1. INTRODUCTION

Global health is being influenced by three trends: population-ageing, rapid unplanned urbanization, and globalization, all of which result in unhealthy environments and behaviors. As a result, the growing prevalence of Non Communicable Diseases (NCDs) and their risk factors has become a global issue affecting both low and middle income countries. Nearly 45% of the adult disease burden in these countries is now attributable to NCDs. Many low- and middle-income countries are beginning to suffer the double burden of communicable and non-communicable diseases, and health systems in these countries now have to cope with the additional costs of treating both.

Non-communicable diseases impose a significant economic burden on already strained health systems, and inflict great costs on society. Health is a key determinant of development and a precursor of economic growth. The WHO Commission on Macroeconomics and Health has demonstrated the disruptive effect of disease on development, and the importance for economic development of investments in health (WHO, 2002).

The burden of mortality, morbidity and disability attributable to non-communicable diseases is currently greatest and continuing to grow in the developing countries, where those affected are, on an average, younger than in developed countries, and where 66% of these deaths occur. Rapid changes in diets and patterns of physical activity are further causing rates to rise. Unhealthy diets and physical inactivity are thus among the leading causes of the major non-communicable diseases, including cardiovascular disease, type 2 diabetes and certain types of cancer, and contribute substantially to the global burden of disease, death and disability. In some developed countries where non-communicable diseases have dominated the national burden of disease, age-specific death and disease rates have been slowly declining. Progress is being made in reducing premature death rates from coronary artery disease,
cerebrovascular disease and some tobacco-related cancers. However, the overall burden and number of patients remain high, and the numbers of overweight and obese adults and children, and of cases, closely linked, and of type 2 diabetes are growing in many developed countries. Non-communicable diseases and their risk factors are initially mostly limited to economically successful groups in low- and middle-income countries. However, recent evidence shows that, over time, patterns of unhealthy behavior and the non-communicable diseases associated with them cluster among poor communities and contribute to social and economic inequalities. In the poorest countries, even though infectious diseases and undernutrition dominate their current disease burden, the major risk factors for chronic diseases are spreading. The prevalence of overweight and obesity is increasing in developing countries, and even in low-income groups in richer countries. An integrated approach to the causes of unhealthy diet and decreasing levels of physical activity would contribute to reducing the future burden of non-communicable diseases. For all countries for which data are available, the underlying determinants of non-communicable diseases are largely the same.

The coexistence of obesity, glucose intolerance, dyslipidemia & hypertension is termed as insulin resistance syndrome (IRS) or Metabolic syndrome. The clinical picture of IRS, however, may be dominated by one of its components. Further, metabolic abnormalities may occur at any given time in an individual (Mishra et al, 2004). It was initially proposed that resistance to insulin mediated glucose disposal is a pathophysiological interface for several metabolic alterations and disease. Interestingly, 13 years after its initial description, its scope and dimensions continue to evolve.

The prevalence of the metabolic syndrome has dramatically increased over the last few decades and has become a major health challenge worldwide, increasing the risk of cardiovascular disease (CVD), Type 2 diabetes (T2D),
nonalcoholic liver disease, renal disease, and some forms of cancer in adults (Steele et al, 2008).

In 1988, Reaven noted that several risk factors (eg, dyslipidemia, hypertension, hyperglycemia) commonly cluster together. This clustering he called Syndrome X, and he recognized it as a multiplex risk factor for CVD. Reaven and subsequently others postulated that insulin resistance underlies Syndrome X (hence the commonly used term insulin resistance syndrome). Other researchers use the term metabolic syndrome for this clustering of metabolic risk factors. ATP III used this alternative term. It avoids the implication that insulin resistance is the primary or only cause of associated risk factors. Although ATP III identified CVD as the primary clinical outcome of the metabolic syndrome, most people with this syndrome have insulin resistance, which confers increased risk for type 2 diabetes. When diabetes becomes clinically apparent, CVD risk rises sharply. Beyond CVD and type 2 diabetes, individuals with metabolic syndrome seemingly are susceptible to other conditions, notably polycystic ovary syndrome, fatty liver, cholesterol gallstones, asthma, sleep disturbances, and some forms of cancer (Grundy et al, 2004).

The underlying pathophysiology of the metabolic syndrome is unclear, but both insulin resistance and abdominal obesity are considered main components (Laaksonen et al, 2004; Alberti et al, 2006). The metabolic syndrome increases the risk of both type 2 diabetes (Laaksonen, 2002) and cardiovascular disease (Lakka et al, 2002; Meigs et al, 2003).
1.1 COMPONENTS OF METABOLIC SYNDROME

ATP III identified 6 components of the metabolic syndrome that relate to CVD:

- Abdominal obesity
- Atherogenic dyslipidemia
- Raised blood pressure
- Insulin resistance /glucose intolerance
- Proinflammatory state/ Prothrombotic state

These components of the metabolic syndrome constitute a particular combination of what ATP III terms underlying, major, and emerging risk factors. According to ATP III, underlying risk factors for CVD are obesity (especially abdominal obesity), physical inactivity, and atherogenic diet; the major risk factors are cigarette smoking, hypertension, elevated LDL cholesterol, low HDL cholesterol, family history of premature coronary heart disease (CHD), and aging; and the emerging risk factors include elevated triglycerides, small LDL particles, insulin resistance, glucose intolerance, proinflammatory state, and prothrombotic state. For present purposes, the latter 5 components are designated metabolic risk factors. Each component of the metabolic syndrome has been defined.

- Abdominal obesity is the form of obesity most strongly associated with the metabolic syndrome. It presents clinically as increased waist circumference.
- Atherogenic dyslipidemia manifests in routine lipoprotein analysis by raised triglycerides and low concentrations of HDL cholesterol. A more detailed analysis usually reveals other
lipoprotein abnormalities, eg, increased remnant lipoproteins, elevated apolipoprotein B, small LDL particles, and small HDL particles. All of these abnormalities have been implicated as being independently atherogenic.

- Elevated blood pressure strongly associates with obesity and commonly occurs in insulin-resistant persons. Hypertension thus commonly is listed among metabolic risk factors. However, some investigators believe that hypertension is less “metabolic” than other metabolic-syndrome components. Certainly, hypertension is multifactorial in origin. For example, increasing arterial stiffness contributes significantly to systolic hypertension in the elderly. Even so, most conference participants favored inclusion of elevated blood pressure as one component of the metabolic syndrome.

- Insulin resistance is present in the majority of people with the metabolic syndrome. It strongly associates with other metabolic risk factors and correlates univariately with CVD risk. These associations, combined with belief in its priority, account for the term insulin resistance syndrome. Even so, mechanisms underlying the link to CVD risk factors are uncertain, hence the ATP III’s classification of insulin resistance as an emerging risk factor. Patients with longstanding insulin resistance frequently manifest glucose intolerance, another emerging risk factor. When glucose intolerance evolves into diabetes-level hyperglycemia, elevated glucose constitutes a major, independent risk factor for CVD.

- A proinflammatory state, recognized clinically by elevations of C-reactive protein (CRP), is commonly present in persons with
metabolic syndrome. Multiple mechanisms seemingly underlie elevations of CRP. One cause is obesity, because excess adipose tissue releases inflammatory cytokines that may elicit higher CRP levels.

- A prothrombotic state, characterized by increased plasma plasminogen activator inhibitor (PAI)-1 and fibrinogen, also associates with the metabolic syndrome. Fibrinogen, an acute-phase reactant like CRP, rises in response to a high-cytokine state. Thus, prothrombotic and proinflammatory states may be metabolically interconnected (Grundy et al, 2004).

According to the American Heart Association (Grundy et al 2005), metabolic syndrome is characterized by a group of risk factors. These include:-

- Abdominal obesity (Excessive fat in & around abdomen).
- Atherogenic dyslipidemia (Blood fat disorder, high triglycerides, low HDL cholesterol and high LDL cholesterol).
- Elevated blood pressure.
- Insulin resistance or glucose intolerance
- Prothrombotic state (High fibrinogen or plasminogen activator inhibitor -1 in the blood).
- Proinflammatory stage (Elevated C – reactive protein in the blood).

The dominant underlying risk factors for this syndrome appear to be abdominal obesity and insulin resistance. Insulin resistance is a generalized metabolic disorder in which the body cannot use its insulin efficiently.
According to Forgoras et al (2008), metabolic syndrome is a group of cardio-risk factors that result from insulin resistance. In the body's attempt to compensate for insulin resistance, extra insulin is produced, leading to elevated insulin levels. The elevated insulin level can lead, directly or indirectly, to the characteristic abnormalities seen in these patients. Frequently, the insulin resistance will progress to overt type 2 diabetes which further increases the risk of cardiovascular complications.

According to Grundy et al (2004), people with metabolic syndrome are at increased risk of coronary heart disease and other diseases related to plaque build ups in the arterial walls.

Other conditions associated with the syndrome include physical inactivity, ageing, hormonal imbalance and genetic predisposition. Some people are genetically predisposed to insulin resistance. Acquired factors, such as excess body fat and physical inactivity, can elicit insulin resistance and the metabolic syndrome in these people. Most people with insulin resistance have abdominal obesity. The biologic mechanism at the molecular level between insulin resistance and metabolic risk factors is not fully understood and appears to be complex. Fig. 1 gives the interaction of various factors in development of insulin resistance, type 2 diabetes and coronary heart diseases in Asian population.
Figure 1.1 Complex interactions of genetic, perinatal and nutritional and other acquired factors in development of insulin resistance, type 2 diabetes and coronary heart diseases in Asian population (Mishra et al, 2006).

1.2 PATHOGENESIS OF METABOLIC SYNDROME

The metabolic syndrome seems to have 3 potential etiological categories: obesity and disorders of adipose tissue; insulin resistance; and a constellation of independent factors (eg, molecules of hepatic, vascular, and immunologic origin) that mediate specific components of the metabolic syndrome. Other factors—aging, proinflammatory state, and hormonal changes—have been implicated as contributors as well.
1.2(a) Obesity and Abnormal Body Fat Distribution

Obesity identified as a nutritional disorder, thirty years ago, still continues to be one of the most important, yet preventable health hazards. Indeed, obesity rates have now reached epidemic proportions with over 25 per cent of the population being obese in US and 15 per cent in Europe. Obesity is considered to be the link between insulin resistance and metabolic abnormalities inclusive of diabetes, hypertension and dyslipidaemia, all of which are risk factors for coronary artery disease. In the recent INTERHEART study, abdominal obesity assessed by waist to hip ratio showed a strong association with myocardial infarction. Obesity is also considered to be a major risk factor for hypertension. Over 70 per cent of hypertension among males and 61 per cent among females were attributed to excess adiposity in the Framingham study. The INTERSALT study also showed a strong association between body mass index and blood pressure.

Measures commonly used for assessing obesity are BMI and waist circumference (WC). Unfortunately, BMI is not considered to be a good estimate of obesity in Asian Indians as they have a characteristic obesity phenotype, with relatively lower BMI but with central obesity. It has been suggested that fat distributed in the abdominal region, particularly visceral fat is more metabolically important than other fat depots. Case control studies, have clearly indicated that visceral fat is associated with diabetes. Hence abdominal adiposity assessed using waist circumference is considered to be more appropriate to predict metabolic disorders than generalized adiposity assessed by BMI.

ATP III considered the “obesity epidemic” as mainly responsible for the rising prevalence of metabolic syndrome. Obesity contributes to hypertension, high serum cholesterol, low HDL cholesterol, and hyperglycemia, and it otherwise associates with higher CVD risk. Abdominal obesity especially correlates with metabolic risk factors. Excess adipose tissue releases several products that
apparently exacerbate these risk factors. They include non esterified fatty acids (NEFA), cytokines, PAI-1, and adiponectin. A high plasma NEFA level overloads muscle and liver with lipid, which enhances insulin resistance. High CRP levels accompanying obesity may signify cytokine excess and a proinflammatory state. An elevated PAI-1 contributes to a prothrombotic state, whereas low adiponectin levels that accompany obesity correlate with worsening of metabolic risk factors. The strong connection between obesity (especially abdominal obesity) and risk factors led ATP III to define the metabolic syndrome essentially as a clustering of metabolic complications of obesity. (Grundy et al, 2004)

1.2(b) Insulin Resistance
A second category of causation is insulin resistance. Insulin resistance is a condition in which the body produces insulin but does not use it properly. Insulin, a hormone made by the pancreas, helps the body use glucose for energy. The body’s digestive system breaks food down into glucose, which then travels in the bloodstream to cells throughout the body. As the blood glucose level rises after a meal, the pancreas releases insulin to help cells take in and use the glucose. When people are insulin resistant, their muscle, fat, and liver cells do not respond properly to insulin. As a result, their bodies need more insulin to help glucose enter cells. The pancreas tries to keep up with this increased demand for insulin by producing more. Eventually, the pancreas fails to keep up with the body’s need for insulin. Excess glucose builds up in the bloodstream, setting the stage for diabetes. Many people with insulin resistance have high levels of both glucose and insulin circulating in their blood at the same time.

Insulin resistance increases the chance of developing type 2diabetes and heart disease. Learning about insulin resistance is the first step toward making lifestyle changes that can help prevent diabetes and other health problems.
Scientists have identified specific genes that make people more likely to develop insulin resistance and diabetes. Excess weight and lack of physical activity also contribute to insulin resistance.

Many people with insulin resistance and high blood glucose have other conditions that increase the risk of developing type 2 diabetes and damage to the heart and blood vessels, also called cardiovascular disease. These conditions include having excess weight around the waist, high blood pressure, and abnormal levels of cholesterol and triglycerides in the blood. Having several of these problems is called metabolic syndrome or insulin resistance syndrome, formerly called syndrome X (NDIC, 2008).

Many investigators place a greater priority on insulin resistance than on obesity in pathogenesis (Grundy et al, 2004). They argue that insulin resistance, or its accomplice, hyperinsulinemia directly causes other metabolic risk factors. Identifying a unique role for insulin resistance is complicated by the fact that it is linked to obesity. Insulin resistance generally rises with increasing body fat content, yet a broad range of insulin sensitivities exists at any given level of body fat (Abbasi et al, 2002). Most people with categorical obesity (body mass index [BMI] ≥30 kg/m²) have postprandial hyperinsulinemia and relatively low insulin sensitivity, but variation in insulin sensitivities exists even within the obese population (Abbasi et al, 2002). Overweight persons (BMI 25 to 29.9 kg/m²) likewise exhibit a spectrum of insulin sensitivities, suggesting an inherited component to insulin resistance. In some populations (eg, South Asians), insulin resistance occurs commonly even with BMI <25 kg/m² and apparently contributes to a high prevalence of type 2 diabetes and premature CVD. South Asians and others who manifest insulin resistance with only mild-to-moderate overweight can be said to have primary insulin resistance. Even with primary insulin resistance, however, weight gain seems to enhance insulin resistance and
metabolic syndrome. Thus, dissociation of obesity and primary insulin resistance in patients with metabolic syndrome is difficult.

This is not to say that insulin resistance per se does not play a significant role in causation of metabolic syndrome. When insulin-resistant muscle is already overloaded with lipid from high plasma NEFA levels, some excess NEFA presumably is diverted to the liver, promoting fatty liver and atherogenic dyslipidemia. Hyperinsulinemia may enhance output of very-low-density lipoprotein triglycerides, raising triglycerides. Insulin resistance in muscle predisposes to glucose intolerance, which can be worsened by increased hepatic gluconeogenesis in insulin-resistant liver. Finally, insulin resistance may raise blood pressure by a variety of mechanisms (Grundy et al, 2004).

1.2(c) Blood Pressure

High blood pressure is called the "silent killer" because it often has no warning signs or symptoms, and many people do not realize they have it. "Blood pressure" is the force of blood pushing against the walls of the arteries as the heart pumps blood. If this pressure rises and stays high over time, it can damage the body in many ways. Hypertension, or high blood pressure, is a key symptom of Metabolic Syndrome/Syndrome X. Both conditions are important risk factors in developing Cardiovascular Disease, which can lead to a heart attack or stroke. If left untreated, hypertension can also lead to a wide variety of other life-threatening conditions, such as kidney damage and congestive heart failure. Hypertension is a very common condition with wide-spread consequences and can remain asymptomatic (undiagnosed) until relatively late in its course. Several studies have proven that Insulin Resistance and the resulting hyperinsulinemia (elevated insulin in the blood) cause increases in blood pressure. This is because elevated levels of insulin can cause atherosclerosis, which directly affects the diameter of the inside of the blood vessel.
India has a large number of hypertensives with projections indicating nearly a doubling from 118 million in 2000 to 213 million by 2025. Hypertension prevalence in adults is between 20% and 40% in urban areas and 12% and 17% in rural areas (Reddy et al, 2005). An earlier meta-analysis reported 25% prevalence among urban adults and 10% among rural adults (Gupta et al, 2004). The Indian Council of Medical Research (ICMR) estimates that 16% of ischemic heart disease (IHD), 21% of peripheral vascular disease, 24% of acute myocardial infarctions and 29% of strokes in India could be attributable to high blood pressure (Shah et al, 2011). National data are unavailable, but many sub-national studies have reported increases in hypertension across the country over the past two decades (Gupta et al, 2004). About 1 in 3 U.S. adults—as estimated 68 million—have high blood pressure, which increases the risk for heart disease and stroke, leading causes of death in the United States.

1.2(d) Independent Factors That Mediate Specific Components of the Metabolic Syndrome

Beyond obesity and insulin resistance, each risk factor of the metabolic syndrome is subject to its own regulation through both genetic and acquired factors. This leads to variability in expression of risk factors. Lipoprotein metabolism, for instance, is richly modulated by genetic variation; hence, expression of dyslipidemias in response to obesity and/or insulin resistance varies considerably. The same holds for blood pressure regulation. Moreover, glucose levels depend on insulin secretory capacity as well as insulin sensitivity. This variation in distal regulation cannot be ignored as an important factor in causation of metabolic syndrome.
1.2(e) Other Contributing Factors
Advancing age probably affects all levels of pathogenesis, which likely explains why prevalence of the metabolic syndrome rises with advancing age. Recently, a proinflammatory state has been implicated directly in causation of insulin resistance, as well as atherogenesis. Finally, several endocrine factors have been linked to abnormalities in body-fat distribution and hence indirectly to metabolic syndrome. Thus, pathogenesis of the metabolic syndrome is complex and ripe with opportunities for further research (Grundy et al, 2004).

1.3 DIAGNOSIS
At least 3 organizations have recommended clinical criteria for the diagnosis of the metabolic syndrome. Their criteria are similar in many aspects, but they also reveal fundamental differences in positioning of the predominant causes of the syndrome.

According to third report of National Cholesterol Education Program (NCEP) expert report (ATPIII) (2008), metabolic syndrome is defined as having three or more of the following abnormalities:-

- Elevated waist circumference: 90 cm or more for men; 80 cm or more for women.
- Elevated triglycerides: 150mg/dl or higher.
- Reduced HDL Cholesterol: less than 40 mg/dl in men, less than 50mg/dl in women.
- Elevated fasting glucose: 100 mg/dl or higher.
- Elevated blood pressure: 130/85 mmHg or higher.
When 3 of 5 of the listed characteristics are present, a diagnosis of metabolic syndrome can be made. The primary clinical outcome of metabolic syndrome was identified as CHD/CVD. Abdominal obesity, recognized by increased waist circumference is the first criterion listed. Its inclusion reflects the priority given to abdominal obesity as a contributor to metabolic syndrome. Also listed are raised triglycerides, reduced HDL cholesterol, elevated blood pressure, and raised fasting glucose. Cutpoints for several of these are less stringent than usually required to identify a categorical risk factor, because multiple marginal risk factors can impart significantly increased risk for CVD. Explicit demonstration of insulin resistance is not required for diagnosis; however, most persons meeting ATP III criteria will be insulin resistant. Finally, the presence of type 2 diabetes does not exclude a diagnosis of metabolic syndrome.

According to **IDF definition (2006)**, a person defined to be having the metabolic syndrome must have:-

- Central obesity + any two of the following four factors:-
  
  1. Raised triglycerides: 150mg/dl or higher
  
  2. Reduced HDL cholesterol: Less than 40mg/dl in males
     
     Less than 50mg/dl in females
  
  3. Raised blood pressure: 130/85 mm hg or higher
  
  4. Raised fasting plasma glucose: 100mg/dl or higher (FPG)
WHO diagnostic criteria (2004) for metabolic syndrome includes:-

1. Insulin resistance as identified by one of the following
   a. Type 2 diabetes
   b. Impaired fasting glucose
   c. Impaired glucose tolerance
   d. Glucose uptake below the lowest quartile for background population under investigation for hyperinsulinemia, euglycemic condition (in patients with normal fasting glucose level < 110 mg/dl)

2. Plus any two of the following:-
   a. Blood Pressure: 140/90 mm hg or higher
   b. Plasma Triglyceride: 150mg/dl or higher.
   c. HDL Cholesterol: Less than 35mg/dl or higher in men, Less than 39 mg/dl or higher in women
   d. Body mass index: > 30kg/m²
   e. Urinary albumin excretion rate: 20mg/min or higher.

According to the American Heart Association and the National Heart Lung, and Blood Institute (AHA/NHLBI, 2008), Metabolic syndrome is defined as having three or more of the following abnormalities:-

- Elevated waist circumference: 40 inches or more for men; 35 inches or more for women.
• Elevated triglycerides: 150mg/dl or higher.

• Reduced HDL Cholesterol: less than 40 mg/dl in men, less than 50mg/dl in women.

• Elevated fasting glucose: 100 mg/dl or higher.

• Elevated blood pressure: 130/85 mmHg or higher.

The American Association of Clinical Endocrinologists (AACE) (Einhorn et al, 2003) proposes a set of clinical criteria for the insulin resistance syndrome (Table 1.1). These criteria appear to be a hybrid of those of ATP III and WHO metabolic syndrome. However, no defined number of risk factors is specified; diagnosis is left to clinical judgment. When a person develops categorical diabetes, the term insulin resistance syndrome no longer applies. In patients without IFG, a 2-hour post glucose challenge is recommended when an abnormality is clinically suspected. Finding abnormal 2-hour glucose will improve prediction of type 2 diabetes.

Table 1.1 AACE Clinical Criteria for Diagnosis of the Insulin Resistance Syndrome

<table>
<thead>
<tr>
<th>Risk Factor Components</th>
<th>Cut points for Abnormality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overweight/obesity</td>
<td>BMI ≥25 kg/m²</td>
</tr>
<tr>
<td>Elevated triglycerides</td>
<td>≥150 mg/dL (1.69 mmol/L)</td>
</tr>
<tr>
<td>Low HDL cholesterol</td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>&lt;40 mg/dL (1.04 mmol/L)</td>
</tr>
<tr>
<td>Women</td>
<td>&lt;50 mg/dL (1.29 mmol/L)</td>
</tr>
<tr>
<td>Elevated blood pressure</td>
<td>≥130/85 mm Hg</td>
</tr>
<tr>
<td>2-Hour post glucose</td>
<td>&gt;140 mg/dL</td>
</tr>
</tbody>
</table>

*Diagnosis depends on clinical judgment based on risk factors.*
1.4 PHYSICAL ACTIVITY

The term “physical activity” is often used interchangeably with energy expenditure, exercise, and physical fitness. These terms have been defined by Caspersen et al (1985) with “physical activity” as “any bodily movement produced by skeletal muscles that results in energy expenditure” and “physical fitness” as a “set of attributes either health or skill related” that is not synonymous with physical activity. “Exercise”, on the other hand, is “a subset of physical activity that is planned, structured, and repetitive” leading to the improvement or maintenance of physical fitness. (Steele et al, 2008).

Physical inactivity is an independent risk factor for chronic diseases and overall is estimated to cause 1.9 million deaths globally (WHO, 2008). Physical inactivity has been identified as the fourth leading risk factor for global mortality (6% of deaths globally). This follows high blood pressure (13%), tobacco use (9%) and high blood glucose (6%). Overweight and obesity are responsible for 5% of global mortality (WHO, 2009). Levels of physical inactivity are rising in many countries with major implications for the general health of people worldwide and for the prevalence of NCDs such as cardiovascular disease, diabetes and cancer and their risk factors such as raised blood pressure, raised blood sugar and
overweight. Physical inactivity is estimated as being the principal cause for approximately 21–25% of breast and colon cancer burden, 27% of diabetes and approximately 30% of ischaemic heart disease burden (WHO, 2009). In addition, NCDs now account for nearly half of the overall global burden of disease. It is estimated currently that of every 10 deaths, 6 are attributable to non-communicable conditions (WHO, 2004). It has been shown that participation in regular physical activity reduces the risk of coronary heart disease and stroke, diabetes, hypertension, colon cancer, breast cancer and depression. Additionally, physical activity is a key determinant of energy expenditure, and thus is fundamental to energy balance and weight control (WHO, 2010).

1.5 HEALTH BENEFITS OF PHYSICAL ACTIVITY

Studies clearly demonstrate that participating in regular physical activity provides many health benefits. Many conditions affected by physical activity occur with increasing age, such as heart disease and cancer. Reducing risk of these conditions may require years of participation in regular physical activity. However, other benefits, such as increased cardiorespiratory fitness, increased muscular strength, and decreased depressive symptoms and blood pressure, require only a few weeks or months of participation in physical activity.

The health benefits of physical activity are seen in children and adolescents, young and middle-aged adults, older adults, women and men, people of different races and ethnicities, and people with disabilities and chronic conditions. The health benefits of physical activity are generally independent of body weight. Adults of all sizes and shapes gain health and fitness benefits by being habitually physically active. The benefits of physical activity also outweigh the risk of injury and sudden heart attacks, two concerns that prevent many people from becoming physically active (Physical Activity Guidelines for Americans, 2008).
1.5(a) Premature Death

Strong scientific evidence shows that physical activity reduces the risk of premature death (dying earlier than the average age of death for a specific population group) from the leading causes of death, such as heart disease and some cancers, as well as from other causes of death. This effect is remarkable in two ways:

- First, only a few lifestyle choices have as large an effect on mortality as physical activity. It has been estimated that people who are physically active for approximately 7 hours a week have a 40 percent lower risk of dying early than those who are active for less than 30 minutes a week.
- Second, it is not necessary to do high amounts of activity or vigorous-intensity activity to reduce the risk of premature death. Studies show substantially lower risk when people do 150 minutes of at least moderate-intensity aerobic physical activity a week.

Research clearly demonstrates the importance of avoiding inactivity. Even low amounts of physical activity reduce the risk of dying prematurely.

1.5(b) Cardiorespiratory Health

The benefits of physical activity on cardio respiratory health are some of the most extensively documented of all the health benefits. Cardio respiratory health involves the health of the heart, lungs, and blood vessels.

Heart diseases and stroke are two of the leading causes of death in the United States. Risk factors that increase the likelihood of cardiovascular diseases include smoking, high blood pressure (called hypertension), type 2 diabetes, and high levels of certain blood lipids (such as low-density lipoprotein, or LDL, cholesterol). Low cardiorespiratory fitness also is a risk factor for heart disease.
People who do moderate or vigorous intensity aerobic physical activity have a significantly lower risk of cardiovascular disease than do inactive people. Regularly active adults have lower rates of heart disease and stroke, and have lower blood pressure, better blood lipid profiles, and fitness. Significant reductions in risk of cardiovascular disease occur at activity levels equivalent to 150 minutes a week of moderate-intensity physical activity. Even greater benefits are seen with 200 minutes (3 hours and 20 minutes) a week. The evidence is strong that greater amounts of physical activity result in even further reductions in the risk of cardiovascular disease.

1.5(c) Metabolic Health

Regular physical activity strongly reduces the risk of developing type 2 diabetes as well as the metabolic syndrome. People who regularly engage in at least moderate intensity aerobic activity have a significantly lower risk of developing type 2 diabetes than do inactive people. Although some experts debate the usefulness of defining the metabolic syndrome, good evidence exists that physical activity reduces the risk of having this condition, as defined in various ways. Lower rates of these conditions are seen with 120 to 150 minutes (2 hours to 2 hours and 30 minutes) a week of at least moderate-intensity aerobic activity. As with cardiovascular health, additional levels of physical activity seem to lower risk even further. In addition, physical activity helps control blood glucose levels in persons who already have type 2 diabetes.

1.5(d) Obesity and Energy Balance

Overweight and obesity occur when fewer calories are expended, including calories burnt through physical activity, than are taken in through food and beverages. Physical activity and caloric intake both must be considered when trying to control body weight. Because of this role in energy balance, physical activity is a critical factor in determining whether a person can maintain a healthy
body weight, lose excess body weight, or maintain successful weight loss. People vary a great deal in how much physical activity they need to achieve and maintain a healthy weight. Some need more physical activity than others to maintain a healthy body weight, to lose weight, or to keep weight off once it has been lost.

Strong scientific evidence shows that physical activity helps people maintain a stable weight over time. However, the optimal amount of physical activity needed to maintain weight is unclear. People vary greatly in how much physical activity results in weight stability. Many people need more than the equivalent of 150 minutes of moderate-intensity activity a week to maintain their weight.

Over short periods of time, such as a year, research shows that it is possible to achieve weight stability by doing the equivalent of 150 to 300 minutes (5 hours) a week of moderate-intensity walking at about a 4 mile-an-hour pace. Muscle-strengthening activities may help promote weight maintenance, although not to the same degree as aerobic activity.

1.5(e) Musculoskeletal Health

Bones, muscles, and joints support the body and help it move. Healthy bones, joints, and muscles are critical to the ability to do daily activities without physical limitations.

Preserving bone, joint, and muscle health is essential with increasing age. Studies show that the frequent decline in bone density that happens during aging can be slowed with regular physical activity. These effects are seen in people who participate in aerobic, muscle–strengthening, and bone-strengthening physical activity programs of moderate or vigorous intensity. The range of total physical activity for these benefits varies widely. Important changes seem to begin at 90 minutes a week and continue up to 300 minutes a week.
Hip fracture is a serious health condition that can have life-changing negative effects for many older people. Physically active people, especially women, appear to have a lower risk of hip fracture than do inactive people. Research studies on physical activity to prevent hip fracture show that participating in 120 to 300 minutes a week of physical activity that is of at least moderate intensity is associated with a reduced risk. It is unclear, however, whether activity also lowers risk of fractures of the spine or other important areas of the skeleton.

Regular physical activity also helps people with arthritis or other rheumatic conditions affecting the joints. Participation in 130 to 150 minutes (2 hours and 10 minutes to 2 hours and 30 minutes) a week of moderate-intensity, low-impact physical activity improves pain management, function, and quality of life. Researchers do not yet know whether participation in physical activity, particularly at low to moderate intensity, reduces the risk of osteoarthritis. Very high levels of physical activity, however, may have extra risks. People who participate in very high levels of physical activity, such as elite or professional athletes, have a higher risk of hip and knee osteoarthritis, mostly due to the risk of injury involved in competing in some sports.

1.5(f) Functional Ability and Fall Prevention

Functional ability is the capacity of a person to perform tasks or behaviors that enable him or her to carry out everyday activities, such as climbing stairs or walking on a sidewalk. Functional ability is the key to a person's ability to fulfill basic life roles, such as personal care, grocery shopping, or playing with the grandchildren. Loss of functional ability is referred to as functional limitation.

Middle-aged and older adults who are physically active have lower risk of functional limitations than do inactive adults. It appears that greater physical activity levels can further reduce risk of functional limitations.
In older adults at risk of falls, strong evidence shows that regular physical activity is safe and reduces this risk. Reduction in falls is seen for participants in programs that include balance and moderate-intensity muscle-strengthening activities for 90 minutes a week plus moderate-intensity walking for about an hour a week. It is not known whether different combinations of type, amount, or frequency of activity can reduce falls to a greater degree. Tai chi exercises also may help prevent falls.

**1.5(g) Cancer**

Physically active people have a significantly lower risk of colon cancer than do inactive people, and physically active women have a significantly lower risk of breast cancer. Research shows that a wide range of moderate-intensity physical activity—between 210 and 420 minutes a week (3 hours and 30 minutes to 7 hours)—is needed to significantly reduce the risk of colon and breast cancer; currently; 150 minutes a week does not appear to provide a major benefit. It also appears that greater amounts of physical activity lower risks of these cancers even further, although exactly how much lower is not clear.

Although not definitive, some research suggests that the risk of endometrial cancer in women and lung cancers in men and women also may be lower among those who are regularly active compared to those who are inactive.

**1.5(h) Mental Health**

Physically active adults have lower risk of depression and cognitive decline (declines with aging in thinking, learning, and judgment skills). Physical activity also may improve the quality of sleep. Whether physical activity reduces distress or anxiety is currently unclear.
Mental health benefits have been found in people who do aerobic or a combination of aerobic and muscle-strengthening activities 3 to 5 days a week for 30 to 60 minutes at a time. Some research has shown that even lower levels of physical activity also may provide some benefits (Physical Activity Guidelines for Americans, 2008).

### 1.6 METABOLIC SYNDROME AND PHYSICAL ACTIVITY

The metabolic syndrome is a constellation of interrelated metabolic risk factors, including abdominal obesity, insulin resistance, hyperglycemia, dyslipidemia, and elevated blood pressure, often accompanied by a prothrombotic and proinflammatory state (Laaksonen et al, 2004; Alberti et al, 2006). Recent recommendations for the prevention and treatment of the metabolic syndrome and its components promote increased physical activity (including aerobic and resistance exercise), a healthy diet, and weight loss (Grundy et al, 2005; Lakka et al, 2007). In lifestyle interventions trials, the incidence of type 2 diabetes has been reduced by more than half in individuals with impaired glucose tolerance, and the prevalence of the metabolic syndrome has also been decreased (Orchard et al, 2005; Ilanne et al, 2008). Figure 1.2 conceptualizes the role of physical activity and nutrition in the etiology of metabolic syndrome and CVD risk.
Figure 1.2 Role of physical activity and nutrition in the etiology of metabolic syndrome and CVD risk.
In the Finnish Diabetes Prevention Study (DPS), increased moderate-to-vigorous leisure-time physical activity (LTPA) was strongly associated with a lower risk of type 2 diabetes, independently of dietary changes and weight loss (Laaksonen et al, 2005).

Some prospective epidemiological studies and uncontrolled trials have suggested that increased moderate-to-vigorous exercise decreases the incidence or prevalence of the metabolic syndrome (Laaksonen et al, 2002; Katzmarzyk et al, 2003). However, data on the role of changes in LTPA in the prevention and treatment of the metabolic syndrome in long-term studies are limited.

Regular physical activity reduces the risk of obesity, blood lipid abnormalities, hypertension and non insulin dependent diabetes mellitus and has been shown to reduce substantially the risk of coronary heart disease. Conversely, a measure of sedentary lifestyle or physical inactivity has been associated with a 1.5 – 2.5 fold elevation in cardiovascular disease risk. It is estimated that 2.4% of the US Health Care expenditure is directly related to a lack of physical activity. As a result of economic changes and increased mechanization, the prevalence of physical inactivity is increasing in India, particularly in urban areas, to levels compared with West (Rastogi et al, 2004).

The association between sedentary behavior and metabolic health has also been explored. In adult studies where sedentary behavior has been defined by sitting time or general screen time (i.e., time spent television viewing and/or computer, video game use), associations with individual components of metabolic risk and the metabolic syndrome have been observed (Aadahl et al, 2007; Dunstan et al, 2005). The associations of television viewing and objectively measured physical activity by hip accelerometry, with individual and clustered metabolic risk factors, were examined in a large population-based sample from EYHS (Ekelund et al, 2006). The positive association between television viewing and clustered
metabolic risk was only of borderline significance, after adjustment for physical activity and other confounding factors. However, these associations were explained by a positive association between television viewing and adiposity. In contrast, physical activity was independently and inversely associated with systolic and diastolic blood pressure, fasting glucose, insulin and triglycerides, and non obesity clustered risk score, independent of obesity and other confounders. Similarly, objectively measured time spent in sedentary behavior (Ekelund et al, 2007) has also been shown to be positively and independently associated with clustered metabolic risk, in the same cohort.

In the late 1970s, several observational studies suggested that mortality or morbidity caused by atherosclerotic disease was inversely related to the individual's physical activity status. Even though exercise is considered a cornerstone in the treatment of diabetes - a condition that is strongly related to metabolic syndrome, only a few studies have investigated its relationship with cardiovascular disease risk in diabetic persons. In a sample of 5,125 diabetic nurses from the Nurses Health Study, after 14 years of follow-up, the investigators found a 45% multivariate-adjusted reduction in cardiovascular disease risk with moderate to vigorous activity compared to sedentary (Hu, 2001).

The Whitehall Cohort Study investigated the relation of two indices of physical activity - walking pace and leisure activity - to total mortality, coronary heart disease and other cardiovascular diseases, in a 25-years follow-up of 6,408 male British civil servants (Batty, 2002). Among 352 diabetic men and 6,056 non-diabetics at study entry, the investigators found that the two indices of physical activity were inversely related to all-cause, coronary heart disease and other cardiovascular disease mortalities in both normoglycemic men and men with diabetes/impaired glucose tolerance.
Tanasescu et al (2003) from the Health Professionals' Study, during a 14-year follow-up of 2803 men, observed a 42% multivariate-adjusted reduction of total mortality and a 33% multivariate-adjusted reduction of cardiovascular disease incidence in the highest quintile of physical activity compared with the lowest. In contrast to the number of studies that investigated the association of exercise with the development of diabetes or cardiovascular disease, data considering specifically the metabolic syndrome are sparse in the literature.

One of the epidemiologic studies that evaluated the association between physical activity and the prevalence of the metabolic syndrome was the ATTICA Study. The results showed that even light-to-moderate leisure time physical activity (<7 kcal/min expended) was associated with a considerable reduction in the prevalence of the metabolic syndrome in 3042 men and women from the general population. Regular, intensive exercise was associated with a much greater decrease (Panagiotakos, 2004).

Mohan et al (2005) conducted a study on association of physical inactivity with components of metabolic syndrome and coronary heart disease – the Chennai urban population study. The study involved two residential areas of Chennai in South India. The study concluded that physical inactivity is associated with the components of metabolic syndrome & coronary heart disease.

Rastogi et al (2004) conducted a research on physical activity & risk of coronary heart disease in India. The study was hospital based case - control study and collected data from 350 cases of acute myocardial infarction and 700 control matched on age and gender in New Delhi and Bangalore. The study showed that physical inactivity and cardiovascular diseases are positively connected.
Delavar (2008) in a study on physical activity and metabolic syndrome in middle aged women in Iran also stated that physical inactivity is positively associated with metabolic syndrome.

A study on occupational and leisure time physical activity in relation to cardiovascular mortality among Finnish subjects with hypertension concluded that moderate or high level of occupational or leisure time physical activity reduced cardiovascular mortality among both men and women with hypertension (Hu et al, 2007).

Reaven et al (2007) in a study on relation between leisure time physical activity and blood pressure in older women showed that the rates of systolic and diastolic hypertension were significantly lower in women participating in light, moderate or heavy physical activity rather than sedentary women.

Irwin et al (2002) carried out a study on physical activity and metabolic syndrome. It investigated the association between physical activity, specifically moderate and vigorous intensity physical activity, treadmill duration and the metabolic syndrome in a sample of African-American, Native-American and White women. The results showed that all associations (moderate intensity physical activity, vigorous intensity physical activity, treadmill duration and the metabolic syndrome) were statistically significant; a strong negative association was observed between maximal treadmill duration and metabolic syndrome.
SIGNIFICANCE OF STUDY

Asians have an unusual high tendency to develop type 2 diabetes mellitus and coronary heart disease; important determinants of both these non communicable diseases are insulin resistance and clustering of other proatherogenic factors. These diseases are escalating due to marked shift in life style in Asian countries caused by economic growth, affluence, urbanization and dietary westernization. Clustering of cardiovascular risk factors in Asians was initially reported from UK. Since then, a number of investigators have reported high prevalence of metabolic syndrome in Asian populations settled in many other countries (Mishra et al, 2007).

Chronic disease in likely to be the primary disease cluster in India in the future. Cardiovascular disease is the leading cause of death and its contribution to mortality is rising. Deaths due to cardiovascular disease are expected to double between 1985 to 2015. The metabolic syndrome is defined as a combination of three or more risk factors for cardiovascular diseases including central obesity, hypertriglyceridemia, high blood pressure, high fasting glucose, and decreased high density lipoprotein (HDL). Physical inactivity is an important risk factor for the development of several chronic diseases. The problem is of particular concern in countries like India that have a transitional economics and changing lifestyle. These changing lifestyles may compound the increased inherent risk of ethnic groups. There are some data that suggest that Indians have genetically determined increased risk of coronary artery disease. Physical inactivity would tend to enhance that risk. In order to understand the epidemiology of these chronic diseases, and plan effective intervention, it is necessary to assess physical activity pattern effectively. Lifestyle changes focused on increasing physical activity could help to prevent the exploring epidemic of metabolic syndrome and coronary heart disease in India.
There are a number of studies which state the relationship between metabolic syndrome and physical activity in the Western countries but the researches are not as vast in the Indian context. The present study has, therefore, been planned to determine the association between physical activity and metabolic syndrome.

**OBJECTIVES**

1. To identify the components of metabolic syndrome in a group of middle aged population as per NCEP(ATPIII) criteria by:-
   - Assessment of specific anthropometric variables.
   - Measurement of blood pressure.
   - Assessment of biochemical parameters viz blood glucose level, blood lipid profile.

2. To determine the habitual level of physical activity of the subjects.

3. To assess the dietary profile of the subjects.

4. To determine the association of physical activity and metabolic syndrome.