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# Late Stage Complications of Diabetes and Insulin Resistance

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**Abstract**

Diabetes mellitus is considered one of the main threats to human health in the 21st century. Diabetes is a metabolic disorder or a chronic condition where the sugar levels in blood are high. Diabetes is associated with long-term complications that affect almost every part of the body and often leads to blindness, heart and blood vessel disease, stroke, kidney failure, amputations, and nerve damage. Also it is associated with significantly accelerated rates of several debilitating microvascular complications such as nephropathy, retinopathy, and neuropathy, and macrovascular complications such as atherosclerosis and stroke. In the present article it has been discussed about the resistance of insulin and its consequences in diabetic patients. Insulin resistance results in various disorders. Metabolic syndrome is predicted to become a major public health problem in many developed, as well as developing countries.

**Keywords:** Diabetes; Complications; Insulin; Insulin resistance; metabolic syndrome

**Abbreviations:** DM: Diabetes mellitus; T2D: Type2 diabetes; Type 2 diabetes mellitus (T2DM); Impaired glucose tolerance (IGT); CVD: cardiovascular disease; MetS: Metabolic syndrome

## Introduction

Diabetes mellitus is considered one of the main threats to human health in the 21st century. In developing countries, the prevalence of diabetes is increasing, where there are, as estimated by the World Health Organization (WHO), around 70 million people suffering from diabetes mellitus [1].Changes in human behaviour and lifestyle over the last century have resulted in a dramatic increase in the incidence of diabetes worldwide [2]. Diabetes is a metabolic disorder or a chronic condition where the sugar levels in blood are high. It is also defined as chronic disorders [3] of carbohydrate metabolism due to the lack of insulin result in the hyperglycemia and glycosuria. Anyone can be affected by this disease at any age. The type 1 diabetes mellitus (T1DM) or type 2 diabetes mellitus (T2DM) is a multifactorial autoimmune disease [4], which susceptibility is determined by a combination of genetic and environmental factors. Diabetes mellitus is one of the most common chronic disorders of childhood [5].

The main cause of diabetes is due to the shortage of insulin or insulin resistance. Glucose is the ultimate source of energy for all metabolic processes. Insulin, a hormone secreted by the pancreas plays a vital role in regulating the movement of glucose and levels of glucose or blood sugar. In the late or advanced stages several complications arise such as related to eyes, kidneys, nerves and blood arteries. As diabetes is a metabolic disorder, people with diabetes are in a risk of other complications associated. The metabolism is affected there by causes various complications. Several changes that occur are due to high rise in blood sugar levels. And hence Diabetes is associated with long-term complications that affect almost every part of the body and often leads to blindness, heart and blood vessel disease, stroke, kidney failure, amputations, and nerve damage. Diabetes is associated with significantly accelerated rates of several debilitating microvascular complications such as nephropathy, retinopathy, and neuropathy, and macrovascular complications such as atherosclerosis and stroke.

## Major kinds of Diabetes

**Type1 diabetes:** Type 1 diabetes (T1D) is an autoimmune disease [6] characterized by the expansion of pathogenic T effector cells which cause the irreversible destruction of insulin producing β cells and thereby limits insulin production and glucose homeostasis [7]. A membrane bound protein expressed by the islet cells is shown to act as a major auto antigen in T1D [8]. Most cases of Type 1 diabetes are thought to have an autoimmune basis [9], with various environmental factors interacting with an underlying genetic predisposition, leading to selective autoimmune destruction of pancreatic beta cells. Diabetes mellitus induces changes in rheological properties [10] i.e. specific changes in mechanical properties eg. Increase in erythrocyte microviscosity, aggregation and adherisivness which cause the changes in lipid composition, dysfunctioning of membrane structure and composition.

And insulin-dependent diabetes is usually seen in children, teens or young adults. If not diagnosed and treated with insulin, a person with type 1 diabetes can lapse into a life-threatening diabetic coma, also known as diabetic ketoacidosis. Symptoms of type 1 diabetes usually develop over a short period, although beta cell destruction can begin years earlier. Symptoms may include increased thirst and urination, constant hunger, weight loss, blurred vision, and extreme fatigue. Management of T1D requires maintaining near-normalized blood glucose levels without the risk of significant hypoglycemia which delays the onset and progression of vascular and neurological complications [11].

**Type 2 diabetes:** Currently, over 200 million individuals worldwide [12] suffer from T2D and this number is projected to reach 438 million by 2030. It is usually non insulin-dependent diabetes. T2DM results from a combination of genetic susceptibility [13], environment, behavior (calorie intake and physical activity), and as yet unexplained

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risk factors. It tends to affect adults and overweight people. The symptoms of type 2 diabetes develop gradually. And onset of symptoms is not as sudden as in case of type1 diabetes. Symptoms may include fatigue, frequent urination, increased thirst and hunger, weight loss, blurred vision, and slow healing of wounds or sores. Symptoms may not appear in some people. The primary pathophysiological defects of type 2 diabetes [14] include: excessive hepatic glucose production, impaired peripheral glucose uptake by insulin-sensitive tissues, and insufficient insulin secretion/ increased β-cell apoptosis.

Type 2 Diabetes can be clinically diagnosed with Fasting glucose; glucose tolerance, fasting plasma glucose (FPG) and also HbA1c can also provide additional prognostic information regarding mortality risk [15]. The increasing prevalence of Type 2 diabetes is mainly due to reduced physical activity and consumption of unhealthy food and larger portion sizes in genetic susceptible individuals [16]. It is essential to note that the progressive nature of type 2 diabetes requires the combination of life style modification (diet and exercise) and antihyperglycemic agents in order to achieve adequate glycemic control [17].

**Gestational diabetes:** Gestational diabetes mellitus (GDM) [18] is defined as glucose intolerance of varying degrees, which appears, or is first diagnosed, during pregnancy and may or may not persist after delivery. It is associated with pregnancy and symptoms usually disappear after the birth. High level blood glucose levels are observed in pregnant women who never had diabetes earlier. Gestational diabetes is brought about by the many hormone changes. Women who have had gestational diabetes have a 40 to 60 percent chance of developing type2 diabetes within 5 to 10 years. Type1 diabetes can be managed by various Continuous subcutaneous insulin infusion therapies [19]. Women with the history of gestational diabetes mellitus (GDM) have a significantly increased risk of type 2 diabetes and of cardiovascular disease during the next years after delivery [20].

## Incidence of Diabetic Complications

There is an incidence of several complications with the long standing diabetes. Diabetes is associated with microvascular complications [21] such as nephropathy, retinopathy, and neuropathy, and macrovascular complications such as atherosclerosis and stroke. These complications occur in the late stages of diabetes and are chronic. Diabetic acidosis is a life-threatening condition caused by the lack of insulin is considered an acute complication. Late-stage complications do not usually develop for 10 to 15 years with Type 1 diabetes. Clinically evident diabetes-related microvascular complications [22] are rare in childhood and adolescence.

Increased levels of albumin [23], the principal form in which glycated albumin exists *in vivo*, associate independently with complications of diabetes and contribute to the pathogenesis of diabetic nephropathy and retinopathy by influencing cell signaling pathways and molecular mediators known to be associated with the development of these complications.

Other complications of diabetes may include: Skin Complications such as infections, sores, and itching; and diabetic osteopathy. It is now well established that humans with type 1 or type 2 diabetes have an increased risk of fracture [24]. Diabetes and osteoporosis are both frequent endocrine disorders [25]. It has been reported that type 2 diabetes is a risk factor for hip, proximal humerus, and foot fractures among older women [26]. It has been recognized that the alterations in mineral and bone metabolism were associated with DM and that the resulting bone loss [27] is one of the chronic complications of diabetic patients. Poorly controlled diabetes [28] is indeed bad to the bone. There is an incidence of new onset diabetes mellitus after transplantation is a serious and common complication following solid organ transplantations [29]. Diabetes can lead to problems with teeth and gums, called gingivitis and periodontitis. Hyperglycemia appears to be the major variable shared among these different clinical forms [30].

### Alterations in Glucose levels

Changes in the normal glucose levels [31] in blood will lead to abnormal physiological states causing either hypoglycemia (low glucose levels) or hyperglycemia (high glucose levels). Low blood glucose or hypoglycemia [32] is the most common immediate health problem for patients with diabetes. It occurs when the body gets too much insulin, too little food, a delayed meal, or more than the usual amount of exercise. Chronic hypoglycemia can be life-threatening if not treated promptly. Insulinoma [33] is an islet beta cell-derived tumor manifesting various clinical symptoms due to hypoglycemia. Hypoglycemia continues to be the major limiting factor [34] in the management of individuals with type 1 diabetes.

Hyperglycemia [35] plays an important role in the development of neuropathic process by causing structural and functional changes on the ion channels which affects metabolic transport. In many cases chronic hyperglycaemia is responsible for most of the long-term complications of diabetes. Hyperglycemia causes excessive amounts of irreversible advanced glycosylation end products to accumulate on long-lived extra cellular proteins and perhaps also on DNA in tissues that develop complications. Prolonged exposure to hyperglycemia is the primary factor associated with most of the diabetic complications [36]. Hyperglycemia-derived oxygen free radicals are also considered mediators of diabetic complications [37]. Hyperglycemia changes platelet function [38] by impairing calcium homeostasis and thereby alters aspects of platelet activation and aggregation, including platelet conformation and release of mediators. Diabetes is much more complicated than hyperglycemia and is associated with several risk factors. T2D involves insulin resistance, obesity, dyslipidemia, environmental factors, nutrition, lifestyle, and genetics, in addition to hyperglycemia. Each of these risk factors could in itself induce epigenetic changes to the chromatin structure, ultimately altering gene expression patterns in conjunction with elevated glucose in various target tissues including kidney, heart, liver, retina, nervous system, muscle, blood vessels, and blood cells. Hyperglycaemia can also occur in alcohol consumed children as a result of the increased cortisol levels due to stimulation of the adrenocorticotropic hormone [39]. Some studies have shown that heavy drinking [40] can increase blood glucose level or risk of type2 diabetes.

Oxidative stress and oxidative damage [41] to tissues are common end points of chronic diseases, such as atherosclerosis, diabetes, and rheumatoid arthritis. Increased oxidative stress [42] induced by hyperglycemia may contribute to the pathogenesis of diabetic complications. Genes also play a role in many processes underlying late diabetic complications [43]. Advanced glycation [44] end products were determined immunologically in blood from diabetics, patients with renal failure and subjects with various other diseases. Patients with end-stage renal disease on dialysis displayed high advanced glycation end products levels in serum. The complications are of two different kinds such as Microvascular complications and Macrovascular complications. Diabetic retinopathy, nephropathy and neuropathy occur in all clinical forms of diabetes mellitus, regardless of the cause of the diabetes.

## Diabetic Retinopathy

Retinopathy is characterized by increased vascular permeability [45], by vascular closure mediated by the formation of new blood vessels - neovascularization, on the retina and posterior surface of the vitreous. Diabetic retinopathy is a micro vascular disease, characterized by damage to the blood vessels and retina of the eyes. This condition occurs in both type 1 and type 2 diabetics. It can be classified as nonproliferative diabetic retinopathy and proliferative diabetic retinopathy or diabetic macular edema. In diabetic retinopathy, the micro vessel supplying blood to the retina of eye is affected and can cause blindness. Retinopathy is related to high blood sugar level and obstructs the flow of oxygen to the cells of the retina. For the vision of eye, retina receives signals of light and sent them to the brain forming a three dimensional figure which is identified. Finally it is sent back to the eye by which one can recognize the things around. This working mechanism of passing light through the retina is hindered by the high glucose levels. The initial stage of this disease is known as Non- proliferate Diabetic retinopathy where as Proliferative diabetic retinopathy is the advanced form of diabetic retinopathy [46] in which new as well as weak blood vessels break and leak blood into vitreous of the eye causing floating spots in the eye. Gradually, the swollen and scar nerve tissue of the retina is totally destroyed and leads to retinal detachment. The ground cause for blindness among diabetes is due to the retinal detachment.

Macular edema is often a complication of diabetic retinopathy which causes vision loss in people with diabetes. It develops when blood vessels in the retina are leaking fluids. The macula does not function properly when it is swollen and vision loss may be mild to severe, but peripheral vision remains. Cataracts [47] were reported as a main cause of blindness and diabetic retinopathy. Longer duration of diabetes uncontrolled diabetes and maculopathy (advanced diabetic retinopathy) were also significantly associated with the presence of cataracts [48] among these type 2 diabetics.

## Diabetic Nephropathy

Diabetic Nephropathy [49] is a common and serious complication where kidneys [50] are damaged and fails to function. The reason is due to persistent high blood sugar level in the blood. In the early phase of nephropathy drugs and diet can control the condition. The condition when protein starts leaking in urine is called as microalbuminuria [51]. The common symptoms of kidney failure are fatigue, decreased appetite, nausea and vomiting. Anaemia [52] may also be observed in diabetic nephropathy. It has been observed that about 30 to 40 % of Type I diabetics and 20 to 30% of Type 2 diabetics develop moderate to severe kidney failure. Diabetes myonecrosis may develop before or at the time of diagnosis of diabetes; generally it is a type of gangrene caused by *Clostridium bacteria*. The toxins produced by the bacterium leads to tissue diabetic mastopathy usually seen in pre-menopausal women suffering from Type 1 diabetes for many years with insulin therapy. Although very rare, it can be seen in men with diabetes as diabetic mastopathy, which is associated with micro-vascular complications such as damage to the eyes, kidneys and heart or other disorders such as thyroid problem.

## Diabetic Neuropathy

Diabetes mellitus, a common metabolic disease with a rising global prevalence, is associated with long-term complications of peripheral nervous system and the central nervous system [53]. Diabetic neuropathy is a chronic microvascular complication [54] affecting both somatic and autonomic peripheral nerves. It may be defined as the presence of symptoms or signs of peripheral nerve dysfunction in people with diabetes, after the exclusion of other causes of neuropathy. Neuropathy is the common complication of diabetes and is due to high blood sugar, chemical changes that occur in the nerves. Generally it starts in the nerves of feet as they are the longest nerves and nourished with longest blood vessels of the body. This condition is called diabetic foot or diabetic peripheral neuropathy or distal symmetric neuropathy. Diabetes can reduce the blood supply to the foot and gradually damages the nerves which carry sensation. Diabetic neuropathy can cause foot ulcers and foot infections as advanced complications in diabetic patients. Signs and symptoms of Diabetic Neuropathy include, decrease or no sweating, numbness, or tingling, and some sort of burning sensation, weakness and loss of reflexes.

Diabetic Polyneuropathy is a major complication of diabetes mellitus that frequently leads to foot ulceration [55]. There is a strong association between the neuropathy and the subsequent development of foot ulcers. Other influential factors are also responsible to cause foot ulcers along with neuropathy. Amputations are common with diabetic patients [56] in case of diabetic foot. In some diabetic complications, autonomic neuropathy [57] may decrease incretin effect.

Atherosclerosis is common in smokers and those with high blood pressure and abnormal fat levels in the blood. It is commonly fatty deposits in arteries or hardening of arteries. It accounts for virtually 80% of all deaths among diabetic patients. It is reported that endothelial injury may be the initial event in the genesis of atherosclerosis, followed by platelet adhesion and aggregation at the site of injury. Prolonged exposure to hyperglycemia is now recognized a major factor in the pathogenesis of atherosclerosis in diabetes. Hyperglycemia induces a large number of alterations [58] at the cellular level of vascular tissue that potentially accelerate the atherosclerotic process. Diabetes mellitus patients carry an increased risk two to four times greater for heart attack [59], stroke [60] and other complications related to poor circulation. Clinical and epidemiologic data have uniformly shown that diabetic patients have more severe atherosclerosis and a higher risk of ischemic heart disease and other arterial disease [61]. Low plasma HDL cholesterol (HDL-C) is consistently associated with increased risk of atherosclerotic disease [62].

## Role of Insulin

Insulin is a natural hormone produced by betacells of Islets of Langerhans in pancreas. It regulates the movement of glucose and levels of glucose or blood sugar. Insulin allows cells to utilize glucose for energy. It plays a vital role in carbohydrate metabolism. When blood sugar rises, insulin acts to cause certain cells of the body to take in glucose, primarily liver and fat cells. High insulin levels (hyperinsulinemia) result in the body for efficient storage of fat, retrieving it for energy. Hyperinsulinemia [63] is a major feature of type 2 diabetes and the metabolic syndrome. Lowering blood glucose lowers blood insulin levels and increases the body's ability to utilize stored fat for energy. When insulin [64] was discovered, it was felt that diabetes was curable. Insulin is a master regulator of metabolic homeostasis [65] and it is secreted from pancreatic beta cells in response to nutrient stimulation. Insulin is used for treatment of type 1 diabetes mellitus, which is characterized by lack of the internally produced hormone [66].

In case of injected insulin regimens have some notable disadvantages as subcutaneously injected insulin [67] does not mimic the natural state

and patients require multiple injects per day. The hepatocyte nuclear factor 4-α (*HNF4α*) gene is responsible for regulating gene transcription in pancreatic beta cells and also been implicated in the regulation of glucose transport and metabolism [68]. Glycosylated haemoglobin [69] (HbA1c) is maintained in diabetes mellitus at < 7%. Such levels of glucose control cannot generally be maintained with oral glucose lowering agents alone and often require use of insulin in addition to, or in place of, oral medications.

## Insulin Resistance Syndrome or a metabolic syndrome

Insulin resistance is well defined as the decreased ability of insulin to regulate glucose metabolism [70]. Insulin and its receptor play important role in the homeostasis of plasma glucose [71]. The physiological condition where the body cells becomes less effective thus leading to high blood glucose level. It is a metabolic syndrome with an increased risk of type 2 diabetes and atherosclerosis early heart disease. A cluster of medical conditions make up insulin resistance syndrome or metabolic syndrome. In insulin resistance, the body's cells have a diminished ability to respond to the action of the insulin hormone. Certain cell types such as fat and muscle cells require insulin to absorb glucose. When these cells fail to respond adequately to circulating insulin, blood glucose levels rise. The liver helps regulate glucose levels by reducing its secretion of glucose in the presence of insulin. This normal reduction in the liver's glucose production may not occur in people with insulin resistance. People with this syndrome have insulin resistance and high levels of insulin in the blood as a marker of the disease rather than a cause. To compensate for the insulin resistance, the pancreas secretes more insulin. Insulin is the body's fat storage hormone and governs appetite, satiety and blood sugar levels. When a person consumes food, the pancreas releases insulin and the insulin then pushes glucose from the consumed food into the cells. Any excess glucose is stored in the fat cells. When a person suffers from insulin resistance glucose cannot enter cells. After many attempts insulin finally succeeds in getting some glucose into some cells and the excess is stored in fat cells. Glucose transport in to adipocytes and skeletal muscles is a major mechanism by which the body disposes excess glucose from the blood stream after a meal [72]. Adiponectin [73] could be an important adipocytokine protective against the development of T2DM and cardiovascular disease. Obesity, physical inactivity, and smoking are implicated in the development of insulin resistance [74].

It has been proposed that insulin resistance can lead to other metabolic risk factors including hypertension, hypertriglyceridemia, hyperglycemia and dyslipidemia. Several diseases are caused by insulin resistance which includes the following:

### Signs of Insulin resistance syndrome

- **Type2 diabetes:** Type 2 diabetes mellitus (T2DM) is characterized by defects in insulin sensitivity and insulin secretion [75]. Also known as impaired fasting blood sugar or impaired glucose tolerance. T2DM is the most common presentation of the disease accounting for almost 90% of all diabetes cases worldwide [76]. This occurs because the pancreas is unable to turn out enough insulin to overcome the insulin resistance. Type 2 diabetes mellitus (T2DM) is a progressive disease characterized by gradual decline in beta-cell function and insulin resistance [77]. Type 2 diabetes is associated with a two-to-three fold higher incidence of macrovascular atherosclerotic disease compared to non diabetic individuals [78].
- **High blood pressure:** The mechanism of High blood pressure is unclear, but studies suggest that the worse the blood pressure, the worse the insulin resistance.
- **Abnormal cholesterol levels:** A westernized diet has led to an increased cholesterol intake in many countries [79]. The typical cholesterol levels of a person with insulin resistance are low HDL, or good cholesterol and high levels of another blood fat called triglycerides.
- **Heart disease:** The insulin resistance syndrome can result in atherosclerosis and an increased risk of blood clots. Cardiovascular disease [80] is the leading cause of morbidity and mortality in patients with diabetes mellitus [81]. Individuals with type 2 diabetes are at higher risk of cardiovascular diseases [82] (CVD) than those without type 2 diabetes.
- **Obesity:** The prevalence of obesity [83] has markedly increased in most countries of the world. A positive association between obesity and the risk of developing type 2 diabetes [84] has been consistently observed in many populations. Obesity is associated with an increase risk for Cardiometabolic diseases [85] such as atherosclerosis and type2 diabetes. A major factor in the development of insulin resistance syndrome is obesity particularly abdominal obesity or belly fat. Obesity promotes insulin resistance and negatively impacts insulin responsiveness in a person. The body's ability to recognize and use insulin appropriately is achieved by weight loss. Obesity, in particular an increase in visceral adipose tissue mass [86], exacerbates insulin resistance through a variety of mechanisms, including secretion of adipokines that impair insulin sensitivity in other target tissues, such as skeletal muscle, liver, and pancreas pigment epithelium-derived factor (PEDF) [87] as an adipocyte secretory factor, was demonstrated to reduce insulin sensitivity and is a candidate for the possible causes of insulin resistance in obesity. Management of diabetes in extremely obese patient is challenging [88]. The link between obesity and diverse metabolic diseases is known for a long time. One important complication of obesity [89] is the higher risk of developing diabetes and atherosclerosis.
- **Kidney damage:** Insulin resistance results in the damage to kidney. Protein in the urine is a sign that kidney damage has occurred.
- **Polycystic ovarian syndrome:** It is a very common disorder of the female endocrine system. Polycystic ovary syndrome is a condition in which there is an imbalance of a woman's female sex hormones.

### Metabolic syndrome

Metabolic syndrome is predicted to become a major public health problem in many developed, as well as developing countries. It has been referred to as Syndrome X [90] or the Insulin Resistance Syndrome and is currently referred to as the Metabolic Syndrome. Metabolic syndrome (Mets), a complex of disorders including the abdominal obesity, dyslipidemia, hypertension and impaired fasting glucose, is one of the known risk factors for cardiovascular disease (CVD). Metabolic syndrome is a number of maladies [91] involving systemic dysregulation, as-well-as tissue, cell and/or molecular pathway dysfunction/ resistance.

Two definitions of metabolic syndrome [92] are used most frequently today – the first according to the IDF – International Diabetes Federation (IDF) and the second according to The National Cholesterol Education Program (NCEP) – Adult Treatment Panel III – ATP III. Several genetic and lifestyle factors [93], such as lack of physical activity

and calorie-rich diets, have been linked to the development of MetS and an increased risk of T2DM and CVD. Dietary composition [94] has been associated with CVD risk and the metabolic syndrome.

In addition, people with metabolic syndrome have a fivefold greater risk of developing type2 diabetes. Obesity and insulin resistance are considered to be the significant factors to cause metabolic syndrome [95]. Metabolic syndrome (MetS) is considered to be a risk factor of diabetes and cardiovascular disease (CVD) [96]. Metabolic syndrome has critical impact not only on the cardiovascular system, but also has adverse effects on the morphology and physiology of the liver [97]. Insulin resistance and hyperinsulinemia also have been implicated in the pathogenesis of the metabolic syndrome. Sequelae of the MetS [98] include stroke, heart disease, fatty liver disease, overt diabetes and types of cancer.

There is a significant overlap between metabolic syndrome and conditions such as polycystic ovarian syndrome, non-alcoholic fatty liver disease, hypogonadism, lipodystrophy, and microvascular disease. Several studies showed a link between severity of osteoarthritis and atherosclerosis in metabolic syndrome [99]. Atherosclerosis [100] and associated cardiovascular disease (acute myocardial infarction and stroke) are the leading causes of death in developed countries. MetS has been shown to be associated with several geriatric problems. Studies showed that prevalence of MetS increases with aging [101]. The treatment of metabolic syndrome is complex and includes both lifestyle changes (physical activity and nutrition) and drug therapy [102].

## Conclusion

In the present review it has been discussed about the various complications occurred due to high rise in blood levels in the diabetic people. The long standing diabetes leads to complications of eyes, kidneys, and in nerves. The functioning of several organs is affected leading to Microvascular and Macrovascular complications. Prolonged exposure to hyperglycemia is the primary factor associated with most of the diabetic complications. Insulin, a natural hormone has its contribution to diabetic people. But the insulin resistance results in various diseases and also metabolic syndrome. Obesity and insulin resistance are considered to be the significant factors to cause metabolic syndrome. Metabolic syndrome (MetS) is considered to be a risk factor of diabetes and cardiovascular disease (CVD) and is predicted to become a major public health problem in many developed, as well as developing countries.

### References

1. David SK, Upadhayaya N, Siddiqui MK, Usmani AM (2010) Knowledge Discovery Technique for Web-Based Diabetes Educational System. J Health Med Informat 1: 102.
2. Zimmet P, Alberti KG, Shaw J (2001) Global and societal implications of the diabetes epidemic. Nature 414: 782-787.
3. Ramanathan K, Karthick H, Arun N (2010) Structure Based Drug Designing for Diabetes Mellitus. J Proteomics Bioinform 3: 310-313.
4. Ribeiro C, de Alencar Mota CS, Voltarelli FA, de Araújo MB, Botezelli JD, et al. (2010) Effects of Moderate Intensity Physical Training in Neonatal Alloxan-Administered Rats. J Diabetes Metab 1: 107.
5. Baş VN, Bideci A, Yeşilkaya E, Soysal AŞ, Çamurdan O, et al. (2011) Evaluation of Factors Affecting Quality of Life in Children with Type 1Diabetes Mellitus. J Diabetes Metab 2: 154.
6. Wilkinson A, Bian L, Khalil D, Gibbons K, Wong PF, et al. (2011) Type 1 Diabetic Children and Siblings Share a Decrease in Dendritic Cell and Monocyte Numbers but are Differentiated by Expansion of CD4+T Cells Expressing IL-17. J Clin Cell Immunol S2: 1.
7. Zhao Y (2011) Autoimmunity and Therapeutic Challenges of Type 1 Diabetes. Translational Medic 1: 104e.
8. Messripour M (2011) A novel Enzyme Inhibition Assay for Screening of Type 1 Diabetes Mellitus. J Mol Biomark Diagn 2: 107.
9. Joffe B, Distiller L, Landau S, Blacking L, Klisiewicz A (2010) Spectrum of Autoimmune Disorders in Type 1 Diabetes – A Cross-Sectional Clinical Audit. J Diabetes Metab 1: 112.
10. Kumar R, Kumar AN, Ahmed S (2011) Changes in Erythrocyte Membrane in Type-2 Diabetes Mellitus with and without Dyslipidemia. J Diabetes Metab 2: 141.
11. Saini A, Devidayal, Verma S, Bhalla AK (2011) Comparative Efficacy of Once Daily Insulin Glargine with Twice Daily NPH Insulin in Children with Type 1 Diabetes. J Diabetes Metab 2: 124.
12. Yang J, Zhao J (2011) Cumulative Effect of Common Genetic Variants Predicts Incident Type 2 Diabetes: A Study of 21,183 Subjects from Three Large Prospective Cohorts. Epidemiol 1: 108.
13. Hansen BC, Shamekh R, Hansson O, Almgren P, Budagov T, et al. (2011) The Rhesus Monkey: A Nonhuman Primate Model For T2DMAssociated Gene Screening. J Diabetes Metab 2: 150.
14. Fouqueray P, Leverve X, Fontaine E, Baquié M, Wollheim C, et al. (2011) Imeglimin - A New Oral Anti-Diabetic that Targets the Three Key Defects of type 2 Diabetes. J Diabetes Metab 2: 126.
15. Reddigan JI, Ardern CI, Riddell MC, Kuk JL (2010) Differences in the Association between Clinically Relevant Classifications of Glycemia Measures and All-Cause and Cardiovascular Disease Mortality Risk. J Diabetes Metab 1: 106.
16. Samadi N, Safavi M, Mahmoodi M (2011) Impact of Quality of Life Education on Self-Concept among Type 2 Diabetes Patients. J Diabetes Metab 2: 132.
17. Shehata MF, Pater A (2011) Incretin-Based Therapies: What Do We Need To Know? J Diabetes Metab 2: 146.
18. Lemos Costa TMR, Detsch JM, Pimazoni-Netto A, de Almeida ACR, Sztal-Mazer S, et al. (2011) Glycemic Variability and Mean Weekly Glucose in the Evaluation and Treatment of Blood Glucose in Gestational Diabetes Mellitus; Evidence for Lower Neonatal Complications. J Diabetes Metab 2: 137.
19. Higuchi C, Tone A, Iseda I, Tsukamoto K, Katayama A, et al. (2010) A Pregnant Patient with Brittle Type 1 Diabetes Successfully Managed by CSII Therapy with Insulin Aspart. J Diabetes Metab 1: 104.
20. Alina S, Barbara R, Krzysztof G, Barbara G, Marek G, et al. (2011) Elevation of sE-Selectin Levels from 2-24 Months Following Gestational Diabetes is Associated with Early Cardiometabolic Risk in Non-Diabetic Women. J Diabetes Metab 2: 138.
21. Brownlee M (2001) Biochemistry and molecular cell biology of diabetic complications. Nature 414: 813-820.
22. El Asrar MA, Adly AAM, El Hadidi E, Gharib M (2011) Serum and Urinary Nitrites and Nitrates and Doppler Sonography in Detection of Early Diabetic Complications. J Diabetes Metab 2: 117.
23. Cohen MP, Hud E, Shea E (2010) Rate of Formation of Glycated Albumin Revisited and Clinical Implications. J Diabetes Metab 1: 102.
24. Fowlkes JL, Bunn RC, Thrailkill KM (2011) Contributions of the Insulin/Insulin-Like Growth Factor-1 Axis to Diabetic Osteopathy. J Diabetes Metab S1: 3.
25. Vestergaard P (2011) Diabetes and Bone. J Diabetes Metab S: 1.
26. Ikeda T, Iwata K (2011) Long-Term Effect of Alendronate on Bone Mineral Density in Postmenopausal Type 2 Diabetes Mellitus. J Diabetes Metab S1: 2.
27. Abo-El-Asrar M, Farid SM, Maraghy MOE, Mohamedeen AK (2011) Serum Osteocalcin, Zinc Nutritive Status and Bone Turnover in Children and Adolescents with Type1 Diabetes Mellitus. J Diabetes Metab 2: 128.
28. Chan L, Terashima T, Urabe H, Lin F, Kojima H (2011) Pathogenesis of diabetic neuropathy: bad to the bone. Ann N Y Acad Sci 1240: 70-76.
29. Pham PT, Pham PC (2011) Predictive Diagnostic Tools for the Development of New Onset Diabetes Mellitus after Transplantation: An Overview. J Transplant Technol Res 1: 103e.
30. Nathan DM (1996) The pathophysiology of diabetic complications: how much does the glucose hypothesis explain? Ann Intern Med 124: 86-89.

31. Uppu RM, Parinandi NL (2011) Insulin Sensitization and Resistance Interrelationship Revisited with a Quantitative Molecular Model Approach. J Diabetes Metab 2: 106e.

32. Furushima K, Tone A, Katayama A, Iseda I, Higuchi C, et al. (2010) A Case of Proinsulin-Secreting Malignant Insulinoma in an Elderly Patient with Cerebral Infarction. J Diabetes Metab 1: 103.

33. Ali ZH (2011) Health and Knowledge Progress among Diabetic Patients after Implementation of a Nursing Care Program Based on Their Profile. J Diabetes Metab 2: 121.

34. Jacobson JD, Midyett LK, Garg U, Sherman AK, Patel C (2011) Biochemical Evidence for Reduced Carnitine Palmitoyl Transferase 1 (CPT-1) Activity in Type 1 Diabetes Mellitus. J Diabetes Metab 2:144.

35. Erdoğan Ç (2011) Comparement of Nerve Excitability Among Diabetics with or without Polyneuropathy with Same Hba1c Levels and Diabetes Duration. J Diabetes Metab S5: 1.

36. Brownlee M (1991) Glycosylation products as toxic mediators of diabetic complications. Annu Rev Med 42: 159-166.

37. Ceriello A (2003) New insights on oxidative stress and diabetic complications may lead to a “causal” antioxidant therapy. Diabetes Care 26: 1589-1596.

38. Emara E, Abdel-Sater KA (2011) Beneficial Effects of Calcium Channel Blocker “Nifedipine” on Abnormalities of Platelets and Lipid Metabolism in Patients with Type II Diabetes Mellitus. J Diabetes Metab 2: 131.

39. Tõnisson M, Tillmann V, Kuudeberg A, Väli M (2011) Effect of CBT on Depressive Symptoms in Methadone Maintenance Patients Undergoing Treatment for Hepatitis C. J Addict Res Ther 2: 111.

40. Li H, Wang G, Wang A, Tong W, Zhang Y (2011) Alcohol Consumption and Risk of Type 2 Diabetes in Mongolian Population, Inner Mongolia, China. J Diabetes Metab 2: 116.

41. Baynes JW, Thorpe SR (1999) Role of oxidative stress in diabetic complications: a new perspective on an old paradigm. Diabetes 48: 1-9.

42. Suzuki S, Hinokio Y, Komatu K, Ohtomo M, Onoda M, et al. (1999) Oxidative damage to mitochondrial DNA and its relationship to diabetic complications. Diabetes Res Clin Pract 45: 161-168.

43. Rogus JJ, Warram JH, Krolewski AS (2002) Genetic studies of late diabetic complications: the overlooked importance of diabetes duration before complication onset. Diabetes 51: 1655-1662.

44. Dolhofer-Bliesener R, Lechner B, Gerbitz KD (1996) Possible significance of advanced glycation end products in serum in end-stage renal disease and in late complications of diabetes. Eur J Clin Chem Clin Biochem 34: 355-361.

45. da Silva SB, Costa JP, Pintado ME, Ferreira DC, Sarmento B (2010) Antioxidants in the Prevention and Treatment of Diabetic Retinopathy – A Review. J Diabetes Metab 1: 111.

46. http://diabetesinformationhub.com/DiabetesComplications_DiabeticRetinopathy.php

47. Rodriguez J, Sanchez R, Munoz B, West SK, Broman A, et al. (2002) Causes of blindness and visual impairment in a population-based sample of U.S. Hispanics. Ophthalmology 109: 737-743.

48. Muaka MM, Longo-Mbenza B, Mbadi A Nsungu NJ (2011) Relationship between Cataract and Metabolic Syndrome among African Type 2 Diabetics. J Diabetes Metab 2: 160.

49. Chowdhury TA, Dyer PH, Kumar S, Barnett AH, Bain SC (1999) Genetic determinants of diabetic nephropathy. Clin Sci (Lond) 96: 221-230.

50. Rossing P (2000) Risk factors in the progression of diabetic nephropathies. Ugeskr Laeger. 162: 5057-5061.

51. Lehmann R, Spinas GA (1995) Diabetic nephropathy: significance of microalbuminuria and proteinuria in Type I and Type II diabetes mellitus. Praxis (Bern 1994) 84: 1265-1271.

52. Thomas M, Tsalamandris C, MacIsaac R, Jerums G (2005) Anaemia in diabetes: an emerging complication of microvascular disease. Curr Diabetes Rev 1: 107-126.

53. Chen D, Huang H, Xing Y, Liu Y, Xu Y, et al. (2011) A New Vanadium Complex Improves the Spatial Learning and Memory by Activation of Caveolin–MAPK–CREB Pathway in Diabetic Mice. J Diabetes Metab 2: 114.

54. Heltianu C, Guja C (2011) Role of Nitric Oxide Synthase Family in Diabetic Neuropathy. J Diabetes Metab S5: 2.

55. Boulton AJ (1994) End-stage complications of diabetic neuropathy: foot ulceration. Can J Neurol Sci. 21: S18-22.

56. Viswanathan V, Kumpatla S (2011) Pattern and causes of amputation in diabetic patients--a multicentric study from India. J Assoc Physicians India 59: 148-151.

57. Kamoi K, Ohara N, Tomoo I, Shinozaki Y, Furukawa K (2011) Normal Response of Active GLP-1 like Substances Level to Test Meal in Non-Obese Type 2 Diabetic Japanese Patients with Complications and Receiving Treatments. J Diabetes Metab 2: 147.

58. Aronson D, Rayfield EJ (2002) How hyperglycemia promotes atherosclerosis: molecular mechanisms. Cardiovasc Diabetol 1: 1.

59. Abougalambou SSI, Hassali MA, Sulaiman SAS, Abougalambou AS (2011) Prevalence of Vascular Complications among Type 2 Diabetes Mellitus Outpatients at Teaching Hospital in Malaysia. J Diabetes Metab 2: 115.

60. http://diabetesinformationhub.com/DiabetesComplications_DiabeticNeuropathy.php

61. Nikkila EA (1985) Are plasma lipoproteins responsible for the excess atherosclerosis in diabetes? Acta Endocrinol Suppl (Copenh). 272: 27-30.

62. Calle MC, Vega-López S, Segura-Pérez S, Volek JS, Pérez-Escamilla R, et al. (2010) Low Plasma Hdl Cholesterol and Elevated C Reactive Protein further Increase Cardiovascular Disease Risk in Latinos with Type 2 Diabetes. J Diabetes Metab 1: 109.

63. Chang Y (2011) A Central Role of PTP1B in Hyperinsulinemia-Enhanced IL-6 Signaling in Dedifferentiated Vascular Smooth Muscle Cells. J Diabet Metabol 2: 118.

64. Ramachandra S (2011) Do we need yet another Insulin? J Diabet Metabol 2: e4.

65. Veronica G, Esther RRM (2011) Metabolic Syndrome: Early Development and Aging. J Diabetes Metab S2: 2.

66. Pechenkin MA, Balabushevich NG, Zorov IN, Staroseltseva LK, Mikhalchik EV, et al. (2011) Design, In Vitro and In Vivo Characterization of Chitosan-Dextran Sulfate Microparticles for Oral Delivery of Insulin. J Bioequiv Availab 3: 244-250.

67. Cook CS, Valaitis PW, Brugger A, Heise T, Gass J, et al. (2011) Differences in Relative Bioavailability (BA) of Inhalation Insulin Determined using Insulin and Glucose Levels Following Subcutaneous and Inhalation Administration in Humans. J Bioequiv Availab 3: 198-201.

68. Hellwege JN, Hicks PJ, Palmer ND, Ng MCY, Freedman BI, et al. (2011) Examination of Rare Variants in HNF4α in European Americans with Type 2 Diabetes. J Diabetes Metab 2: 145.

69. Mansour AA, Wanoose HL, Odaa AH (2011) A Three Year Cohort Prospective Type 2 Diabetes Control Study in Basrah. J Diabetes Metab 2: 119.

70. Ragheb R, Medhat AM (2011) Mechanisms of Fatty Acid-Induced Insulin Resistance in Muscle and Liver. J Diabetes Metab 2: 127.

71. Ramulu P, Giridharan NV, Udayasekhararao P, Janardanasarma MK (2011) Insulin Sensitization and Resistance Interrelationship in a Prediabetic Rat: A Quantitative Molecular Model. J Diabetes Metab 2: 140.

72. Poulose N, Vishnu Prasad CN, Nidhina Haridas PA, Anilkumar G (2011) Ellagic Acid Stimulates Glucose Transport in Adipocytes and Muscles through AMPK Mediated Pathway. J Diabetes Metab 2: 149.

73. Toy WC, Liu JJ, Cheng AKS, Tan CSH, Lau DP, et al. (2011) Adiponectin Gene Polymorphisms and Type 2 Diabetes among Singaporean Chinese Adults. J Diabetes Metab 2: 152.

74. Belmokhtar F, Belmokhtar R, Charef M (2011) Risk Factors Associated With Type 2 Diabetes Mellitus in West Region of Algeria, Maghnia. J Diabetes Metab 2: 148.

75. Florez H, Scranton R, Farwell WR, DeFronzo RA, Ezrokhi M, et al. (2011) Randomized Clinical Trial Assessing the Efficacy and Safety of Bromocriptine-QR when Added to Ongoing Thiazolidinedione Therapy in Patients with Type 2 Diabetes Mellitus. J Diabetes Metab 2: 142.

76. Mungrue K, Roper LA, Chung T (2011) Assessment of Weight Loss in the

Management of Patients with Type 2 Diabetes Mellitus in Primary Care in Trinidad. J Diabetes Metab 2: 120.

77. Esteghamati A, Nakhjavani M, Aminorroaya A, Aboutorabi R, Niafar M, et al. (2011) Biphasic Insulin Aspart 30 (BIAsp 30) is Safe and Improves Glycaemic Control in Insulin Naïve Patients with Type 2 Diabetes. J Diabetes Metab 2: 123.

78. Serre KR, Simmonds MJ, Sabapathy S, Minahan CL, Gass GC (2011) Rapid Communication – Effect of Exercise Training on Asymmetric Dimethylarginine Concentration in Women Aged 65-74 years with Type 2 Diabetes. Endocrinol Metabol Syndrome S5: 1.

79. Nakagami T, Yamamoto Y, Fukushima S, Oya J, Iwamoto Y, et al. (2011) Assessment of Cholesterol Absorption and Synthesis in Japanese Patients with Type-2 Diabetes and Lipid-Lowering Effect of Ezetimibe. J Diabetes Metab 2: 139.

80. Taloyan M, Saleh-Stattin N, Johansson SE, Agréus L, Wändell P (2010) Differences in Cardiovascular Risk Factors in Swedes and Assyrians/Syrians with Type 2 Diabetes: Association with Lifestyle-Related Factors. J Diabetes Metab 1: 110.

81. Li YW, Aronow WS (2011) Diabetes Mellitus and Cardiovascular Disease. J Clinic Experiment Cardiol 2: 114.

82. Anwar AM, Mostafa MM, Nosir YFM (2010) Left Ventricular Remodeling in Diabetic Patients with and without Hypertension. J Diabetes Metab 1: 108.

83. Hegazi MA, Al Kadi HA, Alissa EM, Kirmani A (2011) Prevalence of hyperlipidemia and associated risk factors among healthy young Saudi females: relationship with waist Circumference and body Mass Index. Endocrinol Metabol Syndrome S2: 1.

84. Shanker JH, Mahmood SE, Joshi MC, Shaifali I (2011) Obesity Indices amongst Diabetics in an Urban Population of Western Nepal. J Diabetes Metab 2: 134.

85. Lavoie M, Rabasa-Lhoret R, Ziai S, Lavoie J (2011) Blood Glutathione Peroxidase Activity in Relation with the Risk of Cardiovascular Diseases in Obese Women. J Diabetes Metab 2: 136.

86. Hinton PS, Thyfault JP, Thomas TR, Smith BK, Donnelly JE, et al. (2011) Weight loss-induced increases in osteocalcin are associated with improvements in glucose homeostasis. Endocrinol Metabol Syndrome S1: 2.

87. Ito D, Inukai K, Sumita T, Ono H, Katayama S, et al. (2011) Regulation of Pigment Epithelium-Derived Factor (PEDF), an Insulin Resistance-Inducing Adipocytokine, in 3T3-L1 Adipocytes. J Diabetes Metab 2: 151.

88. Nichol A, Chandra Sekar M (2011) Successful Management of Extremely Insulin-Resistant Obese Diabetic Patient with Insulin Glargine, U-500 Regular Insulin and Pramlintide. J Diabetes Metab 2: 143.

89. Heymann MC, Hofmann SR (2011) Novel Inflammasomes and Type II Diabetes, Intestinal Inflammation and Psoriasis as Newly Inflammasome-Related Diseases. J Genet Syndr Gene Ther S3: 1.

90. Horita S, Seki G, Yamada H, Suzuki M, Nakamura M, et al. (2011) Metabolic syndrome and insulin signaling in kidney. Endocrinol Metabol Syndrome S1: 5.

91. Dodson MV, Hausman GJ (2011) Metabolic syndromes: Resolving a malady that involves numerous tissues, cells, regulators and regulatory pathways. J Metabol Syndro 1: e101.

92. Kubešová HM, Matějovský J, Bychler I, Čejglová Z, Dvorský F, et al. (2011) Metabolic Syndrome in Older Patients. Endocrinol Metabol Syndrome S1: 6.

93. Brenner DR, Arora P, Garcia-Bailo B, Morrison H, El-Sohemy A, et al. (2011) The Relationship between Metabolic Syndrome and Markers of Cardiometabolic Disease among Canadian Adults. J Diabetes Metab S2: 3.

94. Huffman FG, Vaccaro JA, Nusrath NS, Zarini GG (2011) The Effect of Carbohydrate Amount, Quality and Type on Arterial Pulse Pressure in Cuban-Americans with and Without Type 2 Diabetes. J Nutr Food Sci 1: 106.

95. Tehrani FR, Tohidi M, Dovom MR, Azizi F (2011) A Population Based Study on the Association of Thyroid Status with Components of the Metabolic Syndrome. J Diabetes Metab 2: 156.

96. Kaneko M, Suzuki H, Watanabe H, Oda E, Aizawa Y (2011) Metabolic Syndrome is a Poor Predictor of Incident Diabetes Compared with Hemoglobin A1c (Hba1c) in a General Japanese Population. J Diabetes Metab S: 2.

97. Khalil AK, Omar SA, Abdou M, Greesh M, Sliem H (2011) Morphological and Physiological Pattern of the Liver in Patients with Metabolic Syndrome. J Diabetes Metab S2: 4.

98. Ong YC, Su LH, Zaini A (2011) Rapid effects of novel phytoandrogen adjuvant therapy (PAT) on metabolic health: a gender, age and BMI matched case-control study. Endocrinol Metabol Syndrome S1: 4.

99. Martocchia A, Toussan L, Stefanelli M, Falaschi GM, Comite F, et al. (2011) Association of Severity of Osteoarthritis and Carotid Atherosclerosis in Patients with Metabolic Syndrome. Rheumatology 1: 105.

100. Pello OM (2011) Microenviromental factors controlling macrophage polarization in atherosclerosis. Endocrinol Metabol Syndrome S10: 1.

101. Frootan M, Mahdavi R, Moradi T, Mobasseri M, Farrin N, et al. (2011) Prevalence of metabolic syndrome in an elderly population of Tabriz, Iran. Endocrinol Metabol Syndrome S1: 3.

102. Tint D, Anghel M, Lupu DS, Fischer LM, Niculescu MD (2011) Low dose Flaxseed Oil Supplementation Alters the Fatty Acids Profile and the Progression of Metabolic Syndrome in Men without Adequate Medical Treatment. J Nutrition Disorder Ther S7: 1.