In this brief review, an attempt will be made to make an overview of literature on how body composition is related to age, sex and nutritional status. An attempt will also be made to make a brief review of how body composition and nutritional status are related to morbidity, rural-urban setting and socioeconomic conditions. The overview is far from being exhaustive but its intension is to bring out some aspects that may be relevant to the present study.

**Body composition in relation to age and sex**

Body fat or FM varies with age and sex, especially during growth and development. This variation is apparent in early life and it is magnified during adolescent growth spurt and sexual maturation. There is a sex difference in changes in specific components of body composition with advancing age (Malina, 2005). As for adults, middle age (40-50 years) is commonly associated with increasing fatness due to increase in weight gain. In men, this may be a feature of fourth decade (Pierson *et al.*, 1974; Baumgartner *et al.*, 1995). In women, fatness is reported to increase following pregnancies or with the onset of menopause (Ben-Tovim and Walker, 1994; Poskitt, 1995; Kirchengast *et al.*, 1999; Dittmar, 2001; Winkvist *et al.*, 2003; Monisha *et al.*, 2007; Kulkarni *et al.*, 2010).

Various studies among the adults of both sexes in different populations show that FM increases slowly with age and that the rate of increase differs by sex. A study in a large multiethnic population comprising of Asians, Blacks, Puerto Ricans and Whites between the age group of 20 – 94 years reported that except among the Puerto Ricans, age was a significant predictor of body fat and fat percentage. Both FM and fat percentage were maximum between the age group of 49 – 61 years in both the sexes, and FM and fat percentage decreases with the increase in age (Mott *et al.*, 1999). It is reported that the trends in FM and %FM by aging were different between males and females among the Japanese adults age 20 -79 years. Curvilinear changes peaking around 50 years of age were seen for
males, whereas linear increases in FM and %FM were seen for females (Ito et al., 2001).
Study among the elderly adults of Southeast Brazil reveal that underweight was significantly more common among men than women and increased directly with age in both the genders. It also revealed that obesity was more common among women, and prevalence decreased with age (Barreto et al., 2003). A study in Albania showed clear gender differences in the prevalence of overweight and obesity, with women (30.9%) of all age groups being more likely to be more obese than men (22.0%) (Shapo et al., 2003). Among adult Jamaicans of African origin, the prevalence of obesity is higher in women (30.7%) than in men (6.7%) (Jackson et al., 2003). The highest proportions of overweight and obesity, 51.4% and 10.0%, respectively among Italian men are in the age group of 45-64 years, while the proportions of overweight and obesity, 38.8% and 13.8%, respectively among women are in the age group of ≥65 years (Gallus et al., 2006). In the case of adults from Portugal, the prevalence of overweight and obesity is 33.5% and 18.8% in women, and 45.8% and 16% in men, respectively, and overweight and obesity increases with the increase in age in both genders (Santos et al., 2008). Similar findings on the indigenous Surui Indians of Southwest Brazil revealed that body fat or FM was higher in women (38.8%) than in men (13.6%) (Lourenco et al., 2008).

Moreover, a review on a study of 19 populations reported that WC and WHR increased with the increase in age (Molarius et al., 1999). A 10 years longitudinal study among the elderly revealed that waist circumference increased significantly in the women but not in the men, whereas hip circumference decreased significantly in the men (Hughes et al., 2004). An increasing trend of the total FM and five anthropometric indices namely BMI, waist circumference (WC), hip circumference (HC), waist-hip ratio (WHR) and conicity index (CI) in successive older age groups was reported from a study among Chinese adults between the age group of 20 to 40 years (Lei et al., 2006). A study reported that among the middle aged Polish population, males show a higher trend of increasing risk to obesity with increasing age compared to females (Kaczmarck, 2007).

Although such fat patterning seems to be physiological, it increases the risk of high morbidity and mortality (Timperio et al., 2000; WHO/FAO, 2003; Kruger et al., 2005). The association of fat distribution with coronary heart diseases has been reported in many middle aged adult populations (Chang et al., 2000; Yasmin and Mascie-Taylor, 2000; Park et al., 2006). Its association with diabetes (Olinto et al., 2004) and with blood pressure and hypertension (Zhou et al., 2008) has also been reported from the middle-aged adults. An
analysis of anthropometric measures among women aged 20-49 years, in 30 developing countries reported that overweight exceeded underweight in both rural and urban areas (Mendez et al., 2005).

In India, a study of urban population in Mumbai (Shukla et al., 2002) also indicated that the prevalence of overweight was higher in women (30%) than in men (19%). Study among the urban elderly Bengalee Hindus in Calcutta reported that there exists a significantly decrease in adiposity or FM with increase in age (Ghosh et al., 2001). Similar finding was reported by Tyagi et al. (2005) in a study among the urban elderly females of Delhi. Bose (2006) described changes with age in three measures of abdominal obesity, WC, WHR and CI and suggested that the relationship between WC and BMI is influenced by age and sex. Das and Bose (2006) described that the prevalence of FM and fat percentage was greater in females than in males from 20 to 75 years of age in a Marwari population in West Bengal. A study among the elderly from Delhi reported that non-institutionalized senior citizens of both sexes have higher percentages of overweight as compared to institutionalized elderly (Tyagi, 2007). Another study among post menopausal women in Chandigarh reported that there is a general increase in body weight in these women (Monisha et al., 2007). A study among urban slum dwellers in India also reported that menopausal status is associated with lower lean mass and high obesity or body fat (Kulkarni et al., 2010). However, age was found to be significantly negatively related with anthropometric and body composition variables and indices in a study among the men (Bose et al., 2006a), and women of Bathudis tribe in Orissa (Bose et al., 2007b). A study among the Kora Mudi tribe of West Bengal revealed that there exist significant age and sex variation in anthropometry and body composition (Bisai et al., 2008).

FFM is also known to vary systematically with changes in age and sex. It is reported that FFM is usually greater in male adults than in female adults (Gallagher et al., 1997; Wang et al., 2001). It is generally observed that older people tend to have less FFM than young adults, and this age effect is more pronounced after 60 years of age, especially among post-menopausal women (van Loan, 1996; Forbes, 1999). A study among the white adults in the United States reported that mean FFM was greater in males (60.8 kg) than females (41.7 kg) and that the greater amount of FFM in males was due to broad shoulders, wrists and knees (Chumlea et al., 2002). Similarly, an analysis of FFM in urban Gambia reported that FFM was significantly higher in males than females (Siervo et al., 2006). The decline in FFM is also more rapid in aged men than in women (Gallagher et al., 1997; Ito et al., 2001). This
decline in FFM is associated with weakness, disability and morbidity (Frontera et al., 1991; Hughes et al., 2002). It is, however, suggested that low FFM can be improved by increased physical activity (Guo et al., 1999; Hughes et al., 2004). Little is known about such information on Indian populations, although a study carried out in a South Indian population indicated that FFM was higher in men than in women aged 22-38 years (Ferro-Luzzi et al., 1997). A recent study among the Marwaris in West Bengal also reported that males have higher FFM compared to females (Das and Bose, 2006).

Body composition in relation to body dimensions and body shape

Anthropometric measurements and indices are widely used for the assessment of body composition and nutritional status of children and adults. For example, skinfold thicknesses are used in estimating body fat with the help of mathematical equations. The most widely used skinfold-thickness equations are those developed by Durnin and Womersley (1974) and Jackson and Pollock (1978). These equations were developed on the basis of a two-compartment model, which separates the body composition (body weight) into FM and FFM.

It is, however, criticized that skinfold thicknesses may not provide accurate information about body fat because visceral fat cannot be measured (Friedl et al., 2001). Moreover, skinfold thicknesses cannot be used to assess changes in body FM because of age-related fat redistribution (Hughes et al., 2004). Nevertheless, skinfold thicknesses measurement is still used to understand the nutritional status and in epidemiologic research (Andrade et al., 2001).

Body weight and height are another anthropometric measurements commonly used for the assessment of body composition and nutritional status. Both weight and height are correlated with FM and FFM. However, FM is more correlated to body mass index (BMI) developed by Quetelet in 1869 and is suggested to use as an index of FM. This index is derived as weight (in kg) divided by height squared in meters (weight/height²). Since BMI is more correlated with FM (Norgan and Ferro-Luzzi, 1985; Willett, 1990), it is widely used as a good indicator of body fat and also recommended for use by the World Health Organization (WHO, 1983, 1995). Several studies have therefore been done to describe the relation of adult BMI to body fat distribution or obesity (Banegas et al., 2001; Torrance et al., 2002; Kant, 2003; Freedman et al., 2004). Studies have also been carried out to assess the nutritional status of adults by using BMI in several countries (Belahsen et al., 2003; Vorster et al., 2005; Bergman and Hauser, 2006; Lourenco et al., 2008) as well as in India (Reddy, 1998; Khongsdier, 2001; Bose et al., 2006; Bose et al., 2007a; Bose et al., 2007b; Gautam, 2007; Gautam, 2008).
However, recent studies have questioned the validity of BMI as an indicator of fatness (Deurenberg et al., 2001; Frankenfield et al., 2001; Kyle et al., 2003; Goh et al., 2004; Cook et al., 2005; Khongsdier, 2005a; Flint and Rimm, 2006) because it lacks specificity to the variation in body composition, and the confounding effects of various factors such as age, sex, body shape, ethnicity, etc. (Wagner and Heyward, 2000; Prentice and Jebb, 2001; Shiwaku et al., 2004). It is recently proposed to split BMI into two components: body fat mass index (BFMI) and fat-free mass index (FFMI) in which the skinfold thicknesses were correlated (Khongsdier, 2005a), using the predicted equations of Durnin and Womersley (1974) and Siri (1961). The cut-off points are also proposed for both developed countries (Schutz et al., 2002; Kyle et al., 2003) and Asian countries (Khongsdier, 2005) due to wide variation in body fat composition between Asian and European populations (Norgan, 1990; Gallagher et al., 2000). In India, Bose et al. (2008) have reported data on body composition using the equations of BFMI and FFMI among the adults of Bathudis.

Body composition is correlated not only with body dimensions (such as skinfold thickness, body weight and height), but also with body shape, i.e., relative dimensions such as the ratio of sitting height to height known as conic index. It is suggested that BMI is correlated with sitting height, BMI is lower in those populations with higher sitting height, which is a general characteristic of populations in Asian and pacific regions (Norgan, 1990, 1994). A recent study in the United States among the adults of three groups, viz., white, black and Mexican-American ethnicity shows that BMI is significantly influenced by sitting height ratio (Bogin and Beydoun, 2007). Prior to that, an analysis of BMI for 12 population groups in Northeast India seems to support such a contention (Khongsdier, 2001). Another analysis for 38 different population groups in Central India report that there is a positive but statistically insignificant correlation between BMI and conic index (Adak et al., 2006). Again in Central India, a study among the caste populations by Gautam (2008) has reported that the adult males within the same occupational group have the same conic index and BMI. Nevertheless, there is limited literature on the relationship between body composition and conic index from other Indian populations.

Conicity index (CI), waist-hip ratio (WHR) and waist circumference (WC) also measures the body shape and are correlated with body composition. These indices measure the abdominal or central adiposity i.e., it measures the FM and central fat distribution of the body. It is reported that abdominal circumferences, namely waist and hip circumferences, are more susceptible to environmental changes (i.e., diet and exercise) and therefore provide
better estimates of body fat than BMI for women (Friedl et al., 2001). Moreover CI, WHR and WC are widely used in body composition studies because of its association with various obesity related problem such as hypertension, cardiovascular disease (CVD) or coronary heart disease (CHD), diabetes type II, etc. (Valdez et al., 1993; Han et al., 1995; Bose and Mascie-Taylor, 1998; Grundy, 2004; Pitanga and Lessa, 2004; Stein and Colditz, 2004; Swinburn et al., 2004; Neufeld et al., 2007; Welborn and Dhaliwal, 2007). A 10 year long study in a remote Aboriginal community in Australia report that WC, BMI and hip circumference were highly correlated and have a positive association with cardiovascular risk factors (Wang and Hoy, 2004). Among middle aged women in France, WC and WHR have been reported to be important for screening of diabetes and obesity-associated dyslipidaemia (Balkau et al., 2006). Biosocial factors such as age, socioeconomic status, and lifestyles, which included dietary habits and physical activity, have a great influence on the WC, WHR and CI (Laitinen et al., 2004; Suder, 2008; Lourenco et al., 2008). A study in Bangladesh reports that the prevalence of high CI increases with increasing age and better education, and females are 7.5 times more likely to have a high CI than males (Flora et al., 2009). Also, recent review of twenty-eight studies based on WC and WHR among adults, aged 18 to 74 years report that WC and WHR values vary across different ethnic groups, and that there are no universal optimal cutoff values (Qiao and Nyamdorj, 2010).

In India, the association of these indices and measures with overweight, blood pressure, diabetes, heart diseases, etc. has been reported from some adult populations (Das and Bose, 2006; Kaur and Mogra, 2006; Monisha et al., 2007). A comparative study among adult Hindu and Muslim females, aged 18-23 years was reported that Hindu females have significantly higher BMI, WC and WHR compared to Muslim females (Ghosh et al., 2005). An analysis among the elderly in Kolkata reports that WC is preferred over WHR and CI in measuring abdominal fat (Bose, 2006). A study in South India has reported on the relationship between BMI, WHR and CI to age, sex and socioeconomic conditions (Kusuma et al., 2008). Only a limited study has been reported in India with regard to the relationship between WHR, CI and WC with body composition.

**Body composition in relation to nutritional status and associated morbidity**

The influence of nutrition on body composition is a well-established fact. However, the relative proportion of changes in FM and FFM during nutritional deprivation and over-nutrition is not fully understood (Frankenfield et al., 2001; Khongsdier, 2005a). Over-nutrition is characterized by obesity and it is associated with morbidity, such as diabetes
mellitus, cardiovascular disease, hypertension and stroke, osteoporosis, and some forms of cancer (WHO/FAO, 2003). As noted earlier, obesity has become an epidemic in developed countries. It is believed to be a result of an excess accumulation of fat in the body, although it is not clear whether the total amount of fat deposited in the body, or the relative proportion of FM to FFM, that determines health and fitness (Poskitt, 1995; Khongsdier, 2005a). In fact it is without doubt that overweight and obesity are the leading nutrition-related disorders of clinical and public health concern (Kuczmarski and Flegal, 2000). This burden of overweight and obesity is growing fast in developing countries and is shifting towards groups who are from lower socioeconomic status (Monterio et al., 2004).

The association of obesity and morbidity has been reported in a number of body composition studies from various populations. Stene and colleagues (2001) have reported that adult BMI is highly correlated with blood pressure. Similarly, Tawfeek (2002) report that 13.3% of men and 22.5% of women in Baghdad with WCs 94cm and 80cm respectively have hypertension. Olinto et al. (2004) reported that the prevalence of hypertension and diabetes was 25.6% and 6.2%, respectively among Brazilian women. The study showed that increase in WC and BMI is associated with hypertension and diabetes. A similar study among the adult Mexicans show that the prevalence of abdominal obesity, 46.3% of men and 81.4% of women, is associated with increased prevalence of diabetes type II mellitus and hypertension (Sánchez-Castillo et al., 2005). It is reported that there is a strong positive correlation between obesity and hypertension in adult men and women in Uzbekistan, and that obese adults are about 3.1 times more likely to suffer from hypertension than those adults with normal BMI (Mishra et al., 2006). Percent body fat was associated with metabolic and cardiovascular diseases in both men and women (Gregory et al., 2007). In women, measures of body fatness by BMI and WC have reported to identify diabetes and hypertension risks (Neufeld, 2007). Study in a Chinese population has shown that the best indicator of hypertension was BMI for women (Zhou et al., 2008).

In addition, although obesity is declared an epidemic in developed countries and developing countries undergoing rapid nutrition transition, fatness is actually considered desirable in some cultures as it enhances social prestige of the individuals (Wagner and Heyward, 2000). It is also considered to be beneficial for the survival of some tribal groups during the “feast and famine” conditions in the past, but becomes detrimental in a modern society with abundance of food and less physical activity (Neel, 1962). In fact, there is a population variation in perceptions about obesity. A social definition of obesity is related to
fatness beyond the socially accepted norms for a given society, while a medical definition relates the level of fatness (i.e., BMI of > 30.0 kg/m²) to morbidity and mortality, which varies across populations (Ulijaszek, 1999). A worldwide overview from a range of body composition and disease studies report that Asians, Africans and Latin Americans are more likely than whites in the USA and Europe to have greater body fat and central fat for the same BMI and therefore likely to experience morbidity at lower BMI levels (Popkin, 2002). For example, the level of fatness associated with morbidity in Asian populations is lower than that in European populations (Deurenberg-Yap et al., 2000).

Although some studies in urban cities in India have reported the prevalence of obesity or overweight (Ghosh et al., 2001; Shukla et al., 2002; Das and Bose, 2006; Monisha et al., 2007) among adults, the report on its relation to morbidity is limited. Misra et al. (2001) studied the adults of a slum area in urban South Delhi and reported that there is a high prevalence of obesity, diabetes and dyslipidaemia among the middle aged, which is associated with a high BMI, WHR and percent body fat. A study among the postmenopausal women in Udaipur city show a high correlation between body FM measured by BMI and WC in relation to hypertension (Kaur and Morga, 2006). A study in Malda town of West Bengal revealed that adults with higher BMI are at significantly higher risk of hypertension (Das et al., 2005). It is suggested that an increase in body fatness in healthy adults may be responsible for the association between blood pressure and weight (Sidhu and Prabhjot, 2007). Similarly, it is reported that among diabetes mellitus patients in Punjab, percent body fat is highly correlated with weight, BMI and WHR (Arora et al., 2007). It is reported from Bikaner, Rajasthan, that 46.65% patients with type-2 diabetes are overweight or obese by BMI measures, and also WHR measure shows a high rate of abdominal obesity in both male (40.70%) and female (84.84%) patients (Sharma and Jain, 2009). Another study also reported that the means of BMI, WHR, WC and %BF are significantly higher in adults who are patients of type-2 diabetes and coronary artery disease (Kaur et al., 2010). This study also suggested that %BF may be an improved phenotypic characteristic than BMI and WHR when studying obesity related health risks.

As for under-nutrition, the BMI < 18.5 kg/m² is widely used as a practical measure of chronic energy deficiency (CED) i.e. a “steady” underweight in which an individual is in energy balance irrespective of a loss in body weight, or body energy stores. Such a “steady” underweight is likely to be associated with morbidity, or other physiological and functional impairments (James et al., 1988; Shetty and James, 1994; WHO, 1995). However, it is
unclear whether the associated morbidity or mortality with low BMI, especially in developing
countries, also depends upon the variation in body composition. Studies of dietary-induced
weight loss revealed that both body fat mass (BFM) and fat-free mass (FFM) decreased but in
different proportions (Keys et al., 1950). Empirical evidence from Asian populations
indicated that low BMI was associated with low FM and FFM, although there were
differences in the proportion of FM and FFM (Ferro-Luzzi et al., 1997; Strickland and
Tuffrey, 1997). Of course, some studies of the relationship between low BMI and morbidity
in developing countries produced inconsistent results (Garcia and Kennedy, 1994;
Khongsdier, 2002), despite certain evidence of a curvilinear relationship (de Vanconcellos,
1994). In fact, there is lack of information on the relationship between adult body
composition and under-nutrition in relation to morbidity from developing countries,
especially from India (Campbell and Ulijaszek, 1994; Khongsdier, 2002, 2005a), although
there is considerable evidence that undernourished children are more susceptible to infectious
diseases and poor growth and development (Khongsdier, 2005b).

In India, a high prevalence of under-nutrition (57.9%) was reported from the
Bathudis, a tribal population in Orissa (Bose and Chakraborty, 2005). A study among the
adult males in Central India has suggested that the high prevalence of CEDs may be due to
their low BMI (Adak et al., 2006). Relation between low BMI and CEDs are also reported
from the backward populations in the districts of Madhya Pradesh and Chhattisgarh (Gautam
et al., 2006), from the Saharia tribe of Rajasthan (Rao, et al., 2006), from the slum dwellers
in Midnapore, West Bengal (Bose et al., 2007), and from low socioeconomic tribal
populations from South India (Kusuma et al., 2008). A study among War Khasis in North­
East India have found a significant association between BFMI and morbidity, compared to
those with normal BFMI, suggesting that individuals with low BFMI are about 4.7 times
more likely to become sick, and individuals with a high BFMI are about 3.9 times more likely
to become sick (Khongsdier, 2005a). Further studies are needed to test the relationship
between morbidity/mortality and the two components of BMI, namely, BFMI and FFMI, in
both developed and developing countries.

**Nutritional Status in relation to socio-cultural evolution and urbanization**

Despite controversy on the proportion of vegetable and animal foods, it is widely accepted
that the types of food and basic nutrients required for humans are relatively constant through
different stages of human evolution. Also, there were no major morphological changes,
except upright posture and development of brain capacity during the *Homo erectus* stage. The
ways of acquiring foods remained relatively constant till about 10,000 years ago when agricultural revolution started. "The absence of evidence for significant change in technology suggests that each generation had to solve the problems of survival and reproduction with a similar set of behaviours and tools" (Baker, 1984). However, the widespread of agriculture has a profound impact on nutritional and socio-cultural conditions of the people. They started consuming large amounts of grain, milk, and meat of domesticated animals and becoming more sedentary. Population growth started increasing and societies became larger. Thus the shift from foraging to farming was one of the major changes ever seen in the dietary history of humans since the time of *Homo erectus*. This transition has taken place only within the last 10,000 years, which is but a tiny part of our evolutionary history (Larsen, 1998).

With the advent of industrial revolution about 200 years ago in high-income countries, human populations have experienced dramatic changes in food production, processing, storage and distribution. These have brought about major changes in the nutritional composition of the diets. The traditionally plant-based diets have been quickly replaced by high-fat, energy-dense diets with high content of animal-based foods (WHO/FAO, 2003). Although under-nutrition remains a major health problem in many developing countries, there is evidence of rapid changes in dietary patterns compounded by changes in nature of work (lifestyles), often referred to as "nutrition transition" due to increasing urbanization, industrialization and market globalization (Popkin, 1998, 2002; Khongsdier, 2005b). Studies have reported of the influence of such transition from many developing countries (Noor, 2002; Du et al., 2002; Maletnlema, 2002; Benjelloun, 2002; Shapo et al., 2003; Rivera et al., 2004; Lourenco et al., 2008). These dramatic and rapid changes are believed to have a great impact on health and nutritional status of the people in developing countries. The rise in national incomes in developing countries and increased 'westernization' will lead to increase in the levels of obesity in the future (Martorell et al., 2000).

Deficiency of nutrition in early fetal life has been found to have a great impact on the health of the individual during adult life, which is now known as fetal origins hypothesis. The basic principle of this hypothesis is that all human beings are 'plastic' and molded by the environment so as to adapt to different environmental conditions (Barker, 1999; Khongsdier, 2008). For a human fetus it means that when nutrition is less, the fetus can alter the metabolism and slow down the growth process. This kind of adaptation during the early developmental stage leads to permanent changes in the structure and function of the body.
Various studies by Barker and colleagues (1992, 1995, 1998; Barker et al., 2001) have suggested that individuals who were disproportionately thin or small with low birth weight tend to have a higher rate of type-2 diabetes and associated coronary heart diseases including hypertension and stroke in their adult life. A study reported that mothers who are short stature, from low social class and those who smoke during pregnancy influence the development of adult chronic diseases (Power et al., 2003). Another study show a strong positive associations between birth weight and bone mineral content which led to the evidence that the risk of osteoporosis in later life might be programmed by genetic and/or environmental influences during gestation (Gale et al., 2001). Expectant mother nutritional status therefore influences the association of birth weight and certain adult chronic diseases. A cohort study in a high birth weight population in Iceland has reported that high birth weight is related to high BMI, truncal fat and high blood pressure during adulthood without any risk of having coronary heart disease (Gunnarstottir et al., 2004).

In fact studies have found that even childhood BMI have a positive association with BMI during young adulthood. A report based on studies from rural Guatemala suggests that BMI should be measured between the age of 3 and 7 years as increase in BMI between these years have a strong association with fat mass and abdominal fat during adulthood (Corvalán et al., 2007). In another recent study, it is reported that a 5.6 cm increase in childhood height is associated with a unit increase in childhood BMI, and a unit increase in BMI during childhood is associated with about 1.3 units increase in BMI during adulthood (Stovitz et al., 2008). Recent study in Jamaica by Nelson (2009) reported that those individuals who are born between 1959 and 1968, a period when the country was experiencing political and economic instability, have higher BMI and skinfold thickness values. Nutritional stress due to fluctuations in the sociopolitical environment during the critical developmental period is also suggested to contribute to the poor health during adulthood.

Reviews of epidemiological studies in different populations with regard to the fetal origins of diseases have suggested that there is a need to improve the nutritional status of mothers, so as to reduce the prevalence of these diseases (Barker, 1999; Godfrey and Barker, 2001; Fall, 2001; Sachdev, 2004; Khongsdier, 2008). It is also suggested that even chronic under-nutrition during early childhood reduces the ability to burn fat during adulthood, and predisposes the individuals to adult obesity (Frisancho, 2003). According to Leonard (2009), early life under-nutrition and adult obesity are simply two sides of the same coin.
In India, a study by Stein and colleagues (1996) revealed that short height and small size babies whose mothers had with low weight were affected by coronary heart diseases during adulthood. Yajnik and colleagues (2002) have reported that hyperinsulinemia or increase in insulin resistant level is present at birth. Higher insulin resistance is a common feature in Indians, which make them susceptible to type-2 diabetes. It is also reported that the body composition of Indians show a very high amount of central fat and percent body fat for a given BMI, which is responsible for the high insulin resistant level. Also a cohort study in Delhi reported that a high BMI gain during infancy and early childhood is associated with a high increase in lean mass in adulthood, while a high BMI gain in late childhood and adolescence is strongly associated with adult adiposity and central adiposity (Sachdev et al., 2005). More studies pertaining to this hypothesis are needed in India to understand nutritional status and its association with obesity and its related health diseases.

Some studies in Indian urban areas have revealed the increasing trend of obesity, which is likely to exert a great impact on the health and socio-economic systems in the next two decades (Shetty, 2002; Shukla et al., 2002). In the meanwhile, under-nutrition still remains a major health problem in rural areas (Khongsdier, 2005b). There is also evidence that the prevalence of obesity in many developing countries is not only in the higher socio-economic groups (Ball and Crawford, 2005), but also in the lower ones especially in urban areas (Monteiro et al., 2005), which is the common phenomenon in developed countries. More studies are needed to explore the bio-social factors responsible for under- and over-nutrition, which may vary from one population to another, especially in India with diverse socio-cultural and ecological conditions (Khongsdier, 2001, 2002). A better understanding of the biosocial variation in nutritional status is urgently needed not only for scientific interest, but also for policy implementation to reduce the double burden of under- and over-nutrition in the country.

**Body composition and nutrition in relation to rural and urban differences**

Urbanization is an important global phenomenon which has brought about drastic changes such as increase in population size, changes in dietary habits, lifestyle, etc. Urban areas are the place of economic growth and the home for the majority of humanity (Forbes and Lindfield, 1997). In the context of any developing country undergoing rapid nutrition transition, it is necessary to consider the rural-urban difference. It is observed that the shifts in diet, activity patterns and body composition are occurring more rapidly in developing countries (Popkin, 1998, 2004). The emergence of obesity is attributed to the increasing
intake of protein rich and fat rich diets with lessened physical activity. Khongsdier (2008) has pointed that the increase in rural-urban migration along with changes in dietary and physical activity patterns is likely to condition many individuals to obesity and its associated diseases such as diabetes, hypertension, etc. He has further pointed that rural to urban migration and transforming rural settlements to cities in developing countries are the major cause for the rapid growth of population, and that these changes will lead to the decline in rural population. A study among the black adults from a less developed and a developed nation, Nigeria and the United States, respectively revealed that the former have a significantly lower body weight, height, BMI, FFM and FM than the latter, which is due to the different level of physical activity (Luke et al., 2002). Amoah (2003) studied obesity among the adults in Ghana and reported that the rate of overweight and obesity is higher in the urban areas than the rural areas. The study revealed that socio-demographic variables such as older age, female gender, urban, high-class residence, sedentary occupation and tertiary education are associated with higher prevalence of obesity. Study among the rural villagers and urban migrants of Huli-speaking group in Papua New Guinea reported that urban migrants have higher BMI and body fat or FM, and therefore better nutritional status compared to the rural counterparts (Yamauchi and Umezaki, 2005). They concluded that urbanization, especially reduced physical activity, affected the increase in the anthropometric measures and nutritional status. A rural-urban comparison in Eastern China reports that urban dwellers are highly associated with metabolic syndrome, which is a result of high dietary fat intake and lower occupational physical activity (Weng et al., 2007). Also, an extensive study in 26 sub-Saharan countries in Africa reported that rural women were 68% more likely to be malnourished compared to their urban counterparts (Uthman and Aremu, 2008). Thus, differences in nutrition and lifestyle factors seem to contribute for the differences in the body composition between rural and urban populations.

Although generally urban dwellers are considered to be at risk to obesity, studies have reported that obesity does occur in rural dwellers. A very high prevalence of overweight and obesity have been reported from poor and relatively isolated communities of Mexico, the cause of which have been pointed on to less physical activity, sedentary life and intake of fat rich food (Sánchez-Castillo et al., 2001). Torun et al. (2002) reported that a high proportion of young Guatemalan women in both rural and urban areas are overweight and sedentary with a mean body fat of 29.8%, both rural men and women have high abdominal fat, and that migration to a city is the main factor for such increase in both men and women. In another study, it is reported that occupation is the factor among the Guatemalan adults which causes
the prevalence of overweight and abdominal obesity in both rural and urban women, whereby women in both rural and urban areas lead a sedentary life, while the prevalence of overweight and abdominal obesity is higher among adult men from urban area and non-agricultural rural, compared to their agricultural rural counterparts (Gregory et al., 2007). An analysis of body composition in Korean population report that a high abdominal obesity (46.9%) and high blood pressure (45.2%) are prevalent in the rural community and hypertriglyceridemia (37.6%) and low HDL-cholesterolemia (37%) in the urban community, which is attributed to the improving economic conditions (Lim et al., 2006). In Turkey, it has been reported that there is a high prevalence of abdominal obesity and metabolic syndrome, especially among females in both rural and urban areas (Oğuz et al., 2008).

In India, a study in South India on BMI and abdominal fat report that obesity or overweight, hypertension, sedentary lifestyle, etc, are more prevalent among urban population as compared to the rural population and therefore the cardiovascular risk factors are higher in urban population (Venkatramana and Reddy, 2002). In a review of various rural-urban studies in India, Shetty (2002) has described that the prevalence of CHD or coronary heart disease was found to be higher in the urban population as compared to rural population. He suggested that the increase in CHD resulted because of internal migration, urbanization and exposure to changing diet and lifestyle. Also, a study on body fat or FM among middle aged Indian men in rural and urban Pune reported on the high prevalence of FM in men, and has suggested that to assess risk for chronic diseases, adiposity should be measured by anthropometry and bioelectrical impedance (BIA), rather than relying only on BMI (Bhat et al., 2005). Study among the adults of Calcutta and a village about 80 km away from the city was undertaken to investigate the rural-urban differences in the prevalence of cardiovascular diseases (Das et al., 2008). This study showed that significant differences existed for anthropometric, metabolic and blood pressure variables between rural and urban areas. It also revealed that urban population was more susceptible to cardiovascular diseases and that this was due to the influence of effective urbanization and modernization. A study of the body fat distribution among the Meitei women in Manipur showed that body fat composition is higher among urban women. It further reported that dietary habit, physical activity and socioeconomic status are the factors behind the fat distribution difference between rural and urban women (Devi et al., 2008).
Body composition in relation to socioeconomic status

Socioeconomic status is an important factor which has a high impact on the prevalence of obesity. Several studies have reported that obesity differs not only by age and sex, but also by socioeconomic status. A study in Spain shows that older women with low educational level and low income were the most susceptible group to gain weight (Aranceta et al., 2001). Hakeem (2001), reported that in Karachi, Pakistan the relative proportion of overweight males and females increased with age at all income levels. It also reported that in young female adults (19-41 years), overweight decreased with increasing income whereas in the older females (41-60 years) the prevalence of overweight increased significantly with income level. It is reported that in the United States, Hispanic women have FM 9% higher and FFM 5% lower than in white women, and these differences occur in early adulthood among women of similar high educational status (Casas et al., 2001). A study from Brazil reported that there is a linear association between socioeconomic status and body composition (BMI, %BF, lean body mass) for males, and a curvilinear association for females, and this variation in the pattern of association is not only by gender differences but also by caloric demand of labour and social value attached to food (Dos-Santos et al., 2001). The increasing trend in the rate of overweight and obesity among adults in Canada varies by sex, education and smoking status (Torrance et al., 2002).

It is also reported that women from affluent societies or from better socioeconomic background are overweight or obese, and they tend to retain more weight after each pregnancy (Winkvist et al., 2003). A population based study in Sweden revealed that education with the influence of lifestyle factors such as physical inactivity and excess consumption of alcohol has a positive association with obesity, and that it is greater in men than in women (Molarius, 2003). Study also show that marital status influences the high rate of BMI, whereas BMI is lower among cigarette smokers (Jackson et al., 2003). Socioeconomic status such as income, education, social class and lifestyle factors such as TV viewing, are reported to be associated with the risk of overweight and obesity among Peruvian adults living in cities (Jacoby et al., 2003). A 15 year longitudinal study in Denmark has indicated that it is obesity which has lead to physical inactivity in both sexes of adults (Petersen et al., 2004). It is reported that among Balinese women, fatness measured by anthropometry is found to be significantly associated with household wealth and educational level (Huntsman, et al., 2005). Yoon et al. (2006) examined the relationship between socioeconomic status and obesity among Korean adults and reported that in men, as income increased there was a linear increase in mean BMI and mean WC but not in women. They
also found out that in women, higher levels of education were significantly associated with lower BMI and WC. A similar finding was reported by Gallus et al. (2006) in a study among Italian adults. The study showed that underweight was higher (6.7%) in more educated women as compared to less educated women (3.7%). Study in Portugal revealed that women from low socioeconomic status have significantly higher prevalence of overweight (37.6%) and obesity (24.5%) compared with those from middle and high socioeconomic status (Santos et al., 2008). It is also reported that body fat distribution, especially WC is influenced by lifestyle factors, socioeconomic factors and age among working males in Poland (Suder, 2008). Study in a multiethnic population in Hawaii have also revealed that among the pacific islanders group the high rate of obesity was a result of socioeconomic status and lifestyle (Brown et al., 2009).

Obesity related diseases are also found to be strongly determined by socioeconomic status. Winkleby and colleagues (1992), studied adults in the age group of 25-64 years in the United States and reported that there is a positive correlation between education, income and occupation. It is also reported that education was the only measure of socioeconomic status that was significantly associated with disease risk factors. Based on this finding they have further suggested that education should be used to indicate good health. In a longitudinal cohort study consisting of elderly adults (70-79 years) from both black and white community in the United States reveal that low family income is strongly associated with cardiovascular diseases (Rooks et al., 2002). A similar longitudinal cohort study also revealed that elderly adults’ from low socioeconomic status have a high risk to suffer from heart disease, cerebrovascular disease, diabetes mellitus and even depression (Koster et al., 2006).

In India, study on the relationship between socioeconomic status and body composition is very limited. One study among the adults of Mahishyas in West Bengal reported that values of anthropometric measurements and indices, skinfold thickness and body fat are higher as income increases (Bharati, 1989). Anthropometric measures show that adults are taller and heavier who are from upper middle income group compared to the lower income group (Rao et al., 1990). Landless agricultural labourers and low income groups are reported to have a lower mean BMI values (Naidu and Rao, 1994). It is also reported that in urban areas of Hyderabad, the prevalence of overweight and obesity are higher in the higher income groups whereby, 21.8% and 27.4% of males and females, respectively are overweight, and 2.1% and 8.9% of males and females, respectively are obese (Rao et al., 1995). Similarly, a study in a heterogeneous population of Andhra Pradesh also revealed that
in both male and female adults BMI increases with the increase in income (Reddy, 1998). A study among women from urban slum with low income earning reported that their occupational work which involve high physical labour, is associated with higher lean mass (Kulkarni et al., 2010). In the Northeast India, a study among the War Khasis in Meghalaya has reported that BMI along with morbidity are significantly associated with income (Khongsdier, 2002).

In summary, the present overview has clearly revealed that body composition is associated with age, sex, body shape, morbidity and different demographic and socioeconomic factors. However, there are limited studies from India in general and Northeast India in particular. It is, therefore, important to carry out more studies especially in areas related to causes and prevention of obesity, which is an emerging health problem in many developing countries including India. The rural-urban migration and socioeconomic transition are likely to bring about many changes including those that may be influencing the nutritional and health problems in our country.