CHAPTER II

REVIEW OF LITERATURE
2.1 Global nature of obesity:

The World Health Organization (WHO) has coined the term "Globesity" to signify the increasing global epidemic of overweight and obesity. Obesity is a major risk factor for several Noncommunicable Diseases (NCDs) which include diabetes mellitus, hypertension, cardiovascular diseases, stroke and certain cancers. It is now being identified as a major public health problem, both in the developed as well as in the developing countries (WHO, 2011c). Although the identification of overall obesity as a condition that adversely affects the quality of life was realized several centuries earlier, it was in the 1990’s, that the importance of body fat distribution was acknowledged by the western scientific community (Bouchard et al., 1990). Several epidemiological as well as prospective studies from the West have reported that excess abdominal fat is associated with an increased risk of metabolic diseases (Larsson et al., 1984; Lapidus et al., 1984; Kissebah et al., 1989; Despres et al., 1990). Parallel to obesity, abdominal obesity is also on the rise all across the world, especially increasing at a rapid rate among the developing countries, thus aggravating the existing health burden (Balkau et al., 2007).

2.1.1 Overall and abdominal obesity in developed countries: According to the latest estimates by the World Health Organization (WHO), in 2008, 1.5 billion adults were overweight, out of which over 200 million men and nearly 300 million women were obese (WHO, 2011d). The United States (U.S) recognizes obesity as a national health threat since it has some of the highest obesity rates in the developed world. Obesity is a leading cause of U.S mortality, morbidity, disability and healthcare costs. The Centre for Disease Control and Prevention (CDC) revealed that in 2007-2008, based on measured weights and heights, approximately 72.5 million adults in the U.S.A were obese (CDC unpublished data, 2010). While, the National Health And Nutrition Examination Survey (NHANES) data from 2007-2008, showed that about 32.2 % of men and 35.5 % of women, aged more than 20 years (Flegal et al., 2010) as well as 17 % of children (Ogden et al., 2010) in U.S. were obese. Abdominal obesity was reported to be present in about 29.8% of men and 46.3% of women aged more than 20 years in the U.S. (Ford et al., 2002). Adjacent to the U.S, Canada had about 23.1% (about 5.5 million) obese and 36% (about 8.6 million) overweight adults, aged
more than 18 years in 2004 (Tjepkema, 2006). In 2007-2009, 35.6% of Canadian adults aged between 20-69 years were reported to be abdominally obese (Janssen et al., 2010). The Health Survey for England (HES) conducted in 2008 by the National Health Service (NHS, 2010) in U.K found that almost a quarter of adults (24% of men and 25% of women aged more than 16 years) were classified as obese. A higher prevalence of abdominal obesity as compared to overall obesity, especially among U.K men (44%) as compared to women (34%) was reported in the survey. Among the other European countries, varying rates of abdominal obesity have been reported viz. 8% among men and 18% among women in Greenland and Denmark (Jorgensen et al., 2003); 21% among men and 24% among women in Belgium (Moreau et al., 2004); 8% among men and 13% among women in France (Balkau et al., 2003); 23% among men and 65% among women in Spain (Lorenzo et al., 2003); 18% among men and 39% among women in Turkey (Erem et al., 2004).

2.1.2 Overall and abdominal obesity in Asia: The developing countries also have not been spared the burden of obesity and abdominal obesity as rapidly increasing prevalence is being reported among several countries from the Asian sub-continent. In China, the world’s most populous country, accounting for one-fifth of the world’s population, Wang et al. (2007) reported that from 1992 to 2002, the combined prevalence of overweight and obesity increased from 14.6% to 21.8% in all gender and age groups and across all geographical areas within the country. These statistics are reflective of the impressive economic development that China has enjoyed, that has resulted in remarkable changes in the lifestyles of its citizens. Hu et al. (2007) reported among Chinese adults aged between 35-74 years in an InterASIA Study in 2000-2001 that the prevalence of obesity according to the Chinese standard for Body Mass Index (BMI>28 kg/m$^2$) was 9.78%, while that of abdominal obesity was 33.97% [based on waist circumference (WC) > 85 cm for men and > 80 cm for women]. It can be noted here that the prevalence of abdominal obesity was much higher than that of overall obesity and is one of the characteristic features among the Asian populations.

Among the other Asian countries, Kim et al. (2004a) reported based on data from the 1998 South Korean National Health and Nutrition Survey, that low rates of obesity (men: 1.7% , women: 3.2%) were observed among Korean adults aged more than 20 years. On the contrary, Park et al. (2004) reported high abdominal obesity rates of 21% about among men and 42% among women from South Korea. Similar
findings were reported from Sri Lanka, as prevalence of abdominal obesity (16.4%) was higher than that of overall obesity (9.9%) among adult men aged 30-64 years (Fernando et al., 1994).

In view of the increasing prevalence of abdominal obesity across the world, an International Day for the Evaluation of Abdominal Obesity (IDEA) study was conducted in 63 countries (except U.S) at a same time-point (Balkau et al., 2007). Data from the study showed that the prevalence of overall obesity among countries from the South-East Asian regions was lower (7-15%) as compared to the developed countries, however that of abdominal obesity was comparable. The average abdominal obesity prevalence for all countries was 56% among men and 71% among women. These findings clearly demonstrate that the Asian populations are predisposed to abdominal obesity.

This important consideration is now being acknowledged by health agencies such as the WHO, the International Association for the Study of Obesity (IASO) and the International Obesity Task Force (IOTF) who have jointly released the report on the ‘The Asia-Pacific perspective: Redefining Obesity and its Treatment’ (WHO, 2000b). In this report, it is acknowledged that ethnic differences exist in the pattern of body fat distribution across populations from different regions of the world. Asians have higher amounts of percent body fat (BF %) which they tend to deposit preferentially in the abdominal region. This further leads to a different pattern of metabolic diseases being observed among them. Specifically, NCDs are seen to occur at lower levels of overall obesity (assessed by BMI) among Asians as compared to Caucasian populations, which can be attributed mainly to the higher amounts of the more potent abdominal fat among Asians. As a consequence, there need to be population-specific cutoffs for obesity and abdominal obesity indicators for assessing risk of obesity related NCDs. Current cutoffs based on data from the Caucasian populations are certainly not suitable for use among the Asian populations (WHO, 2000b).

**Differences in adiposity within the Asian populations:** Finally, it has also been reported that differences may exist within the Asian populations, with certain groups being at higher risk for NCDs due to relatively higher amounts of body fat, specifically abdominal body fat.
Significant variation in the association between adiposity and BMI within Asian populations was reported by Deurenberg and Deurenberg-Yap (2003) when they found that lower levels of BMI at a given percentage of BF were seen among Hong Kong Chinese, Indonesians, Singaporeans and urban Thai populations as compared to Europeans, whereas individuals from Northern China and rural Thailand had similar values. Tan et al. (2004) examined the prevalence of abdominal obesity based on suggested cutoffs for Asians (>90 cm for men, >80 cm for women) among adults aged 18-69 years from Singapore having different ethnic origins viz. Chinese, Malay and Asian-Indians. Among the three groups, Indians (men: 41.4%, women: 53.8%) had the highest prevalence of abdominal obesity followed by the Malays (men: 29.8%, women: 43.2%) and the Chinese (men: 26.2%, women: 21.0%). The prevalence of abdominal obesity using cutoffs (>102 cm for men, >88 cm for women) given by the (National Cholesterol Education Program – Adult Treatment Panel 3 (NCEP-ATP3, 2001) was much lower. Parallel to abdominal obesity, the prevalence of metabolic syndrome (MS) which is a clustering of several NCD risk factors was also the highest among Indians (28.8%) followed by Malays (24.2%) and Chinese (14.8%), which could be attributed to the higher abdominal fat observed among Indians. These findings were parallel to those reported by other studies among the ethnic groups residing in Singapore (Hughes et al., 1990; Tan et al., 1999). It thus becomes apparent that Asians are more vulnerable to abdominal obesity and its health consequences as compared to Caucasians and within the Asian community, it is the Indians who are more at risk.

2.1.3 Overall and abdominal obesity in the Indian scenario: India is one of the fastest developing countries in the Asian sub-continent experiencing rapid socio-economic changes that have led to improvements in the health indicators such as reduction in infant and child mortality and increases in adult longevity. However, with the rise in the socio-economic status, particularly in the urban areas, there had been a rise in the levels of over-nutrition, as reflected by a high prevalence of overall and abdominal obesity. Changes in diet and activity patterns along with a sedentary lifestyle are prime components of this “Nutritional Transition” and this in turn has reflected in the high prevalence of NCDs in urban India (Shetty, 2002; Griffiths and Bentley, 2001). An overview of Indian studies is given in Table 2.1.
It can be observed that the prevalence of obesity and abdominal obesity show a steady increase from the 1990’s to 2010. With the earliest reports by Chadha et al., (1997) in urban Delhi where 20.7% of men and 32.6% of women were obese, to Gupta et al. (2004a) reporting 54% of men and 69.4% of women to be obese in Jaipur, both cities being from the northern part of India. It may be noted here that most of the studies were reported from the northern and the southern parts of India. There are very few studies from the western and the eastern parts of India.

Differences are clearly observed in the prevalence between urban and rural areas (Visweswara Rao et al., 1995; Chadha et al., 1997; Reddy et al., 2002), with the urban areas consistently having much higher rates of obesity. However it may be noted that in recent years, prevalence of overall and abdominal obesity in rural areas has also increased considerably, especially among women (Reddy et al., 2002). According to Gopalan (1998), urbanization involves changes in occupational patterns, lifestyles, family structures and value systems that are reflected in changes in diet and activity patterns, further leading to obesity. A similar trend is seen with respect to different socio-economic groups within the urban community. With a rise in the socio-economic status, the prevalence of overall and abdominal obesity is seen to increase (Visweswara Rao et al., 1995; Gopalan, 1998; Mohan et al., 2001). Thus, the urban affluent populations seem to be more vulnerable to adiposity.

It is also worthwhile to mention here that part of the variation in the prevalence is also due to use of different indicators used for assessment of obesity. For example, use of various cutoffs of Waist to hip ratio (WHR). Thus, Misra et al. (2001) have used WHR>0.95 for men and >0.8 for women, Ramachandran et al. (2001) have used WHR> 0.9 for men and >0.8 for women, while, Mohan et al. (2001) have used WHR> 0.9 for men and >0.85 for women. It therefore makes difficult the comparison of prevalence between the reported studies. It can also be noted that BMI seems to be the most preferred indicator used for assessing obesity, while BF (%) has been used scarcely. Similarly, for assessing abdominal obesity, WC and WHR are commonly used, while Abdominal circumference (AC) is rarely used. In fact, researchers (Bouchard et al., 1990; Despres et al., 1990) have always had reservations against the use of WHR as an indicator of abdominal obesity due to several reasons viz. ratios are difficult to interpret biologically and changes in the visceral fat such as due to weight loss, may or may not produce little change in the ratios.
Table 2.1 Overall and Abdominal obesity among Indian adults

<table>
<thead>
<tr>
<th>Reference</th>
<th>Place</th>
<th>Population</th>
<th>Criteria</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dua and Seth, 1988</td>
<td>Delhi, North India</td>
<td>24-40 years, urban women</td>
<td>BMI &gt; 25 kg/m²</td>
<td>Overall: 23.4</td>
</tr>
<tr>
<td>Dhurandhar and Kulkarni, 1992</td>
<td>Mumbai, Western India</td>
<td>31-50 years, Urban male doctors</td>
<td>BMI &gt; 25 kg/m²</td>
<td>Males: 53.1</td>
</tr>
<tr>
<td>Visweswara Rao et al., 1995</td>
<td>Hyderabad, South India</td>
<td>Urban - Rural</td>
<td>BMI</td>
<td>Urban (H.S.E): 23.9, Rural (L.S.E): 0.8</td>
</tr>
<tr>
<td>Chadha et al., 1997</td>
<td>Delhi, North India (1984-87)</td>
<td>25-64 years, Urban - Rural</td>
<td>BMI &gt; 25 kg/m²</td>
<td>Overall: 20.7, Males: 20.7, Females: 32.6</td>
</tr>
<tr>
<td>Gopalan, 1998</td>
<td>Delhi, North India</td>
<td>20-65 years; Urban middle class and Slums</td>
<td>BMI &gt; 25 kg/m²; WHR &gt; 1.0 M, 0.85 F</td>
<td>H.S.E (OB; AO): 32.0; 39.0, M.S.E (OB; AO): 16.0; 29.0, L.S.E (OB; AO): 7.0; 16.0, Slums(OB; AO): 1.0; 4.0</td>
</tr>
<tr>
<td>Singh et al., 1998a</td>
<td>5 urban cities</td>
<td>25-64 years, Urban women</td>
<td>WHR</td>
<td>Highest (Calcutta): 62.2, Lowest (Mumbai): 47.4</td>
</tr>
<tr>
<td>Zargar et al., 2000</td>
<td>Kashmir, North India</td>
<td>&gt; 40 years</td>
<td>BMI</td>
<td>Overall: 7.0, Males: 23.7</td>
</tr>
<tr>
<td>Misra et al., 2001</td>
<td>Delhi, North India</td>
<td>18-50 years; Slum L.S.E</td>
<td>BMI &gt; 25 kg/m²; WHR &gt; 0.95 M, 0.8 F</td>
<td>Overall: 13.0, Males: 16.0, Females: 9.0</td>
</tr>
</tbody>
</table>

M: Males; F: Females; H.S.E: High Socio-Economic Class; L.S.E: Low Socio-Economic Class; M.S.E: Middle Socio-Economic Class; OB: Obesity; AO: Abdominal Obesity
Table 2.1 continued....

<table>
<thead>
<tr>
<th>Reference</th>
<th>Place</th>
<th>Population</th>
<th>Criteria</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>Ramachandran et al., 2001</td>
<td>6 Indian cities</td>
<td>&gt; 20 years</td>
<td>BMI &gt; 25 kg/m²; WHR &gt; 0.9 M, 0.8 F</td>
<td>31.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urban</td>
<td></td>
<td>50.0</td>
</tr>
<tr>
<td>Mohan et al., 2001</td>
<td>Chennai, South India</td>
<td>&gt; 20 years</td>
<td>BMI &gt; 25 kg/m²; WHR &gt; 0.9 M, 0.85 F</td>
<td>M.S.E (OB; AO)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urban</td>
<td></td>
<td>L.S.E (OB; AO)</td>
</tr>
<tr>
<td>Shukla et al., 2002</td>
<td>Mumbai, Western India</td>
<td>&gt; 35 years</td>
<td>BMI &gt; 25 kg/m²</td>
<td>19.0</td>
</tr>
<tr>
<td>Reddy et al., 2002</td>
<td>Delhi, North India</td>
<td>35-64 years</td>
<td>BMI &gt; 25 kg/m²; WHR &gt; 0.95 M, 0.8 F</td>
<td>Urban (OB; AO)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rural</td>
<td></td>
<td>Rural (OB; AO)</td>
</tr>
<tr>
<td>Gupta et al., 2004a</td>
<td>Jaipur, North India</td>
<td>Urban</td>
<td>BMI &gt; 25 kg/m²; BMI &gt; 30 kg/m²; WHR &gt; 0.9 M, 0.8 F</td>
<td>54.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>69.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>77.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>34.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>55.6</td>
</tr>
<tr>
<td>Bhadra et al., 2005</td>
<td>Kolkatta, Eastern India</td>
<td>20-50 years</td>
<td>BMI &gt; 25 kg/m²; WC &gt; 72 cm; WHR&gt;0.85</td>
<td>BMI: 25; 30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urban women</td>
<td></td>
<td>WC; WHR</td>
</tr>
<tr>
<td>Kamble et al., 2010</td>
<td>Wardha, Western India</td>
<td>&gt;18 years</td>
<td>WC(cm)&gt;102M, 88 F</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rural</td>
<td></td>
<td>17.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WC(cm)&gt;90M, 80 F</td>
<td>16.5</td>
</tr>
<tr>
<td>Kinra et al. 2010</td>
<td>1600 villages across 18</td>
<td>20-69 years</td>
<td>BMI &gt; 25 kg/m²; WC(cm)&gt;90M, 85 F</td>
<td>18.8</td>
</tr>
<tr>
<td></td>
<td>Indian states</td>
<td>Rural adults</td>
<td></td>
<td>27.7</td>
</tr>
</tbody>
</table>
It was apparent that the prevalence of abdominal obesity was higher than that of overall obesity in most of the Indian studies, and that although there was non-uniformity in the criteria used, obesity and abdominal obesity was highly prevalent among the higher socio-economic class in urban areas. For example, Ramachandran et al. (2001) found that about 50% of urban adults aged more than 20 years from six different cities in India were abdominally obese in comparison to 30% who were diagnosed as having overall obesity. Similar observations were made by Reddy et al. (2002) as they observed 72% abdominal obesity vs. 35% overall obesity among urban men from North India. These studies indicate that Indians have an increased susceptibility to abdominal fat deposition. Consequently, for assessing adiposity among Indians, abdominal obesity markers may be of more relevance rather than use of BMI. These findings are consistent to those observed among immigrant Indians, often referred to as ‘South Asians’ as discussed earlier.

2.2 Etiology of obesity:

Obesity is a chronic condition that develops as a result of a complex interaction between a person’s genes and the environment characterized by long-term energy imbalance due to excessive caloric consumption, insufficient energy output [sedentary lifestyle, low resting metabolic rate] or both (WHO, 2000a; Lindpainter, 1995).

2.2.1 Genetic factors: Although, genetic influence may be associated with the origin of obesity, a strong obesogenic environment is required for its phenotypic expression (Loos and Bouchard, 2003). Familial prevalence of obesity has been reported in different populations, including a community based study in South India among a total of 1295 individuals from 300 families that showed a high rate of heritability for abdominal obesity (Davey et al., 2000). Family members share not only genes, but also diet and lifestyle habits that may contribute to obesity. Separating these causes from the genetic influence is difficult, yet increasing evidence directs attention towards heredity as a strong determinant of obesity (Stunkard, 1996).

Studies on individuals with a wide range of BMI and information available on parents, siblings and spouses suggest that about 25-40% of the individual differences in body mass or body fat may depend on genetic factors (Vogler et al., 1995; Bouchard et al., 1988). However, reports on identical twins that had been reared apart
suggest that the genetic contribution to BMI may be higher at about 70% (Stunkard, 1996). More studies on interactions between different genes as well as between genes and environment are required to understand the etiology of obesity (Ramachandran and Snehalatha, 2010).

2.2.2 Nutritional transition: According to noted scientist, Dr. Barry Popkin (2006), the concept of ‘nutrition transition’ focuses on large shifts in diet and activity patterns which are often reflected in nutritional outcomes. Humankind has undergone five major patterns of nutrition transition. First was the Paleolithic pattern where diet was very healthy but infectious diseases and other natural causes resulted in a short life span. The second pattern saw the emergence of modern agriculture, but nutritional status worsened due to famine. In pattern three, famine receded as income increased. In pattern four, new diseases and disability emerged as diet and activity patterns changed. The shift towards increased obesity and NCDs is the latest pattern of this transition. Particularly among countries of the developing world, the speed of dietary and activity pattern shifts is great, resulting in major shifts in obesity (Popkin, 2006).

Major cause of this transition is the tremendous socio-economic improvement in Asia, including India, in the last couple of decades and that has resulted in an increased availability of food, better transport facilities and improved health care facilities (Ramachandran and Snehalatha, 2010). These trends occur at a rapid rate in the urban areas, however they are also gradually being seen in rural areas. Data from urban, semi-urban and rural populations in South India clearly reflect this changing scenario (Ramachandran et al., 2008, 2002, 2004).

Diets of the populations undergoing nutritional transition, especially in the urban areas, seem to be dominated by higher intakes of fats and sugars with a decline in whole grain cereals, pulses and overall fiber intake (Gopalan, 1998). Reduction in the energy expenditure has occurred due to shifts in activity patterns at home, at work, during leisure and during travel. Large scale decreases in food prices with increased access to supermarkets, emergence of fast food and bottled soft drinks industries have also contributed to this phenomenon in the urban areas (Popkin, 2006). As a result, the pandemic of obesity that was restricted to the developed countries until a few decades ago, has now penetrated even the poorest of nations in the world (Ramachandran and Snehalatha, 2010). Thus, abdominal obesity has been appropriately expressed to be a “Civilization Syndrome” (Bjorntorp, 1993).
2.2.3 Role of diet: In simple terms, obesity is a consequence of energy imbalance where energy intake exceeds energy expenditure over a considerable period of time. Thus, dietary factors affecting the energy intake and physical activity patterns affecting the energy expenditure influence the energy balance equation and can be considered as major modifiable factors affecting weight gain (WHO, 2000a).

An excellent review article by Deaton and Dreze (2009), summarizes the recent food intake and nutrition pattern in India. Based on data from the Indian National Sample Survey (NSS, 2001), it was seen that in the last 25 years, there was a sustained decline in the per capita calorie consumption, although it was less evident in urban areas. Consumption of total calories, proteins and several other nutrients declined, except fat consumption that increased steadily both in the urban and rural areas. It was also observed that food expenditures differed between higher and lower income families, with less consumption of cereals and more consumption of edible oils, meat, and sugar in the higher income families. Thus, excess consumption of fat rich foods leading to higher dietary intake of fat may be an important causative factor for high rates of obesity in India. Similar findings have been reported from China where percent fat calories of total energy (>30%) among adults increased from 15% to 44% between 1989 to 2000 (Popkin, 2006).

High fat foods are also preferentially selected by individuals because of their palatability and a weak satiety effect. At the same time, our body had virtually unlimited capacity for fat storage. Excess dietary fat does not even markedly increase fat oxidation, but is readily stored in adipose tissue depots with a very high efficiency of about 96% (WHO, 2000a). Data from the Confederation of the Indian Food Trade and Industry shows the growth in major industries producing milk products, breads, biscuits, chocolates, soft drinks and instant noodles which reflects a shift in the eating habits of Indians. The sales of potato chips and cold drinks were seen to have gone up three times between 1995 and 2001 (The Centre for Science and Environment, 2005). It has been suggested by some researchers that the fast food sector and soft drink industry in the U.S have led to the decline in the quality of diets throughout the developing world. The growth of American fast food companies has certainly spread across the globe with more than 50% of the McDonald’s sales coming from countries other than U.S. Several studies document these shifts in the U.S, but very few studies are reported from lower-income countries, although large amount of heterogeneity exists among them. For instance, as compared to the U.S, outside food intake and
snacking are very rare in China and Russia but are comparable in Philippines (Popkin, 2006).

Although, India may be in the midst of a ‘nutrition transition’, where changes in diet parallel an expanding industrial economy and a rapidly progressing epidemic of obesity and chronic NCDs, yet diets across India have not been widely investigated. And so a major study called the India Health Study was conducted in Mumbai, Delhi and Trivandrum on adults aged 35-69 years. The researchers found a relatively less evidence of a westernized diet and a continued preference for the traditional Indian sweets that contain not only sugar but also substantial amounts of saturated fat from ghee or coconut components. They also found dietary patterns characterized by animal products, fried snacks, or sweets to be positively associated with abdominal adiposity (Daniel et al., 2011).

One more relevant study in this context was reported among middle-aged Bengalee Hindu men of Calcutta, India by Ghosh et al. (2003). Out of the several foods studied, frequency of egg, fried snacks and Bengalee sweets consumption were positively and significantly related with abdominal obesity. In contrast, frequency of chicken and fish consumption was negatively associated with abdominal obesity. These results however cannot be generalized since the dietary patterns of Bengalee populations are very different from other cultural groups in India. Since the dietary patterns vary drastically across various regions, religions and socio-economic classes in India, additional studies are required to determine the influence of diet on obesity and abdominal obesity.

2.2.4 Role of activity: Physical activity patterns affect the physiological regulation of body weight by influencing the total energy expenditure, fat balance and food intake (WHO, 2000a). Physical activity is defined as any bodily movement produced by skeletal muscle that results in a substantial increase over the resting energy expenditure. It has 3 main components: 1) Occupational work: activities undertaken during the course of the work; 2) household and other chores: activities undertaken as a part of day to day living; 3) leisure-time physical activity: activities undertaken in the individual’s discretionary free time and includes exercise and sports. The time allocated for each of the three components varies considerably between individuals and populations (Bouchard and Shephard, 1994). Physical inactivity or sedentary
behavior can be defined as a state when body movement is minimal and energy expenditure approximates resting metabolic rate (Dietz, 1996).

The importance of physical activity in reducing obesity, especially abdominal obesity was demonstrated in the adult men (>35 years) and women (>40 years) participating in the large Framingham Heart study, wherein higher physical activity was associated with lower amounts of visceral and subcutaneous adipose tissue (Molenaar et al., 2009). There is much debate about how much physical activity is required to lose weight and it always narrows down to the fact that the duration and intensity of the activity should lead to an energy expenditure that is higher than the energy intake (WHO, 2003a). Studies among Caucasians have shown that increase in either the intensity or duration are beneficial (Brown et al., 2003). Importance of decreasing sedentary behavior also has been demonstrated by large epidemiological studies among Caucasians such as the Nurses Health Study which showed that higher time spent in sedentary activities such as television watching was independently related to obesity and type 2 diabetes (Hu et al., 2003).

Studies among immigrant Asian Indians have demonstrated that Asian Indians are more sedentary than Caucasians. A study comparing pre-menopausal adult women in Chicago, U.S, showed that Indian and Pakistani women were less physically active as compared to American women (Kamath et al., 1999). Similar findings were reported from New Castle, U.K (Hayes et al., 2002), where adult men and women of Indian, Pakistani and Bangladeshi origin had lower levels of habitual physical activity than Europeans. Europeans participated more in moderate to vigorous sports and recreational activities as compared to the other ethnic groups. Physical activity was inversely associated with BMI and WC thus indicating its beneficial effect on both obesity and abdominal obesity. There is however a paucity of similar studies regarding physical activity among native Indians.

The National Sample Survey data (NSS, 2001) shows that over the last two decades, there has been a huge increase in the ownership of vehicles such as bicycles, motorcycles and cars that are likely to reduce energy expenditure in both urban and rural areas. At the same time, television watching, a sedentary leisure activity, has increased with about 30% of rural and 74% of urban households owning a television. Similar findings were also reported in China (Popkin, 2006) as TV viewer ship was found to triple over a decade with about 95% of all households having working TV sets during the 1900’s.
It is thus apparent that a sedentary lifestyle with low levels of physical activity is one of the major contributors to the increasing prevalence of obesity in India. With most of the international physical activity guidelines based on data on Caucasian populations, more studies in this aspect are required in the Indian scenario to demonstrate its association with obesity, abdominal obesity and to provide data on guidelines for Indian populations.

2.3 Assessment of overall and abdominal obesity:

Obesity is often defined simply as a condition of abnormal or excessive fat accumulation in the adipose tissue to the extent that health may be impaired, while overweight is a state in which the weight exceeds a standard based on height. (WHO, 2000a). The importance of body fat distribution was first realized when Professor Jean Vague (1956) demonstrated that upper body obesity (android obesity) was associated with increased health risk in terms of diabetes, gout and atherosclerosis, whereas lower body obesity (gynoid obesity) was associated with minor health effects. Later, Kissebah et al. (1982) provided the first scientific evidence between body fat distribution and impaired glucose-insulin metabolism and dyslipidemia. Acknowledging the importance of body fat distribution, in 1991, noted scientist, Dr. C. Bouchard proposed 4 types of obesity phenotypes:
1) excess body mass or percentage of fat: refers to an overall predominance of fat;
2) excess subcutaneous truncal-abdominal fat (android fat): more common in men;
3) excess abdominal visceral fat: more common in men and increases with aging;
4) excess gluteofemoral fat (gynoid fat): heavier deposits around the hip and thighs, more common in women to facilitate demands of pregnancy and lactation.

Modern and sophisticated techniques for precise measurement of obesity in terms of body mass, body fat and its distribution are available, however they are very expensive and not suitable for practical use in large field based studies. Anthropometric measurements are non-invasive, in-expensive and practical methods that can give a relatively accurate assessment of obesity in epidemiological studies for health assessment of individuals and for population screening (Rao, 2011).

2.3.1 Body Mass Index (BMI): BMI is a simple and universally used anthropometric index for assessing overall obesity. It is based on weight and height and is commonly used to classify underweight, overweight and obesity in adults, both in clinical as well
as in research settings. BMI is defined as the weight in kilograms divided by the square of the height in meters (kg/m²). The WHO classification of BMI is based primarily on the association between BMI and mortality mainly due to NCDs as reported by studies among Caucasians. Accordingly, a BMI >30 kg/m² is defined as obesity while a BMI >25 kg/m² is defined as overweight (WHO, 2000a). However, in view of the recent findings that Asians have a different patterns of body frame, body fat as well as the distribution of body fat, WHO (2000b) have suggested lower cutoffs of BMI for Asians. Accordingly, a BMI >25 kg/m² has been suggested as the obesity cutoff, while a BMI >23 kg/m² has been suggested as the overweight cutoff for Asians. More data from the Asian region is required for validation of these cutoffs in terms of assessing risk of NCDs.

However, use of BMI has certain limitations. For example, it does not distinguish between the weight associated with fat and the weight associated with muscle. A body builder with higher proportion of lean muscle content may thus be falsely diagnosed as obese. Also, a given BMI may not correspond to the same degree of fatness across populations. For example, Asians have higher body fat while Polynesians have lower body fat at identical BMI’s as compared to Caucasians. Thus, even though BMI is used to estimate prevalence of obesity in large population-based studies because of its simplicity and practicality, it does not account for the wide variation in the nature of obesity between different individuals and populations (WHO, 2000a, 2000b).

2.3.2 Body Fat (%): Sophisticated techniques such as Dual Energy X-ray Absorptiometry (DEXA), under-water weighing for measuring body density and Bio-electrical Impedance Analysis (BIA) are used for assessing body composition, it allows for the separation of body weight into its sub-compartments such as fat mass and lean mass. Modern imaging techniques such as Computed Axial Tomography (CT-scanning) and Magnetic Resonance Imaging (MRI), allow for the separation of abdominal obesity into visceral and subcutaneous components. It is therefore possible to determine the contribution of specific components rather than just weight for height. Some of these techniques are more accurate than BIA, but they are extremely difficult, require highly trained personnel and are very expensive for large-scale epidemiological studies (Rao, 2011; Yajnik, 2004). BIA is a relatively affordable and simple technique for the determination of body fat (%). According to Houtkooper et
al. (1996), BIA may be most appropriate for estimating adiposity of groups in epidemiologic and field studies, although it has limited accuracy for estimating body composition in individuals. BIA is based on the principle that as compared to fatty tissue, lean tissue has a higher electrical conductivity and lower impedance, relative to water content. Therefore, an inverse relation between resistance and total body water and fat free body mass is seen, whereas high positive correlations are found between resistance and total body fat (Heshka et al., 1994).

Several studies among native as well as immigrant Indians have shown that at a given level of BMI, Indians have higher body fat content, especially abdominal fat, as compared to white Caucasians and African Americans (Shelgikar et al., 1991; McKeigue et al., 1991; Ramachandran et al., 1992; Banerji et al., 1999; Chandalia et al., 1999; Raji et al., 2001; Misra et al., 2001). In view of these reports, it is essential that measurement of body fat should be performed whenever possible, as BMI alone would be unable to assess the level of adiposity among Indians. Singh et al. (1999) used the BIA method to estimate the BF (%) among urban Indian men (25-64 years) from Moradabad, with low rates of obesity based on BMI. They found that even though these men had low levels of BMI, they had high BF (%) which was significantly associated with coronary risk factors. Thus, measurement of body fat (%) using the BIA technique may be suitably employed among Indians not just to assess overall adiposity, but also the health risk associated with it.

2.3.3 Circumferences: With the realization that abdominal obesity substantially increases the risk of NCDs, a need was felt to include its measurement in epidemiological studies. It was therefore suggested that, standardized anthropometric techniques that could accurately predict abdominal fat should be developed and validated on a sub-sample from large epidemiological studies (Bouchard, 1991). Waist circumference (WC) is often used as a surrogate marker of abdominal fat mass, because it correlates well with both subcutaneous and intra-abdominal abdominal fat mass as demonstrated in studies among Caucasians (Pouliot et al., 1994) as well as Asian Indians (Brundavani et al., 2006).

WC is actually a perimeter which provides an estimate of the body girth at the level of the abdomen (Klein et al., 2007). However, different sites for measurement of WC have been used in different studies. Agarwal et al. (2009) compared WC measured according to existing and experimental protocols varying by posture,
respiratory phase, and time since last meal among healthy volunteers aged >16 years from North India and found that the WC measurements though highly correlated, were not statistically same. The researchers are of the opinion that differences in WC due to differences in protocols may influence the classification of abdominal obesity, establishment of ethnic-specific cutoffs of WC, and prediction of cardio metabolic risk, especially affecting research studies on Asian populations who have higher cardio-metabolic risk profile at lower cutoffs of BMI and WC.

On the contrary, a systematic review of 120 studies evaluating the association of WC with morbidity from CVD and diabetes and mortality was performed by Ross et al. (2008). The most commonly used sites were the mid-point between the lowest rib and the iliac crest (36%), the umbilicus (28%), and the narrowest WC (25%). However, they concluded that the site of measurement did not affect the relationship of WC with risk of diseases or mortality. Nevertheless, this issue was considered as important by the recent report of a WHO Expert Consultation (2011b) on WC and waist to hip ratio (WHR), in which standard protocols for measurement of WC as well as hip circumference (HC) which is required for calculating WHR, have been established. These instructions were followed for the circumference measurements in the present study as well.

Although significant correlations of WC with intra-abdominal fat as measured by both MRI and CT-scanning have been reported, among certain ethnic groups such as Chinese and South Asians, a greater amount of visceral adipose tissue for a given WC is observed as compared to Europeans (Han et al., 1997; Lear et al., 2007a). Similarly, Kagawa et al. (2007) documented that East Asian populations had higher percentage of body fat across a range of WC values. Thus, the recent report of a WHO Expert Consultation (2011b) on WC and WHR commented that if health outcomes are going to be affected by the cutoffs of WC and WHR that are used for diagnosis of abdominal obesity, then a revision of cutoffs may be required for these ethnic populations. However additional data is required from the Asian region for arriving at definite conclusions.

Currently, WC cutoffs used in the developed countries are for substantial risk of metabolic complications are 102 cm for men and 88 cm for women. Lower cutoffs for Caucasians of 94 cm for men and 80 cm for women also have been suggested as levels when increased risk is observed. For Asians, WC cutoffs of 90 cm for men and 80 cm for women have been suggested (WHO, 2000a, 2000b).
Apart from the direct measurement of WC, ratios based on WC such as WHR (Snehalatha et al., 2003; Esmaillzadeh et al., 2004) and waist to height ratio (Hsieh et al., 2003; Ho et al., 2003; Sayeed et al., 2003) have also been used in several studies as indicators of abdominal obesity, but there have been contradictory reports regarding their use, especially that of WHR. Lean and Han (2002) are of the opinion that WHR is an artificial term with no biological meaning and is not better than WC in reflecting body fat distribution or health risk. Majority of studies have in fact demonstrated the superiority of WC over other indicators. Among Brazilian adults, the superiority of WC over WHR was demonstrated as it was more strongly correlated with BMI as well as BP (Picon et al., 2007). Wang and Hoy (2004) also reported WC to be a better predictor of cardiovascular risk than BMI, WHR or HC in terms of higher relative risks for first CVD event, among the ethnic group of Australian Aboriginal adults aged 20-74 years. Reported Indian studies however, have not attempted to find the most appropriate indicator among the different anthropometric indicators routinely used for assessing abdominal obesity and for predicting risk of NCDs. Thus, studies on examining the relative efficiency of abdominal obesity indicators for predicting NCD risk and then determining their optimum cutoffs are needed to be performed among Asian Indian populations.

2.3.4 Skinfolds: Traditionally, skinfold thickness has been used for the assessment of body composition and they predominantly measure the subcutaneous fat. For large field based studies, skin fold measurements at various sites can be preferred as an alternative to sophisticated technologies for estimating body fat distribution. Skinfolds are commonly measured at four sites i.e. biceps (BSF), triceps (TSF), sub-scapular (SSF) and supra-iliac (SUF) and are used either in isolation or in combination. Central skinfolds (SSF and SUF) are positively linked to cardiovascular risk factors in contrast to peripheral skinfolds (BSF and TSF) (Blair et al., 1988; Yarnell et al., 2001). Skinfold ratios have been also widely used for the assessment of fat distribution (Katz et al., 2000) and correlate well with several factors of cardiovascular disease (van Lenthe et al., 1998a).

Ketel et al. (2007) tried to determine the most suitable anthropometric measurement that could be used as a reliable alternative for fat distribution as measured by DEXA in a population-based survey among 376 adults (mean age: 36.5 years) from The Netherlands. They found that in both sexes, central skinfolds (SSF
and SUF) and WC were the most reliable alternatives for central fat mass (subcutaneous and visceral fat of the abdomen and trunk), while WHR was found to be inappropriate. Thus skinfolds along with WC may be good substitutes for assessing abdominal obesity in adults.

The role of abdominal obesity for predicting NCD risk using the technique of skinfold measurement was explored by Nguyen et al. (2006, 2007) among Vietnamese older adults. They measured skinfold at a point A8 on the Erdheim diagram and developed a new formula using the sum of high WC ($\geq 90$ cm) and high skinfold at A8 ($\geq 30$ mm) for predicting metabolic syndrome (MS) without the use of laboratory testing and found the prevalence to be almost similar to MS calculated as per the International Diabetes Federation (2006) definition. Alternately, they also found this new skinfold plus presence of two biochemical abnormalities to be useful for diagnosis of MS in absence of high WC. Also, this new skinfold was found to highly correlate with fasting insulin and homeostasis model assessment – insulin resistance (HOMA-IR) among subjects with essential hypertension. Such novel reports indicate the need to explore the utility of the skinfold measurement technique in predicting the risk of NCD’s.

2.4 Prevalence of NCDs:

Historically, NCDs have been regarded as diseases of affluence, primarily affecting developed regions (Boutayeb & Boutayeb, 2005). However, current statistics (WHO, 2011a) reveal a much different story. Available data indicates that about 80% of all global NCD deaths occur in the developing nations. NCDs are the leading causes of death globally, with a high mortality rate as compared to all other causes combined. Out of the 57 million deaths that occurred globally in 2008, 36 million were due to NCDs, comprising mainly of CVDs, diabetes, cancers and chronic lung diseases. Additionally, about one-fourth of global NCDs occur before the age of 60 years. It is indeed unfortunate to observe such grim statistics when it is well documented that NCDs are largely caused due to modifiable behavioral risk factors viz. unhealthy diet, insufficient physical activity, tobacco and alcohol use. These are all consequences of economic and nutrition transition, rapid urbanization and changing lifestyles. Thus, although these diseases have reached epidemic proportions, yet they can be significantly reduced and millions of lives could be
saved, through reduction of their risk factors, early detection and timely treatments (WHO, 2011a).

2.4.1 Global prevalence of NCDs: According to WHO global estimates (2011a), the leading causes of NCD deaths in 2008 were: cardiovascular diseases (17 million deaths, or 48% of NCD deaths); cancers (7.6 million, or 21% of NCD deaths); and respiratory diseases, including asthma and chronic obstructive pulmonary disease (COPD), (4.2 million). Diabetes caused an additional 1.3 million deaths. Latest statistics from the U.S database of the Center for Disease Control and Prevention (CDC, 2011) among non-institutionalized adults (aged ≥20 years) indicate that about 33% had hypertension, 12% had heart disease, 15% had high serum cholesterol and 11% had diagnosed or undiagnosed diabetes.

With reports of increasing prevalence of NCDs among both developed and developing regions, several large international epidemiological studies have been recently conducted to arrive at global estimates of this health burden. Balkau et al. (2007) reported based on data from the International Day for Evaluation of Abdominal Obesity (IDEA) study involving 69,409 men and 98,750 women aged 18-80 years from over 63 countries (except U.S), that overall frequency of CVD was 16% in men and 13% in women. However, there was a wide variability across regions, ranging from 27% among men and 24% among women from Eastern Europe to other regions where frequencies ranged from 8% (Canadian women) to 16% (northwestern European men). Diabetes mellitus showed more regional variability than CVD with an overall prevalence of 13% among men and 11% among women. Both diabetes mellitus and CVD were more common in men than women in all regions except southern Asia. The Middle East region showed the highest age-adjusted prevalence of diabetes (22% in men, 19% in women), followed by northern Africa (19% and 16%) and southern Asia (17% and 18%).

Another huge international study called ‘the INTERHEART study’ (Yusuf et al., 2004) from 52 countries across the world demonstrated that among reported cases of myocardial infarction, 85% of cases in South Asia and 86% in the Middle East occurred in men as compared with 74% in western Europe, 68% in central and eastern Europe, and 70% in China. Among regions, striking variations were noted in the age of first presentation of acute myocardial infarction, with the youngest patients in South Asia (median age: 53 years) and the Middle East (51 years), and the oldest
Chapter II: Review of Literature

patients in Western Europe, China, and Hong Kong (63 years). This indicates that it is the men from South East Asian regions who are perhaps the most vulnerable to CVD mortality.

In a recent review article, Shaw et al. (2010) predicted the global prevalence of diabetes based on studies from 91 countries to be 6.4% among adults (aged 20–79 years) affecting 285 million adults in 2010. Among the top 10 countries listed for adults (20-79 years) with diabetes, it was sadly India that topped the list with 50.8 million diabetic Indian adults, followed by China, U.S, Russia, Brazil, Germany Pakistan, Japan, Indonesia and Mexico. Thus, it was the Asian countries dominating the scenario with India being the worst hit due to this current epidemic.

2.4.2 NCD epidemic in India: In view of the widely debated hypothesis of fetal programming of adult diseases, the NCD risks are expected to be high in Indian population as low birth weight prevalence is as high as 25%. According to this hypothesis (Barker, 1998), fetal adaptation to maternal undernutrition is believed to ‘programme’ NCD risk in early life and when the population is exposed to an environment where the food is plenty, the risks are expected to be high. However, the hypothesis is supported by retrospective cohort studies which are only observational and therefore do not imply causal relationships. On the other hand, to test this hypothesis, one needs long term prospective studies which are not available and are extremely difficult to undertake.

Although, several published studies from India confirm the increasing burden of NCDs in India, it is difficult to compare the prevalence rates due to differences in the locations, age groups as well as the criteria used to define the NCDs. As there is large variability in diets owing to different cultures and religions and lifestyles across the various regions in India, this further complicates the comparison. For example, there is a substantial difference in the reported prevalence between two cities Vadodara and Godhra, in spite of being from the same State of Gujarat and from the same study (Iyer et al., 2011). Nevertheless, it is evident that there is a large section of the Indian population which is suffering from the burden of NCDs. From the earliest reports by Chadha et al. (1997) to the latest reports by Iyer et al. (2011), there has been a substantial rise in the prevalence of NCDs. Chadha et al. (1997) report a diabetes prevalence of just 1.6% for North Indian men, while Misra et al. (2006)
Chapter II: Review of Literature

### Table 2.2 Prevalence of NCDs among Indian adults

<table>
<thead>
<tr>
<th>Reference</th>
<th>Place</th>
<th>Population</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chadha et al. (1997)</td>
<td>Delhi, North India</td>
<td>Urban males (25-64 years)</td>
<td>Hypertension (10.8); Diabetes (1.6); High TC (44.1); Low HDL (2.2)</td>
</tr>
<tr>
<td>Mohan et al. (2001)</td>
<td>Chennai, South India</td>
<td>Urban adults (&gt; 20 years)</td>
<td>Hypertension (14.9%); Diabetes (12.4%); Hyperinsulinemia (16.7%); Glucose Intolerance (7.5%); High TC (24.2%); High TG (7.6%); Coronary artery disease (9.5%)</td>
</tr>
<tr>
<td>Ramachandran et al. (1998)</td>
<td>Chennai, South India</td>
<td>Urban adults (&gt; 40 years)</td>
<td>Hypertension (22%); High insulin (55%); Glucose Intolerance (39%); Dyslipidemia (61%)</td>
</tr>
<tr>
<td>Gupta et al. (2004)</td>
<td>Jaipur, North India</td>
<td>Urban males (&gt; 20 years)</td>
<td>Hypertension (51.3%); High TC (33.2%); High TG (24.3%); Low HDL (74.8%); MS (36.2%)</td>
</tr>
<tr>
<td>Misra et al. (2006)</td>
<td>Delhi and Jaipur North India</td>
<td>Urban males (&gt; 18 years)</td>
<td>Hypertension (41.4%); Diabetes (9.6%); High TC (27.3%); High TG (28.3%); Low HDL (39.2%)</td>
</tr>
<tr>
<td>Kamble et al. (2010)</td>
<td>Wardha, West India</td>
<td>Rural males (&gt; 18 years)</td>
<td>Hypertension (53.5%); High FBG (13.5%); High TG (33.5%); Low HDL (50%); MS (8.2%)</td>
</tr>
<tr>
<td>Kaur et al. (2010)</td>
<td>Chennai, South India</td>
<td>Urban adult males</td>
<td>Hypertension (39.6%); High FBG (45.9%); High TG (45.2%); Low HDL (70.3%); MS (51.4%)</td>
</tr>
<tr>
<td>Iyer et al. (2011)</td>
<td>Gujarat West India</td>
<td>Urban adult males</td>
<td>Diabetes (Vadodara: 14.8%; Godhra: 25%); Hypertension (Vadodara: 28.7%; Godhra: 47.7%)</td>
</tr>
</tbody>
</table>

TC: Total Cholesterol; TG: Triglycerides; HDL: High Density Lipoprotein; MS: Metabolic Syndrome; FBG: Fasting Blood Glucose
report about 8-9 % prevalence of diabetes for North Indian men. Similarly, there has been a tremendous increase in the percentage of adults suffering from hypertension. Gupta et al. (2004), Misra et al. (2006) report a prevalence of hypertension of about 40-50% in urban areas which is surprisingly and disturbingly matched by Kamble et al. (2010) in a study in rural area. These reports clearly indicate alarming prevalence of NCDs in India that need to be addressed by health-care agencies with urgency.

2.5 Predictors of NCD risks:

Increased food intake and reduced physical activity are the consequences of unrestrained affluence and contribute to the development of obesity which is a major risk factor for NCDs. Whether obesity, diet and activity have an independent effect towards the risk of NCDs or they operate mainly through a synergistic interaction is yet not clearly understood.

In the 1930s, the U.S Metropolitan Life Insurance Company reported that, a striking death rate was associated with excess body weight, with an extra all-cause mortality risk of 50% for overweight men with abdominal girth exceeding chest girth by two inches or more (Metropolitan Life Insurance Company, 1937). Thus the importance of abdominal obesity was realized and since then, several prospective and cross-sectional epidemiological studies among different populations have shown varied associations of both obesity and abdominal obesity with NCD risk.

2.5.1 Abdominal obesity and NCD risk: Until recently, adipocytes were considered to be passive storage cells for fat, but with advancing research it was realized that they are critical components of metabolic control and act as endocrine organs (Greenberg and Obin, 2006). Abdominal adipocytes are metabolically more active because of several reasons viz. they have more cells per unit mass, higher blood flow, more receptors, higher responsiveness to lipolytic stimulation and greater resistance to antilipolytic stimuli. As a result, there is increased release of free fatty acids (FFA) from the abdominal adipocytes which are directly drained into the portal circulation. Increased FFA reduces glucose utilization in the liver tissues which further leads to reduced insulin clearance. FFA also increases storage of fat in the liver which may lead to insulin resistance (Randle et al., 1963; Bergman et al., 2001). Increased delivery of FFA in the muscle tissues may lead to insulin resistance of those tissues (Hegarty et al., 2003). Increased levels of FFA may also lead to excess synthesis of
triglycerides and cholesterol, thus causing abnormalities of lipid metabolism (Ramachandran and Snehalatha, 2010). There is also an increased release of cytokines such as tumor necrosis factor (TNF-α) and interleukin-6 from the abdominal adipocytes that may lead to an inflammation of the liver and play a role in the production of C-reactive protein, a marker of inflammation and a characteristic of abdominal adiposity and CVD (Greenberg and Obin, 2006). Also, the angiotensinogen from the fat cells may be involved in increasing the quantity of circulating angiotensin and development of hypertension in obesity (Bray, 2004). With advancing research, more theories explaining the physiological mechanisms whereby obesity, especially abdominal obesity increases the risk of NCDs are bound to arise, thus improving our understanding of this association.

Abdominal obesity & hypertension: The prominent INTERSALT study (Dyer et al., 1989) studied the association of BMI and BP in over 10,000 adults (aged 20-59 years) sampled from 52 centers around the world and found that BMI was significantly associated with systolic and diastolic BP, independent of age, alcohol and smoking. However, more recent studies among different populations started including abdominal obesity indicators such as WC and WHR along with BMI in examining the health risks, and observed more prominent associations for abdominal obesity. Gus et al. (2004) reported among 1089 Brazilian adults that WC identified the risk of hypertension better than BMI. Similar findings were reported among Italian adults (Siani et al. 2002) and Canadian adults (Janssen et al., 2004). Another prominent study (INTERHEART) on over 28,000 individuals from 52 countries, showed that abdominal obesity indicators (WC or WHR) predicted clinical events related to hypertension with little added value from measurement of BMI, among all ethnic groups (Yusuf et al., 2004).

Although abdominal obesity is a characteristic of Indian population (Yajnik, 2004), published Indian studies have focused mainly on reporting trends in the prevalence of hypertension in India (Gupta et al., 2011), while hardly any studies have examined the relative efficiency of abdominal obesity indicators in comparison with BMI for predicting the risk of hypertension. Based on data from the Chennai Urban Population Study (CUPS), Shanthirani et al. (2003) reported that both BMI and WHR were higher among hypertensive adults, however on performing multiple logistic regression analysis (MLRA), significant association of hypertension was seen only
with BMI. Using WHR instead of WC has yielded inconsistent results among other populations as well such as Brazilian adults (Picon et al., 2007) and Australian aboriginals (Wang and Hoy, 2004). As such, WHR is not a good predictor of visceral adipose tissue (VAT) and hence is not preferred by several researchers (Friedl, 2009). A stronger association of WC as compared to BMI was reported by Bhadra et al. (2002) in a study among young Indian adults (18-22 years) from Kolkata. Thus, similar studies on adults from India are required to determine the efficiency of WC for predicting the risk of hypertension.

### Abdominal obesity & impairment of glucose metabolism:

Early reports from the Gothenburg prospective study on adult Swedish women demonstrated that localization of body fat could predict development of diabetes over a 13 year period (Lapidus et al., 1984). Later however, Okosun et al. (1998) reported a substantially high risk of type 2 diabetes among Jamaican men (10 times) and African-American women (23 times) with a high WC. They suggest that since WC is more correlated with VAT and is not profoundly influenced by height, it may be a better NCD predictor, while use of BMI is controversial because its correlation with fatness is not consistent across populations. Similar strong associations of glucose metabolism with WC rather than with BMI have also been reported among several native (Wildman et al., 2005; Ko et al., 1997; Ho et al., 2001) and migrant Asian populations (Riste et al. 2001).

When Ramachandran et al. (1997) compared South Indians with Mexicans and Caucasians from U.S, they observed that although BMI was predictive of diabetes among all groups, WHR was significant only among Indians and Mexicans, thus indicating the importance of abdominal obesity among ethnic groups. In an earlier study as well, Ramachandran et al. (1992) had demonstrated that upper body obesity was a significant predictor of diabetes among South Indian adults with low rates of obesity. Thus, the association of abdominal obesity with glucose-insulin metabolism is evident from the above reports.

### Abdominal obesity & dyslipidemia:

A strong positive correlation of overall obesity indicated by BMI with serum lipids has been demonstrated among several studies on Caucasian populations (Denke et al., 1993). However, recent reports among Canadians (Janssen et al., 2004), Australian Aboriginals (Wang and Hoy, 2004) as
Chapter II: Review of Literature

well as Iranian adults (Chehrei et al., 2007) indicate stronger correlation of WC and WHT with dyslipidemia as compared to BMI. Misra and Vikram (2002) are of the opinion that Asian Indians, characterized by high abdominal fat deposition, appear to be pre-disposed to developing dyslipidemia. This is based on their study among urban adults from slum areas of North India (Misra et al., 2002) showing that, individuals with hyperlipidemia were non-obese based on BMI, but had higher WC, WHR, truncal skinfolds and body fat (%). Among other reported Indian studies, abdominal obesity as assessed by WHR was found to be more correlated than BMI, with lipid abnormalities among urban Indian adults (aged > 20 years) from North India by Gupta et al. (2007). Abnormal lipid profile observed among Indians can thus be attributed to increased abdominal fat deposition.

**Abdominal obesity & metabolic syndrome:** Professor Gerald Reaven introduced the concept of Insulin Resistance Syndrome in 1988 (Reaven, 1988), which is now more commonly known as the ‘Metabolic Syndrome’ (MS). MS essentially involves a clustering of NCDs such as insulin resistance, disorders of glucose and lipid metabolism and hypertension. The importance of abdominal obesity and its assessment using WC has now become most evident as WC has been consistently included in the recent definitions of MS given by several health agencies such as NCEP-ATP3 (2001), IDF (2006) and WHO (1998). Its relative importance amidst the cluster of diseases characterizing the MS was made evident in a study reported by Lorenzo et al. (2003) as they compared the expression of MS among two very different adult populations in Spain and San Antonio (Texas, U.S). They found that among subjects with MS, most women had increased abdominal adiposity and most men had either increased abdominal adiposity or BP. Similarly, Okosun et al. (2000) also have reported consistent association of WC with clustering of metabolic disorders among different ethnic populations in U.S.

Among the Asian populations, Yeh et al. (2005) reported that Chinese adults who had normal BMI but high WC had higher risk of developing MS as compared to those with isolated BMI elevation. McKeigue et al. (1991) reported among Asian Indian adults that, every 0.04 unit increase in WHR was associated with multiple NCDs such as a 4-fold increase in diabetes, 2-fold increase in post-glucose insulin levels and significantly higher Triglycerides (TG) and low High Density Lipoprotein (HDL) levels.
It is thus apparent that the risks for NCDs are aggravated in the presence of abdominal obesity and hence, appropriate indicators of abdominal obesity as well as their thresholds should be determined for population screening of NCDs. However, in view of large differences existing among different populations in terms of numerous factors viz. genetic background, body composition, dietary and physical activity patterns, socio-economic levels and so on, universal cutoffs may not be suitable for all and population-specific guidelines may be needed.

2.5.2 Diet, activity, lifestyle factors and risk of NCDs: Epidemiological studies documenting the effect of diet and physical activity on NCD risk factors have yielded inconsistent results. Although, these inconsistencies arise from differences in populations, it cannot be overlooked that large part of it can be attributed to methodological differences. Further, majority of the studies have interest in examining the prevalence of NCDs and relate it to the most obvious factor i.e. adiposity and overlook the relative importance of physical activity and diet which are major contributors to NCD risk. In fact, there are very few studies which investigate whether these factors have independent influence or their effect is mediated through adiposity in predicting the NCD risk.

Diet: The term ‘unhealthy diet often refers to the amount or quality of fat in the diet, yet the role of dietary fat remains controversial. Findings based on animal experiments suggest that relative to high carbohydrate diets, high fat diets with the exception of omega-3 fatty acids, result in insulin resistance (Storlien et al., 1991). However, data from epidemiological and human intervention studies are less consistent. Some studies have shown that a high fat intake predicts development of hyperinsulinemia (Marshall et al., 1997), lower insulin sensitivity (Lovejoy and DiGirolamo, 1992), impaired glucose tolerance (Feskens et al., 1995) and also the progression from impaired glucose tolerance to type 2 diabetes (Marshall et al., 1994). Contrary to this, there are studies that do not show any association between total fat intake and the risk of diabetes (Salmeron et al., 2001).

In recent years, dietary-patterning analysis by using the food frequency questionnaire method has been increasingly used as an alternative method to traditional single nutrient analysis, since it can assess the cumulative effects of the overall diet (Hu, 2002). Freire et al. (2005) examined the dietary pattern of Japanese
Brazilians (aged > 30 years) with respect to the risk of developing MS, and found that subjects with high fried food consumption as well as a high total fat intake had the highest risk of MS. He et al. (2004) performed a meta-analysis of cohort studies based on fish consumption and CHD mortality and found that as compared with individuals who never consumed fish or ate fish less than once per month, individuals with a higher intake of fish had lower CHD mortality.

Findings from a large international study from 52 countries covering the different regions of the world (North America, Western Europe, Australia, Central Europe, Middle East, Africa, South Asia, Southeast Asia, China, and South America) called the INTERHEART study (Iqbal et al., 2008), revealed that a ‘prudent diet’ i.e. a diet high in fruits and vegetables was inversely associated with the risk of myocardial infarction (MI). The investigators concluded that unhealthy diets could explain 30% of MI worldwide. According to Hu (2008), this particular study is the first large study to quantify eating patterns in all geographic regions of the world and provides evidence that even though food habits differ in various populations, reproducible dietary patterns can still be traced.

Although the Indian population exhibits the highest prevalence of diabetes and other NCDs in the world (Shaw et al., 2010), very few Indian studies have examined the association of dietary patterns with NCD risk. Ghosh et al. (2003) reported among middle-aged Bengalee Hindu men from Calcutta, India, that high consumption of milk-based Bengalee sweets was associated with high total cholesterol and fasting blood glucose while high consumption of fried snacks was associated with total cholesterol. However the researchers did not take any measure of physical activity into consideration while performing the analysis.

The India Health Study among adults aged 35-69 years, across 3 cities reported that, a diet high in “fruit-dairy,” that included fruit, fruit juice, and mixed dishes likely to contain cheese, yogurt, or other types of dairy, was positively associated with hypertension among subjects from Delhi. In Trivandrum, the “pulses and rice” pattern was inversely related to diabetes, while in Mumbai, the “fruit and vegetable” pattern was inversely associated with hypertension. It can be observed here that certain findings from this study are not in accordance with common nutritional knowledge such as fruits to be associated with hypertension. The researchers justify this phenomenon by explaining that higher concordance of the ‘fruit-dairy’ pattern was observed among participants of higher socio-economic status and lower physical
activity which may affect the association and additionally may also reflect dietary choices or substitutions to manage a chronic condition (Daniel et al., 2011). This further suggests that diet and activity patterns cannot be studied in isolation and in fact they need to be examined along with adiposity to determine their independent contributions towards the risk of NCDs.

**Activity:** Studies have also been performed to determine the effect of both physical activity and inactivity on the risk of NCDs, however the results yielded have been inconsistent. A positive effect of physical activity on reducing the risk for CVD, diabetes and MS has been reported (Katzmarzyk et al., 2005). It has also been observed that overweight or obese people who are active and fit have less CVD and lower all cause mortality than normal weight unfit people (Church et al., 2004).

Two large epidemiological studies from the U.S, Harvard Alumni Study (Paffenbarger et al., 1983) and Aerobics Center Longitudinal Study (Blair et al., 1984) seem to suggest that normotensive individuals with a low level of physical activity or fitness have an increased risk of developing hypertension in the future. On the other hand, the results from epidemiological studies that have prospectively studied the association between changes in physical activity and blood pressure are inconsistent, with the majority finding no attenuation of the rise in blood pressure among subjects who improved their fitness or increased their physical activity (Puddey and Cox, 1995). These inconsistencies may be attributed to the fact that the level of physical activity is very difficult to measure reliably and many confounding factors, such as diet and body weight, may play an influential part (van Baak, 1998). Age and ethnicity may also have an effect in this aspect, as Hagberg and Brown (1995) conclude that it is possible that more beneficial effect of exercise training is seen on middle-aged hypertensives rather than their younger and their older counterparts and also among Asians and Pacific Islanders rather than Caucasians.

In a study among male physicians (Manson et al., 1992), the incidence of self reported diabetes was negatively related to the frequency of vigorous exercise and the strength of this relationship was greater in those with higher BMI. For equivalent degrees of obesity, more physically active subjects have a lower incidence of the disease. Weinstein et al. (2004) also found that both BMI and physical activity were important predictors for the development of type 2 diabetes. There is thus still debate regarding the magnitude of influence exerted by obesity and physical activity in
combination and in isolation on health outcomes and additional studies are required in these aspects. Akbartabartoori et al. (2008) further emphasized this point as they reported among 5460 adults (aged 16–74 years) based on data from the cross-sectional Scottish Health Survey that, achievement of recommended physical activity levels may reduce some CVD risk factors, coronary heart disease (CHD) risk and improve psychosocial health, but may not eliminate the extra risk imposed by overweight/obesity toward CHD risk. And hence, continued physical activity as well as weight reduction may be essential to maintain a reduced CHD risk. This was also demonstrated by Goodpaster et al. (2003) in a sophisticated study among obese (BMI >30 kg/m²) non-diabetic volunteers (mean age: 39 years) that exercise combined with weight loss enhances post-absorptive fat oxidation that is crucial to the improvement in insulin sensitivity in obesity.

It thus becomes evident that although the beneficial effects of physical activity and the harmful effects of physical inactivity are evident, the associations may be influenced by the presence of adiposity. Also, as seen in the earlier reports, the role of diet cannot be denied and the synergistic effect of all these factors needs to be assessed to arrive at a complete overview of the contributory factors towards the risk of NCDs.

Only one reported Indian study (Beegom et al., 1995) examined the effect of all major confounding factors i.e. diet, activity, obesity, central obesity on the risk of hypertension on adults (25-64 years) from South India. They found no association of obesity, diet and activity on hypertension, while high prevalence of hypertension was seen only among subjects in the highest category of central obesity. Although no independent association of diet and activity was observed, subjects in the highest category of abdominal obesity also had higher dietary fat intake and lower energy expenditure. The authors suggest that Indians could benefit by decreasing total fat intake to 21% kcal/day and by increasing physical activity with the aim of decreasing central obesity, to prevent hypertension in the community.

Thus, more studies are required in the Indian scenario where large diversity, especially in the dietary patterns exists. In developed countries, collection of information on diet is relatively easier as food products bought from supermarkets are standardized in size and weight. Therefore interviews conducted even via telephone or internet have reasonable degree of accuracy. In contrast, in India, foods available in local markets are of varying sizes and weights. Further, daily diet usually comprises
of homemade foods with recipes differing in ingredients and style of cooking in almost every family. And hence, apart from recall errors estimating portion sizes accurately is difficult when 24 hour recall method is used.

**Lifestyle factors:** Consumption of alcohol and tobacco use, both have detrimental health consequences and are highly prevalent both in developed as well as developing countries, especially among men. Recent estimates indicate that approximately 2.3 million humans die each year from the harmful use of alcohol, accounting for about 3.8% of all deaths in the world. More than half of these deaths occur from NCDs including cancers, cardiovascular disease and liver cirrhosis (WHO, 2011a).

A recent review article by Parry et al. (2011) examined patterns of alcohol consumption and NCD risks and concluded that there is a strong link between alcohol and NCDs, particularly cancer, cardiovascular disease, liver disease, pancreatitis and diabetes. Smoking has been reported to lower HDL and to increase Low Density Lipoprotein (LDL) and TG, thus increasing the risk of CVD (Shimokata et al., 1989). However very few Asian studies have considered the confounding effects of these two major risk factors while assessing the relationship between diet, activity, obesity and NCDs (Lee et al., 2005).

**2.5.3 Optimal cutoffs for NCD risks:** The pattern of metabolic diseases is different among Asian populations as risks for NCDs are observed at much lower levels of BMI, as compared to the Caucasian populations (WHO, 2000b). For example, Inoue et al. (1997) observed that among Japanese adults, risk of hypertension was low for BMI < 22 kg/m\(^2\) and was almost two-fold beyond the value of 25 kg/m\(^2\). Yajnik et al. (2003) observed among middle-aged Indian adults a similar risk for impairment of glucose tolerance or diabetes beyond BMI of >23 kg/m\(^2\) as compared to those with a lower BMI. However, these cutoffs are arbitrary and are not optimal which can be used for screening purposes in masses.

The WHO consultation on WC and WHR (WHO, 2011b) recognized the importance of a universal method that should be used to arrive at the optimum cutoff levels. It emphasizes on the most common approach based on the use of sensitivity and specificity as interpreted from receiver operating characteristic (ROC) curves.
ROC is directly related to diagnostic decision-making and hence is the preferred method used in subsequent research (Rao, 2011)

Published studies from the Asian regions using the ROC method have given different ethnicity-specific cut-off points of BMI and WC, thus indicating population-dependent variations in the association of disease risk with measures of overall and abdominal obesity. Thus, Pan et al. (2004) report for adults (aged ≥ 20 years) a BMI cutoff of 22.5 kg/m² for Taiwanese men, as compared to 26 kg/m² for US white men and 27.5 kg/m² for US black men for predicting risk of NCDs. Lower cutoff viz. BMI value of 22.3 kg/m² is also reported in case of Indians (Singh et al., 2004), for identification of type 2 diabetics among Punjabi adults.

Similar variation is seen in case of WC cutoffs estimated for NCD risks to be 85 cm for Chinese men (Li et al., 2002) and Korean men (Park et al., 2010), while it is 82 cm in case of Thai adults (Aekplakorn et al., 2006). In contrast, Misra et al. (2006) report Action Level cutoffs as low as 78 cm for men and 72 cm for women for identifying subjects having risk of at least one of the NCDs.

The available literature on abdominal obesity and NCD risk reveals that despite large number of studies, there is a scope for investigating the association between the two, owing to the fact that the population differences, the differences in the indicators used, the differences in defining the NCD risks and finally, the differences in methods of examining the associations. Secondly, large evidence points towards the increasing abdominal adiposity and the parallel increase in the NCD risks, especially in Asian populations and in particular, in Indian sub-continent. In view of the fact that India is considered to be the diabetic capital of the world, it is highly pertinent to investigate the association of abdominal adiposity and NCD risk in a holistic manner. Unfortunately, such studies reported from India are scarce. The present study therefore attempts to examine the effect of various factors such as diet, activity, lifestyle factors and obesity, both in isolation and jointly, in predicting the NCD risk. Studies considering these factors in isolation will have limited implications, unlike the holistic approach which has enormous implications.