences, age and gender also have significant influence on relation between percentage body fat and BMI (e.g., Deurenberg-Yap et al., 2000; Shah et al., 2005; Kolt et al., 2007; Shaikh et al., 2016).

Owing to general nature of BMI and the rise of studies supporting central obesity as the cause of actual obesity related morbidity, the 1997 WHO Expert Consultation on Obesity recognized the importance of abdominal fat mass (WHO, 2008). The abdominal adiposity may fall between total body fat and BMI which is also referred as abdominal, central or visceral obesity. This change in the focus from general obesity to central obesity is largely based on the rationale that increased visceral adipose tissue is associated with a range of metabolic abnormalities, including decreased glucose tolerance, reduced insulin sensitivity and adverse lipid profiles, which are risk factors for type 2 diabetes and CVD (Feldstein et al., 2005; Kaplan et al., 2014; Qi et al., 2015). The alternative measures that reflect abdominal adiposity, such as waist circumference, waist–hip ratio and waist–height ratio, have been suggested as being superior to BMI in predicting CVD risk.

The waist circumference (WC) is a simple and direct measure of central adiposity. It was found associated with increase risk in hypertension and diabetes in African American women (Warren et al., 2012). WC is well considered as a metabolic syndrome along with high triglycerides, low cholesterol, high glucose levels and high blood pressure etc (Vakil et al., 2012; Takata and Fujimoto, 2013; Adedoyin et al., 2013; Despres, 2014). One of the reason behind acceptance of WC as a metabolic syndrome for clinical use could be easy to measure and no need for tedious calculations. It has been observed that both general and abdominal adiposity are associated with disability and support the use of WC in addition to BMI to assess risk of mortality in older adults (Nam et al., 2012). Studies have utilized the WC successfully to assess the prevalence of adiposity related risks (Gutierrez-Fisac et al., 2012; Bajaj et al., 2014; Khan et al., 2017).

Additional measure of body fat distribution is waist–hip ratio (WHR) which is the WC divided by the hip circumference (HC). It is consider more precise than skin folds, and it provides an index of both subcutaneous and intra-abdominal adipose tissue (Bjorntorp 1987; Al-Lawati and Jousilahti, 2008). The use of these anthropometric indicators arose from a 12-year follow-up of middle-aged men, which showed that abdominal obesity (measured as WHR) was associated with an increased risk of myocardial infarction, stroke and premature death, whereas these diseases were not associated with measures of generalized obesity such as BMI (Larsson et al., 1984). In women, BMI was associated with increased risk of these diseases; however, WHR appeared to be a stronger independent risk factor than BMI (Lapidus et al., 1984). Hence, these indices are best for complementing BMI to identify individuals at increased risk for various obesity related morbidity due to accumulation of abdominal fat (WHO, 2000a, 2008). Unlike WC the interpretation of HC is usually based on WHR rather than comparison against cut-off values. Early reports of the health effects of central adiposity based on WHR included increased risk of diabetes in women (Hartz et al., 1983) and cardiovascular disease in men (Larsson et al., 1984).

The studies evaluating different indices of adiposity indicates that waist to height ratio (WHtR), is a better predictor of diabetes, hypertension, dyslipidaemia, metabolic syndrome and other cardiovascular outcome measures than BMI or WC in both men and women (Ashwell et al., 2012). A WHtR cut-off of <0.5 can be presented as a simple public health message to keep waist circumference less than half the height (Browning et al., 2010; Ashwell et al., 2012). Studies has supported WHtR being better indicator of adiposity than BMI (Ashwell et al., 2012; Savva et al., 2013) and as sensitive as WC and WHR (Yoo, 2016). Significant associations were reported for obesity assessed by WHtR in predicting risk factors for cardiovascular diseases, metabolic syndrome and diabetes compared to other anthropometric parameters like WC and BMI (Correa et al., 2016). Other meta-analysis supported the usefulness of WHtR (Ashwell et al., 2012; Savva et al., 2013). Researchers have emphasized the usefulness of WHtR as a screening tool for obesity and related cardiometabolic risk in children and adolescents (Gamble et al., 2012; Martin-Calvo et al., 2016; Yoo, 2016).

Combined use of abdominal adiposity with BMI is suggested for intervention studies. There are differences in central fat distribution in relation to age, sex and ethnicity. Infact WHO (1995) has cautioned the interpretation of BMI in isolation. WHO (2008) presented the sex and region wise cut-offs for WC, WHR and WHtR. In this regard, Lear et al. (2010) suggested further studies. Publications after WHO (2008) have suggested cut-offs for various population (Browning et al., 2010; Katulanda et al., 2011; Zeng et al., 2014; Guo et al., 2016; Okada et al., 2016).

Other important measures of central obesity is conicity index (CI) which is a better indicator of central adiposity like WC, WHR and WHtR. Valdez et al. (1993) studied association of CI with abdominal adiposity and other related risk factors. This index is also found to be associated with cardiovascular risk factors and has clinical significance (Ruperto et al., 2013, 2017; Motamed et al., 2015; Caitano et al., 2017). Other noticeable studies are Yasmin and Mascie-Taylor (2003), Flora et al. (2009). Andrade et al. (2016) has reported inconclusive findings.

1.2.3.3 Determinants of overweight/obesity

Studies from western countries reported an inverse relationship between degree of obesity and SES. Women are affected more than men and children (Markwick et al., 2013; Bradshaw et al., 2017; Newton et al., 2017). This has also been reported from the developing countries (Monteiro et al., 2004a, 2004b; Ball and Crawford, 2005; Lee, 2010). It has also been found that gender and poverty are two major risk factors that contribute to a high prevalence of weight related problems irrespective of age (Bowen et al., 1991; de Marins et al., 2001; Gigante et al., 2013; Boylan et al., 2014). Now the situation is similar in both the developed and developing countries. The direct relationship between SES and obesity was also common in the developing countries (Gittelsohn, 1991; Stunkard, 1996; Hindin, 2000; Barker et al., 2006; Rengma et al., 2015). Number of studies has reported relationship between SES and BMI among different populations (Khongsdier, 2001, 2002, 2005; Clausen et al., 2006; Shannon et al., 2008; Gigante et al., 2013; Kim et al., 2014; Compernolle et al., 2016; Moon et al., 2017). Path ways through which SES mediate its influence on high adiposity and act as etiology of related morbidity demands different approach of investigation.

Studies have assessed the association of SES with measures of central adiposity and BMI (Baltrus et al., 2010; Blanquet et al., 2016). SES like education, occupation and residential area were found to be associated with obesity measured using WC and BMI individually (Lao et al., 2015). Associations of education, household income, employment status, marital status with WC and BMI were studied by Sarlio-Lahteenkorva et al. (2006) among Finish adults from 1992 to 2002. Another such follow up study is among the multi-ethnic Asian population conducted by Ong et al. (2009). The association between SES and annual relative change in anthropometric markers in the general German adult population was reviewed by Herzog et al. (2016). Similar trend analysis in a Chinese population with rapid economic development is published by Lao et al. (2015). There is an increasing positive association of obesity with social position among the Inuit men and women of Greenland (Bjerregaard et al., 2013). The relationship between WC with SES among Nigerian adults was also reported (Adedoyin et al., 2013).

Overweight is relatively common among Turkish and Moroccan migrants, especially women. Education and employment are relevant in explaining ethnic differences in overweight. Compared to Dutch men, migrant men seem to have a more favourable fat distribution with less abdominal fat (Ujcic-Voortman et al., 2011). High-income men and poorly-educated women were at higher risk of obesity in Zhejiang province, China where economic transformation is under process (Xiao et al., 2013). After adjustment for covariates, BMI and waist circumference increased with decreasing neighborhood socioeconomic status, especially with neighborhood education measured within 500-m radius buffers around residences; associations were stronger for women (Leal et al., 2011).

Physical activity was inversely associated with BMI and body fat percentage among adults (Du et al., 2013; Bradbury et al., 2017). Bradbury et al. (2017) reported lower body fat percentage among the more active people compared to less active people with similar BMI. In contrary co-existence of high level of physical activity and obesity was observed among Inuit adults of Arctic Canada (Hopping et al., 2010).

1.2.3.4 Other Complementary Indices

The inability of BMI to identify risk of high adiposity among various ethnic populations and individuals with a BMI of < 30kg/m^2 was major concern for researchers (Norgan, 1994; Deurenberg et al., 2002; Garrido-Chamorro et al., 2009; Rahman and Berenson, 2010). These considerations provide impetus for a more suitable direct index of adiposity which leads to the formulation of Body Adiposity Index (Bergman et al., 2011). The study claims that Body Adiposity Index (BAI) can predict Percentage Body Fat (PBF) among male and female unlike BMI without correction. The study was conducted on the Mexican-American Adults and validated on the African-American population. A gold standard of percentage body fat Dual-energy X-ray absorptiometry (DEXA), was used to derived PBF. PBF calculated using DEXA was highly correlated with BAI than BMI. The BAI is independent of weight which may provide advantage in some context. Other advantages are its formulation and validation on Non-Caucasian population as the majority of the world populations are Non-Caucasian. However, the index needs validation on other ethnic population around the world including European population. Validation of BAI in a paediatrics sample over-estimates the %BF in children and leads to development of a valid BAI for paediatrics (El Aarbaoui et al., 2013).

Consequently after Begman et al., (2011) a large number of studies have been published from around the world including India. Study conducted on Colombian adult concluded limitation of PBF assessed using newly proposed BAI among Caucasian population (González-Ruíz et al., 2015a). Metabolic syndrome components (waist circumference ≥ 90 cm; fasting plasma glucose ≥ 100 mg/dL, blood pressure ≥ 135/85 mm Hg; triglycerides ≥ 150 mg/dL and HDL-c ≤ 40 mg/dL etc) were shown to have positive correlations with BAI (González-Ruíz et al., 2015b). The study by Elia et al. (2016) compared its prognostic ability with BMI for cardiovascular diseases and its component such as hypertension, blood pressure and sub-clinical organ damage. The study is based on the Olivetti Heart Study. Statistically positive associations with cardiovascular risk factors such as levels of cholesterol, triglycerides, LDL cholesterol and glucose were observed and subsequently a high prevalence of obesity was observed based on BAI (Garcia et al., 2015). Adaptation of different BAI cut-offs for Caucasian male and female has been already emphasized (Lopez et al., 2011; Elisha et al., 2013; Zwierzchowska et al., 2013).

Over representation of females in the study of Bergman et al. (2011) was criticized as possible reason for higher correlation of HC with PBF. Even possible alternative has been suggested to consider hip for female and waist for male, as usually waist among men correlates highly with percentage body fat (Schulze and Stefan, 2011). Study by Marques-Vidal et al., (2012) has shown stronger association of BMI and waist circumference than that of BAI with CVD risk factors and cytokine. The study was conducted using CoLaus study of large sample from Switzerland. Similarly a study based on 1140 female sample drawn from SUNSET study which consisted of three ethnic groups of Netherlands concluded BMI, WHR and WHtR to better predictors of CVD risk factors (Snijder et al., 2012). A study among Xavante Indians clearly shows that BAI is not a better predictor of adiposity than waist circumference in men or BMI and waist circumference in women (Kuhn, 2014). Other important studies in this regard conclude BAI indicates only total adiposity not risk factors (e.g., Hung et al., 2012; Lima et al., 2012). Studies suggest further investigation (Hung et al., 2012; Marques-Vidal et al., 2012; Snijder et al., 2012; Gupta and Kapoor, 2014).

Neck circumference is another proxy measure of adiposity that can be used at par with waist circumference, WHR and WHtR (Ben-Noun et al., 2001; Ambady et al., 2010; Yang et al., 2010; Kee et al., 2011). Precisely it can be consider as a measure of upper body adiposity which is relatively easy to assess. Studies has reported significant and strong association of NC with conventional measure of abdominal adiposity like WC, WHR, WHtR and BMI (Hingorjo et al., 2012; Ozkaya and Tunckale, 2016; Joshipura et al., 2016; Assyov et al., 2017). Further, metabolic syndrome were found to be associated with NC (Joshipura et al., 2016; Yan et al., 2014; Assyov et al., 2017; Pereira et al., 2014; Liang et al., 2015). Studies has investigated the cardiovascular risk, diabetes and other mortality risk based on NC (Liu et al., 2015; Dai et al., 2016; Junior et al., 2016; Yoon et al., 2016; Medeiros et al., 2011; Cho et al., 2015). The regional fat distribution has implication on obesity related morbidity especially upper body and lower body fat (Kanaley et al., 1993). Like the use of WC, WHR and WHtR as complementary to BMI in the assessment of nutritional status is well established (Norgan, 1994, 1995; WHO, 1995). The BAI and NC can be considered as additional measure of nutritional status for complementing BMI.

1.2.3.5 Body composition

There are populations and individuals who have a normal body weight based on BMI but an elevated percentage of body fat. Such metabolically obese but normal-weight (normal-weight obesity) individuals may be at a much higher risk for cardiometabolic dysregulation, endothelial dysfunction, insulin resistance and cardiovascular complications (Batsis et al., 2013; De Lorenzo et al. 2016). Even more surprising is the phenomenon known as “obesity paradox” in which obesity is seen to provide better survival in critically ill patients of CHD (Lavie and Milani, 2003, 2005; Lavie et al., 2009). The inability of BMI to discriminate between fat mass and lean mass is responsible for the “obesity paradox” (Bastein et al., 2014; Lavie et al., 2009; Weig et al., 2016). Further, studies has emphasized that visceral adipose tissue is the surrogate marker of subcutaneous adipose tissue dysfunction (Bays 2014; Smith 2015). When subcutaneous adipose tissue becomes unable to accumulate excess fat, it gets deposited as visceral adipose tissue. This phenomenon suggests imperative need for assessment body fat distribution and percentage body fat in clinical and population studies.

Percentage body fat is usually assessed using skinfolds technique based on the two-compartment model of body composition analysis and useful for field based studies. The skinfold measurement of Biceps (BSF), Triceps (TSF), Sub-scapular

(SSF) and Supra-iliac (SISF) are used to estimate subcutaneous adiposity and thus nutritional status (Hastuti et al., 2013; Temple et al., 2015; Banik et al., 2016; Madden and Smith, 2016). These skinfolds measurements are further use to derived fat mass and lean mass. The combination of MUAC and TSF provides idea about upper arm composition in terms of Upper Arm Muscle Area (UMA), Upper Arm Fat Area (UFA). UMA, UFA along with MUAC is utilized for the assessment of undernutrition or loss of weight due to infection and poor condition (Johnston, 1982; WHO, 1995; Sen and Mondal, 2013; Han et al., 2017). It is basically a marker of protein reserves and marker of arm muscle mass commonly used among children (Frisancho, 1974). Like MUAC it is suitable for nutritional assessment of hospitalized and bed ridden patients. This is an additional index of regional fat distribution. Decrease in the lean mass and fat mass is considered parallel to weight loss and undernutrition (Borzek, 1961). So, quantification of fat mass and lean mass is useful for identification of obese individuals with actual increase in fat mass rather than in lean mass (Hull et al., 2011; Lu et al., 2012; Batsis et al., 2013; De Lorenzo et al., 2016). However, few studies have used the skinfolds measurements to assess the fat mass and lean mass or arm muscle area among adults (Rao et al., 2010; Sillanpaa et al., 2013; Banik et al., 2016; Ghosh and Bose, 2018).

Age related changes were assessed among the Jat-Sikh and Bania females (Singal and Sidhu, 1983). Studies have shown the influence of age on body fatness and central adiposity and other components of body composition with change in fat free mass in women (Nassis and Geladas, 2003; Ghosh and Chaudhuri, 2005; Kaur and Talwar, 2011). Similarly other study based on NHANES III reported age related decline in fat free mass (FFM) and fat free mass index (FFMI) in older Americans is higher for African men and women compared to white men and women (Obisesan et al., 2005). The study has found similar FFM and FFMI among the males of African and European ancestry but higher among African women compared to European (Obisesan et al., 2005). Similar, difference was reported between Australian aboriginals and European Australian in percentage body fat (Norgan, 1994a,b, 1995). Due to ethnic difference in body fat distribution studies has emphasized the need for race based prediction equations (Heyward, 1996; Duerenberg and Duerenberg-Yap, 2001, 2003).

Association of indices of fat mass and lean mass with metabolic syndrome was reported (Liu et al., 2013; Rao et al., 2012). Yao et al. (1991) observed the association of body fat measured using skinfolds and other anthropometric indicator with coronary heart diseases mortality. Study based on NHANES I and II observed association of low fat free mass with mortality among males (Allison et al., 2002) and no such association was found among females (Zhu et al., 2003). Another study based on NHANES III also reported similar association (Kuk and Ardern, 2009). Other similar studies are Spataro et al. (1996) and Ducimetiere et al. (1986). In the foregoing paragraphs, the body composition variables have shown clear influence of age, sex, and ethnicity. In addition its association with metabolic syndrome has important implication in the study of nutritional assessment.

1.2.4 INDIAN STUDIES DONE ON THE ASSESSMENT OF NUTRITIONAL STATUS AMONG ADULTS

In India, undernutrition and overnutrition has been observed to affect the impoverished and the affluent both at group and individual level (Subramanian and Smith 2006). Studies have been alerting about the rising prevalence of undernutrition and overnutrition in India as a result of nutritional transition (Griffiths and Bentley, 2001; Uauy et al., 2001; Shetty, 2002; Ghosh et al., 2009). The country has one of the highest burdens of undernutrition in the world and simultaneously facing the emerging problem of overweight and obesity (Vas et al., 2005; Sengupta et al., 2014; NCD-RisC, 2016). Inspite of huge economic development only modest decline can be noticed in the prevalence of undernutrition in the country (Vijayraghavan, 2016). The failure has been attributed to prevailing poverty, low socio-economic status, poor living conditions and inadequate dietary intake (Ramachandran, 2007; Antony and Laxmaiah, 2008; Mahal and Karan, 2008). The country with such a varied geography, ethnicity, culture, language and religion can provide opportunities and challenges in such endeavor.

According to National Nutrition Monitoring Bureau (NNMB) prevalence of underweight/CED (BMI < 18.5 kg/m^2) was 35% among adult men and women of rural India. Similarly, the combined prevalence of overweight/obesity (BMI > 25 kg/m^2) was 10% and 13.5%, respectively among adult men and women. The NNMB also reported the prevalence of 13.6% and 30.0% of abdominal obesity (WC > 90cm for men & > 80 cm for women) among men and women respectively (NNMB, 2012). The underweight reported by NFHS-3 (2005-06) was 34.2% and 35.5% for men and women respectively. Recently NFHS-4 reported 20.2% and 22.9% underweight among men and women respectively. The decline in underweight has come with increase in the prevalence of overweight/obesity with 18.6% and 20.7% among men and women respectively (NFHS-4, 2015-2016). However, estimated underweight prevalence by NCD-RisC (2016) is higher than that reported by NNMB (2012) and NFHS-4 (2015-2016). On the other hand prevalence of obesity is lower. Although there is difference in the reported prevalence, yet, these estimates provide general view of the prevailing nutritional status of the country.

Numbers of studies have investigated the problem of undernutrition among men and women of India. A large number of adults were found underweight in the states of Bihar, Odisha, Madhya Pradesh, Chhattisgarh and West Bengal (Das et al., 2013; Patil and Shinde, 2014; Das and Bose, 2015; Sengupta et al., 2015; Rai et al., 2018; Ghosh et al., 2018). Beside the prevalence of underweight among adults were also reported from the state of Rajasthan, Uttarakhand, (Arlappa 2005, 2009; Gautam and Thakur, 2009; Singh et al., 2008; Mandal et al., 2011). The highest prevalence of underweight men in India is reported from Tripura (39.8%), followed by Rajasthan (39.3%), Chhattisgarh (37.2%) and Gujarat (35.7%) based on NFHS-3 data (Patil and Shinde, 2014). Similarly prevalence of underweight among women was high in Gujarat (41.8%), followed by Orissa (41.5%), Uttar Pradesh (38.3%) and West Bengal (37.0%) based on NNMB data of 2011-12 (Meshram et al., 2016a). Among the young female Bengalee of Kolkata the prevalence underweight was 30.3% (Ghosh et al., 2009). A cross-sectional study reported higher underweight for female (31.7%) compared to male (23.6%) among Bengalee individuals (Bose et al., 2009).

According to the study conducted by Shukla et al., (2002) the 19% men and women of main city of Mumbai were underweight. Recently studies have reported 22.7% prevalence of underweight from rural Tamil Nadu and 38.0% from the rural areas of Andhra Pradesh (Little et al., 2016; Subasinghe et al., 2014). Such prevalence of underweight from south India was also reported by some earlier studies (Hutter, 1996; Kusuma et al., 2008). It is clear from the above discussion that the reported prevalence of underweight ranges from high prevalence (20% - 39%) to very high prevalence (above 40%), which according to WHO (1995) classification of CED prevalence the situation is serious to critical in the country.

The MUAC is a portable and less expensive measure of undernutrition suitable for emergency field situation and for bedridden patients (Sen et al., 2010b; WHO, 1995). Further it is an alternative and additional measure of thinness among children below 5 years and among adults during emergency crisis and for intervention (WHO, 1995). It is used with BMI for the assessment of thinness among adult for more refined result (James et al., 1994). The measure of BMI and MUAC was used to assess undernutrition among Indians adults Bose et al. (2006c), Banik (2008), Bisai and Bose (2009), Chakraborty et al. (2011), Datta (2011). Now a day it is frequently used to assessed the nutritional status of hospitalized patients in India (e.g., Roy et al., 2013).

The state of Kerala, Delhi and Punjab were considered as overweight province of India (Sengupta et al., 2015). The study by Bharati et al. (2007) has shown highest prevalence of obesity in Punjab and lowest in the Bihar. A recent study from rural Tamil Nadu reported 14.9%, 16.1% and 3.3% prevalence of overweight, obesity I and obesity II respectively among adults (Little et al., 2016). The prevalence of obesity reported from residents of Tamil Nadu, Maharashtra, Jharkhand and Chandigarh was 24.6%, 16.6%, 11.8% and 31.3% respectively (Pradeepa et al., 2015). Prevalence of overweight and obesity among adult Bengalee slum dwellers of Kolkata were 20.1% and 8.3% respectively (Chakraborty et al., 2011). Increase in the prevalence of both overweight and obesity from 1960 to 1999 have been noticed among Nicobarese adults in Nicobar Islands (Sahani et al., 2010). A study conducted on adult individuals of Berhampur, Odisha reported the prevalence of overweight and obesity to be 17.6% and 36.8% respectively based on revised Asian-Pacific population reference (Prasad et al., 2013). The other mentionable studies reporting prevalence of obesity using BMI were Sen et al. (2013), Pradeepa et al. (2015), Kshatriya and Acharya (2016b) , Rengma et al. (2015).

Among the adults of Tamil Nadu, Maharashtra, Jharkhand and Chandigarh the prevalence of abdominal adiposity reported was 26.6%, 18.7%, 16.9% and 36.1% respectively (Pradeepa et al., 2015). A study has found the significantly higher central adiposity among south Indians compared to US population (Bajaj et al., 2014). The prevalence of 29.8% of central obesity was found among the urban slum of Chennai, South India (Anuradha et al., 2012). Prevalence of central obesity using the cut-offs of 102 cm, 90 cm and 80 cm were 0.46%, 5.08% and 24.7%, respectively among the adult slum dweller of Kolkata (Chakraborty et al., 2011). These studies were conducted using waist circumference.

The tribal population of the country constitutes 8.6% of the total population. Of them, 89.97% live in rural areas and 10.03% in urban areas (Census of India, 2011). Generally tribal people of India inhabit two distinct region of the country – the Central India and the Northeast India. The Gonds, Bhils and the Minas of the central and western region of India, and the Santals and the Oraons of eastern and central region, are the major tribes of India. Though the Indian tribal are a heterogeneous group, most of them remain at the lowest stratum of the society due to various factors like geographical and cultural isolation, low levels of literacy, primitive occupations, and extreme levels of poverty. Their nutritional status is still poor and influence health outcomes inspite of constitutional safeguard. Studies conducted among the tribes of northeast India are discussed in a different section later.

A review among the tribal populations by Bisai and Bose, (2008) reported the highest prevalence of CED to be in West Bengal (64.2%) and lowest in Sikkim

(4.8%). According to a previous study, the prevalence of CED was the lowest in Arunachal Pradesh and highest in Odisha. East zone of the country including West Bengal, Odisha and Jharkhand were at the bottom of the list with the highest degree of malnutrition (Bharati, 2007). The prevalence of CED was also reported to be high among the tribes of Maharashtra, ranging from 16.82 kg/m^2 - 18.33 kg/m^2 (Adak et al., 2006). However, a recent study observed high prevalence of undernutrition among Koras (51.9%), Bathudis (51.3%), and Oraons (49.6%) (Kshatriya and Acharya, 2016). Another study by Datta Banik (2011) has reported the prevalence of very high percentage of CED among Oraon and Saraks, 62.50% and 46.36% respectively. Similarly, 41.0% and 42.0% CED among men and women of Chenchu tribal population of Telangana and Andhra Pradesh were reported (Rao et al., 2015). More women (64.7%) then men (54.4%) based on MUAC and women (59.4%) then men (34.6%) based on BMI were undernourished among Santals of Purulia (Das and Bose, 2012). Studies have also reported 55.3% undernutrition based on BMI and 51.2% based on MUAC (Bisai and Bose, 2009). Prevalence of MUAC based undernutrition was 35.1% among Oraon adults of Jharkhand (Chakraborty et al., 2011) and 33.7% among Santals men of Odisha (Bose et al., 2006c). Other studies in the field of adult nutritional assessment include that of Mittal and Srivastava, (2006) among the Oraon and Banik et al. (2007) among the Dhimal. In a subsequent study, Banik et al. (2009) further documented high prevalence of undernutrition and poor health condition among the Dhimals, Meches and Rajbanshis. In yet another study, Banik (2011) validated arm span as a surrogate measure of nutritional status.

A single study have observed overweight among Bhumijs (17.7%), Dhodias (23.8%), Kuknas (15.8%), Santals of West Bengal (12.2) and Santals of Odisha (15%) (Kshatriya and Acharya, 2016). The prevalence of overweight/obesity in adult tribal men and women was 7% and 8%, respectively (NNMB, 2009). The proportion of adult tribal men (waist circumference ≥90 cm) and women (waist circumference ≥ 80 cm) with abdominal obesity was 2.4% and 7.6%, respectively (NNMB, 2009).

The access to good quality life which ensures health, optimum diet and hygienic living are main determinants of desired nutritional health and fitness. Such accessibility is facilitated by number of socio-economic factors like age, sex, education, residence, income etc. In India, the prevalence of undernutrition based on BMI has been reported to be associated with age, sex, land own, education, residence, family size, social status and income (Khongsdier, 2002, 2005; Arlappa, 2005, 2009; Barker et al., 2007; Chakraborty et al., 2009a; Das and Bose 2010; Das et al., 2013; Patil and Shinde, 2014; Sengupta et al., 2015). Further, study by Subasinghe et al. (2014) has found association farming and low income with CED.

Studies have concluded BMI and other measure of central adiposity reflects on the economic and social condition of a population (Kusuma et al., 2008; Pradeepa et al., 2015; Meshram et al., 2016b). Studies conducted on India reported influence of age, sex, income, education, residence, social status and rural-urban migration on the prevalence of obesity among Indian adults (Prasad et al., 2013; Varadharajan et al., 2013; Som et al., 2014; Pengpid and Peltzer, 2014; Gouda and Prusty, 2014; Pradeepa et al., 2015; Rai, 2015; Little et al., 2016). Influence of caste on the prevalence of overweight and obesity were studied among some population of south India (Gaiha et al., 2010; Adinatesh et al., 2013; Little et al., 2016). Some studies are also published on the association of food habits with obesity (Gupta et al., 2010; Singh and Kirchengast, 2011; Satija et al., 2013; Prasad et al., 2013 Agarwal et al., 2014). Incidence of obesity was noted higher even among rural people of some states and in some states its incidence was confined to urban people only (Sengupta et al., 2015). The trends noted elsewhere have been started to appearing in India (Stunkard, 1996; Ball and Crawford, 2005).

General obesity, central adiposity and sedentary life style were found to be related among the inhabitants of Trivandrum, Kolkata, Mumbay, Moradabad and Nagpur (Singh, 2007). Lack of physical activity was found to be associated with adiposity (Pradeepa et al., 2015; Little et al., 2016). Similar obesogenic environment within the family was also reported responsible for prevalence of obesity (Swaminathan et al., 2013). Increase television viewing was related with increase WC among women of Santiniketan, West Bengal (Ghosh and Bhagat, 2014). Bus drivers of Karnataka were more overweight and obese than their conductor (Joshi et al., 2013). Tobacco use, alcohol use and unhealthy diets lacking fruits and vegetables were found to be related with diseases factor such as hypertension and obesity among adults from Assam and Gujarat (Bhagyalaxmi, 2013; Misra, 2014).

In India, non-communicable diseases caused an estimated 50% of all deaths and 60% of total disease burden in the year 2004 excluding different types of cancers (Patel et al., 2011). The obesity measured by BMI and central obesity was found to be associated with a range of metabolic abnormalities, including decreased glucose tolerance, reduced insulin sensitivity and adverse lipid profiles, which are risk factors for type 2 diabetes and CVD. Studies from India have reported clustering of these risk factors among young adults (Ghosh, 2007; Gupta et al., 2010; Nag and Ghosh, 2016; Naval et al., 2016). A frequently reported CVD risk factor associated with overweight and obesity among Indian adult is hypertension (Chakraborty et al., 2011; Prasad et al., 2013; Midha et al., 2014; Pal et al., 2014; Shukla et al., 2014; Panda et al., 2017).

Hypertension was strongly associated with BMI, WC, WHR, WHtR (Midha et al., 2014; Panda et al., 2017; Chakraborty and Bose, 2012). Studies have concluded the steady increase of hypertension from underweight to normal and then to overweight/obese individuals (Pal et al., 2014; Datta Banik, 2014). Similar, risk of hypertension was reported among overweight and obese tribes of Kerala. Less increase in hypertension with age was observed among educated and high SES group (Meshram, 2012). High BMI along with high blood glucose and abnormal serum cholesterol were also found to be responsible for non-communicable diseases (Patel et al., 2011). A study conducted among the youth of Hyderabad and nearby rural area reported significantly high WC, WHR, diastolic blood pressure, blood glucose, total cholesterol and LDL among the urban youth (Bhongir et al., 2011).

Indian studies have also supported the validity of indices abdominal obesity (WHR, WHtR, WC) as risk factor of metabolic syndrome and related morbidity (Gopinath et al., 2012; Naval et al., 2016; Panda et al., 2017). Some studies have shown WC as better CVD risk factor (Kurpad et al., 2003; Chakraborty et al., 2011; Ghosh and Bandyopadhyay, 2012) and useful screening measure for hypertension and high BMI (Chakraborty et al., 2011; Chakraborty and Bose, 2012; Gupta and Kapoor, 2012). There has been efforts to give valid regional cut-offs for Indian population (Misra et al., 2006; Singhal et al., 2011; Chakraborty et al., 2011; Gupta and Kapoor, 2012).

Association of CI and the above discussed central adiposity measures with various metabolic syndrome, diabetes and CVD risks were also studied (Ghosh et al., 2000;Venkatramana and Reddy, 2002; Mamtani and Kulkarni, 2005; Ghosh, 2006, 2007, 2009; Ghosh and Bandyopadhyay, 2007). Studies also reported influences of age, sex and ethnicity on CI (Das and Bose, 2006; Kusuma et al., 2008).

Neck circumference (NC) is a marker of upper body subcutaneous adipose tissue distribution. Its correlation was high with other anthropometric study makes it a reliable and easy measure regional adiposity. NC was found higher among diabetics compared to non-diabetics (Aswathappa et al., 2013). Correlation of metabolic syndrome was higher among the individuals with high NC (Kumar et al., 2014). NC was good predictors of Metabolic Syndrome and cardiovascular risk factors among Asian Indians (Selvan et al., 2016). It can serve as screening measure for efficient detection of metabolic syndrome (Duki and Naidoo, 2016). Association of NC, abdominal obesity and obstructive sleep apnea is estabalished (Sharma et al., 2004; Krishnan et al., 2012). The NC and WC were compared between normal and overweight/obese adolescents to validate these measures with BMI (Patnaik et al., 2017). NC is now a established measure of regional body adiposity. Recently study by Mondal et al. (2016) has published cut-offs for defining NC to diagnose obesity.

A study reported from Haryana, found negative correlation between BAI with PBF assessed using bio-impedance analyzer in contrast to other measure of adiposity (Verma et al., 2016). Gupta and Kapoor (2014) found BAI to be a not much reliable as BMI, however suggest the possible use of BAI among the populations. Study among three endogamous population of south Bengal found higher correlation of PBF assessed using bio-impedance analyzer with BMI than BAI (Datta Banik and Das, 2015). However, BAI is not found suitable for predicting and screening hypertension compared to measure WC, WHtR and BMI (Chakraborty and Bose, 2012).

Studies from India have utilized skinfolds to define body adiposity among children and adults (Mukhopadhyay et al., 2005, Khatoon et al., 2008, Banik 2011, Rao et al. 2012; Sen and Mondal, 2013). Impact of undernutrition on the body composition variables were documented (Bose et al., 2006a; Khatoon et al., 2008; Datta Banik, 2011). The Oraon and Sarak tribal adult of Ranchi, India suffering very high CED were characterized with very low body fat mass (FM) and high fat free mass (FFM) (Datta Banik, 2011). The increase in the body adiposity was observed with increase of regional adiposity in the upper arm, triceps skinfold and mid upper arm circumference among Muslims females (Khatoon et al., 2008).

Higher arm muscle area and FFM was reported among the rural men compared to women from West Bengal (Nag and Ghosh, 2016). Similarly, Das and Bose (2006) reported higher FFM among men and higher PBF, FMI, mid upper arm muscle area of among women Marwaris of Howrah. Both studies used skinfolds, central obesity measures, height and weight. Similarly, among young Bengalee women of Kolkata, the mean BMI and skinfolds were significantly high (Bhadra et al., 2002). There were significant sex differences in these measures of adiposity among Bathudis, tribal people of Odisha (Bose et al., 2005). Body composition and fat distribution among rural and urban Jat females were compared (Kaur and Talwar, 2011).

Studies have investigated age related changes in the body compostion variable among Indian tribal and non-tribal (Singal and Sidhu, 1983; Ghosh et al., 2001; Bose and Das Chaudhuri, 2003; Ghosh, 2004; Ghosh and Das Chaudhuri, 2005; Bose et al., 2006a, 2005; Kaur and Talwar, 2011). Age related change was assessed among the Jat-Sikh and Bania females (Singal and Sidhu, 1983) and among Jat females of

Haryana (Kaur and Talwar, 2011). Study by Ghosh and Chaudhuri (2005) observed the impact of age, age at menopause, age at first conception, educational level and frequency of walking on PBF, FFMI and FMI of elderly women of Calcutta (Kolkata). Age had significant negative association with all anthropometric body composition measures such as PBF, FM, MUAC, UMA and UFA in both sexes (Ghosh, 2004). Age had significant negative association with most variables and indices in both sexes. In general, the associations were much stronger in men (Ghosh et al., 2001). Similar, negative impact of increasing age was observed on the body adiposity and composition among elder Bengalee women (Bose and Das Chaudhuri, 2003). Significant negative correlation of age with body composition variables were also noted among the Bathudis tribal men of Odisha (Bose et al., 2006a).

Metabolic syndrome like hypertension was also found to be associated with body composition. In this regard study by Ghosh and Bala (2011), Rao et al. (2012), Chowdhury and Roy (2016) among tribal and non-tribal are mentionable. There are studies of body composition in India which uses various reference methods like Dual-energy X-ray absorptiometry (DEXA), densitometry etc (Satwanti et al., 1980; Kuriyan et al., 1998; Josehp et al., 2011; Singhal et al., 2011; Nigam et al., 2013; Kuriyan et al., 2014; Marwaha et al., 2014a, b). Studies conducted using such complex methods which are not feasible for field based studies are outside the scope of the present work.

1.2.5 STUDIES DONE ON THE ASSESSMENT OF NUTRITIONAL STATUS AMONG ADULTS OF NORTHEAST INDIA

Northeast India is home to a large number of ethnic groups with distinct customs and traditions. All three main type of physical features like East Asian, European type and Australoid can be encounter in this part of the country. In India, Northeast region occupy a distinct place due its geographical, historical, social, cultural and political features. Northeast India comprises of Assam, Nagaland, Mizoram, Manipur, Meghalaya, Tripura, Arunachal Pradesh and Sikkim. Of which Sikkim was included in North Eastern Council in the year 2000. All these Indian states are frontier states. A long narrow passage in the west connects the regions with mainland India. Northeast India occupies an area of 255,000 sq km which comprises of hilly area and Bramhaputra valley. This ecological setting has profound impact on their subsistence as they can be divided into hill dwelling and valley dwelling. Hinduism is the major religion with Hindu Caste and Hinduised Tribals. Islam is the other major religion followed by Christianity and Buddhists (Irshad Ali and Das, 2003). Population professing animistic religion small and mostly located in Arunachal Pardesh. Some of the tribes of this region are Bodos, Khasis, Khynriams and Pnars, Garos, Mizos, Karbis, Mishings, Konyak Naga, Ao Naga, Sema Naga and Angami Naga, Tangkhul, Kabui, Thado and Hmar, Galong, Nishi, Wancho, Adi, Bodo Kacharis, Rabhas and Mishings.

According to NFHS-3 the prevalence of CED among the Northeast states was below 20% except Assam where the prevalence is 20-34%. Similarly, prevalence of overweight and obesity was below 10% among the Northeast states except Manipur and Mizoram where prevalence is 10-14% (NFHS-3, 2005-2006). This is also supported by an earlier study by (Bharati et al., 2007). The prevalence of chronic energy deficiency (CED) was also lower in the tribal (19%) than in the Hinduized (49%) and caste (52%) populations (Khongsdier, 2001). The mean values of BMI reported from tribal populations of Northeast India were significantly higher than the caste groups (Khongsdier, 2001, 2002, 2005). The prevalence of CED among male

Dibongiya Deoris of Assam was 21.43% (Gogoi and Sengupta, 2002). The prevalence of CED was higher among tribal (20.45%) than non-tribal (7.43%) college students of Tripura (Datta et al. 2015). Based on NFHS-3 data highest prevalence of male undernutrtion was reported from Tripura (Patil and Shinde, 2014).

A recent study conducted among the Nyishi tribal women of Arunachal Pradesh reported simultaneous prevalence of underweight (10.50%), overweight (9.94%) and obesity (9.57%), which is a suggests nutritional transition (Bharali et al., 2017). Another recent study among Rengma Naga observed the prevalence of 32.57% (males: 39.34%; females: 25.50%) and 10.77% (males: 9.95%; females: 11.63%) overweight and obesity respectively (Rengma et al., 2015). Trend was also observed among Tangkhul Naga tribal women of Manipur where the prevalence of overweight and obesity was 25.1% and 2.0%, respectively (Mungreiphy and Kapoor, 2010). The measure of abdominal adiposity like waist hip ratio is successful in predicting pre-diabetes/diabetes among the tribes of northeast (Mungreiphy and Kapoor, 2014).

Age, education occupation and income appear to have higher associations with overweight and obesity among adults Rengma Naga (Rengma et al., 2015). Similarly, changing life style among Tangkhul Naga tribe with improve SES are the contributing factor for increasing prevalence of overweight and obesity and related morbidity like diabetes (Mungreiphy and Kapoor, 2014).

Urban and tribal difference on CVD risk factors was assessed among adults of Tripura using anthropometry, biochemical tests and lifestyle variables (Saha et al., 2013). Serum lipid concentrations were strongly influenced by anthropometric indices of obesity like high WC and BMI in both sexes of Gauhati Assam (Bora et al., 2015). Tobacco use, alcohol use and unhealthy diet habits were high among men and women of Mishing tribes of Assam which predisposed them to various non-communicable diseases (Misra et al., 2014). There was non-significant relation between BMI and self reported morbidity. Similarly non-significant relation of BMI with self reported morbidity was reported by later studies however, it was found that Body Fat Mass Index was significantly associated with self reported morbidity after adjusting for age, income and FFMI (Khongsdier, 2002, 2005).

Some of the recent study among children has highlights on the nutritional scenario of Northeast India (Sikdar, 2012; Singh and Mondal, 2014). The prevalence of thinness varies from 17.18% to 27.73% among the boys and from 19.21% to 28.23% among the girls. On the other hand the prevalence of overweight varies from 1.95% to 7.81% among the boys and 1.96% to 9.41% among the girls. Such prevalence of overweight despite a persistently high burden of thinness suggests existence of nutrition transition among the Mising population (Sikdar, 2012). Study conducted among the children and adolescents of Sonowal Kacharis shown thinness using upper-arm composition (Singh and Mondal, 2014).

Other significant study conducted among the children and adolescents of northest are (Khongsdier et al., 2005; Khongsdier and Mukherjee, 2003a, b). The overall prevalence of CED was significantly greater in boys than in girls among the Khynriam Khasis, War Khasis and Hmars, respectively. The patrilineal and matrilineal forms of society were not reflected in the prevalence of CED among adolescents. This could be the interest of further research (Khongsdier et al., 2005). A study also reported difference in growth and body size among the three exogamous group of Khasi society such as Niam Khasi, Muslim Khasi and Christian Khasi (Khongsdier and Mukherjee, 2003a). Similar finding was reported among the Khasi girls. Such effect of heterosis on growth is subject of further research (Khongsdier and Mukherjee, 2003b). The rising epidemic is not restricted to highly urbanized societies but now has penetrated even to traditional and transitional tribes owing to their changing lifestyle (Mungreiphy and Kapoor, 2014).

1.2.6 STUDIES IN THE DIFFERENT FIELDS OF BIOLOGICAL ANTHROPOLOGY, INCLUDING NUTRITION AMONG ADULTS FROM SIKKIM

Studies in the different research areas of biological anthropology among the populations of Sikkim are relatively less in number. There are some studies on dermatoglyphic patterns among the Lepchas by Miki et al. (1960, 1961) and Miki and Hasekura (1961). A recent study by Dorjee et al. (2015) has investigated dermatoglyphic variation among the Limboos of Sikkim. Comparative evaluation of growth patterns among different caste and tribal groups of Sikkim was reported by Bhasin et al. (2008). Sporadic studies have been found on the life style and genetic influences on the metabolic syndrome (Sarkar et al., 2005), affects of perceived stress on CVD risk factors (Sarkar and Mukhopadhyay, 2008a), age related changes in blood pressures, influence on obesity and relation with anthropometric indices (Sarkar and Mukhopadhya, 2008b) and the possible seasonal variation (summer and winter) in blood pressures (Sarkar and Mukhopadhya, 2009) among the Bhutias. A study among the Bhutia and Rai populations reported a significant correlation of hypertension with use of tobacco and alcohol consumption, level of education and activity patterns (Mishra et al., 2010). Other studies investigated eating and weight concern among adolescent girls and their biocultural correlates (Mishra and Mukhopadhya, 2011). Prevalence of obesity, overweight, and hypertension was 2.04%, 14.5% and 5.62%, respectively among the adolescents of urban areas of Gangtok, Sikkim. The average fast food intake, screen time and limited outdoor activities were significantly associated with obesity (Kar and Khandelwal, 2015).

Sikkim is a state where fundamental studies on nutritional assessment appear to be almost non-existent, except the NFHS-3 (2005-2006) and NFHS-4 (2015-2016) reports.

1.3 OBJECTIVES OF THE PRESENT STUDY

Given the above, the present study is an attempt to document the prevalence of undernutrition or overnutrition among adult individuals belonging to an ethnic population from Sikkim using anthropometry. The objectives are as follows:

- To assess the nutritional status and body fat distribution using anthropometric measurements and derived indices using internationally accepted cut-off points.
- To document the association of different socio-economic variables with nutritional status and body fat distribution.
- To assess the age and sex related changes in nutritional status and body fat distribution.
- To compare the findings of present study with other available international and national data.

The present study is basically fundamental in nature and has the potential to provide the basic data on undernutrition, overweight and obesity along with body composition that is sorely lacking for the ethnic populations of Sikkim.