"ESTIMATION OF SUBCUTANEOUS FAT THICKNESS USING VARIOUS ANTHROPOMETRIC MEASURES AND THEIR CORRELATION IN TYPE 2 DIABETES MELLITUS – A ONE YEAR CROSS SECTIONAL STUDY"

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This is to certify that the dissertation entitled **ESTIMATION OF SUBCUTANEOUS FAT THICKNESS USING VARIOUS ANTHROPOMETRIC MEASURES AND THEIR CORRELATION IN TYPE 2 DIABETES MELLITUS – A ONE YEAR CROSS SECTIONAL STUDY** is a bonafide research work done by **(REG NO. BG0114004).**

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LIST OF ABBREVIATIONS

A.D.	-	Anno Domini
AIR	-	Acute insulin response
ATP	-	Adenosine triphosphate
ATP	-	Adenosine Triphosphate
AUC	-	Area under curve
BIA	-	Bioelectrical impedance analysis
BMI	-	Body mass index
Cbl	-	E3 ubiquitin-protein ligase
cm	-	Centimeter
CT	-	Computer tomography
CVD	-	Cardiovascular disease
DCCT	-	Diabetes Control and Complications Trial
DM	-	Diabetes mellitus
DNA	-	Deoxyribo nucleic acid
e.g.,	-	For example
ESRD	-	End-stage renal disease
FBS	-	Fasting blood sugar
FPG	-	Fasting plasma glucose
g	-	grams
GDM	-	Gestational diabetes mellitus
GWAS	-	Genome-wide association scans
h	-	Hourly
HbA1c	-	Glycosylated haemoglobin
HDL	-	High density lipoprotein
HDL-C	-	High density lipoproteins cholesterol

HIV	-	Human immunodeficiency virus
HNF	-	Hepatocyte nuclear transcription factor
HOMA	-	Homeostatic model assessment
ICMR	-	Indian Council of Medical Research
ICO	-	Index of central obesity
IDDM	-	Insulin dependent diabetes mellitus
IGF	-	Impaired fasting glucose
IGT	-	Impaired glucose tolerance
IHHP	-	Isfahan healthy heart program
IL	-	Interleutin
IOTF	-	International Obesity Taskforce
IPF	-	Insulin promoter factor
IR	-	Insulin resistance
IRS	-	Insulin receptor substrates
K^+	-	Potassium
kg/m^2	-	Kilograms per square meter
LDL	-	Low density lipoprotein
MEIA	-	Microparticle enzyme immune assay
mg/dL	-	Milligrams per litre
min.	-	Minutes
mmol/L	-	Millimole per litre
MODY	-	Maturity onset diabetes of young
MRI	-	Magnetic resonance imaging
n	-	Total number
NC	-	Neck circumference

NCEP	-	National Cholesterol Education Program
NGT	-	Normal glucose tolerance
NHANES	-	National Health and Nutrition Examination Survey
NIDDM	-	Non-Insulin dependent diabetes mellitus
OGTT	-	Oral glucose tolerance test
OR	-	Odds ratio
p	-	Probability
PI-3-kinase	-	Phosphatidylinositol-3'-kinase
PPBS	-	Post prandial blood sugar
r	-	Pearson correlation coefficient
ROC	-	Receiver Operating Characteristic
SAD	-	Sagittal abdominal diameter
SAT	-	Subcutaneous adipose tissue
SC	-	Subcutaneous
SD	-	Standard deviation
TOPS	-	Take Off Pounds Sensibly
U.S.	-	United States
UPR	-	Unfolded protein response
VAT	-	Visceral adipose tissue
VLDL	-	Very low density lipoprotein
vs.	-	Versus
W/H	-	Waist to hip ratio
WC	-	Waist circumference
WHR	-	Waist-to-hip ratio
µU/L	-	Micro units per litre

ABSTRACT

Background and objectives

Overweight and obesity leads to a number of diseases including diabetes mellitus that contribute to increased morbidity and mortality. This study was aimed to estimate subcutaneous fat thickness using various anthropometric measures like body mass index, waist hip ratio, Neck circumference, inter-scapular skin thickness and to correlate these parameters with type 2 diabetes mellitus.

Methodology

This one year hospital based cross-sectional study was conducted in the Department of Medicine, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belgaum from January 2016 to December 2016. A total of 100 Patients presenting with type 2 diabetes mellitus were studied. These patients were evaluated for anthropometric measures like body mass index, waist hip ratio, Neck circumference, inter-scapular skin thickness

Results

Majority of patients were males amounting to 68% and 32% of the patients were females with the male female ratio of 2.12:1. the most common age group was 51 to 60 years (41%). The mean age was 58.98 ± 9.86 years. Majority of the patients (69%) had elevated fasting blood sugar levels (≥126 mg/dL). The mean FBS levels were 163.67±70.87 mg/dL. Also majority of the patients (66%) had elevated post prandial blood sugar levels (≥200 mg/dL). The mean PPBS levels were 243.16±87.75 mg/dL. 40% of the patients had HbA1c levels between 7.0-8.5 and 39% of the patients had HbA1c levels of > 8.5. The mean HbA1c levels were 8.72 ± 2.08. Most

of the patients i.e., 63% were overweight (25.00-29.99 kg/m^2) while 20% of the patients were obese (≥30 Kg/m^2). The mean BMI was 28.34±7.28 Kg/m^2. Majority of the patients (96%) had abnormal waist hip ratio. The mean WHR was 1.21 ± 0.17. 97% of the patients had abnormal waist circumference. 77% of the patients had normal inter-scapular skin thickness (<2.2) while 23% of the patients had abnormal inter-scapular skin thickness (≥2.2). The mean inter-scapular skin was 1.86±0.52. The mean waist circumference was 96.90±7.77 cms. 84% of the patients had abnormal neck circumference. The mean neck circumference was 38.33±2.25 cms. 56% of the patients had raised HOMA-IR (≥2.41). The mean HOMA IR was 4.20±4.98. The mean FBS levels (195.1 ± 79.2 mg/dL vs 123.61 ± 24.60 mg/dL; p<0.001), PPBS levels (727.60 ± 95.00 mg/dL vs 196.77 ± 47.44 mg/dL; p<0.001) compared to those with normal HOMA IR levels, HBA1c levels (9.60 ± 2.20 vs 7.65 ± 1.22; p<0.001) and neck circumference (38.9± 2.20 mg/dL vs 37.65 ± 2.14 cms; p=0.006) was significantly high in patients with insulin resistance compared to those with normal HOMA IR levels. Moderate positive correlation was observed between neck circumference with HOMA IR (r=0.4196; R^2=0.1761; p<0.001), fasting blood sugar levels (r=0.4196; R^2=0.1954; p<0.001), post prandial blood sugar levels (r=0.4196; R^2=0.2495; p<0.001) and Glycosylated haemoglobin (r=0.4181; R^2=0.1761; p<0.001) and this correlation was statistically significant.

Conclusion and interpretation

Neck circumference was significantly high in patients with insulin resistance compared to those with normal HOMA IR. Incidentally we also found that FBS, PPBS, HbA1c levels were high in patients with insulin resistance compared to those

with normal HOMA IR levels. Also there is moderate positive correlation between neck circumference and FBS, PPBS, HbA1c and HOMA IR.

Keywords

Body mass index; Inter-scapular skin thickness; Neck circumference; Type 2 Diabetes mellitus; Waist hip ratio;

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INTRODUCTION

Obesity has become a major worldwide epidemic affecting more than 300 million people.[1] Overweight and obesity are terms used for people who weigh more than the limits recommended for their age and gender. This leads to a number of diseases that contribute to increased morbidity and mortality. The presence of obesity worldwide has led to the usage of the term 'globesity' to describe the epidemic trend towards increased body weight.[2]

According to International Obesity Taskforce (IOTF) analysis (2010),[3] the numbers of overweight and obese adults are approximately 1.0 billion and 475 million respectively. Using Asian cut-off values, the number of obese people rises to 600 million. A similar trend is seen in children of school-going age with an estimated 200 million classified as either overweight or obese.[3] The National Health and Nutrition Examination Survey (NHANES) has observed that the proportion of American adults who are obese has doubled from 15% in 1971-74 to 34% in 2003-6.[4] Countries having the lowest rates of obesity, such as Japan and Korea, are also experiencing a similar trend.[5]

Obesity is an important risk factor for diabetes mellitus, type 2, a chronic disorder of carbohydrate, fat, and protein metabolism.[6] Diabetes Mellitus has afflicted mankind since time immemorial. The implications of diabetes have prompted never ending search and research into intriguing pathogenesis of the metabolic illness and its several ensuing complications.[1]

Diabetes Mellitus is a metabolic disorder of multiple etiologies characterized by chronic hyperglycemia with disturbances of carbohydrate, fat and protein

metabolism resulting from defects in insulin secretion, insulin action or both. The vast majority of cases of diabetes fall into two broad categories: those having little or no endogenous insulin secretory capacity (IDDM or type 1 DM) and those who retain endogenous insulin secretory capacity but have a combination of resistance to insulin action and an inadequate compensatory insulin secretory response (NIDDM, or Type 2 DM).[7,8]

Type 2 diabetes mellitus (DM) accounts for more than 90% of the diabetic population world wide. Rates of diabetes are increasing worldwide. The International Diabetes Federation predicts that the number of people living with diabetes will rise from 366 million in 2011 to 552 million by 2030.[9]

The top 10 countries in number of people with diabetes are currently India, China, the United States, Indonesia, Japan, Pakistan, Russia, Brazil, Italy, and Bangladesh. The prevalence of diabetes and its adverse health effects have risen more rapidly in South Asia than in any other region of the world.[10]

The prevalence of diabetes in India based on the Indian Council of Medical Research (ICMR) multicentric survey[11] was around two percent in urban India and one percent in rural India before 30 years. In just three decades, these prevalence rates have shot up to 12 to 16% in urban India and 3 to 8% in rural India, in adults over 20 years of age representing a 600 to 800% increase in prevalence rates of diabetes. Indeed, India is now referred to as the "Diabetic Capital" of the world.

The field of diabetology has seen new developments occurring at a bewildering pace. Diabetes mellitus is associated with an increased risk of atherosclerosis, and macrovascular complications are a major cause of morbidity and

mortality in this disease.[12] It is estimated that, 80% of patients with diabetes mellitus die a thrombotic death[13] and 75% of these deaths are due to cardiovascular complications and remainder due to cerebrovascular events and peripheral vascular complications.[14]

Endothelial dysfunction is the earliest event that precedes the development and progression of diabetic vascular complications.[15] The pathogenesis of endothelial dysfunction in diabetes is complex. Multiple cellular and molecular mechanisms are involved in the development of diabetic dysfunctional endothelium (hyperglycemia, insulin resistance, impaired lipid metabolism and lipoproteins, oxidative stress).[12,16]

From the clinical perspective, visceral adipose tissue is known to generate diabetogenic substances[6] and, as such, may be more informative than total fat for diagnostic evaluation. The standard epidemiologic translation of these important clinical facts uses anthropometric measures. Waist circumference and waist/hip ratio have been used as measures of central obesity (where visceral adipose tissue is stored), and body mass index (kg/m^2) has been used as a measure of general obesity.[1,17]

Clinical evidence suggests that the association of diabetes with central obesity is stronger than the association with general fat. Studies using computed tomography and magnetic resonance imaging have provided further evidence to support that central obesity, visceral adipose tissue, and upper-body non-visceral fat are the major contributors to the metabolic complications. Central obesity has been associated with decreased glucose tolerance, alterations in glucose insulin homeostasis, reduced metabolic clearance of insulin, and decreased insulin-stimulated glucose disposal.[1,18-20]

In addition, studies that have analyzed the association of anthropometric measures and abdominal visceral fat have found waist circumference to be a better measure of central obesity because it is a better predictor of abdominal visceral fat obtained with computed tomography than is waist/hip ratio, and it can be easily measured and interpreted.[1] However, waist circumference cannot distinguish abdominal subcutaneous fat, total abdominal fat, and total body fat, and it is strongly correlated with body mass index. Body mass index has been shown to be a good indicator of general fatness (fat areas in the arm, thigh, and waist using computed tomography scans), muscularity (muscle area in the thigh), and frame size (bone area in thighs).[21]

As expected, epidemiologic studies have demonstrated that these three obesity indicators are strong and consistent predictors of diabetes mellitus, type 2. However, despite the clear, clinical difference between visceral and other forms of fat, little epidemiologic difference would be expected in the relations of diabetes with body mass index versus waist circumference. From a statistical perspective, the two measures yield similar information, with the correlation coefficient typically about 0.8.[22] Several studies have shown that waist circumference is a better predictor of diabetes mellitus, type 2, than is body mass index, but these findings are inconclusive,[23-25] while other studies provide evidence that waist/hip ratio has a positive effect independent of body mass index.[26-28] In addition, the ability of these obesity indicators to predict diabetes may differ by ethnicity, age, and sex.[1] For example, among Asian populations, central obesity has been shown to be a more consistent predictor of diabetes than is total obesity,[1] while general obesity has been shown to be a better predictor among White US populations and Europeans.[1]

Body mass index, waist circumference, and waist/hip ratio have been shown to be associated with type 2 diabetes. From the clinical perspective, central obesity (approximated by waist circumference or waist/hip ratio) is known to generate diabetogenic substances and should therefore be more informative than general obesity (body mass index). Because of their high correlation, from the statistical perspective, body mass index and waist circumference are unlikely to yield different answers.[1]

Practical and easily performed methods for measuring obesity include various anthropometric measures such as body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), as well as the not-so-easy method of measuring the thickness of subcutaneous fat layer at specific sites for estimating body fat percentage. BMI has been adopted by most health professionals for obesity surveys, as it is easy to perform on a large scale. However, it does not depict the true body composition. Furthermore, visceral obesity, which closely relates to cholesterol levels in the body and its associated coronary artery disease, is better defined by measuring the waist circumference.[6] Measurement of neck circumference (NC) has recently been used to identify overweight and obesity and is observed to have good correlation with age, weight, waist and hip circumferences, waist-to-hip ratio, and BMI for both genders.[7] Besides, NC is considered an index of upper body obesity and correlates positively with changes in systolic and diastolic blood pressure and other components of the metabolic syndrome.[2,29]

NC is found to be a simple and time-saving screening measure that could be used to identify overweight and obese individuals. It has been shown that men with a NC of less than 37 cm and women with a NC of less than 34 cm require a more

comprehensive evaluation of their status as overweight or obese in the settings of metabolic syndrome.[30]

Considering the burden of type 2 diabetes mellitus, the fact that obesity being an important risk factor in the pathogenesis of diabetes, and advantages of measuring neck circumference this study was undertaken to estimate subcutaneous fat thickness using various anthropometric measures like body mass index, waist hip ratio, Neck circumference, inter-scapular skin thickness and to correlate these parameters with type 2 diabetes mellitus.

OBJECTIVES

The objectives of this study were;

- To estimate subcutaneous fat thickness using various anthropometric measures like body mass index, waist hip ratio, Neck circumference, inter-scapular skin thickness.

- Correlation of the said parameters with type 2 diabetes mellitus.

REVIEW OF LITERATURE

Diabetes Mellitus

Diabetes mellitus refers to a group of common metabolic disorders that share the phenotype of hyperglycemia. Several distinct types of DM exist and are caused by a complex interaction of genetics and environmental factors. Depending on the etiology of the DM, factors contributing to hyperglycemia include reduced insulin secretion, decreased glucose utilization, and increased glucose production.[7]

The metabolic dysregulation associated with DM causes secondary path physiologic changes in multiple organ systems that impose a tremendous burden on the individual with diabetes and on the health care system. DM is the leading cause of end-stage renal disease (ESRD), non-traumatic lower extremity amputations, and adult blindness. It also predisposes to cardiovascular diseases. With an increasing incidence worldwide, DM will be a leading cause of morbidity and mortality for the foreseeable future.[1]

History of Diabetes Mellitus

For 2,000 years diabetes has been recognized as a devastating and deadly disease. In the first century A.D. a Greek, Aretaeus, described the destructive nature of the affliction which he named "diabetes" from the Greek word for "siphon."[31]

Physicians in ancient times, like Aretaeus, recognized the symptoms of diabetes but were powerless to effectively treat it. Aretaeus recommended oil of roses, dates, raw quinces, and gruel. And as late as the 17th century, doctors prescribed gelly of viper's flesh, broken red coral, sweet almonds, and fresh flowers of blind nettles.[31]

In the 17th century a London physician, Dr. Thomas Willis, determined whether his patients had diabetes or not by sampling their urine. This method of monitoring blood sugars went largely unchanged until the 20th century.[31]

In 1921, in Ontario, Canada, a young surgeon Frederick Banting, and his assistant Charles Best, kept a severely diabetic dog alive for 70 days by injecting it with a murky concoction of canine pancreas extract. With the help of Dr. Collip and Dr. Macleod, Banting and Best administered a more refined extract of insulin to Leonard Thompson, a young boy dying of diabetes. Within 24 hours, Leonard's high blood sugars had dropped to near normal levels.[31]

Since insulin's discovery, medical breakthroughs continued to prolong and ease the lives of people with diabetes. In 1935 Roger Hinsworth discovered there were two types of diabetes: "insulin sensitive" (type I) and "insulin insensitive" (type II). By differentiating between the two types of diabetes, Hinsworth helped open up new avenues of treatment.[31]

The HbA1c test was devised in 1979 in order to create a more precise blood sugar measurement. The A1c became a standard measurement for blood sugar control in the comprehensive ten-year study from 1983 to 1993 the Diabetes Control and Complications Trial (DCCT). With the conclusion of the DCCT in 1993, studies showed that people who were able to keep their blood glucose levels as close to normal as possible had less chance of developing complications associated with diabetes.[31]

Before this, many doctors had not put much emphasis on tight control of blood glucose levels. The common belief for decades was that diligent monitoring of blood

sugars and intensive insulin therapy had little consequence for people with diabetes. Since the DCCT's findings, statistics have proven that tight blood glucose control can be extremely beneficial for people with diabetes.[31]

CLASSIFICATION OF DIABETES MELLITUS

DM is classified on the basis of the pathogenic process that leads to hyperglycemia, as opposed to earlier criteria such as age of onset or type of therapy. The two broad categories of DM are designated as;[7]

- Type 1
- Type 2

Both types of diabetes are preceded by a phase of abnormal glucose homeostasis as the pathogenic processes progresses. Type 1 diabetes is the result of complete or near-total insulin deficiency. Type 2 DM is a heterogeneous group of disorders characterized by variable degrees of insulin resistance, impaired insulin secretion, and increased glucose production. Distinct genetic and metabolic defects in insulin action and/or secretion give rise to the common phenotype of hyperglycemia in type 2 DM and have important potential therapeutic implications now that pharmacologic agents are available to target specific metabolic derangements. Type 2 DM is preceded by a period of abnormal glucose homeostasis classified as impaired fasting glucose (IFG) or impaired glucose tolerance (IGT).[1]

Table 1. Spectrum of glucose homeostasis and diabetes mellitus[7]

Type of diabetes	Normal glucose tolerance (NGT)	Impaired fasting glucose or impaired glucose tolerance	Hyperglycemia: Diabetes mellitus		
			Not insulin required	Insulin required for control	Insulin required for survival
Type 1					
Type 2					
Other Specific types					
Gestational diabetes					
Time (years)					
FPG (mg/dl)	< 100	100-125		≥ 126	
2-h plasma glucose (mg/dl)	< 140	140 – 199		≥ 200	

Etiologic classification of diabetes mellitus[7]

I. Type 1 diabetes (-cell destruction, usually leading to absolute insulin deficiency)

A. Immune-mediated

B. Idiopathic

II. Type 2 diabetes (may range from predominantly insulin resistance with relative insulin deficiency to a predominantly insulin secretory defect with insulin resistance)

III. Other specific types of diabetes

A. Genetic defects of β-cell function characterized by mutations in :

1. Hepatocyte nuclear transcription factor (HNF) 4α maturity onset diabetes of young (MODY) 1
2. Glucokinase (MODY 2)
3. HNF – 1α (MODY 3)
4. Insulin promoter factor (IPF) 1 (MODY 4)
5. HNF – 1β (MODY 5)
6. Neuro D1 (MODY 6)
7. Mitochondrial deoxyribo nucleic acid (DNA)
8. Sub units of adenosine triphosphate (ATP) – sensitive potassium channel.
9. Proinsulin or insulin conversion

B. Genetic defects in insulin action.

1. Type A insulin resistance
2. Leprechaunism
3. Rabson-Mendenhall syndrome
4. Lipodystrophy syndromes.

C. Diseases of the exocrine pancreas – pancreatitis, pancreatectomy, neoplasia, cystic fibrosis, hemochromatosis, fibrocalculouspancreatopathy.

D. Endocrinopathies – acromegaly, Cushing's syndrome, glucagonoma, pheochromocytoma, hyperthyroidism, somatostatinoma, aldosteronoma

E. Drug or chemical induced – Vacor, pentamidine, nicotinic acid, glucocorticoids, thyroid hormone, diazoxide, beta-adrenergic agonists,

thiazides, phenytoin, α– interferon, protease inhibitors, clozapine, beta blockers.

F. Infections – congenital rubella, cytomegalovirus, coxsackie.

G. Uncommon forms of immune-mediated diabetes – "stiff-man" syndrome, anti-insulin receptor antibodies.

H. Other genetic syndromes sometimes associated with diabetes – Down's syndrome, Klinefelter's syndrome, Turner's syndrome, Wolfram's syndrome, Friedreich's ataxia, Huntington's chorea, Laurence-Moon-Biedl syndrome, myotonic dystrophy, porphyria, Prader-Willi syndrome.

IV. Gestational diabetes mellitus (GDM)

EPIDEMIOLOGY

The worldwide prevalence of DM has risen dramatically over the past two decades, from an estimated 30 million cases in 1985 to 177 million in 2000. Based on current trends, more than 360 million individuals will have diabetes by the year 2030. Although the prevalence of both type 1 and type 2 DM is increasing worldwide, the prevalence of type 2 DM is rising much more rapidly because of increasing obesity and reduced activity levels as countries become more industrialized. This is true in most countries, and 6 of the top 10 countries with the highest rates are in Asia. The prevalence of type 2 DM and its harbinger, IGT, is highest in certain Pacific islands, intermediate in countries such as India and the United States, and relatively low in Russia. This variability is likely due to genetic, behavioral, and environmental factors.[7]

In India it is estimated that presently 19.4 million individuals are affected by this deadly disease, which is likely to go up to 57.2 million by the year 2025.[32]

The prevalence of diabetes is four to six fold lower in rural areas, which is probably attributed to a conventional lifestyle which has beneficial effect on glucose tolerance (IGT). National Urban Diabetes Survey done in six cities, found age standardized prevalence rates of 12% for diabetes; with a slight male preponderance and 14% for impaired glucose tolerance. Subjects under the age of 40 years, had a prevalence of five percent for DM and 13% prevalence of impaired glucose tolerance.[33]

DIAGNOSIS OF DIABETES

Criteria for the Diagnosis of Diabetes Mellitus[7]

- Symptoms of diabetes plus random blood glucose concentration more than or equal to 11.1 mmol/L (200 mg/dL)[a] *or*
- Fasting plasma glucose more than or equal to 7.0 mmol/L (126 mg/dL)[b] *or*
- Two-hour plasma glucose more than or equal to 11.1 mmol/L (200 mg/dL) during an oral glucose tolerance test[c]

[a]Random is defined as without regard to time since the last meal.

[b]Fasting is defined as no caloric intake for at least 8 h.

[c]The test should be performed using a glucose load containing the equivalent of 75 g anhydrous glucose dissolved in water; not recommended for routine clinical use.

In the absence of unequivocal hyperglycemia and acute metabolic decompensation, these criteria should be confirmed by repeat testing on a different day.

Glucose tolerance is classified into three categories based on the FPG:

1. FPG less than 5.6 mmol/L (100 mg/dL) is considered normal;
2. FPG equal to 5.6–6.9 mmol/L (100–125 mg/dL) is defined as IFG; and
3. FPG more than or equal to 7.0 mmol/L (126 mg/dL) warrants the diagnosis of DM.

Oral glucose tolerance test

The test uses the following procedures.

- It first employs an FPG test.
- A blood test is then taken two hours after drinking a 75 g anhydrous glucose solution.

Based on the OGTT, IGT is defined as plasma glucose levels between 7.8 and 11.1 mmol/L (140 and 199 mg/dL). Diabetes is defined when plasma glucose is more than 11.1 mmol/L (200 mg/dL), 2 h after a 75 g oral glucose load.

The current criteria, for the diagnosis of DM emphasize that the FPG is the most reliable and convenient test for identifying DM, in asymptomatic individuals. A random plasma glucose concentration more than or equal to 11.1 mmol/L (200 mg/dL) accompanied by classic symptoms of DM (polyuria, polydipsia, weight loss) is sufficient for the diagnosis of DM.

Hemoglobin A1C (HbA1c) was advocated as a diagnostic test for DM. There is a strong correlation between elevations in the plasma glucose and the A1C, the relationship between the FPG and the A1C in individuals with normal glucose tolerance or mild glucose intolerance and thus the use of the A1C is currently recommended to diagnose diabetes.[7]

PATHOPHYSIOLOGY

Insulin biosynthesis

Insulin is produced in the beta cells of the pancreatic islets. It is initially synthesized as preproinsulin. Subsequent proteolytic processing removes the amino terminal signal peptide, giving rise to proinsulin. Cleavage of an internal 31-residue fragment from proinsulin generates the C peptide and the A (21 amino acids) and B (30 amino acids) chains of insulin, which are connected by disulfide bonds. The mature insulin molecule and C peptide are stored together and co-secreted from secretory granules in the beta cells.

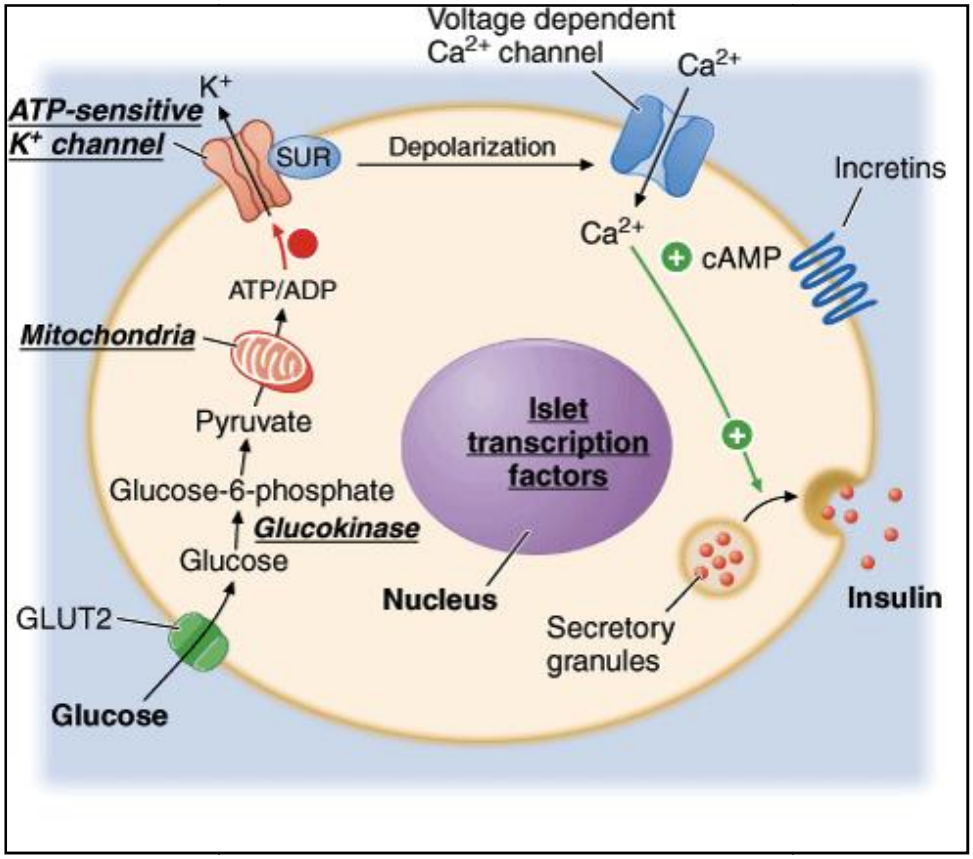


Figure 1. Diabetes and abnormalities in glucose-stimulated insulin secretion[7]

Glucose and other nutrients regulate insulin secretion by the pancreatic beta cell. Glucose is transported by the GLUT2 glucose transporter; subsequent glucose metabolism by the beta cell alters ion channel activity, leading to insulin secretion.

The SUR receptor is the binding site for drugs that act as insulin secretagogues. Mutations in the events or proteins underlined are a cause of maturity onset diabetes of the young (MODY) or other forms of diabetes.[7]

Secretion

Glucose is the key regulator of insulin secretion by the pancreatic beta cell, although amino acids, ketones, various nutrients, gastrointestinal peptides, and neurotransmitters also influence insulin secretion. Glucose levels > 3.9 mmol/L (70 mg/dL) stimulate insulin synthesis, primarily by enhancing protein translation and processing. Glucose stimulation of insulin secretion begins with its transport into the beta cell by the GLUT2 glucose transporter. Glucose phosphorylation by glucokinase is the rate-limiting step that controls glucose-regulated insulin secretion. Further metabolism of glucose-6-phosphate via glycolysis generates ATP, which inhibits the activity of an ATP-sensitive K^+ channel. This channel consists of two separate proteins: one is the binding site for certain oral hypoglycemics (e.g., sulfonylureas, meglitinides); the other is an inwardly rectifying K^+ channel protein. Inhibition of this K^+ channel induces beta cell membrane depolarization, which opens voltage-dependent calcium channels, and stimulates insulin secretion. Insulin secretory profiles reveal a pulsatile pattern of hormone release, with small secretory bursts occurring about every 10 min.[7]

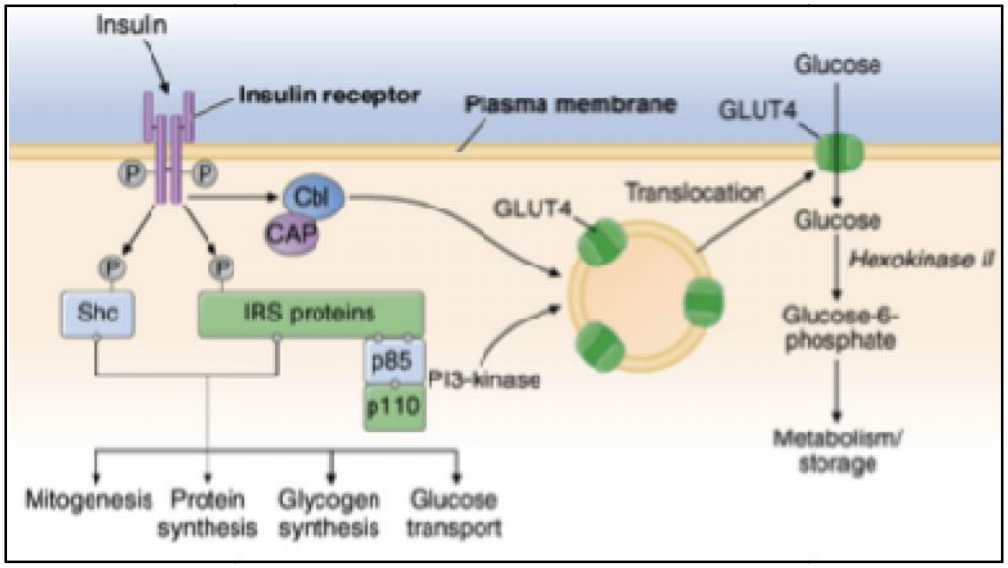


Figure 2. Insulin signal transduction pathway in skeletal muscle[7]

The insulin receptor has intrinsic tyrosine kinase activity and interacts with insulin receptor substrates (IRS and Shc) proteins. A number of "docking" proteins bind to these cellular proteins and initiate the metabolic actions of insulin [GrB-2, SOS, SHP-2, p65, p110, and phosphatidylinositol-3'-kinase (PI-3-kinase)]. Insulin increases glucose transport through PI-3-kinase and the Cbl pathway, which promotes the translocation of intracellular vesicles containing GLUT4 glucose transporter to the plasma membrane.[7]

Action

Once insulin is secreted into the portal venous system, about 50% is degraded by the liver. Unextracted insulin enters the systemic circulation where it binds to receptors in target sites. Insulin binding to its receptor stimulates intrinsic tyrosine kinase activity, leading to receptor autophosphorylation and the recruitment of intracellular signaling molecules, such as insulin receptor substrates (IRS). IRS and other adaptor proteins initiate a complex cascade of phosphorylation and

dephosphorylation reactions, resulting in the widespread metabolic and mitogenic effects of insulin.[7]

Glucose homeostasis reflects a balance between hepatic glucose production and peripheral glucose uptake and utilization. Insulin is the most important regulator of this metabolic equilibrium, but neural input, metabolic signals, and other hormones result in integrated control of glucose supply and utilization. In the fasting state, low insulin levels increase glucose production by promoting hepatic gluconeogenesis and glycogenolysis and reduce glucose uptake in insulin-sensitive tissues, thereby promoting mobilization of stored precursors such as amino acids and free fatty acids. Glucagon, secreted by pancreatic alpha cells when blood glucose or insulin levels are low, stimulates glycogenolysis and gluconeogenesis by the liver and renal medulla. Postprandially, the glucose load elicits a rise in insulin and fall in glucagon, leading to a reversal of these processes.[7]

Type 2 Diabetes mellitus

Insulin resistance and abnormal insulin secretion are central to the development of type 2 DM. Although the primary defect is controversial, most studies support the view that insulin resistance precedes an insulin secretory defect but that diabetes develops only when insulin secretion becomes inadequate.[7]

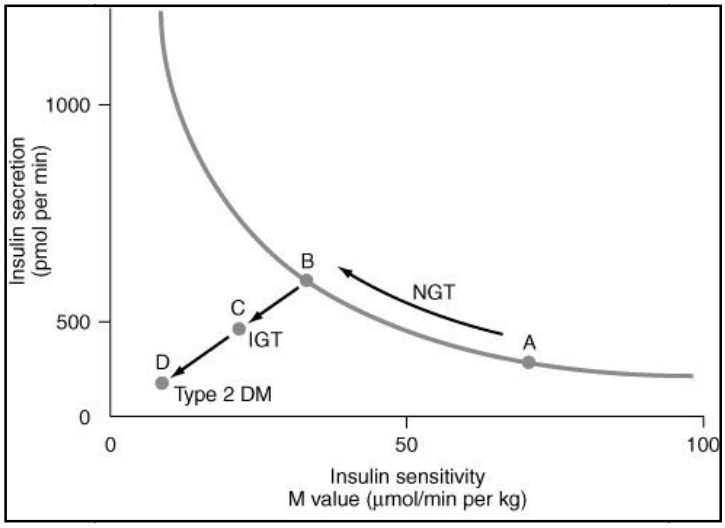


Figure 3. Metabolic changes during the development of type 2 diabetes mellitus[7]

Insulin secretion and insulin sensitivity are related, and as an individual becomes more insulin resistant (by moving from point A to point B), insulin secretion increases. A failure to compensate by increasing the insulin secretion results initially in impaired glucose tolerance (IGT; point C) and ultimately in type 2 DM (point D).[7]

Pathophysiology of type 2 DM

Type 2 DM is characterized by impaired insulin secretion, insulin resistance, excessive hepatic glucose production, and abnormal fat metabolism. Obesity, particularly visceral or central, is very common in type 2 DM. In the early stages of the disorder, glucose tolerance remains near normal, despite insulin resistance, because the pancreatic beta cells compensate by increasing insulin output. As insulin resistance and compensatory hyperinsulinemia progress, the pancreatic islets in certain individuals are unable to sustain the hyperinsulinemic state. IGT, characterized by elevations in postprandial glucose, then develops. A further decline in insulin secretion and an increase in hepatic glucose production lead to overt diabetes with fasting hyperglycemia. Ultimately, beta cell failure may ensue.[7]

Complications of type 2 diabetes mellitus[7]

Acute

- Diabetic Ketoacidosis
- Hyperglycemic Hyperosmolar State

Chronic

- Microvascular
    - Eye disease
        - Retinopathy (nonproliferative/proliferative)
        - Macular edema
    - Neuropathy
        - Sensory and motor (mono- and polyneuropathy)
        - Autonomic
    - Nephropathy
- Macrovascular
    - Coronary artery disease
    - Peripheral vascular disease
    - Cerebrovascular disease
- Other
    - Gastrointestinal
    - Genitourinary
    - Dermatologic
    - Cataracts
    - Glaucoma
    - Infectious
    - Periodontal disease

Chronic complications

The risk of chronic complications increases as a function of the duration of hyperglycemia; they usually become apparent in the second decade of hyperglycemia. Since type 2 DM often has a long asymptomatic period of hyperglycemia, many individuals with type 2 DM have complications at the time of diagnosis.[7]

The microvascular complications of both type 1 and type 2 DM result from chronic hyperglycemia. Large, randomized clinical trials of individuals with type 1 or type 2 DM have conclusively demonstrated that a reduction in chronic hyperglycemia prevents or delays retinopathy, neuropathy, and nephropathy. Other incompletely defined factors may modulate the development of complications.[7]

Evidence implicating a causative role for chronic hyperglycemia in the development of macrovascular complications is less conclusive. However, coronary heart disease events and mortality are two to four times greater in patients with type 2 DM. These events correlate with fasting and postprandial plasma glucose levels as well as with the A1C. Other factors like dyslipidemia and hypertension also play important roles in macrovascular complications.[7]

Obesity (including distribution of obesity and duration) Behavioral and lifestyle-related risk factor for type 2 diabetes

Most patients with type 2 diabetes are obese, and the global epidemic of obesity largely explains the dramatic increase in the incidence and prevalence of type 2 diabetes over the past 20 years. Currently, over a third (34%) of U.S. adults are obese (defined as BMI >30 kg/m^2), and over 11% of people aged ≥20 years have diabetes,[34] a prevalence projected to increase to 21% by 2050.[35] However, the precise

mechanisms linking the two conditions remain unclear, as does our understanding of interindividual differences. Improved understanding will help advance identification and development of effective treatment options.[36]

Excess weight is an established risk factor for type 2 diabetes, yet most obese individuals do not develop type 2 diabetes. Recent studies have identified "links" between obesity and type 2 diabetes involving proinflammatory cytokines (tumor necrosis factor and interleukin-6), insulin resistance, deranged fatty acid metabolism, and cellular processes such as mitochondrial dysfunction and endoplasmic reticulum stress. These interactions are complex, with the relative importance of each unclearly defined. Further genetic studies may elucidate additional common pathophysiological pathways for obesity and diabetes and identify promising new treatment targets. As physicians frequently prescribe glucose-lowering medications associated with weight gain, trade-offs between glycemic control and body weight with current therapeutic options need more consideration. This issue is particularly pressing given accumulating evidence that even modest weight reduction—whether through lifestyle/behavioral interventions, obesity medications, or bariatric surgery—can improve glycemic control and reduce diabetes risk.[36]

These intriguing, but still largely unexplored, connections between obesity and type 2 diabetes suggested the timely need to convene a group of scientific experts in the fields to more closely examine underlying pathophysiology and treatment options for patients with type 2 diabetes addressing issues of excess weight and glycemic control simultaneously. Participants in the January 2011 conference (Supplementary Data) were tasked with examining what is known about the relationship between obesity and type 2 diabetes and the heterogeneity of these conditions, what needs to

be learned, and how to direct future research in these areas to advance effective interventions and improve patient care.[36]

Mechanisms of obesity-associated insulin resistance

The influence of obesity on type 2 diabetes risk is determined not only by the degree of obesity but also by where fat accumulates. Increased upper body fat including visceral adiposity, as reflected in increased abdominal girth or waist-to-hip ratio, is associated with the metabolic syndrome, type 2 diabetes, and cardiovascular disease,[37] although underlying mechanisms remain uncertain. Whether subcutaneous fat lacks the pathological effects of visceral fat or is simply a more neutral storage location, for example, requires further study. Beyond differences in body fat distribution, emerging evidence suggests that different subtypes of adipose tissue may be functionally distinct and affect glucose homeostasis differentially. Adult humans have limited and variable numbers of brown fat cells, which play a role in thermogenesis and potentially influence energy expenditure and obesity susceptibility. Improved understanding of the function of different fat cell types and depots and their roles in metabolic homeostasis is a priority for investigation into the pathogenesis and complications of obesity. Likewise, adipose tissue is composed of heterogeneous cell types. Immune cells within adipose tissue also likely contribute to systemic metabolic processes. As the study of adipose biology progresses, it will be important to consider whether additional subtypes of adipocytes or other cell types can be identified to refine our understanding of obesity complications and generate novel approaches to prevention.[36]

At least three distinct mechanisms have been proposed to link obesity to insulin resistance and predispose to type 2 diabetes: *1*) increased production of

adipokines/cytokines, including tumor necrosis factor-α, resistin, and retinol-binding protein 4, that contribute to insulin resistance as well as reduced levels of adiponectin; *2*) ectopic fat deposition, particularly in the liver and perhaps also in skeletal muscle, and the dysmetabolic sequelae; and *3*) mitochondrial dysfunction, evident by decreased mitochondrial mass and/or function. Mitochondrial dysfunction could be one of many important underlying defects linking obesity to diabetes, both by decreasing insulin sensitivity and by compromising β-cell function.[36]

Mechanisms of progressive β-cell dysfunction in obese individuals

The link between obesity and hyperinsulinemia, first identified ~50 years ago,[38] reflects compensation by insulin-secreting β-cells to systemic insulin resistance. Although mechanisms underlying this coupling (e.g., mild hyperglycemia and raised levels of circulating free fatty acids) remain elusive, obese normoglycemic individuals have both increased β-cell mass and function. Obesity-induced glucose intolerance reflects failure to mount one or more of these compensatory responses.[36]

Factors predisposing to β-cell decompensation could also be primarily genetic or epigenetic. A clear, mechanistic basis for this decompensation has remained elusive. Genetic studies have helped identify the role of some key molecules in β-cell biology that may be important in this regard. For example, recent rodent studies have demonstrated diabetogenic effects of reduced pancreatic expression of the *Pdx1* gene.[36] While these animal studies have demonstrated that PDX1 deficiency relates mechanistically to diabetes through β-cell apoptosis, and PDX1 deficiency is linked to MODY4,[39] it is not clear yet that PDX1 deficiency has a role in common forms of type 2 diabetes in humans.[36]

This example illustrates how a growing understanding of genetics and cellular function of the β-cell can identify potential mediators predisposing obese individuals to type 2 diabetes and further may provide insights for the development of new therapeutic agents.[36]

Genetic factors linking obesity and diabetes

Genome-wide association scans (GWAS) and candidate gene approaches now have identified ~40 genes associated with type 2 diabetes and a similar number, albeit largely different, with obesity. Most type 2 diabetes genes appear to be related to β-cell dysfunction, with many fewer involved in pathways related to insulin resistance independent of obesity. Not surprisingly, many obesity gene variants appear to be involved in pathways affecting energy homeostasis. Although numerous diabetes- and obesity-associated genes have been identified, the known genes are estimated to predict only 15% of type 2 diabetes and 5% of obesity risk. Although additional genes with important roles will undoubtedly be discovered, this low predictive power may reflect the importance of environmental factors, less frequent genetic variants with stronger effects, or gene-environment, gene-gene, and epigenetic interactions that are not readily identified through methods based on population genetics. Methods for detecting gene-gene interactions exist, but the population size needed to detect them is substantially greater than is required for detection of single genes of relatively small effect. Alternatively, pathway analyses or a systems biology approach combining information from DNA variations with transcript, protein, and metabolite profiles may better capture the genetic influences on metabolism than studying single genes. One should also keep in mind that the missing heritability could be an illusion of inferring additive genetic effects from epidemiological data.[36]

Does a shared pathogenesis underlie both obesity and type 2 diabetes?

Although the link between obesity and type 2 diabetes is widely held to involve two discrete lesions—obesity-induced insulin resistance and β-cell failure—both disorders may share an underlying defect. This "unified field theory" raises questions about whether defects favoring progressive weight gain and metabolic impairment also contribute to β-cell decompensation.

One potential link could be sustained cell exposure to nutrient concentrations exceeding energy requirements. Deleterious cellular effects of nutrient excess can include impaired inflammatory signaling, endoplasmic reticulum stress, excess production of reactive oxygen species, mitochondrial dysfunction, accumulation of triglycerides and/or fatty acyl intermediates, and activation of serine-threonine kinases. These responses are not mutually exclusive, and induction of one may trigger another, leading to a cascade of damage. Obesity-associated cellular injury can in turn recruit and activate macrophages and other immune cells that exacerbate tissue inflammation. Collectively, these responses contribute to the pathogenesis of insulin resistance in the liver, skeletal muscle, and adipose tissue, and some (e.g., acquired mitochondrial dysfunction and inflammation) may occur in β-cells as well via mechanisms discussed above. In susceptible individuals, therefore, obesity-induced metabolic impairment can favor insulin resistance on the one hand and progressive β-cell dysfunction on the other. Reduced insulin secretion can in turn worsen the nutrient excess problem by raising circulating concentrations of glucose, free fatty acids, and other nutrients. In this way, a vicious cycle arises whereby obesity-induced nutrient excess triggers inflammatory responses that cause insulin resistance, placing a greater demand on the β-cell, and as β-cell function declines the cellular toll taken

by nutrient excess increases. Since not all obese individuals develop hyperglycemia, however, an underlying abnormality of the β-cell must coexist with nutrient excess to promote type 2 diabetes.[36]

Brain neurocircuits governing energy homeostasis also affect insulin sensitivity in the liver and perhaps other peripheral tissues, and inflammation similar to that induced by obesity in peripheral insulin-sensitive tissues also occurs in these areas of the brain. If obesity is associated with impairment of neurocircuits regulating both energy balance and insulin action, obesity-induced insulin resistance may arise not only as a direct consequence of excessive adipose mass but via neuronal mechanisms as well. Whether disturbed neurocircuits also contribute to deteriorating β-cell dysfunction as obesity and its sequelae progress is an active area of investigation.[36]

Adipose tissue is anatomically distributed in different proportions throughout the human body, and the pattern of distribution is dependent upon many factors including sex, age, race, ethnicity, genotype, diet, physical activity, hormone levels and medication. The percentage of adipose tissue is higher in women, the elderly and overweight individuals.[40]

Body fat tissue is traditionally distributed into two main compartments with different metabolic characteristics: subcutaneous adipose tissue (SAT) and visceral adipose tissue (VAT). While both of these tissue types are important, particular attention has been directed to visceral adiposity owing to its association with various medical pathologies.[40]

Although fat and adipose tissue are differentiated by distinct biochemical and metabolic features, these terms will be used interchangeably for the purpose of this review. Abdominal obesity, which is characterised as increased adipose tissue surrounding the intra-abdominal organs, is also referred to as visceral or central obesity. It has been distinctly linked to several pathological conditions including impaired glucose and lipid metabolism, insulin resistance, increased predisposition to cancers of the colon, breast and prostate, and it is associated with prolonged hospital stays, increased incidence of infections and non-infectious complications, and increased mortality in hospital. Visceral obesity itself is an independent component of metabolic syndrome and the magnitude of obesity directly relates to the prognosis of this condition. VAT accumulation also determines a comprehensive cardiovascular risk profile and increases the susceptibility to ischaemic heart disease and arterial hypertension. As a hormonally active tissue, VAT releases different bioactive molecules and hormones, such as adiponectin, leptin, tumour necrosis factor, resistin and interleutin 6 (IL-6). Among these hormones, adiponectin is of particular significance owing to its protective antiangiogenic activity. Circulating adiponectin is inversely correlated with the amount of VAT, while decreased concentrations of adiponectin are associated with Type 2 diabetes, elevated glucose levels, hypertension, cardiovascular disease and certain malignancies. Consequently, it may be important to complement adiponectin measures with calculations of VAT to better understand the pathogenesis of obesity-related disorders in the human population. As visceral obesity is associated with poor prognosis, metabolic disturbances and degree of pathology in several chronic diseases, it is of great importance to identify methods that quantify adipose tissue accurately and can specifically depict VAT from total adipose tissue.[40]

The necessity for precise and clinically expedient measures for quantifying VAT is evident. However, it is also essential to develop quantitative criteria for defining visceral obesity relative to these metabolic disturbances. To date, these criteria have not been clearly defined in any modality. Currently, techniques for measuring visceral adiposity have ranged from simple, indirect methods of evaluation, such as body mass index (BMI) (weight divided by height squared) to crudely predict visceral adiposity through to CT imaging to provide a cross-sectional area of visceral fat as an accurate and reliable equivalent to visceral fat volume measurement. However, without precise measures of visceral obesity, an index of abdominal obesity cannot be clearly characterised and defined.[40]

Thus, obesity has been reported to be associated with insulin resistance, dyslipidemia, and hypertension, thus increasing the risk for cardiovascular disease (CVD). Regarding body fat distribution, abdominal visceral fat has been more strongly associated with cardiovascular risks than body mass index (BMI), waist circumference, and abdominal subcutaneous fat. Therefore, evaluation and management of visceral fat accumulation is important to reduce cardio-metabolic burdens. Recently, we have reported that increased visceral fat with normal BMI is associated with arterial stiffening in patients with type 2 diabetes. On the other hand, there is evidence that subcutaneous fat has a beneficial role against cardio-metabolic risks such as diabetes or dyslipidemia. These observations suggest the importance of direct evaluation of visceral and subcutaneous fat accumulation for the management of atherosclerosis; therefore it is possible that increased visceral fat with decreased subcutaneous fat accumulation is positively associated with atherosclerosis.[41]

Clinically expedient techniques for measuring visceral adiposity often lack precision

Numerous techniques have been developed to assess visceral fat. The most clinically expedient are those that can be performed quickly, provide instant results and can be performed by the bedside without extensive technical training. Anthropometric measures as well as bioelectrical impedance analysis (BIA) are designed to provide expedient, albeit crude, measures of body composition; however, VAT is only an indirect measure when using these approaches. Only CT and MRI can provide direct measures of cross-sectional areas or volumetric measures of VAT.[40]

Techniques for measuring visceral adiposity vary in accessibility, specificity, accuracy and the ability to quantitatively assess visceral fat. Where MRI and CT images are available, these generate the most accurate, specific and comprehensive data in comparison with all modalities discussed in this paper. The precision of CT imaging for measuring visceral fat tissue provides a clinical venue for body composition analysis, particularly the quantification of visceral fat. Owing to the costs of both CT and MRI, retrospective analysis of images taken during routine clinical care in a given disease population can be valuable for assessing changes in VAT relative to other body composition features and relative to clinical and metabolic parameters. However, prospective analysis using MRI is less feasible because it is costly and relatively inaccessible in smaller clinical centres. Prospective analysis using CT imaging is also relatively unfeasible owing to the radiation exposure involved.[40]

Anthropometric techniques

Body mass index

BMI is the most commonly used diagnostic tool for characterising generalised obesity.[42] A BMI greater than 25 kg m^{-2} is defined as overweight while a BMI over 30 kg m^{-2} is characterised as obese (World Health Organization]).[43] Visceral fat cross-sectional area, measured by CT imaging, correlated well (males: r=0.813; females: r=0.825) with normal BMI ranges (18.5–24.9 kg m^{-2}).[42] Despite the frequent use of BMI, it cannot distinguish between lean and fat body mass and it certainly does not appreciate differences between subcutaneous and visceral fat compartments.[40]

Body mass Index (BMI) is a traditional measure of obesity, and individuals with values between 25 and 29.9 kg/m^2 are considered as being overweight while those with values of 30 kg/m2 or higher as obese. According to WHO, alarming increases in obesity are being observed in Asian countries, including India.[44]

Overweight, obesity, or weight gain has shown to be an important risk factor for the development of type 2 diabetes. In a cohort study of 51,529 U.S. male health professionals aged 40-75 years, a strong positive association between overall obesity as measured by BMI and risk of incident diabetes was observed during the 5-year follow-up.[45] In this study[45] men with a BMI of at least 35 kg/m2 had a multivariate RR of 42.1, compared to men with a BMI of less than 23 kg/m2 (P<0.001). Fat distribution, measured by WHR, was a good predictor of diabetes only among the top 5%, while WC was positively associated with the risk of diabetes among the top 20% of the cohort.

Recently, the Health Professionals Follow-Up Study of 27,270 American men reported that both overall and abdominal adiposity strongly and independently predicted the risk of type 2 diabetes, and WC was a better predictor than WHR.[46]

In a national cohort of 8,545 U.S. adults from the National Health and Nutrition Examination Survey[47] Epidemiologic Follow-up Study, 5- < 8 kg, 11- < 20 kg and over 20 kg weight gains were associated with a 2.1-fold, 2.6-fold, and 3.9-fold increased risk of incident diabetes during the 9-year follow-up, respectively, compared with participants whose weights remained relatively stable. The authors found no evidence that the results differed by age, sex, or race. They estimated that the population attributated risk was 27% for weight increases of 5 kg or more.

Of an age- and sex-stratified random sample of 1,000 individuals aged 40-79 years, the Bruneck Study confirmed that BMI was a predictor of incident diabetes, independently of other components of MetS such as IFG, IGT, insulin resistance, hypertension, and dyslipidaemia.[48]

Insulin resistance

In a prospective study of Pima Indians the 90th percentile of fasting insulin level was associated with a 15.8-fold increased risk of incident diabetes compared with the 10th percentile adjusted only for gender.[49]

Many studies have shown that hyperinsulinemia and/or insulin resistance are related to various metabolic and physiological disorders including hypertension, dyslipidemia, and non-insulin-dependent diabetes mellitus. This syndrome has been termed Syndrome X. An important limitation of previous studies has been that they all have been cross sectional, and thus the presence of insulin resistance could be a

consequence of the underlying metabolic disorders rather than its cause. We examined the relationship of fasting insulin concentration (as an indicator of insulin resistance) to the incidence of multiple metabolic abnormalities in the 8-yr follow-up of the cohort enrolled in the San Antonio Heart Study, a population-based study of diabetes and cardiovascular disease in Mexican Americans and non-Hispanic whites. In univariate analyses, fasting insulin was related to the incidence of the following conditions: hypertension, decreased high-density lipoprotein cholesterol concentration, increased triglyceride concentration, and non-insulin-dependent diabetes mellitus. Hyperinsulinemia was not related to increased low-density lipoprotein or total cholesterol concentration. In multivariate analyses, after adjustment for obesity and body fat distribution, fasting insulin continued to be significantly related to the incidence of decreased high-density lipoprotein cholesterol and increased triglyceride concentrations and to the incidence of non-insulin-dependent diabetes mellitus. Baseline insulin concentrations were higher in subjects who subsequently developed multiple metabolic disorders. These results were not attributable to differences in baseline obesity and were similar in Mexican Americans and non-Hispanic whites. These results support the existence of a metabolic syndrome and the relationship of that syndrome to multiple metabolic disorders by showing that elevations of insulin concentration precede the development of numerous metabolic disorders.[50]

The relationship between insulin sensitivity and overall obesity is well established. Furthermore, visceral abdominal tissue (VAT) and subcutaneous abdominal tissue (SAT), which were measured from computed tomography scans performed at the L4/L5 vertebral region, and their joint interactions were each inversely and significantly associated with ISI, adjusting for age, sex, ethnicity, and

BMI. SAT, but not VAT, was positively associated with acute insulin response (AIR). Thus, fat distribution is an important determinant of both insulin resistance and insulin secretion.[51]

The NHANES II (National Health and Nutrition Examination Survey II) study[52] found obese women to be four times more likely to develop diastolic hypertension than non-obese women.

In the Framingham population,[53] weight gain had a stronger relationship with blood pressure in males than in females.

There appears to be a consensus that obesity is an important risk factor of type 2 diabetes.[54]

Waist-to-hip ratio (WHR)

Waist-to-hip ratio (WHR), waist circumference (WC) or sagittal abdominal diameter (the height of the abdomen when the patient is in the supine position) are additional measures used in clinical practice to derive estimates of fat distribution.[55] It is thought that WC represents visceral and subcutaneous fat while hip circumference reflects subcutaneous fat only. With this in mind, it is not surprising that Ashwell et al.[56] found a significant correlation between the WHR and the ratio of VAT-to-SAT cross-sectional area (quantified by CT images taken in the abdominal region). In other words, an elevated WHR ratio is associated with a high proportion of intra-abdominal fat. Despite this association, Ashwell and his colleagues[56] did not find a significant correlation between VAT-to-SAT ratios and degree of generalised obesity, which may be attributed to the imprecision of the WHR approach. However, a recent study found WC to be the most reliable surrogate of visceral adiposity across a wide age range in a population with a high incidence of the metabolic syndrome.[57]

In adult men and women, the proportion of the body representing intra-abdominal fat was found to increase with age, whereas subcutaneous fat cross-sectional areas had a tendency to increase with the degree of obesity but not with age.[58] Interestingly, men are reported to have a significantly higher percentage of VAT than women.[57] From anthropometric measurements, BMI and WC have demonstrated similar correlations to total, visceral and subcutaneous fat areas in all age categories, whereas correlations between skin-fold measures and intra-abdominal fat areas become weaker with increasing age.[58] Kvist et al.[42] examined several relationships between total and visceral fat tissue volumes measured by CT and compared these measurements against BMI and various diameters, circumferences and subcutaneous fat thicknesses of the trunk. They found BMI to be the single superior predictor for total adipose tissue volume with errors of up to 11%. For the prediction of VAT volume, simple equations based entirely on the diameter of the trunk at the third to fifth lumbar vertebrae resulted in up to a 21% variation in both sexes.

Kullberg et al.[59] found a strong correlation between anthropometric measurements and, in particular, abdominal diameters and VAT assessed with MRI; however, since these measures are usually performed in standing position and MRI images are obtained in a supine position, there are challenges when comparing the two measures. Although anthropometric measurements, such as WHR and sagittal abdominal diameter, are simple and quick indicators of visceral fat accumulation, these indices were fundamentally inaccurate in predicting VAT.[40]

International criteria for body mass index (BMI) suggest the following: Underweight (<18.5 kg/m^2), normal weight (18.5-24.9 kg/m^2), overweight (25-29.9

kg/m^2), and obesity (>30 kg/m^2).[60] But the revised guidelines for diagnosis of obesity in Asian Indian populations are: A normal BMI of 18.0-22.9 kg/m^2, an overweight BMI of 23.0-24.9 kg/m^2, and obesity of BMI greater than or equal to 25 kg/m^2. The healthy waist circumference (WC) limits are 90 cm for men and 80 cm for women.[61] Diabetes and its complications pose a major public health concern worldwide and are a major challenge to patients, health-care systems, and national economies. Usually, BMI has been used as a measure to diagnose obesity. Other types of anthropometric measures like WC, waist to hip ratio (W/H), and index of central obesity (ICO) have all been associated with increased body fat and have predicted the distribution of body fat.[62]

Shah A. et al.[63] in 2009 to find out WHR and WC as predictor of Type 2 DM in the population of Kavre district of Nepal studied 65 "known type 2 diabetic" and Thirty-five "self-reported non-diabetic" subjects above thirty years of age were included in the present study. Height, Weight, Waist Circumference and Hip Circumference were recorded for every subject. BMI and WHR were calculated by the standard formula. The data was analyzed using SPSS Evaluation Version 15.0 and STATA Special Edition Version 8.2. Our results showed that the optimal cut-off values for WHR, WC. BMI and age in female are 0.87, 0.85 cms, 21.40 kg/m2 and 40 years respectively and for male the respective values are 0.96, 0.87 cms, 23.63 kg/m2 and 44 years. In female, age (82.9%) is the strongest predictor followed by WHR (78.1%), WC (70.2%) and least for BMI (55.0%) whereas for male WC (87.0%) is the strongest followed by WHR (81.6%), BMI (68.5%) and least: for age (6.4.6%) using Receiver Operating Characteristic (ROC) curves. Optimum sensitivity and specificity obtained from the ROC curves corresponded to these cutoff values and area under curve for their predictive ability. This study showed that the WC and WHR are the

best predictors of type 2 DM in both male and female population of Kavre district.

Qiao Q and Nyamdorj R.[64] reviewed 17 prospective and 35 cross-sectional studies among adults aged 18-74 years, with the aim of comparing between body mass index (BMI), waist circumference (WC) and waist-to-hip ratio (WHR) in their relation to the incidence and prevalence of type II diabetes. Among these studies, only a few have used C-statistic, paired homogeneity test or log-likelihood ratio test for formally comparing the differences. Five prospective studies, in which formal statistic tests have been made, came out with inconsistent findings: two results were in favour of WC in Mexicans African Americanss, respectively, one result was in favour of BMI in Pima Indians, and no difference was found in the other 2 studies. Among the 11 cross-sectional studies that have formally tested the differences, most found a higher odds ratio or slightly larger area under the ROC curve (AUC) for WC than for BMI. A meta-analysis based on the individual data of the Asian cohorts using a paired homogeneity test showed, however, that there was no difference in odds ratio between BMI and WC in Chinese, Japanese, Indian, Mongolian and Filipino men. In conclusion, all studies included in this review showed that either BMI or WC (WHR) predicted or was associated with type II diabetes independently, regardless of the controversial findings on which of these obesity indicators is better.

Neck circumference

Visceral adipose tissue (VAT) is recognized as a unique, pathogenic fat depot, conferring metabolic risk above and beyond standard anthropometric measures, such as body mass index (BMI) and waist circumference.[65]

Individuals with large amounts of visceral fat are at increased risk of insulin resistance, type 2 diabetes, and atherosclerosis. However, VAT accounts for only modest correlations between cardiometabolic risk factors, suggesting that other mechanisms, or other fat depots, may also contribute to the development of cardiovascular disease (CVD) risk factors.[66]

Upper body SC fat, as estimated by neck circumference, may confer risk above and beyond visceral abdominal fat. Anatomically, upper-body SC fat is a unique fat depot located in a separate compartment compared with VAT. Systemic free fatty acid concentrations are primarily determined by upper-body SC fat, suggesting that this fat depot may play an important role in risk factor pathogenesis. Elevated free fatty acid concentrations have been associated with insulin resistance, increased very-low-density lipoprotein cholesterol production, and endothelial cell dysfunction.[66]

Recent research has focused extensively on body composition and CVD risk. Emphasis has been placed on whether an individual has an upper-body or lower-body fat distribution or what proportion of fat is stored in visceral *vs.* SC fat depots. Typically, central obesity, particularly high levels of upper-body visceral fat, is associated with adverse metabolic outcomes such as insulin resistance, diabetes, hypertension, and elevated triglycerides, whereas individuals with lower-body obesity tend to have lower levels of these adverse metabolic outcomes.[67]

Upper-body SC fat is a novel, easily measured fat depot, which may be an important predictor of cardiometabolic risk. This fat depot may lead to a better understanding of the differential effects of adiposity in men and women.

Different body morphologies or types of fat distribution are related to the health risks associated with obesity. This was first shown by Jean Vague who himself used a neck skin fold in his index of masculine differentiation to assess upper-body fat distribution.[68] Neck circumference (NC), a measure of upper body obesity has been proposed as a useful indicator in different studies in the past.[69-71] These studies have shown that men with NC < 37 cm and women with NC < 34 cm have a low body mass index.[70]

NC measurement potentially has distinct cultural advantages. Due to cultural inhibitions measurement of hip, thigh or waist circumference is cumbersome in females. The specific research questions for this study are that among in-patients in medical wards, aged 35 years or more a) does a higher neck circumference also reflects a higher BMI or waist circumference; b) do those who are in highest tertile of neck circumference, as compared to those with in lowest tertile, have a higher prevalence of cardiovascular risk factors like hypertension and diabetes.[44]

Some studies[69-71] have indicated that neck circumference may be an independent correlate of metabolic risk factors above and beyond BMI and waist circumference. In addition, a small study of men demonstrated that higher levels of upper-body SC fat, as measured by magnetic resonance imaging, were associated with higher LDL and HDL cholesterol levels. However, studies examining the joint impact of neck circumference and VAT have not as yet been reported.[65]

Several previous studies have examined the association between neck circumference and cardiometabolic risk factors. However, none of these previous studies have compared neck circumference directly with VAT with respect to their association with cardiometabolic risk factors.[65]

In a first cross sectional study[70] in 2001 which was done to identify overweight or obese patients solely by measuring the circumference of the neck, it was seen that Men with NC <37 cm and women with NC <34 cm are not to be considered overweight. In this study they used a test sample and a second validation sample included 979 subjects (460 men and 519 women), who visited a family medicine clinic in a southern Israeli urban district for any reason. They observed that NC >37 cm for men and >34 cm for women were the best cutoff levels for determining the subjects with BMI >25.0 kg/m2 using the receiver output curve analysis. In the validation unrelated group, the test characteristics were excellent with 98% sensitivity, 89% specificity, and 94% accuracy for men, and 100% sensitivity, 98% specificity, and 99% accuracy for women. In this study they also observed same characteristics as NC 38 cm for men and 34.7 cm for women identified subjects with BMI >25.0 kg/m2 with 75% to 86% sensitivity for men and 63% to 93% for women, 80% to 90% specificity for men and 80% to 100% for women.

The author[72] once again in 2004 observed relationship between changes in neck circumference and changes in blood pressure. In this longitudinal cohort study the study group was comprised of 364 subjects (155 men and 209 women) with no known major medical conditions who were not receiving any medication therapy. They found that changes in systolic BP and diastolic BP correlated positively with changes in NC and other components of the metabolic syndrome.

In a cross-sectional study of 43,595 women participating in the Take Off Pounds Sensibly (TOPS) Club, those with a self-reported neck circumference in the top tertile were found to have a 2-fold increased risk of diabetes relative to those in the bottom tertile, even after adjustment for multiple other measures of adiposity.[73]

In a cross-sectional analysis of 541 Finnish individuals, neck circumference in the highest quintile was associated with nearly a 5-fold increased risk of impaired fasting glucose in women after adjustment for BMI.[74] No association was seen for men.

Additionally, neck circumference was associated with approximately a 3-fold increased OR of hypertension, after adjustment for BMI, in both men and women. Although neck circumference is a proxy measure for upper-body SC fat, only one study has examined the association of upper-body SC fat as measured by MRI.[66]

Among 258 men from the control group of the Fat Redistribution and Metabolic Change in HIV Infection study, upper-body SC fat was shown to be independently associated with insulin resistance even after adjustment for VAT.[75]

Additional analyses of 145 control participants from the Fat Redistribution and Metabolic study showed that increased levels of upper-body SC fat were positively associated with LDL cholesterol and inversely associated with HDL cholesterol levels, after adjustment for demographic and lifestyle factors.[76]

One interesting finding from a study was a greater association of neck circumference with cardiometabolic risk factors in women compared with men. This differential effect of neck circumference by sex has previously been observed.[71]

Previous analyses in the Framingham Heart Study have also shown that fat depots, especially VAT, are more strongly associated with an adverse risk factor profile in women compared with men.[65]

The mechanisms by which there is a stronger adverse effect associated with increased body fat in women are unknown. However, it has been suggested that in

women, there is a greater proportion of free fatty acid delivery to the liver from VAT than in men.[66]

Obesity and elevated levels of plasma free fatty acids are associated with insulin resistance and increased very-low-density lipoprotein triglyceride production. Increased levels of free fatty acids have also been correlated with markers of oxidative stress and vascular injury and are associated with the development of hypertension. Much of the literature has focused on the adverse effects of visceral fat; however, whereas visceral fat may be a marker for excess free fatty acids, it is not the primary source of circulating levels. It has been demonstrated that upper-body SC fat is responsible for a much larger proportion of systemic free fatty acid release than visceral fat, particularly in obese individuals.[66]

Obese men and women have a 2- to 3-fold larger fraction of fatty acids stored in SC fat compared with normal-weight men and women.[66] The excess free fatty acid release associated with upper-body SC fat may be one mechanism to explain the association between neck circumference and cardiometabolic risk. Although free fatty acid release from upper-body SC fat is the primary contributor of abnormal free fatty acid metabolism in obese individuals, lipolysis of VAT is also an important contributor to hepatic free fatty acid delivery, which may explain why there is an interaction between neck circumference and VAT.[66]

Differences in free fatty acid metabolism between men and women may explain the sex differences observed in the relationship between neck circumference and cardiometabolic risk factors. It has been shown that women store a much larger proportion of free fatty acids in SC tissue than do men.[66]

This difference in free fatty acid storage between men and women may account for the stronger association found between neck circumference and cardiometabolic risk factors among women.[66]

A study[44] from India hypothesized that NC (primary outcome measure) could be a predictor of obesity and overweight in rural Indian population and that higher tertile of neck circumference may be associated with higher prevalence of cardiovascular risk factors like hypertension and diabetes (secondary outcome measure). After adjustment for age, weight and height, significant association was found between NC and conventional overweight and obesity indexes. Authors also found that higher tertile of NC correlated positively with the presence of cardiovascular risk factors like hypertension and diabetes. A study concluded that, NC may be used as a simple and time-saving screening measure to identify overweight and obese patients. Men with NC <36.6 cm and women with NC <32.1 cm are not to be considered overweight. Patients with NC >36.6 cm for men and >32.1 cm for women require additional evaluation of overweight or obesity status.

In a study[44] from India significant negative correlation was found between NC and height among women, but not in men. This finding can be explained by differences in bodily structures between men and women especially in rural area of India. It seems, therefore, that with an increase in NC, the likelihood of risk factors for cardiovascular disease also increases.

These observations indicate that NC as an index of upper body fat distribution can be used to identify overweight and obese patients. Results of these studies, performed by various set of investigators, have not been externally validated. In India study of neck circumference as a measure of obesity and metabolic syndrome has not

been done. NC measurement potentially has distinct cultural advantages. Due to cultural inhibitions measurement of hip, thigh or waist circumference is cumbersome in females. In contrast measurement of NC is a simple, time saving, and least invasive measurement tool.

Neck circumference (NC) is a relatively new method of differentiating between normal and abnormal fat distribution. It is a marker of upper body subcutaneous (SC) adipose tissue distribution. Adipose tissue is found in specific locations, which are referred to as adipose depots. Adipose tissue contains several cell types, with the highest percentage of cells being adipocytes, which contain fat droplets. Upper body obesity characterized by upper body SC fat is related to metabolic disorders like glucose intolerance, diabetes, hypertriglycerdemia, etc., Free fatty acid release from this upper body SC fat was reported to be larger than that from lower body SC fat.[77] As a result of insulin resistance in adipose tissue, lipolysis and free fatty acid flux from adipocytes are increased, leading to increased lipid [very low density lipoprotein (VLDL) and triglyceride] synthesis in hepatocytes. This lipid storage or steatosis in the liver may lead to nonalcoholic fatty liver disease and abnormal liver function tests. This is also responsible for the dyslipidemia found in type 2 DM.[7] It has been shown that NC >37 cm in men and NC >34 cm in women are probably the best cutoff points to determine subjects with central obesity.[78]

More recently Ashwathappa J et al.[62] in 2013 compared NC in diabetics and non-diabetics and to correlate NC with other anthropometric measure in a A cross-sectional study among 350 type 2 diabetics and 350 non-diabetics of >30 years of age. Anthropometric parameters like body mass index (BMI), waist circumference (WC), hip circumference, and NC were measured. There was positive correlation of NC,

BMI, and index of central obesity. The NC in diabetics was significantly higher than in non-diabetics ($P < 0.001$). NC >36 cm in diabetics and >37 cm in non-diabetics was the best cutoff value to determine subjects with central obesity. These findings indicated that NC may be used both in clinical practice and in epidemiologic studies as a straightforward and reliable index. It is an economical easy to use test with less consumption of time and correlates well with other standard anthropometric parameters.

Li HX et al.[79] in 2014 investigated the usefulness of neck circumference (NC) to indicate Visceral adipose tissue (VAT). Participants aged 35 to 75 years who had taken abdomen and neck computer tomography (CT) examination were included in this study. Neck adipose tissue, abdominal VAT and subcutaneous adipose tissue (SAT) areas, as well as sagittal abdominal diameter (SAD) were measured by CT. Body anthropometrics and metabolic parameters including blood glucose, lipid profiles and blood pressure were also measured. A lower abdomen CT examination was carried out on a total of 177 patients (87 male and 90 female) with a mean age of 59 years. Of the 177 participants, 15 men and 15 women also took a neck CT examination. With a comparable age and BMI, neck adipose area was correlated with abdominal VAT area significantly in men ($r = 0.57$, $p = 0.028$) and women ($r = 0.53$, $p = 0.041$). NC is positively correlated with VAT both in men ($r = 0.49$, $p < 0.001$) and women ($r = 0.25$, $p = 0.012$). Meanwhile, SAD is the best predictor for visceral fat both in men ($r = 0.83$, $p < 0.001$) and women ($r = 0.73$, $p < 0.001$). Body mass index (BMI), waist circumference (WC), and waist to height ratio (WHtR) correlated significantly with VAT both in men and women ($r = 0.68$, 0.42, 0.46 in men and 0.50, 0.23, 0.39 in women, $p < 0.001$), while waist hip ratio (WHR) displayed the weakest least correlation in men ($r = 0.32$, $p = 0.001$) and no correlation in women ($r = 0.08$,

$p = 0.442$). Additionally, BMI was more strongly correlated with VAT than NC in both sexes (both $p < 0.01$). Authors concluded that Significant correlation between NC and VAT was present in Chinese men and women, which may be accounted by the fact that neck fat area is significantly correlated with abdominal VAT. Meanwhile, SAD is the best predictor for visceral fat in the Chinese population.

Yang GR et al.[78] in 2010 investigated the association between neck circumference and central obesity, overweight, and metabolic syndrome in Chinese individuals with type 2 diabetes. A total of 3,182 diabetic subjects (aged 20–80 years) were recruited from 15 community health centers in Beijing using a multistage random sampling approach. Receiver operating characteristic analysis showed that the area under the curve for neck circumference and central obesity was 0.77 for men and 0.75 for women ($P < 0.001$). Furthermore, a neck circumference of ≥38 cm for men and ≥35 cm for women was the best cutoff point for determining overweight subjects. A neck circumference of ≥39 cm for men and ≥35 cm for women was the best cutoff point to determine subjects with metabolic syndrome. It was observed that, neck circumference is positively related with BMI, waist circumference, and metabolic syndrome in Chinese individuals with type 2 diabetes.

Freedman DS and Rimm AA[80] reported that, independently of the amount of adipose tissue, certain patterns of fat distribution increase the risk of non-insulin-dependent diabetes. Although the ratio of waist to hip (WHR) circumferences has been consistently related to diabetes mellitus, it is possible that only two measures do not completely characterize fat topography. Earlier in their study during 1989 authors, examined the cross-sectional relation of six girths (waist, hip, neck, bust, wrist, and ankle) to diabetes mellitus in 43,595 women. As compared with non-diabetics,

Quetelet index (kg/m2) and all circumferences were elevated among diabetics. Stratified analyses showed that WHR, and waist, neck, and bust girths were consistently related to diabetes independently of the degree of overweight. As estimated from a logistic regression model that simultaneously controlled for age and all anthropometric variables, the prevalence of diabetes mellitus was positively related to Quetelet index, and to the waist, bust, and neck girths, with odds ratios (ORs) ranging from 1.4 to 2.6. However, diabetes was inversely related to hip (OR = 0.61) and ankle (OR = 0.73) girths; p less than 0.005 for each association. Although cross-sectional in nature, these results suggest that an adverse body fat distribution is not limited to the abdominal region, but that a relative preponderance of adipose tissue in various regions of the upper body is associated with diabetes mellitus in women.

METHODOLOGY

The present study was conducted in the Department of Medicine, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belgaum from January 2015 to December 2016.

Study design and duration

The study design was a hospital based cross-sectional study.

Study period

The present study was done for the period of one year from January 2015 to December 2015.

Place

The present study was carried out in the Department of Medicine, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belgaum a tertiary care teaching hospital attached to Jawaharlal Nehru Medical College, Belgaum.

Source of Data

Patients presenting with type 2 diabetes mellitus in the Department of General Medicine, KLES Dr Prabhakar Kore Hospital and MRC, Belgaum were studied

Sample size

A total of 100 patients with type 2 diabetes mellitus were studied.

Sampling procedure

The sample size was calculated using the following formula as below.

Sample Size $Y = a+b_1x_1+b_2x_2+---------b_nx_n$

Where,

Y = Dependent variable

a = Constant

b = regression co-efficients

x = independent variables

Hence the sample size of 100 was considered for this study.

Sample Method

All consecutive patients fulfilling the selection criteria were included in the study.

Selection criteria

Inclusion Criteria

- Patients aged 18 and above.
- Patients with type 2 diabetes mellitus.

Exclusion Criteria

- Known case of type 1 diabetes mellitus.
- Diagnosed case of thyroid disease.
- History of using corticosteroids.
- Current treatment with statins and glucocorticoids.
- Cushing's syndrome or other disorders of pituitary or adrenal glands.
- Substantial weight gain / loss

Ethical clearance

The study was approved by the Institutional Ethics Committee, Jawaharlal Nehru Medical College, Belgaum prior to the commencement.

Informed consent

The patients who fulfilled the selection criteria were informed about the nature of study and a written informed consent was obtained (Annexure–I).

Data collection

The selected patients were interviewed for demographic data, the history of presenting illness and other comorbid conditions. Further these patients underwent clinical examination followed by systemic examination. All these findings were noted on a predesigned and pretested proforma (Annexure-II).

Investigations

Venous blood samples (10ml) were collected from the selected patients and were subjected following investigations.

- Fasting blood sugar (FBS).
- Post prandial blood sugar (PPBS).
- Glycosylated haemoglobin (HbA1c)
- Lipid profile
- Serum insulin levels

Outcome variables

BODY MASS INDEX

For the calculation of body mass index, height was obtained in cms using standard protocols. Body weight was measured using standardized equipment to the nearest 100 g. and height was measured by stadiometer. Body mass index was calculated based on formula;

$$\text{Body Mass Index} = \frac{\text{Weight (Kg)}}{\text{Height}^2 \text{ (m)}}$$

Body mass index was classified according to Overweight and obesity by BMI in adult Asians as below.[81]

Classification	**BMI (Kg/m^2)**	**Risk of co-morbidities**
Underweight	< 18.5	Low (But increased risk of other clinical problems
Normal range	18.5 to 22.9	Average
Overweight	≥ 23	
At risk	23.0 to 24.9	Increased
Obese I	25.0 to 29.9	Moderate
Obese II	≥ 30.0	Severe

WAIST CIRCUMFERENCE

The waist circumference was measured using a standard measuring tape in cms. Waist circumference of > 85 cms in males and > 80 cms in females was considered abnormal.

WAIST-TO-HIP RATIO

The WHR was calculated as;

$$\text{WHR} = \frac{\text{Waist circumference (Cms)}}{\text{Maximum hip circumference (Cms)}}$$

Waist hip ratio of less than 0.9 in males and 0.85 in females was considered as normal.[82]

NECK CIRCUMFERENCE

Neck circumference was measured to the nearest 0.1 centimeter just below the laryngeal prominence (Adam's apple) perpendicular to the long axis of neck in both sexes with the subjects standing upright, with shoulders relaxed using flexible measuring tapes. Neck circumference of ≥ 37 cms in males and ≥ 34 cms in females was considered abnormal.[70]

INTER-SCAPULAR SKIN THICKNESS

Inter-scapular skin thickness is measured at the level of inferior angle of the scapula using the harpenden calipers to the nearest cm possible. Inter-scapular skin thickness of ≥ 2.2 cms is considered abnormal in both males and females.

LIPID PROFILE

Based on NCEP (National Cholesterol Education Program) guidelines[83] normal values of lipid parameters were;

- Low density lipoprotein < 100 mg/dL.
- High density lipoprotein;
    - Female > 50 mg/dL.
    - Males > 40 mg/dL.
- Total Cholesterol < 200 mg/dL.
- Triglycerides < 150 mg/dL.

HOMA IR

Fasting blood sample was drawn for measuring plasma insulin levels and insulin levels were measured by microparticle enzyme immune assay (MEIA) method. Insulin resistance was calculated by HOMA;

$$\frac{\text{Fasting Insulin } \mu\text{U/L X Fasting plasma glucose mmol/L}}{22.5}$$

Subjects also underwent other investigations like fasting lipid profile.

Patients were considered as insulin resistant if HOMA IR was more than 2.41.[84]

Statistical methods

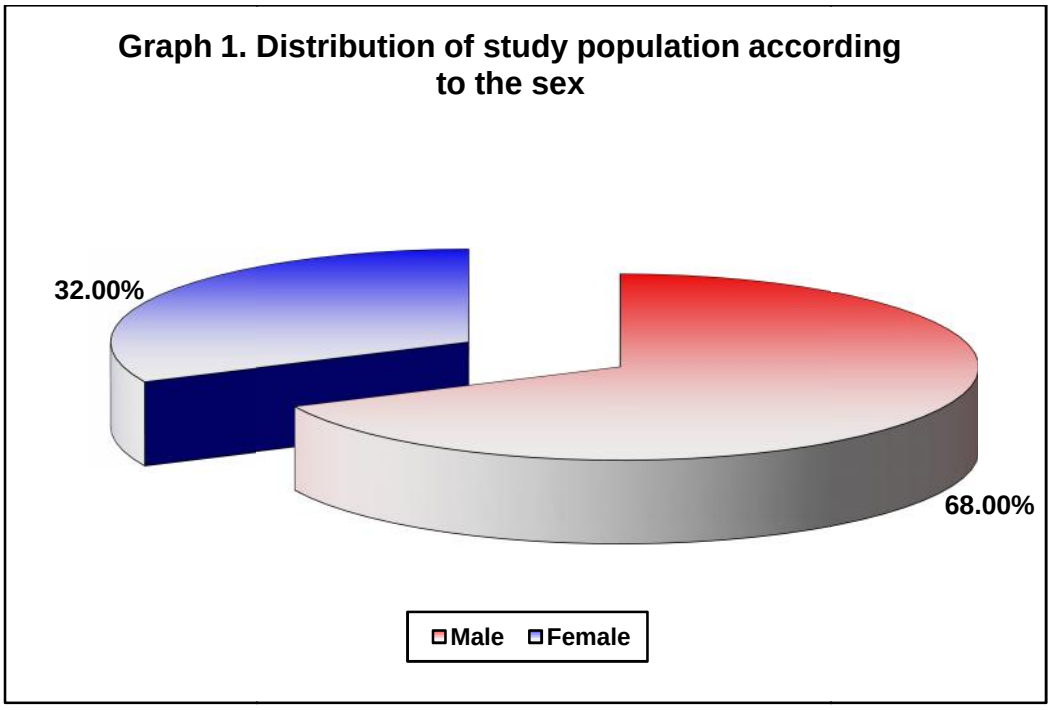
The data obtained was coded and entered into Microsoft excel spreadsheet and data was analyzed using SPSS version 21. The categorical data was expressed in terms of rates, ratios and percentages and the continuous data was expressed in terms of mean ± standard deviation. Continuous data was compared using independent sample 't' test. Correlation between blood glucose levels, HOMA IR and Neck circumference was tested with Pearson's correlation coefficient. At 95% confidence interval, a probability (p) value of ≤ 0.050 was considered as statistically significant.

RESULTS

The present hospital based cross-sectional study was conducted in the Department of Medicine, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belgaum from January 2016 to December 2016. A total of 100 Patients presenting with type 2 diabetes mellitus were studied. The data obtained was analyzed and the final observations were tabulated as below.

Table 1. Distribution of study population according to the sex

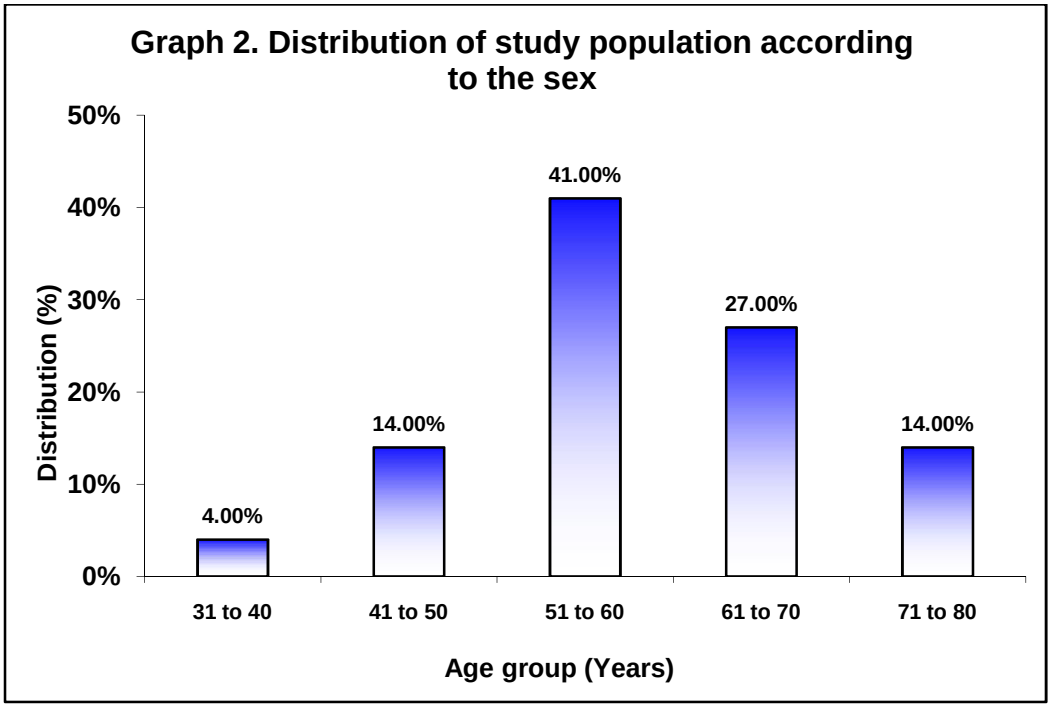
Sex	Distribution (n=100)	
	Number	**Percentage**
Male	68	68.00
Female	32	32.00
Total	**100**	**100.00**



In the present study 68.00%, majority of patients were males and 32% of the patients were females. The male female ratio was 2.12:1.

Table 2. Distribution of study population according to the age

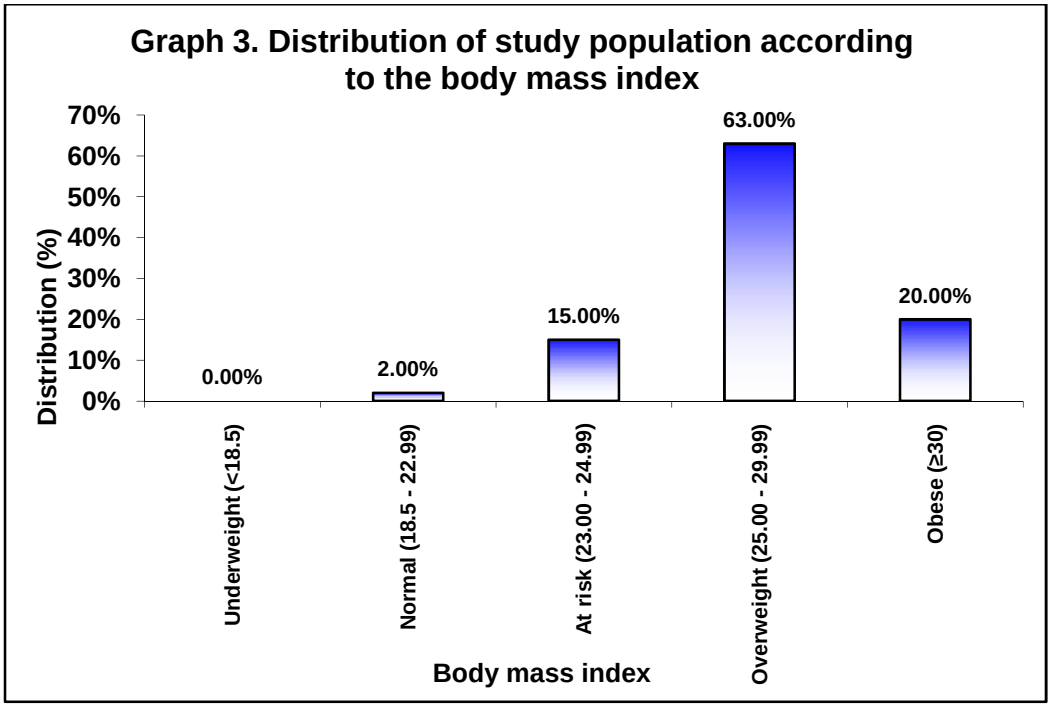
Age group (Years)	Distribution (n=100)	
	Number	**Percentage**
31 to 40	4	4.00
41 to 50	14	14.00
51 to 60	41	41.00
61 to70	27	27.00
71 to 80	14	14.00
Total	**100**	**100.00**
Mean ± SD	**58.98 ± 9.86 years**	
Median (Range)	**57.5 (31-80)**	



In this study most of the patients (41%) were aged between 51 to 60 years followed by 61 to 70 years (27%). The mean age was 58.98 ± 9.86 years and median age was 57.5 years with range 31 being minimum and 80 being maximum.

Table 3. Distribution of study population according to the body mass index

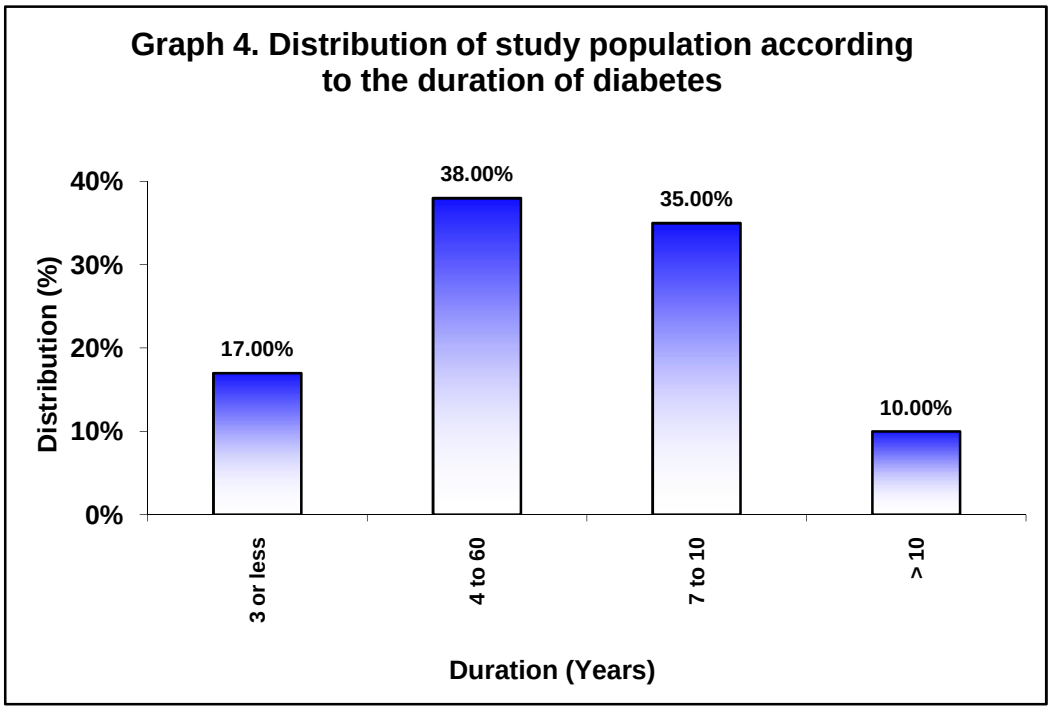
Body mass index	Distribution (n=100)	
	Number	Percentage
Underweight (<18.5)	0	0.00
Normal (18.5 -22.99)	2	2.00
At risk (23.00-24.99)	15	15.00
Overweight (25.00-29.99)	63	63.00
Obese (≥30)	20	20.00
Total	**100**	**100.00**
Mean ± SD	**28.34 ± 7.28 years**	
Median (Range)	**27.15 (21.8-37.17)**	



In the present study most of the patients i.e., 63% were overweight (25.00-29.99 kg/m^2) while 20% of the patients were obese (≥30 Kg/m^2). The mean BMI was 28.34±7.28 Kg/m^2 and median BMI was 27.15 Kg/m^2 with range 21.8 Kg/m^2 being minimum to 37.2 Kg/m^2 maximum.

Table 4. Distribution of study population according to the duration of diabetes

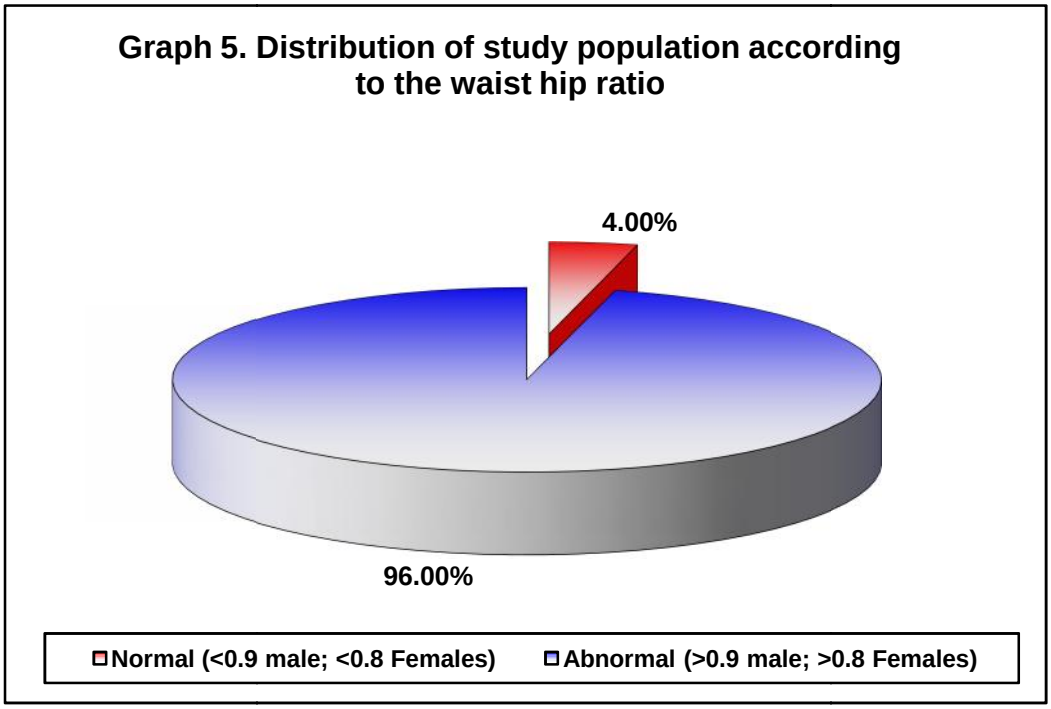
Duration (Years)	Distribution (n=100)	
	Number	Percentage
3 or less	17	17.00
4 to 6	38	38.00
7 to 10	35	35.00
> 10	10	10.00
Total	**100**	**100.00**
Mean ± SD	**6.50 ± 3.23**	
Median (Range)	**6 (1-16)**	



In this study 38% of the patients were reported duration of diabetes between 4 to 6 years. The mean duration of diabetes was 6.50 ± 3.23 years and median duration was 6 years with range 1 year being minimum and 16 years being maximum.

Table 5. Distribution of study population according to the waist hip ratio

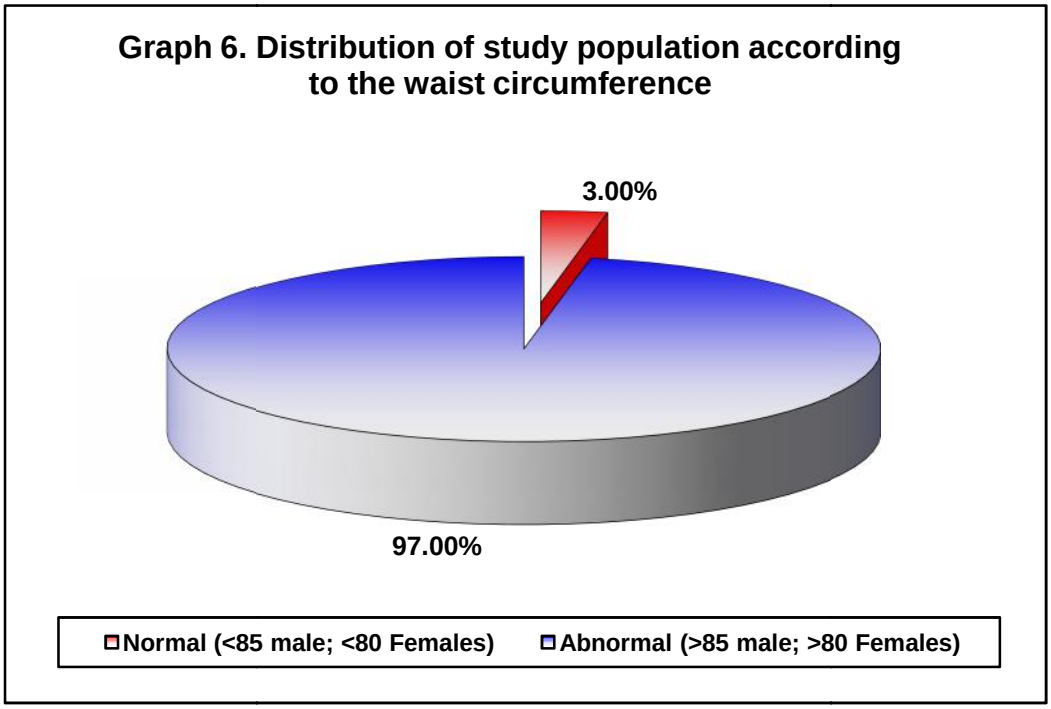
Waist circumference	Distribution (n=100)	
	Number	Percentage
Normal (<0.9 male; <0.8 Females)	4	4.00
Abnormal (>0.9 male; >0.8 Females)	96	96.00
Total	**100**	**100.00**
Mean ± SD	**1.21 ± 0.17**	
Median (Range)	**1.2 (0.87-1.65)**	



In the present study majority of the patients (96%) had abnormal waist hip ratio. The mean WHR was 1.21 ± 0.17 and median WHR was 1.2 with range 0.87 being minimum and 1.65 being maximum.

Table 6. Distribution of study population according to the waist circumference

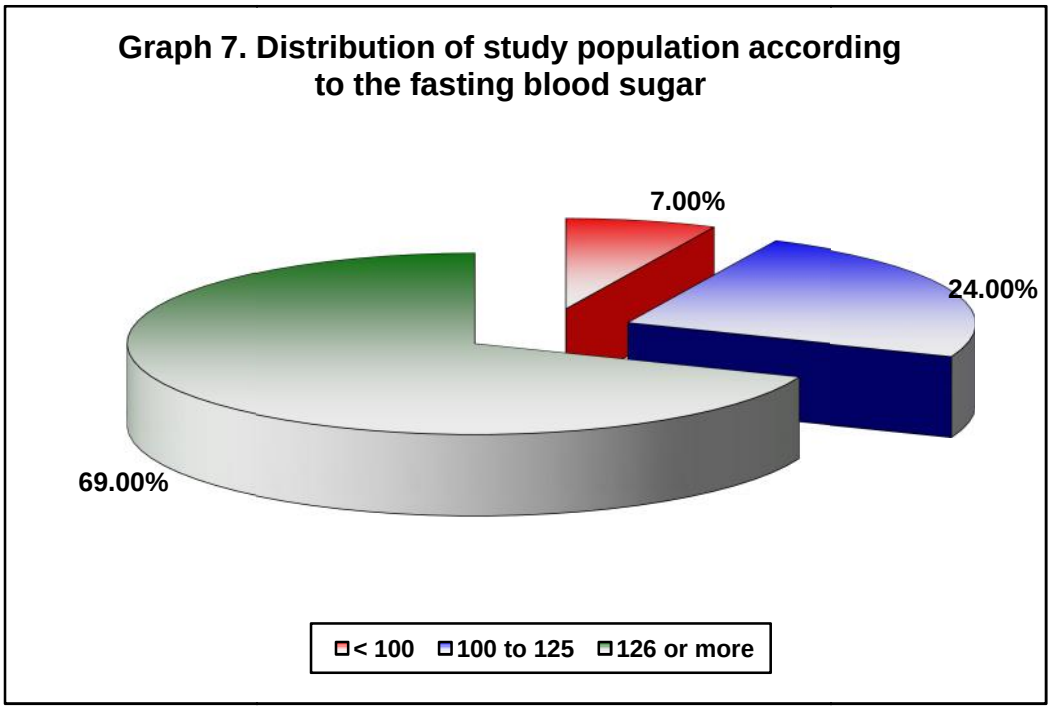
Waist circumference	Distribution (n=100)	
	Number	Percentage
Normal (<85 male; <80 Females)	97	97.00
Abnormal (>85 male; >80 Females)	3	3.00
Total	**100**	**100.00**
Mean ± SD	**96.90±7.77**	
Median (Range)	**98 (80-112)**	



In this study 97% of the patients had abnormal waist circumference. The mean waist circumference was 96.90±7.77 cms and median waist circumference was 98 cms with 80 cms being minimum and 112 cms being maximum.

Table 7. Distribution of study population according to the fasting blood sugar

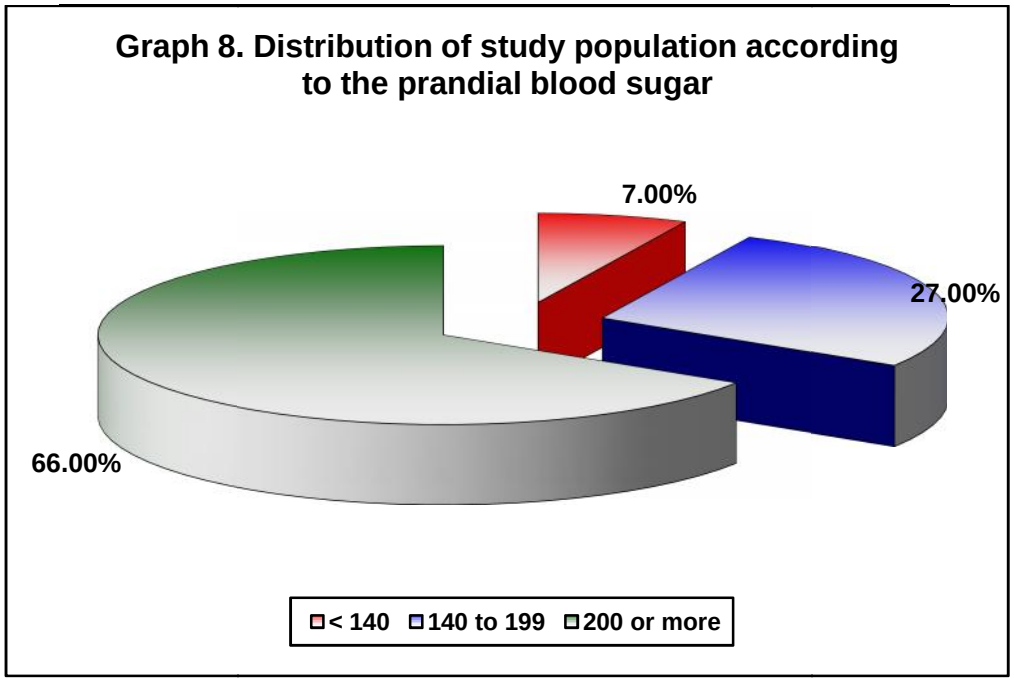
Fasting blood sugar (mg/dL)	Distribution (n=100)	
	Number	Percentage
<100	7	7.00
100 to 125	24	24.00
126 or more	69	69.00
Total	**100**	**100.00**
Mean ± SD	**163.67±70.87**	
Median (Range)	**148 (82-536)**	



In the present study majority of the patients (69%) had elevated fasting blood sugar levels (≥126 mg/dL). The mean FBS levels were 163.67±70.87 mg/dL and median FBS levels were 148 mg/dL with 82 mg/dL being minimum and 536 mg/dL being maximum.

Table 8. Distribution of study population according to the post prandial blood sugar

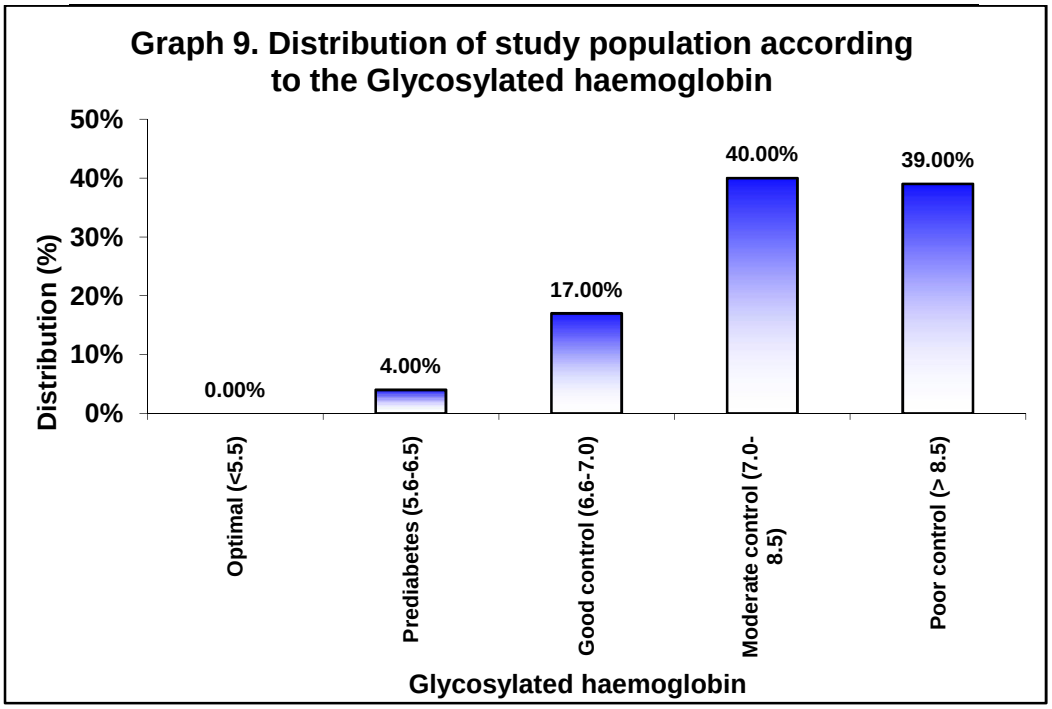
Post prandial blood sugar (mg/dL)	Distribution (n=100)	
	Number	Percentage
<140	7	7.00
140 to 199	27	27.00
200 or more	66	66.00
Total	**100**	**100.00**
Mean ± SD	**243.16 ± 87.75**	
Median (Range)	**227 (101-625)**	



In this study majority of the patients (66%) had elevated post prandial blood sugar levels (≥200 mg/dL). The mean PPBS levels were 243.16±87.75 mg/dL and median PPBS levels were 227 mg/dL with 101 mg/dL being minimum and 625 mg/dL being maximum.

Table 9. Distribution of study population according to the Glycosylated haemoglobin

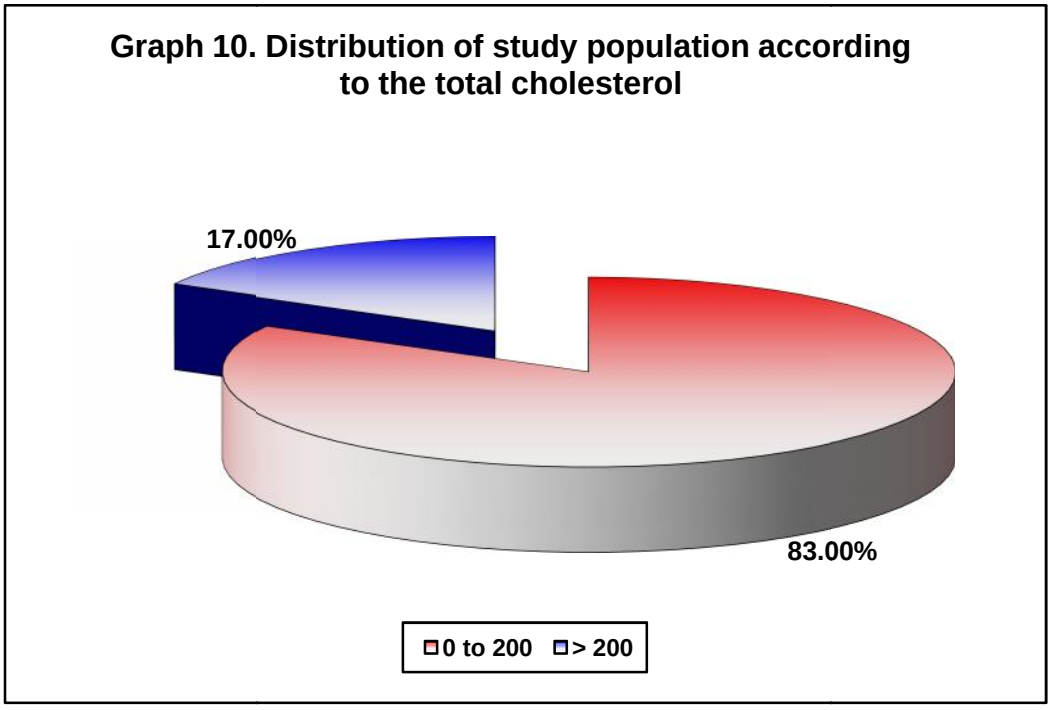
Glycosylated haemoglobin	Distribution (n=100)	
	Number	Percentage
Optimal (<5.5)	0	0.00
Prediabetes (5.6-6.5)	4	4.00
Good control (6.6-7.0)	17	17.00
Moderate control (7.0-8.5)	40	40.00
Poor control (> 8.5)	39	39.00
Total	**100**	**100.00**
Mean ± SD	**8.72 ± 2.08**	
Median (Range)	**8.2 (6.1-15.4)**	



In the present study 40% of the patients had HbA1c levels between7.0-8.5 and 39% of the patients had HbA1c levels of > 8.5. The mean HbA1c levels were 8.72 ± 2.08 and median HbA1c levels were 8.2 with 6.1 being minimum and 15.4 being maximum.

Table 10. Distribution of study population according to the total cholesterol

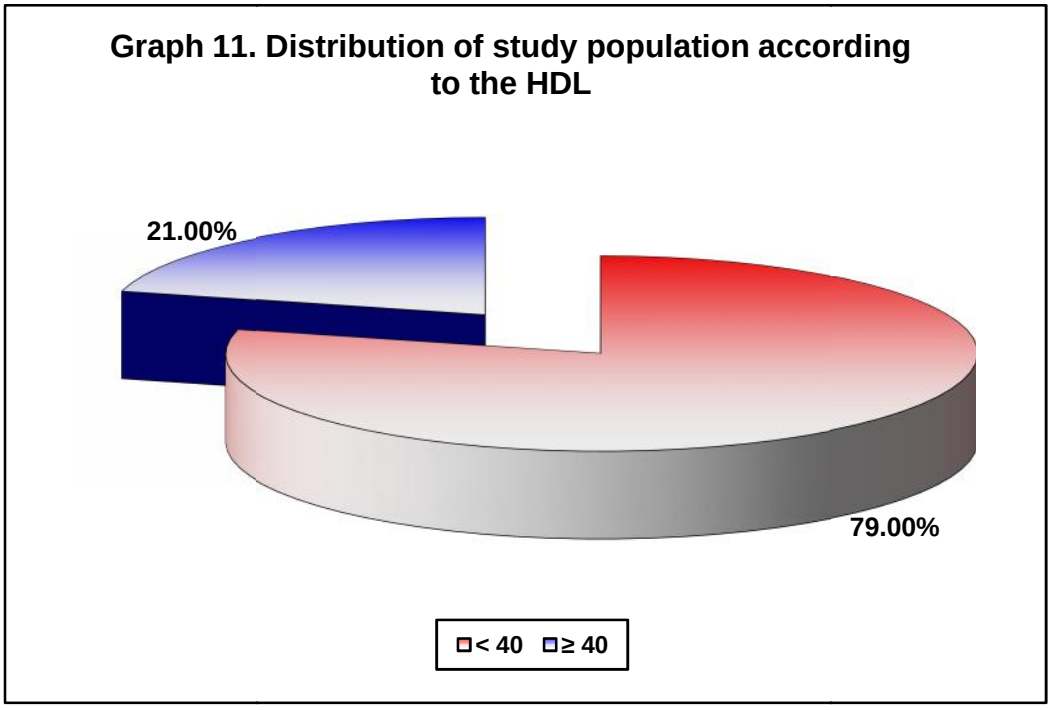
Total cholesterol (mg/dL)	Distribution (n=100)	
	Number	Percentage
0 to 200	83	83.00
> 200	17	17.00
Total	**100**	**100.00**
Mean ± SD	**165.67±41.35**	
Median (Range)	**162 (75-314)**	



In this study majority of the patients had normal total cholesterol levels (<200 mg/dL) while 17% of the patients had raised cholesterol levels (>200 mg/dL). The mean total cholesterol levels were 165.67±41.35 mg/dL and median total cholesterol levels were 162 mg/dL with 75 mg/dL being minimum and 314 mg/dL being maximum.

Table 11. Distribution of study population according to the HDL

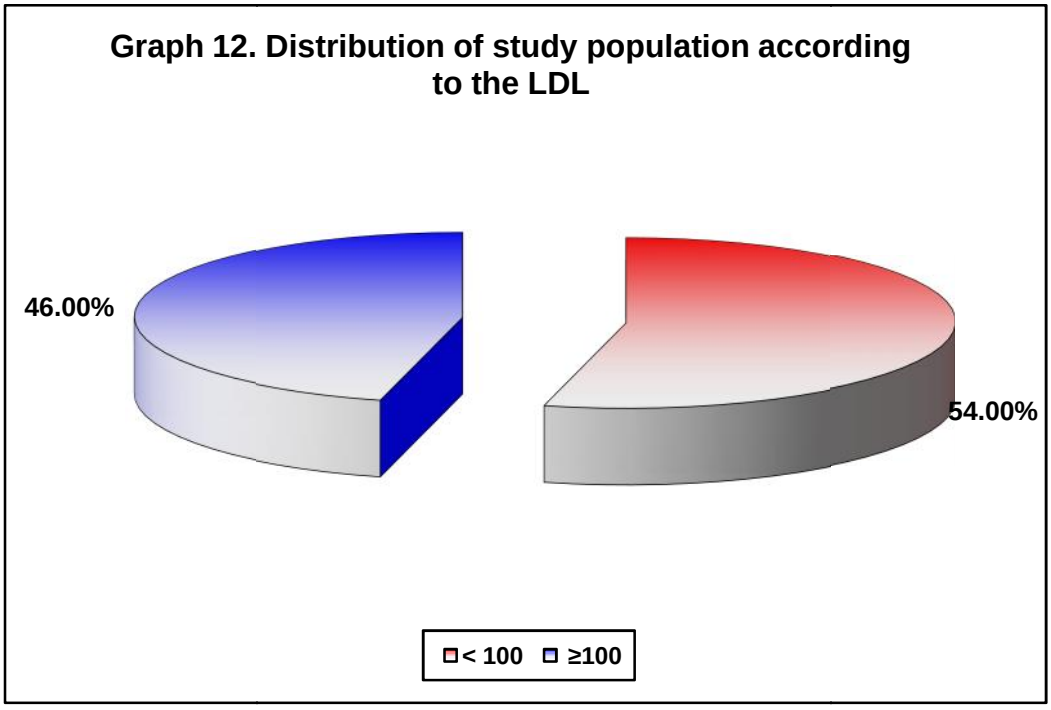
HDL (mg/dL)	Distribution (n=100)	
	Number	Percentage
< 40	79	79.00
≥ 40	21	21.00
Total	**100**	**100.00**
Mean ± SD	**34.09±7.83**	
Median (Range)	**32.5 (23-65)**	



In the present study 79% of the patients had low HDL (< 40 mg/dL). The mean HDL levels were 34.09±7.83 mg/dL and median HDL levels were 32.5 mg/dL with 23 mg/dL being minimum and 65 mg/dL being maximum.

Table 12. Distribution of study population according to the LDL

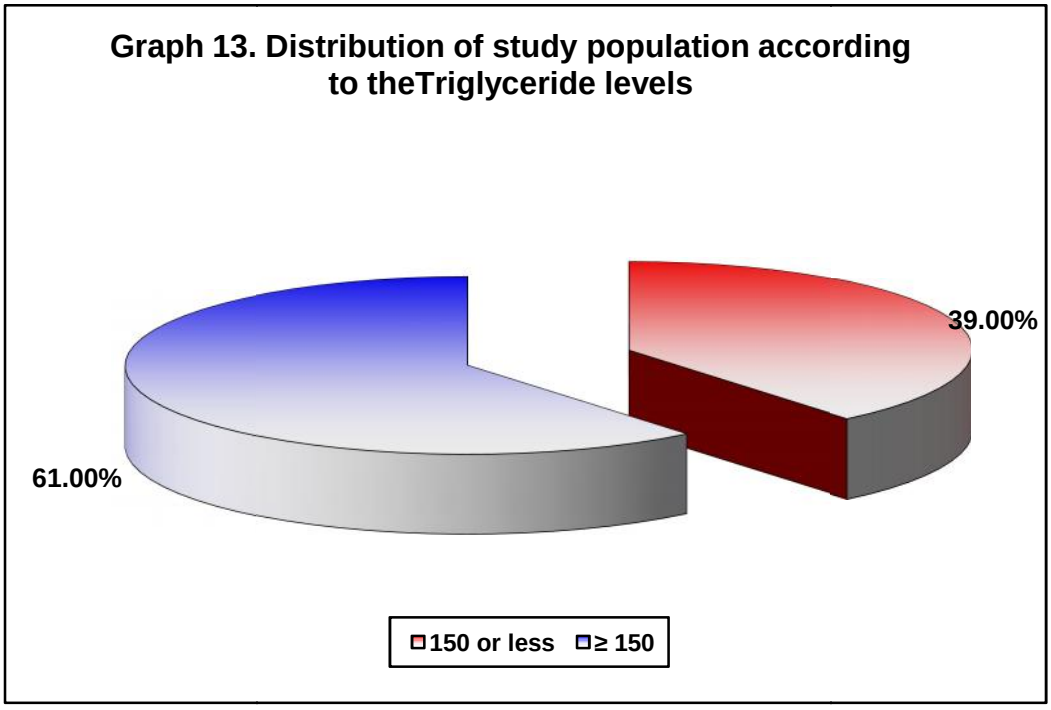
LDL (mg/dL)	Distribution (n=100)	
	Number	Percentage
< 100	54	54.00
≥100	46	46.00
Total	**100**	**100.00**
Mean ± SD	**95.13±39.87**	
Median (Range)	**93 (26-214)**	



In this study 46% of the patients had raised LDL levels (≥100 mg/dL). The mean LDL levels were 95.13± 39.87 mg/dL and median LDL levels were 93 mg/dL with 26 mg/dL being minimum and 214 mg/dL being maximum.

Table 13. Distribution of study population according to the Triglyceride levels

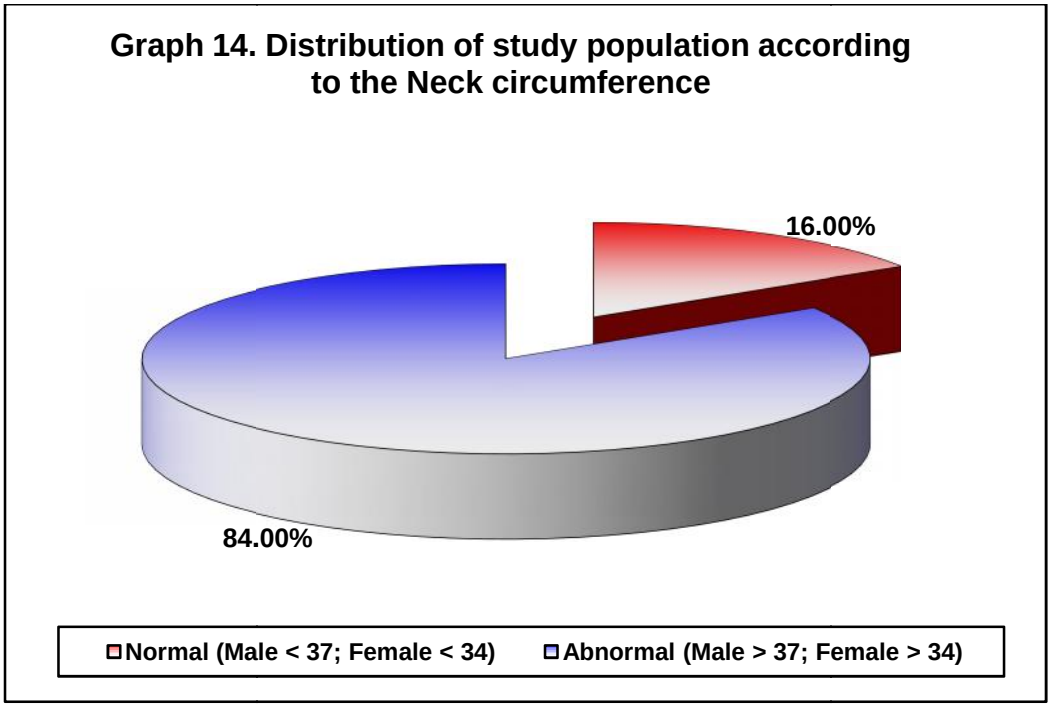
Triglycerides (mg/dL)	Distribution (n=100)	
	Number	Percentage
<150	39	39.00
≥ 150	61	61.00
Total	**100**	**100.00**
Mean ± SD	**185.43±77.17**	
Median (Range)	**178 (54-369)**	



In the present study 39% of the patients had raised triglycerides levels (< 150 mg/dL). The mean triglycerides levels were 185.43±77.17 mg/dL and median triglycerides levels were 178 mg/dL with 54 mg/dL being minimum and 369 mg/dL being maximum.

Table 14. Distribution of study population according to the Neck circumference

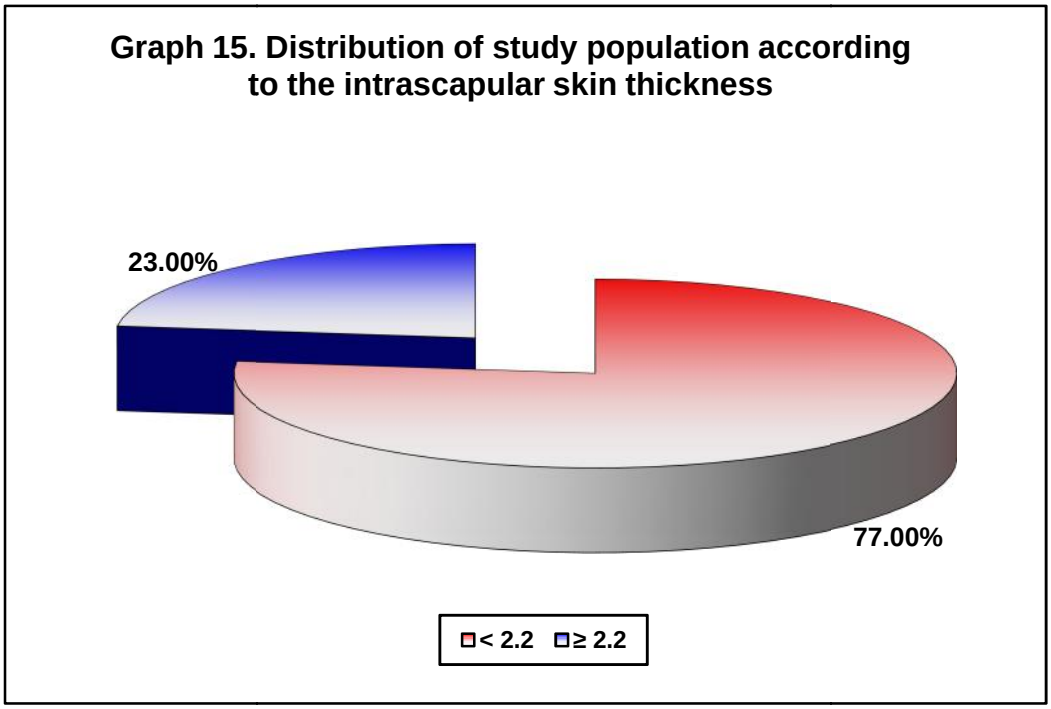
Neck circumference (Cm)	Distribution (n=100)	
	Number	Percentage
Normal (Male < 37; Female < 34)	16	16.00
Abnormal (Male > 37; Female > 34)	84	84.00
Total	**100**	**100.00**
Mean ± SD	**38.33±2.25**	
Median (Range)	**38.6 (33-44)**	



In this study 84% of the patients had abnormal neck circumference. The mean neck circumference was 38.33±2.25 cms and median neck circumference was 38.6 cms with 33 cms being minimum and 44 cms being maximum.

Table 15. Distribution of study population according to the inter-scapular skin thickness

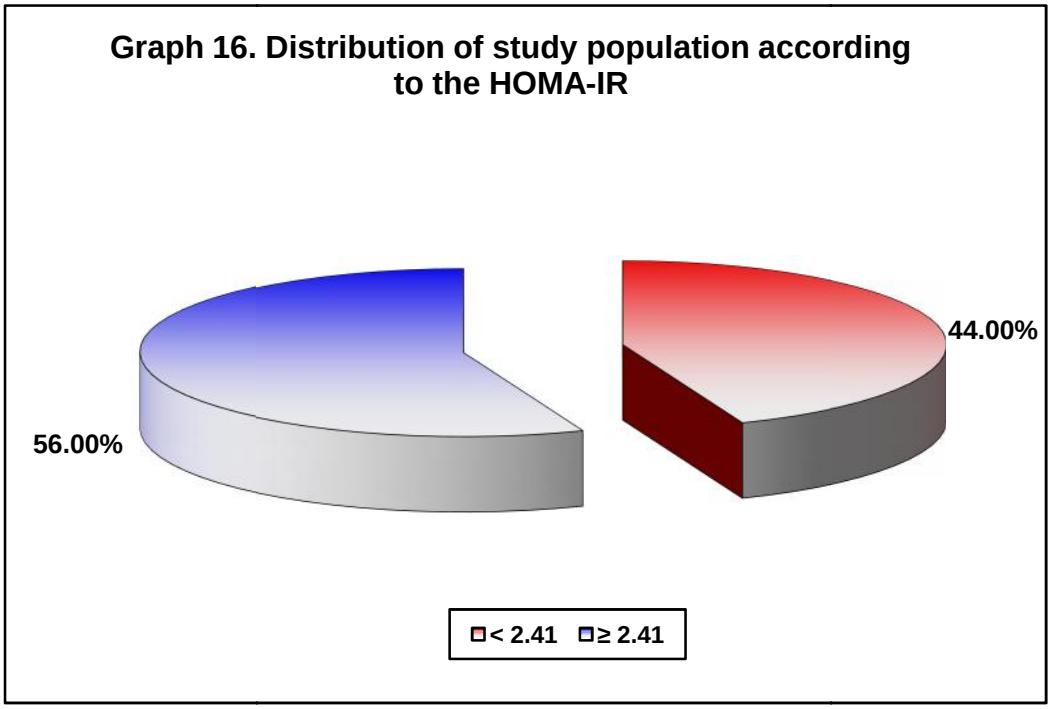
inter-scapular skin thickness	Distribution (n=100)	
	Number	**Percentage**
< 2.2	77	77.00
≥ 2.2	23	23.00
Total	**100**	**100.00**
Mean ± SD	**1.86±0.52**	
Median (Range)	**1.8 (0.8-3.0)**	



In the present study 77% of the patients had normal inter-scapular skin thickness (<2.2) while 23% of the patients had abnormal inter-scapular skin thickness (≥2.2). The mean inter-scapular skin was 1.86±0.52 and median neck circumference was 1.8 with 0.8 being minimum and 3.0 being maximum.

Table 16. Distribution of study population according to the HOMA-IR

HOMA-IR	Distribution (n=100)	
	Number	Percentage
< 2.41	44	44.00
≥2.41	56	56.00
Total	**100**	**100.00**
Mean ± SD	**4.20±4.98**	
Median (Range)	**2.7 (0.7-34.4)**	



In this study 56% of the patients had raised HOMA-IR (≥2.41). The mean HOMA IR was 4.20±4.98 and median HOMA IR was 2.7 with 0.7 being minimum and 34.4 being maximum.

Table 17. Characteristics of the study population

Variables	Distribution (n=100)		Median	Range	
	Mean	SD		Minimum	Maximum
Age	58.98	9.86	57.5	31.0	80.0
diabetic duration	6.50	3.23	6	1.0	16.0
Height (Cms)	166.77	6.31	166.5	143.0	182.0
Weight (Kgs)	76.93	9.26	78	60.0	98.0
Body mass index (kg/m2)	28.34	7.28	27.15	21.8	94.0
Waist circumference (Cms)	96.90	7.77	98	80.0	112.0
Hip circumference (Cms)	81.78	10.15	80	60.0	112.0
Waist hip ratio	1.19	0.16	1.15	0.9	1.7
Respiratory rate	14.26	1.97	14	11.0	18.0
Pulse	74.33	10.95	76	50.0	100.0
Systolic	135.21	16.99	136	90.0	178.0
Diastolic	82.60	10.72	80	56.0	114.0
FBS	163.67	70.87	148	82.0	536.0
PPBS	243.16	87.75	227	101.0	625.0
HBA1C	8.72	2.08	8.2	6.1	15.4
Total cholesterol	165.67	41.35	162	75.0	314.0
HDL	34.09	7.83	32.5	23.0	65.0
LDL	95.13	39.87	93	26.0	214.0
Triglycerides	185.43	77.17	178	54.0	369.0
serum insulin	8.81	4.73	7.8	3.2	26.0
Neck circumference (Cms)	38.33	2.25	38.6	33.0	44.0
Inter-scapular skin thickness (Cm)	1.86	0.52	1.8	0.8	3.0
HOMA IR	4.20	4.98	2.7	0.7	34.4

The clinical profile of the study population is as shown in table 17.

Table 18. Comparison of clinical characteristics of the study population with HOMA-IR

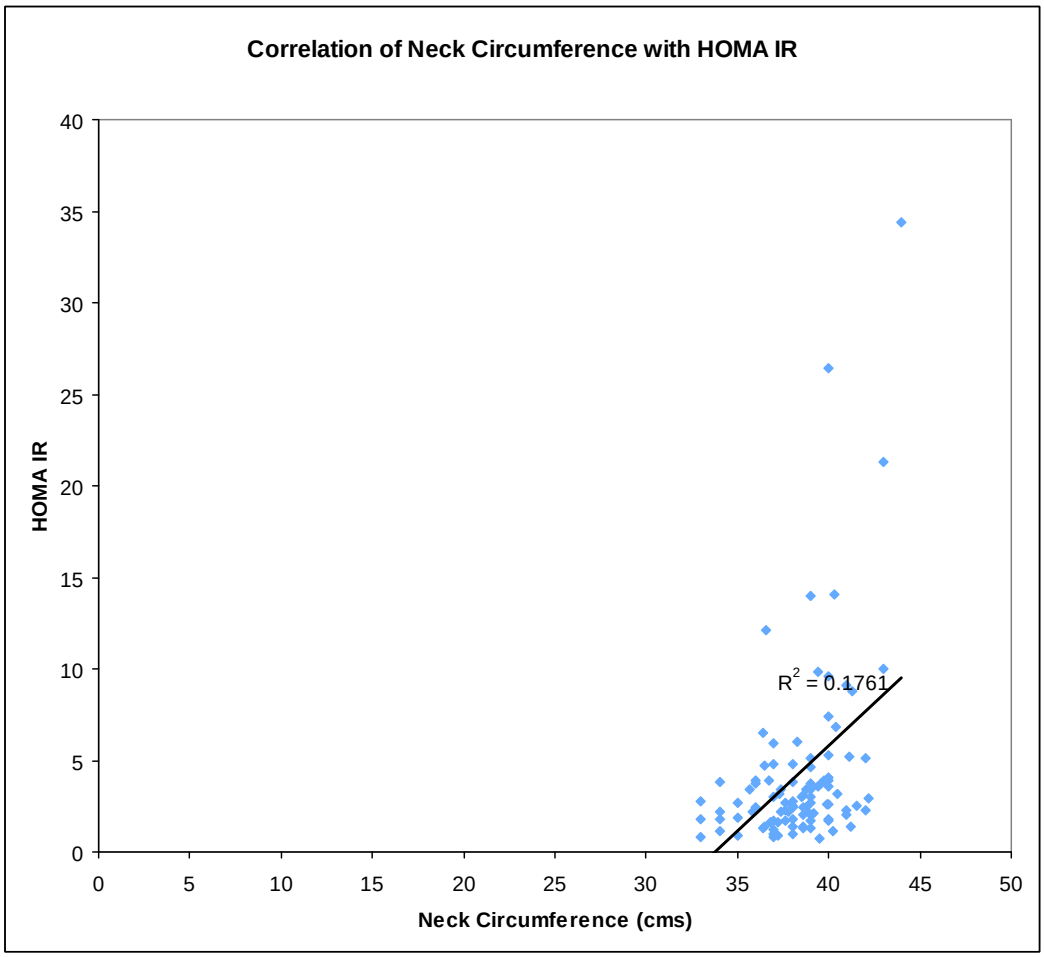
Variables	HOMA IR <2.41 (n=44)		HOMA IR >2.41 (n=56)		p value
	Mean	SD	Min.	Max.	
Age (Years)	59.48	8.89	58.6	10.6	0.650
Diabetic duration (Years)	6.52	3.19	6.5	3.3	0.950
Height (Cms)	166.80	6.08	166.8	6.5	0.971
Weight (Kgs)	77.09	9.42	76.8	9.2	0.879
Body mass index (kg/m2)	29.18	10.51	27.7	2.8	0.359
Waist circumference (Cms)	98.24	7.95	95.8	7.5	0.129
Hip circumference (Cms)	81.49	10.28	82.0	10.1	0.804
Waist hip ratio	1.21	0.17	1.2	0.1	0.311
Respiratory rate (/Minute)	14.18	1.92	14.3	2.0	0.726
Pulse (/Minute)	73.45	9.14	75.0	12.2	0.466
Systolic (mm Hg)	134.73	16.02	135.6	17.9	0.800
Diastolic (mm Hg)	82.95	9.90	82.3	11.4	0.767
FBS (mg/dL)	123.61	24.60	195.1	79.2	**<0.001**
PPBS (mg/dL)	196.77	47.44	279.6	95.0	**<0.001**
HBA1C	7.65	1.22	9.6	2.2	**<0.001**
Total cholesterol (mg/dL)	164.43	40.19	166.6	42.6	0.791
HDL (mg/dL)	33.82	7.28	34.3	8.3	0.756
LDL (mg/dL)	95.07	40.61	95.2	39.7	0.989
Triglycerides (mg/dL)	186.41	75.74	184.7	78.9	0.911
Serum insulin	5.46	1.31	11.4	4.8	<0.001
Neck circumference (Cms)	37.65	2.14	38.9	2.2	**0.006**
Inter-scapular skin thickness (Cm)	1.78	0.49	1.9	0.5	0.165

The Comparison of clinical characteristics of the study population with HOMA-IR is as shown in Table 18. It was observed that, FBS, PPBS, HbA1c and Neck circumference were significantly high in patients with HOMA IR > 2.41 ($p<0.050$).

Table 19. Correlation of neck circumference with glucose triad

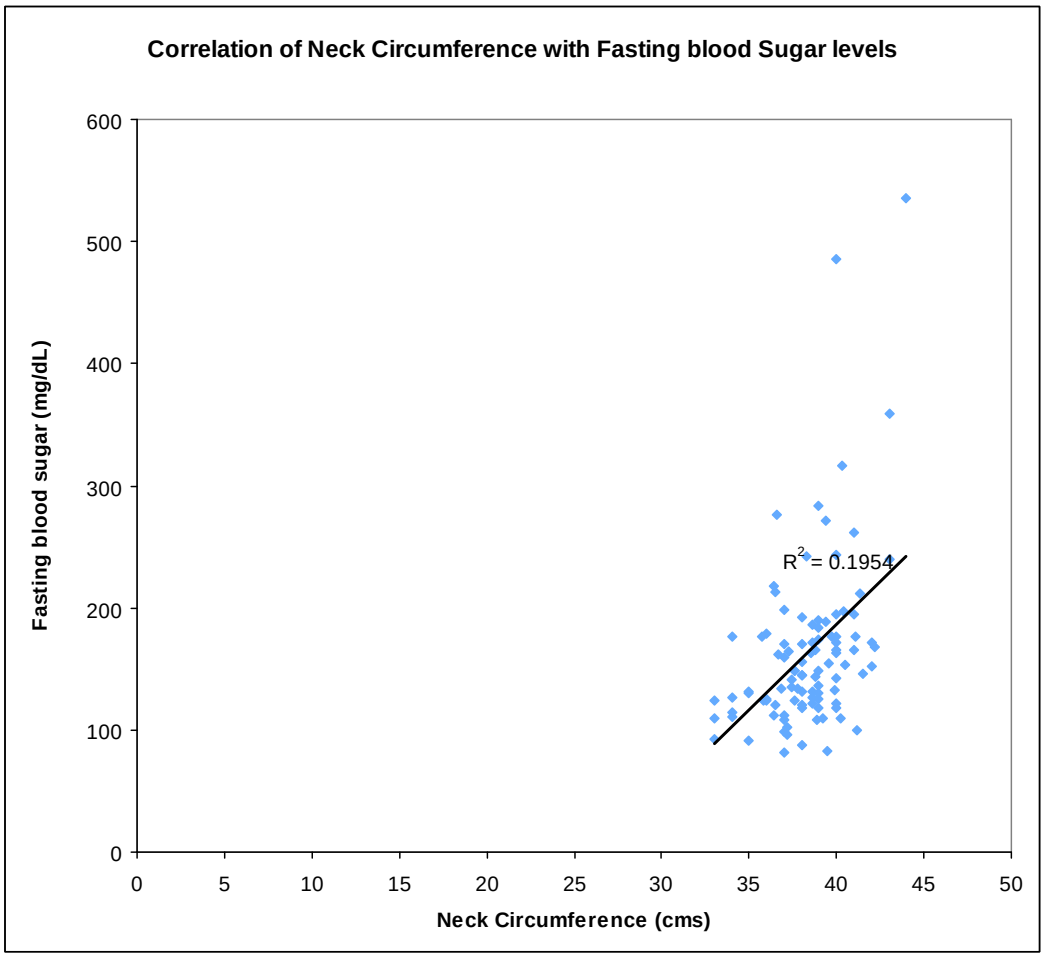
variables	Distribution (n=100)	
	Pearson correlation co-efficient (*r*)	**p value**
NC with HOMA IR	0.4196	<0.001
NC with FBS	0.441	<0.001
NC with PPBS	0.4995	<0.001
NC with HbA1c	0.4181	<0.001

In this study significant moderate positive correlation was observed between neck circumference with HOMA IR, fasting blood sugar levels, post prandial blood sugar levels and Glycosylated haemoglobin



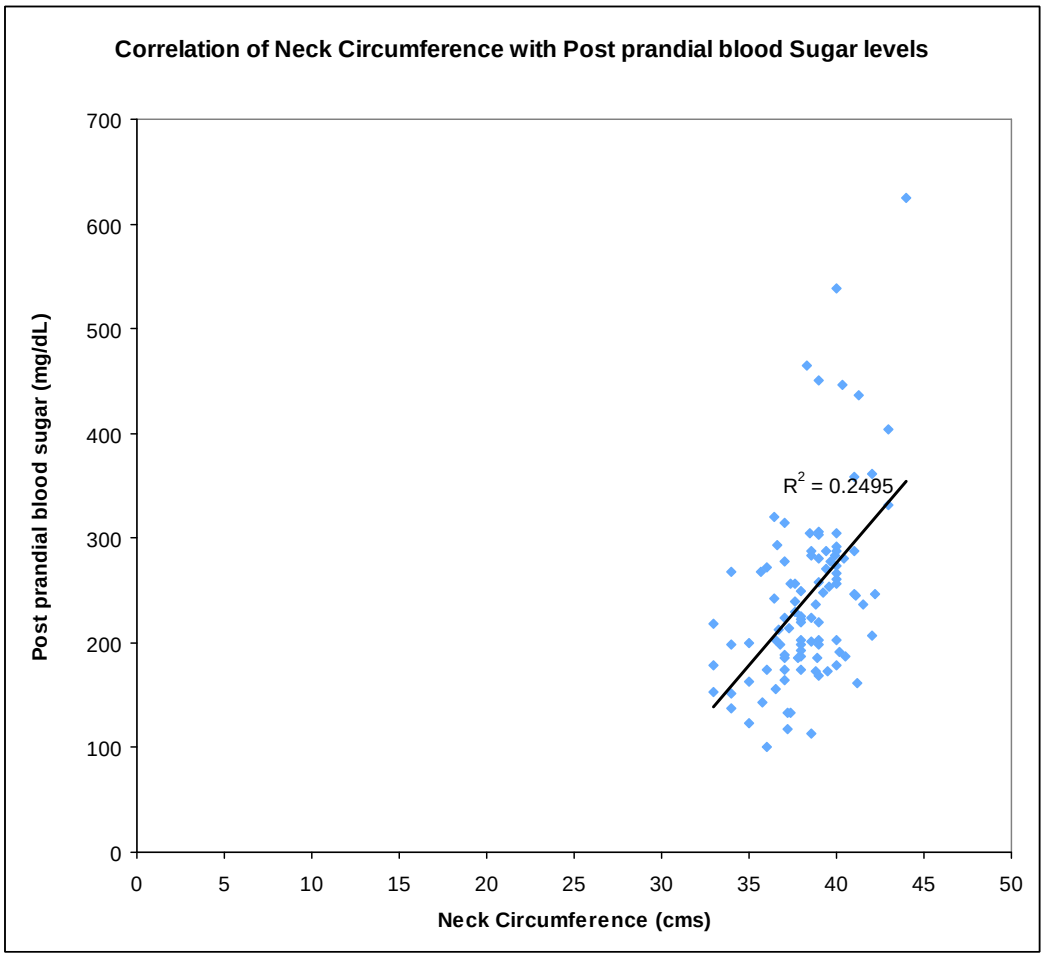
r=0.4196; R^2=0.1761; p<0.001

In the present study moderate positive correlation was observed between neck circumference and HOMA IR (r=0.4196; R^2=0.1761; p<0.001)



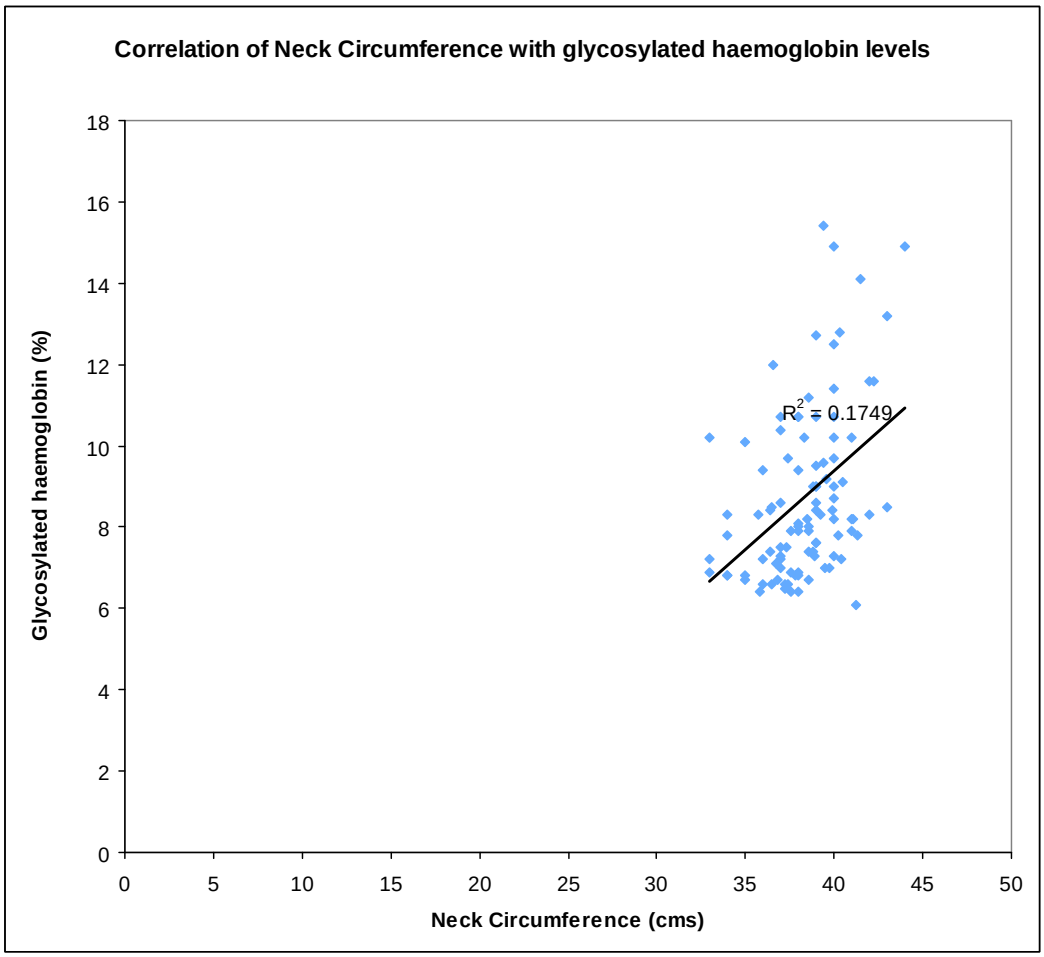
r=0.4196; R^2=0.1954; p<0.001

In this study moderate positive correlation was observed between neck circumference and Fasting blood sugar levels (r=0.4196; R^2=0.1954; p<0.001)



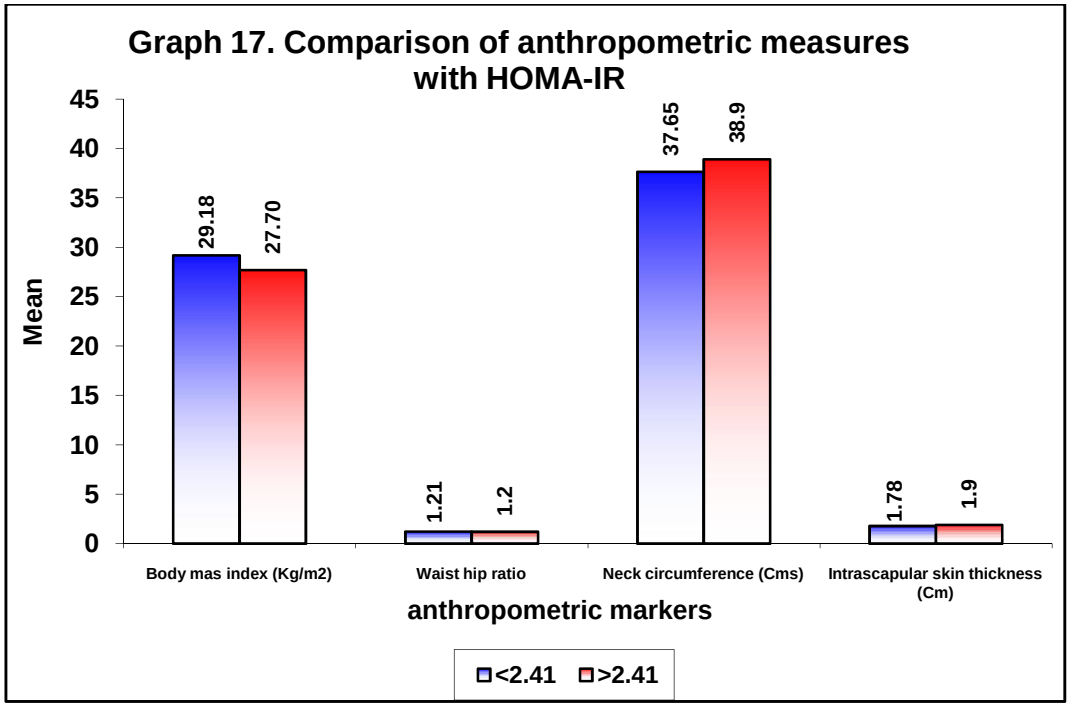
r=0.4196; R^2=0.1761; p<0.001

In the present study moderate positive correlation was observed between neck circumference and post prandial blood sugar (r=0.4196; R^2=0.2495; p<0.001)



r=0.4196; R^2=0.1749; p<0.001

In this study moderate positive correlation was observed between neck circumference and Glycosylated haemoglobin (r=0.4181; R^2=0.1761; p<0.001).



Comparison of various anthropometric measures like BMI, WHR, neck circumference and inter-scapular skin thickness with HOMA IR

DISCUSSION

Overweight and obesity leads to a number of diseases including diabetes mellitus that contribute to increased morbidity and mortality. The presence of obesity worldwide has led to the usage of the term 'globesity' to describe the epidemic trend towards increased body weight.[2]

Obesity has been reported to be associated with insulin resistance, dyslipidemia, and hypertension, thus increasing the risk for cardiovascular disease (CVD). Regarding body fat distribution, abdominal visceral fat has been more strongly associated with cardiovascular risks than body mass index (BMI), waist circumference, and abdominal subcutaneous fat. Therefore, evaluation of visceral fat accumulation is important to reduce cardio-metabolic burdens. Recently, we have seen that increased visceral fat with normal BMI is associated with arterial stiffening in patients with type 2 diabetes. On the other hand, there is evidence that subcutaneous fat has a beneficial role against cardio-metabolic risks. These observations suggest the importance of direct evaluation of visceral and subcutaneous fat accumulation for the management of atherosclerosis; therefore it is possible that increased visceral fat with decreased subcutaneous fat accumulation is positively associated with atherosclerosis.[41]

Practical and easily performed methods for measuring obesity include various anthropometric measures such as body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), as well as the not-so-easy method of measuring the thickness of subcutaneous fat layer at specific sites for estimating body fat percentage. BMI has been adopted by most health professionals for obesity surveys, as it is easy

to perform on a large scale. However, it does not depict the true body composition. Furthermore, visceral obesity, which closely relates to cholesterol levels in the body and its associated coronary artery disease, is better defined by measuring the waist circumference.[2,85]

Measurement of neck circumference (NC) has recently been used to identify overweight and obesity and is observed to have good correlation with age, weight, waist and hip circumferences, waist-to-hip ratio, and BMI for both genders.[70] Besides, NC is considered an index of upper body obesity and correlates positively with changes in systolic and diastolic blood pressure and other components of the metabolic syndrome.[72]

Body mass index, waist circumference, and waist/hip ratio have been shown to be associated with type 2 diabetes. From the clinical perspective, central obesity (approximated by waist circumference or waist/hip ratio) is known to generate diabetogenic substances and should therefore be more informative than general obesity (body mass index). Because of their high correlation, from the statistical perspective, body mass index and waist circumference are unlikely to yield different answers.[1]

NC is found to be a simple and time-saving screening measure that could be used to identify overweight and obese individuals. It has been shown that men with a NC of less than 37 cm and women with a NC of less than 34 cm require a more comprehensive evaluation of their status as overweight or obese in the settings of metabolic syndrome.[70]

Considering the burden of type 2 diabetes mellitus, the fact that obesity being an important risk factor in the pathogenesis of diabetes, and advantages of measuring neck circumference this study was undertaken to estimate subcutaneous fat thickness using various anthropometric measures like body mass index, waist hip ratio, Neck circumference, inter-scapular skin thickness and to correlate these parameters with type 2 diabetes mellitus.

The present hospital based cross-sectional study was conducted in the Department of Medicine, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belgaum from January 2016 to December 2016. A total of 100 Patients presenting with type 2 diabetes mellitus were studied. The data obtained was analyzed and the final observations were tabulated as below.

It is reported that, the prevalence of diabetes is higher in men than women.[85-92] Same was true in the present study as 68% of patients were males and 32% of the patients were females. The male female ratio was 2.12:1. These findings suggest that, type 2 diabetes mellitus is widely prevalent among males which was consistent with other reports in the literature.[85-92]

Unlike in the West, where older persons are most affected, diabetes in Asian countries is disproportionately high in young to middle-aged adults.[93] Accordingly in this study most of the patients (41%) were aged between 51 to 60 years followed by 61 to 70 years (27%). The mean age was 58.98 ± 9.86 years and median age was 57.5 years with range 31 being minimum and 80 being maximum. These findings show that, diabetes mellitus was widely prevalent among elderly. The higher prevalence of diabetes among aged can be explained by the rise in the segment of geriatric population.

With regard to diabetic characteristics, more than one third of the diabetics (38%) reported duration of diabetes between 4 to 6 years. The mean duration of diabetes was 6.50 ± 3.23 years and median duration was 6 years with range 1 year being minimum and 16 years being maximum. Majority of the patients that is, 69% had elevated fasting blood sugar levels (≥126 mg/dL). The mean FBS levels were also high (163.67±70.87 mg/dL) and median FBS levels were 148 mg/dL with 82 mg/dL being minimum and 536 mg/dL being maximum. Similarly Majority of the patients (66%) had elevated post prandial blood sugar levels (≥200 mg/dL). The mean PPBS levels were high 243.16±87.75 mg/dL and median FBS levels were 227 mg/dL with 101 mg/dL being minimum and 625 mg/dL being maximum. One notable findings was that only 7% of the patients in this study had normal FBS (<100mg/dL) and PPBS (<140 mg/dL) levels. Furthermore 40% of the patients had HbA1c levels between 7.0-8.5 suggesting moderate glycaemic control and 39% of the patients had HbA1c levels of > 8.5 suggesting poor glycaemic control. The mean HbA1c levels were 8.72 ± 2.08 and median HbA1c levels were 8.2 with 6.1 being minimum and 15.4 being maximum suggesting poor glycaemic control in the study population.

Most patients with type 2 diabetes are obese, and the global epidemic of obesity largely explains the dramatic increase in the incidence and prevalence of type 2 diabetes over the past 20 years.[36] In the present study majority of the patients (63%) were overweight (25.00-29.99 kg/m^2) while 20% of the patients were obese (≥30 Kg/m^2) and only 2% of the patients has normal BMI (18.5 to 22.9 kg/m^2). The mean and median BMI was also suggestive of overweight population that is, 28.34±7.28 Kg/m^2 and median BMI was 27.15 Kg/m^2 with range 21.8 Kg/m^2 being minimum to 37.2 Kg/m^2 maximum.

BMI and WC are indices of general and central (visceral) obesity respectively, and are an important first step in determining the level and distribution of obesity.[94] The cutoff values of WC for overweight and obesity vary widely over different geographic regions of the world. Furthermore, for WC, 'underweight' and 'normal weight' has not been properly defined as there has been no mention in the literature of the lower limit of normal WC.[2] In this study majority of the diabetics (97%) had abnormal waist circumference. The mean waist circumference was above the normal reference range that is 96.90±7.77 cms and median waist circumference was 98 cms with 80 cms being minimum and 112 cms being maximum suggesting normal waist circumference and obesity.

In the present study majority of the patients (96%) had abnormal waist hip ratio suggesting that higher frequency of obesity among diabetics. Furthermore the mean WHR was 1.21 ± 0.17 and median WHR was 1.2 with range 0.87 being minimum and 1.65 being maximum suggesting higher rate of obesity among diabetics.

Diabetic dyslipidemia is a complex cluster of potentially atherogenic lipid and lipoprotein abnormalities involving both quantitative and qualitative changes. Increased plasma triglycerides, low concentration of high density lipoproteins cholesterol (HDL-C), preponderance of small, dense low density lipoproteins (LDL) and excessive postprandial lipemia are its main components. As it has been recently shown, the abnormalities in lipid metabolism are not isolated but rather closely linked to each other.[95]

In this study majority of the patients had normal total cholesterol levels (<200 mg/dL) while 17% of the patients had raised cholesterol levels (>200 mg/dL)

suggesting hypercholesterolaemia. The mean total cholesterol levels were 165.67±41.35 mg/dL and median total cholesterol levels were 162 mg/dL with 75 mg/dL being minimum and 314 mg/dL being maximum. Epidemiologic studies have demonstrated that diabetes mellitus is an independent risk factor for cardiovascular disease and that it amplifies the effects of other common risk factors, such as smoking, hypertension and hypercholesterolemia.[96,97]

In the present study majority of the patients that is, 79% of the patients had low HDL (<40 mg/dL). The mean and median HDL levels were also suggestive of abnormal HDL levels that is, mean HDL 34.09±7.83 mg/dL and median HDL levels were 32.5 mg/dL with as low as 23 mg/dL being minimum and 65 mg/dL being maximum.

In the Iranian IHHP-study,[98] significantly low levels of HDL were reported in type 2 diabetics. In San Antonio Heart Study[99] 30% of patients with type 2 diabetes were reported to have low HDL levels. In the Turkish study mentioned above low HDL levels were found in 30% of diabetic patients.[100]

In this study 46% of the patients had raised LDL levels (≥100 mg/dL). The mean LDL levels were 95.13± 39.87 mg/dL and median LDL levels were 93 mg/dL with 26 mg/dL being minimum and 214 mg/dL being maximum. In a Turkish study by Avsar A et al,[100] 45% of the patients were found to have high LDL cholesterol levels. In a study[101] from Pakistan applying American Diabetic Association guidelines to classify lipoprotein concentrations, the proportion of patients who had an LDL level that was within low-, borderline-, and high-risk categories was 54, 29, and 16% respectively. In another recent study by Firdous S. et al.,[67] the percentage of diabetic

patients affected by high LDL cholesterol was 32%. In another study done by Khalid AM and coworkers,[102] LDL was found high in 30% of the patients.

In the present study more than one third (39%) of the diabetic patients had raised triglycerides levels (<150 mg/dL) suggesting hypertriglyceridemia. Also the mean triglycerides levels were also high 185.43±77.17 mg/dL and median triglycerides levels were 178 mg/dL with 54 mg/dL being minimum and 369 mg/dL being maximum. These findings strongly propose very high risk of hypertriglyceridemia in patients with type 2 diabetes mellitus compared to healthy individuals. In the Palestinian study[103] and also in the Iranian IHHP study,[98] 35 to 40% of the diabetic population was found to have high risk category hypertriglyceridemia.

BMI and WC are indices of general and central (visceral) obesity respectively, and are an important first step in determining the level and distribution of obesity.[94] The cutoff values of WC for overweight and obesity vary widely over different geographic regions of the world. Furthermore, for WC, 'underweight' and 'normal weight' has not been properly defined as there has been no mention in the literature of the lower limit of normal WC.[2] Therefore, the study used BMI instead of WC as the primary reference point.

In the present study 77% of the patients had normal inter-scapular skin thickness (<2.2) while 23% of the patients had abnormal inter-scapular skin thickness (≥2.2). The mean inter-scapular skin was 1.86±0.52 and median neck circumference was 1.8 with 0.8 being minimum and 3.0 being maximum.

Overall based on BMI, 63% of the patients were overweight (25.00-29.99 kg/m^2) and 20% of the patients were obese (≥30 Kg/m^2), 96% of the patients had abnormal waist hip ratio, 97% of the patients had abnormal waist circumference, 77% of the patients had normal inter-scapular skin thickness (<2.2) and with regard to neck circumference, 84% of the patients had abnormal neck circumference.

In this study unlike inter-scapular skin thickness, 96% of the patients has abnormal WHR, 97% of the patients had abnormal waist circumference and 84% of the patients had abnormal neck circumference. The mean neck circumference was 38.33±2.25 cms and median neck circumference was 38.6 cms with 33 cms being minimum and 44 cms being maximum suggesting higher rate of obesity in patients with diabetes mellitus. Although obesity results in metabolic abnormalities, upper body obesity is more strongly associated with glucose intolerance, hyperinsulinemia, diabetes, hypertriglyceridemia, gout and uric calculus disease than lower body obesity. Upper body obesity can be assessed by various techniques such as NC, waist circumference (WC), waist-to-hip ratio, waist-to-thigh ratio, subscapular-to-triceps skinfold ratio and abdominal sagittal diameter. Besides, NC is considered an index of upper body obesity. NC measurements are an alternative and innovative approach for determining body fat distribution.[104]

Guo et al.[105] and Kurtoglu et al.[106] observed a correlation between NC and anthropometric indicators of obesity. Guo et al.[105] evaluated 6,802 Chinese children and adolescents between five and 18 years old, dividing them into BMI categories, and found a significant correlation between NC and WC. Despite a decrease in correlation coefficients after the adjustment for age, sex, and BMI, NC remained positively correlated with WC. The authors also observed an association between NC

and BMI in the three BMI categories, but no significance was found in the obese group after the adjustment for age, sex and WC. In the study by Kurtoglu et al,[106] with 581 Turkish children and adolescents between five and 18 years old, there was also a significant correlation between NC, WC and BMI in pubertal and prepubertal adolescents of both sexes.

Hingorjo MR et al.[2] showed a strong positive correlation of NC with BMI and WC in both male and female subjects. Several studies have examined the association of conventional anthropometric measures of obesity with NC.[78,107-110] The association between obstructive sleep apnoea and NC was even greater than WC in case of males.[107] In another study by Yang et al, NC was found to be positively related with BMI, WC, and metabolic syndrome in Chinese subjects having type 2 diabetes mellitus.[78]

Insulin resistance is a complex metabolic disorder that defies explanation by a single etiological pathway. Accumulation of ectopic lipid metabolites, activation of the unfolded protein response (UPR) pathway, and innate immune pathways have all been implicated in the pathogenesis of insulin resistance. However, these pathways are also closely linked to changes in fatty acid uptake, lipogenesis, and energy expenditure that can impact ectopic lipid deposition. Ultimately, these cellular changes may converge to promote the accumulation of specific lipid metabolites (diacylglycerols and/or ceramides) in liver and skeletal muscle, a common final pathway leading to impaired insulin signaling and insulin resistance.[111] In this study more than half of the study population (56%) had raised HOMA-IR (≥2.41). The mean and median HOMA IR levels were also found to be high that is 4.20±4.98 and

median HOMA IR was 2.7 with 0.7 being minimum and 34.4 being maximum suggestive of insulin resistance.

It was observed that FBS, PPBS, HbA1c and Neck circumference were significantly high in patients with insulin resistance (HOMA IR > 2.41). The mean FBS levels were significantly high in patients with insulin resistance (195.1 ± 79.2 mg/dL vs 123.61 ± 24.60 mg/dL; p<0.001) compared to those with normal HOMA IR levels. Similarly PPBS levels were high in patients with insulin resistance (727.60 ± 95.00 mg/dL vs 196.77 ± 47.44 mg/dL; p<0.001) compared to those with normal HOMA IR levels. Furthermore, HbA1c levels were also high were high in patients with insulin resistance (9.60 ± 2.20 vs 7.65 ± 1.22; p<0.001) compared to those with normal HOMA IR levels. One notable finding was that the neck circumference was significantly high in patients with insulin resistance (38.9± 2.20 mg/dL vs 37.65 ± 2.14 cms; p=0.006) compared to those with normal HOMA IR levels. Further more moderate positive correlation was observed between neck circumference with HOMA IR (r=0.4196; R^2=0.1761; p<0.001), fasting blood sugar levels (r=0.4196; R^2=0.1954; p<0.001), post prandial blood sugar levels (r=0.4196; R^2=0.2495; p<0.001) and Glycosylated haemoglobin (r=0.4181; R^2=0.1761; p<0.001) and this correlation was statistically significant. Surprisingly other obesity measures including body mass index, WHR, waist circumference, inter-scapular skin thickness were comparable in patients with insulin resistance and patients with normal HOMA IR Index. These findings suggest that, neck circumference is strong predictor of insulin resistance. These findings were consistent with a recent study by da Silva Cde C, et al.[112] To evaluate the correlation between neck circumference and insulin resistance and components of metabolic syndrome in adolescents with different adiposity levels and pubertal stages, as well as to determine the usefulness of neck circumference to

predict insulin resistance in adolescents concluded that, the neck circumference is a useful tool for the detection of insulin resistance and changes in the indicators of metabolic syndrome in adolescents. The easiness of application and low cost of this measure may allow its use in Public Health services.[112]

Regarding markers of IR, Kurtoglu et al.[106] found a positive correlation between NC, insulin, and HOMA1-IR in pubertal and pre-pubertal adolescents of both sexes. Androutsos et al.[113] presented a positive correlation of NC with insulin and HOMA-IR in both sexes. The results remained significant after adjustments for age, sex, Tanner stage, physical activity, and intake of proteins, carbohydrates and fat. Onat et al.[107] also reported that NC correlated strongly with BMI, WC ($r > 0.6$), homeostatic model-assessed insulin resistance and blood pressure.

Overall the present study showed that, NC is a useful tool and a strong predictor of insulin resistance. NC has some advantages over other obesity indicators viz. good inter-rater and intra-rater reliability; no need for multiple accuracy and reliability measurements;[114] no influence of time of measurement (fasting and postprandial period); more stable body surface; easier for both examiners and participants, particularly during winter and in crowded locations; more socially acceptable and more convenient, especially for overweight and obese adolescents. However, NC does not have international reference values yet.

The present study has the following limitations Mainly the study design that is cross-sectional study. we presume that case controls design study would have yielded the relative risk of obesity for insulin resistance Furthermore the sample was selected by convenience, with a higher proportion of obese individuals; The study did not analyze the correlations with imaging studies that directly quantify fat deposits.

Evaluation of NC based on single measurements might be considered a minor limitation. Despite these limitations, our results were in agreement with the results of the cited studies. Its simplicity and low cost may enable its use in Public Health services and in large epidemiological community based studies.

Conclusions reached may not be fully applicable to a population because of the relative small sample size of the present study. Further studies with larger sample sizes are needed to identify the relationship of NC with central obesity in general population.

CONCLUSION

Based on the present study it may be concluded that,

- In this study regard to BMI 63% of the patients were overweight (25.00-29.99 kg/m^2) and 20% of the patients were obese (≥30 Kg/m^2).
- 96% of the diabetics had abnormal waist-hip ratio in this study.
- Waist circumference is abnormal in 97% of the study population.
- With regard to neck circumference, in this study 84% of the patients had abnormal neck circumference.
- While 77% of the patients had normal inter-scapular skin thickness (<2.2).
- More than half of the study population (56%) was insulin resistant, who had raised HOMA-IR (≥2.41).
- Neck circumference was significantly high in patients with insulin resistance compared to those with normal HOMA IR.
- Incidentally we also found that FBS, PPBS, HbA1c levels were high in patients with insulin resistance compared to those with normal HOMA IR levels.
- Moderate positive correlation was observed between neck circumference with HOMA IR ($r=0.4196$; $R^2=0.1761$; $p<0.001$), fasting blood sugar levels ($r=0.4196$; $R^2=0.1954$; $p<0.001$), post prandial blood sugar levels ($r=0.4196$;

R^2=0.2495; p<0.001) and Glycosylated haemoglobin (r=0.4181; R^2=0.1761; p<0.001) and this correlation was statistically significant.

- Neck circumference is a simple and time-saving screening measurement that could be useful in clinical screening for persons at an enhanced risk for insulin resistance.

SUMMARY

Overweight and obesity leads to a number of diseases including diabetes mellitus that contribute to increased morbidity and mortality. Considering the burden of type 2 diabetes mellitus, the fact that obesity being an important risk factor in the pathogenesis of diabetes, this study was undertaken to estimate subcutaneous fat thickness using various anthropometric measures like body mass index, waist hip ratio, Neck circumference, inter-scapular skin thickness and to correlate these parameters with type 2 diabetes mellitus.

The present hospital based cross-sectional study was conducted in the Department of Medicine, KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belgaum from January 2016 to December 2016. A total of 100 Patients presenting with type 2 diabetes mellitus were studied. The data obtained was analyzed and the salient findings of the study are summarized as below.

- In the present study 68% of the patients were males and 32% of the patients were females with the male female ratio of 2.12:1.
- 41% of the patients were aged between 51 to 60 years followed by 27% who are aged 61 to 70 years. The mean age was 58.98 ± 9.86 years and median age was 57.5 years with range 31 being minimum and 80 being maximum.
- 38% of the patients were reported duration of diabetes between 4 to 6 years. The mean duration of diabetes was 6.50 ± 3.23 years and median duration was 6 years with range 1 year being minimum and 16 years being maximum.
- 63% of the patients were overweight (25.00-29.99 kg/m^2) while 20% of the patients were obese (≥30 Kg/m^2). The mean BMI was 28.34±7.28 Kg/m^2 and

median BMI was 27.15 Kg/m^2 with range 21.8 Kg/m^2 being minimum to 37.2 Kg/m^2 maximum.

- 96% of the patients had abnormal waist hip ratio. The mean WHR was 1.21 ± 0.17 and median WHR was 1.2 with range 0.87 being minimum and 1.65 being maximum.
- 97% of the patients had abnormal waist circumference. The mean waist circumference was 96.90±7.77 cms and median waist circumference was 98 cms with 80 cms being minimum and 112 cms being maximum.
- 84% of the patients had abnormal neck circumference. The mean neck circumference was 38.33±2.25 cms and median neck circumference was 38.6 cms with 33 cms being minimum and 44 cms being maximum.
- 77% of the patients had normal inter-scapular skin thickness (<2.2) while 23% of the patients had abnormal inter-scapular skin thickness (≥2.2). The mean inter-scapular skin was 1.86±0.52 and median neck circumference was 1.8 with 0.8 being minimum and 3.0 being maximum.
- 56% of the patients had raised HOMA-IR (≥2.41). The mean HOMA IR was 4.20±4.98 and median HOMA IR was 2.7 with 0.7 being minimum and 34.4 being maximum.
- The neck circumference was significantly high in patients with insulin resistance (38.9± 2.20 mg/dL vs 37.65 ± 2.14 cms; p=0.006) compared to those with normal HOMA IR levels.
- 69% of the patients had elevated fasting blood sugar levels (≥126 mg/dL). The mean FBS levels were 163.67±70.87 mg/dL and median FBS levels were 148 mg/dL with 82 mg/dL being minimum and 536 mg/dL being maximum.

- The mean FBS levels were significantly high in patients with insulin resistance (195.1 ± 79.2 mg/dL vs 123.61 ± 24.60 mg/dL; p<0.001) compared to those with normal HOMA IR levels.
- 66% of the patients had elevated post prandial blood sugar levels (≥200 mg/dL). The mean PPBS levels were 243.16±87.75 mg/dL and median PPBS levels were 227 mg/dL with 101 mg/dL being minimum and 625 mg/dL being maximum.
- PPBS levels were high in patients with insulin resistance (727.60 ± 95.00 mg/dL vs 196.77 ± 47.44 mg/dL; p<0.001) compared to those with normal HOMA IR levels.
- 40% of the patients had HbA1c levels between 7.0-8.5 and 39% of the patients had HbA1c levels of > 8.5. The mean HbA1c levels were 8.72 ± 2.08 and median HbA1c levels were 8.2 with 6.1 being minimum and 15.4 being maximum.
- HBA1c levels were also high were high in patients with insulin resistance (9.60 ± 2.20 vs 7.65 ± 1.22; p<0.001) compared to those with normal HOMA IR levels.
- Moderate positive correlation was observed between neck circumference with HOMA IR (r=0.4196; R^2=0.1761; p<0.001), fasting blood sugar levels (r=0.4196; R^2=0.1954; p<0.001), post prandial blood sugar levels (r=0.4196; R^2=0.2495; p<0.001) and Glycosylated haemoglobin (r=0.4181; R^2=0.1761; p<0.001) and this correlation was statistically significant.
- In this study majority of the patients had normal total cholesterol levels (<200 mg/dL) while 17% of the patients had raised cholesterol levels (>200 mg/dL). The mean total cholesterol levels were 165.67±41.35 mg/dL and median total

cholesterol levels were 162 mg/dL with 75 mg/dL being minimum and 314 mg/dL being maximum.

- 79% of the patients had low HDL (< 40 mg/dL). The mean HDL levels were 34.09±7.83 mg/dL and median HDL levels were 32.5 mg/dL with 23 mg/dL being minimum and 65 mg/dL being maximum.
- 46% of the patients had raised LDL levels (≥100 mg/dL). The mean LDL levels were 95.13± 39.87 mg/dL and median LDL levels were 93 mg/dL with 26 mg/dL being minimum and 214 mg/dL being maximum.
- 39% of the patients had raised triglycerides levels (< 150 mg/dL). The mean triglycerides levels were 185.43±77.17 mg/dL and median triglycerides levels were 178 mg/dL with 54 mg/dL being minimum and 369 mg/dL being maximum.

Overall in this study based on BMI, 63% of the patients were overweight (25.00-29.99 kg/m^2) and 20% of the patients were obese (≥30 Kg/m^2), considering waist hip ratio 96% of the patients were obese, 97% of the patients had abnormal waist circumference and 84% of the patients had abnormal neck circumference while 77% of the patients had normal inter-scapular skin thickness (<2.2). Neck circumference was significantly high in patients with insulin resistance compared to those with normal HOMA IR. Incidentally we also found that FBS, PPBS, HbA1c levels were high in patients with insulin resistance compared to those with normal HOMA IR levels. Also there is moderate positive correlation between neck circumference and FBS, PPBS, HbA1c and HOMA IR.

BIBLIOGRAPHY

1. Vazquez G, Duval S, Jacobs DR Jr, Silventoinen K. Comparison of body mass index, waist circumference, and waist/hip ratio in predicting incident diabetes: a meta-analysis. Epidemiol Rev. 2007;29:115-28.
2. Hingorjo MR, Qureshi MA, Mehdi A. Neck circumference as a useful marker of obesity: a comparison with body mass index and waist circumference. J Pak Med Assoc. 2012 Jan;62(1):36-40.
3. International Obesity Taskforce (IOTF). The Global Epidemic. (Online) (Cited 2011 Jan 26). Available From URL: http://www.iaso.org/ iotf/obesity/ obesitytheglobalepidemic/. Access Date 28.008.2016
4. Centers for Disease Control and Prevention. Prevalence of overweight, obesity and extreme obesity among adults: United States, trends 1960-62 through 2005-2006. Updated 23 December 2009. (Online). Available From URL: http://www.cdc.gov/nchs/data/hestat/overweight/overweight_adult.htm. Access Date 28.008.2016
5. OECD Health Data 2010. Overweight or Obese population - Measured data. Updated October 2010. (Online) (Cited 2011 Jan 27). Available From URL: http://www.ecosante.fr/index2.php?base=OCDE&langh=ENG&langs=ENG&sessionid=. Access Date 28.008.2016
6. DeFronzo RA. Pathogenesis of type 2 diabetes mellitus. Med Clin North Am 2004;88:787–835.
7. Fauci AS, Kasper DS, Longo DL, Braunwald E, Hauser SL, Jameson JL, et al. Harrison's principles of internal medicine. United States; McGraw Hill: 2015.
8. American Diabetes Association. Clinical practice recommendations 2007. Diabetes Care 2007;30:S4.

9. One adult in ten will have diabetes by 2030. International Diabetes Federation. 2011. Available from: URL: Available at http://www.idf. org/media-events/press-releases/2011/diabetes-atlas-5th-edition Access date: 08.07.2011.
10. Ghaffar A, Reddy KS, Singhi M. Burden of non-communicable diseases in South Asia. BMJ 2004;328(7443):807-10.
11. Tripathy BB, Chandalia HB. RSSDI:Textbook of diabetes mellitus.2nd ed., New Delhi: Jaypee Brothers; 2008.
12. Pandoli A, De Filips 1. EA. Chronic hyperglycemia and nitric oxide bioavailability play a pivotal role in pro-atherogenic vascular modiications. Genes Nutr 2007;2:195-208.
13. Carr ME. Diabetes mellitus:A hypercoagulable state. J Diabetes Complications 2001;15:44-54.
14. Madan R, Gupt B, Saluja S, Kansra UC, Tripathi BK, Guliani BP. Coagulation profile in diabetes and its association with diabetic microvascular complications. J Assoc Physicians India. 2010;58:481-4.
15. De Vriese AS, Verbeuren TJ, Van De Voorde J, Lameire NH, Vanhoutte PM. Endothelial dysfunction in diabetes. Br J Pharmacol 2000;130:963-74.
16. Guerci B, Bohme P, Kearney-Schwartz A, Zannad F, Drouin P. Endothelial dysfunction and type 2 diabetes. Diabetes Metab 2001;27:436-47.
17. Molarius A, Seidell JC. Selection of anthropometric indicators for classification of abdominal fatness a critical review. Int J Obes Relat Metab Disord 1998;22:719–27.
18. Despres JP, Moorjani S, Lupien PJ, Tremblay A, Nadeau A, Bouchard C. et al. Regional distribution of body fat, plasma lipoproteins, and cardiovascular disease. Arteriosclerosis 1990;10:497–511.

19. Peiris AN, Mueller RA, Smith GA, Struve MF, Kissebah AH. Splanchnic insulin metabolism in obesity.Influence of body fat distribution.J Clin Invest 1986;78:1648–57.
20. Jensen MD. Is visceral fat involved in the pathogenesis of the metabolic syndrome? Human model. Obesity (Silver Spring) 2006;14(suppl):20S–4S.
21. Seidell JC, Bjorntorp P, Sjostrom L, Sannerstedt R, Krotkiewski M, Kvist H. et al. Regional distribution of muscle and fat mass in men—new insight into the risk of abdominal obesity using computed tomography. Int J Obes 1989;13:289-303.
22. Ford ES, Mokdad AH, Giles WH. Trends in waist circumference among U.S. adults. Obes Res 2003;11:1223–31.
23. Wei M, Gaskill SP, Haffner SM, Stern MP. Waist circumference as the best predictor of noninsulin dependent diabetes mellitus (nIDDM) compared to body mass index, waist/hip ratio and other anthropometric measurements in Mexican Americans - a 7-year prospective study. Obes Res 1997;5: 16–23.
24. Janssen I, Katzmarzyk PT, Ross R. Waist circumference and not body mass index explains obesity-related health risk. Am J Clin Nutr 2004;79:379–84.
25. Stevens J, Couper D, Pankow J, Folsom AR, Duncan BB, Nieto FJ, et al. Sensitivity and specificity of anthropometrics for the prediction of diabetes in a biracial cohort. Obes Res 2001;9:696–705.
26. Ohlson LO, Larsson B, Bjorntorp P, et al. Risk factors for type 2 (non-insulin-dependent) diabetes mellitus. Thirteen and one-half years of follow-up of the participants in a study of Swedish men born in 1913. Diabetologia 1988;31:798–805.

27. Lundgren H, Bengtsson C, Blohme G, Lapidus L, Sjöström L. et al. Adiposity and adipose tissue distribution in relation to incidence of diabetes in women: results from a prospective population study in Gothenburg, Sweden. Int J Obes 1989;13:413–23.

28. Cassano PA, Rosner B, Vokonas PS, Weiss ST. Obesity and body fat distribution in relation to the incidence of non-insulindependent diabetes mellitus. A prospective cohort study of men in the Normative Aging Study. Am J Epidemiol 1992; 136:1474–86.

29. Ben-Noun LL, Laor A. Relationship between changes in neck circumference and changes in blood pressure. Am J Hypertens 2004;17:409-14.

30. Ben-Noun LL, Laor A. Relationship between changes in neck circumference and cardiovascular risk factors. Exp Clin Cardiol 2006;11(1):14-20.

31. Sattley M. The history of diabetes. 1996; Available from: URL: http://www.diabeteshealth.com/read/2009/11/23/6456/the-history-of- diabetes-/ Access date; 18.09.2010.

32. Pradeepa R. Epidemiology of diabetes in India – Current perspective and future projection. J Indian Med Assoc 2002; 100(3): 144-8.

33. Hales CN, Barker DJ, Clark PM, Cox LJ, Fall C, Osmond C, Winter PD. Fetal and infant growth and impaired glucose tolerance at age 64. BMJ 1991; 303(6809): 1019-22.

34. Centers for Disease Control and Prevention. National diabetes fact sheet: national estimates and general information on diabetes and prediabetes in the United States, 2011. Atlanta, GA, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2011

35. Boyle JP, Thompson TJ, Gregg EW, Barker LE, Williamson DF. Projection of the year 2050 burden of diabetes in the US adult population: dynamic modeling of incidence, mortality, and prediabetes prevalence. Popul Health Metr 2010;8:29.

36. Eckel RH, Kahn SE, Ferrannini E, Goldfine AB, Nathan DM, Schwartz MW, et al. Obesity and type 2 diabetes: what can be unified and what needs to be individualized? Obesity and type 2 diabetes: what can be unified and what needs to be individualized? J Clin Endocrinol Metab. 2011 Jun; 96(6): 1654–1663.

37. Björntorp P. Metabolic implications of body fat distribution. Diabetes Care 1991;14:1132–1143

38. Bagdade JD, Bierman EL, Porte D., Jr The significance of basal insulin levels in the evaluation of the insulin response to glucose in diabetic and nondiabetic subjects. J Clin Invest 1967;46:1549–1557.

39. Stoffers DA, Ferrer J, Clarke WL, Habener JF. Early-onset type-II diabetes mellitus (MODY4) linked to IPF1. Nat Genet 1997;17:138–139.

40. Shuster A, Patlas M, Pinthus JH, Mourtzakis M. The clinical importance of visceral adiposity: a critical review of methods for visceral adipose tissue analysis. Br J Radiol. 2012;85(1009):1-10.

41. Bouchi R, Takeuchi T, Akihisa M, Ohara N, Nakano Y, Nishitani R, High visceral fat with low subcutaneous fat accumulation as a determinant of atherosclerosis in patients with type 2 diabetes. Cardiovasc Diabetol. 2015;14:136.

42. Kvist H, Chowdhury B, Grangard U, Tylén U, Sjöström L. Total and visceral adipose-tissue volumes derived from measurements with computed

tomography in adult men and women: predictive equations. Am J Clin Nutr 1988;48:1351–61.

43. World Health Organization (Switzerland) Global strategy on diet, physical activity and health. Geneva: WHO; 2004.
44. Kumar S, Gupta A, Jain S. Neck circumference as a predictor of obesity and overweight in rural central India. Int J Med Public health 2012;2(1):62-6.
45. Chan JM, Rimm EB, Colditz GA, Stampfer MJ, Willett WC. Obesity, fat distribution, and weight gain as risk factors for clinical diabetes in men. Diabetes Care. 1994;17:961-9.
46. Wang Y, Rimm EB, Stampfer MJ, Willett WC, Hu FB. Comparison of abdominal adiposity and overall obesity in predicting risk of type 2 diabetes among men. Am J Clin Nutr. 2005;81:555-563.
47. Ford ES, Williamson DF, Liu S. Weight change and diabetes incidence: Findings from a national cohort of US adults. Am J Epidemiol. 1997;146:214-22.
48. Bonora E, Kiechl S, Willeit J, Oberhollenzer F, Egger G, Meigs JB, et al. Population-based incidence rates and risk factors for type 2 diabetes in white individuals:the Bruneck study. Diabetes. 2004;53:1782-9.
49. Lillioja S, Mott DM, Spraul M, Ferraro R, Foley JE, Ravussin E, et al. Insulin resistance and insulin secretory dysfunction as precursors of non-insulin dependent diabetes mellitus. Prospective studies of Pima Indians. N Engl J Med. 1993;329:1988-92.
50. Haffner SM, Valdez RA, Hazuda HP, Mitchell BD, Morales PA, Stern MP. Prospective analysis of the insulin-resistance syndrome (syndrome X). Diabetes. 1992;41:715-22.

51. Wagenknecht LE, Langefeld CD, Scherzinger AL, Norris JM, Haffner SM, Saad MF, Bergman RN. Insulin sensitivity, insulin secretion, and abdominal fat:the Insulin Resistance Atherosclerosis Study (IRAS) Family Study. Diabetes. 2003;52:2490-6.

52. Van Itallie TB. Health implications of overweight and obesity in the United States. Ann Intern Med. 1985;103:983-8.

53. Faloia E, Giacchetti G, Mantero F. Obesity and hypertension. J Endocrinol Invest. 2000;23:54-62.

54. Zimmet PZ. Kelly West Lecture 1991. Challenges in diabetes epidemiology--from West to the rest. Diabetes Care. 1992;15:232-52.

55. Ball SD, Swan PD. Accuracy of estimating intraabdominal fat in obese women. J Exerc Physiol Online 2003;6:1–7.

56. Ashwell M, Cole TJ, Dixon AK. New insight into the anthropometric classification of fat distribution shown by computed tomography. Br Med J Clin Res Ed 1985;290:1692–4.

57. Onat A, Avci GS, Barlan MM, Uyarel H, Uzunlar B, Sansoy V. Measures of abdominal obesity assessed for visceral adiposity and relation to coronary risk. Int J Obes Relat Metab Disord 2004;28:1018–25.

58. Seidell JC, Oosterlee A, Deurenberg P, Hautvast JG, Ruijs JH. Abdominal fat depots measured with computed tomography: effects of degree of obesity, sex, and age. Eur J Clin Nutr 1988;42:805–15.

59. Kullberg J, von Below C, Lönn L, Lind L, Ahlström H, Johansson L. Practical approach for estimation of subcutaneous and visceral adipose tissue. Clin Physiol Funct Imaging 2007;27:148–53

60. World health organization. Report of a WHO consultation on obesity. Obesity: Preventing and managing the global epidemic. Geneva: World health organization; 1997. p. 158.

61. Ambady R, Ronald C, Chamukuttan S. Diabetis in Asia. Lancet 2010;375:408-18.

62. Aswathappa J, Garg S, Kutty K, Shankar V. Neck circumference as an anthropometric measure of obesity in diabetics. North Am J Med Sci 2013;5:28-31.

63. Shah A, Bhandary S, Malik SL, Risal P, Koju R. Waist circumference and waist-hip ratio as predictors of type 2 diabetes mellitus in the Nepalese population of Kavre District. Nepal Med Coll J. 2009;11(4):261-7.

64. Qiao Q, Nyamdorj R. Is the association of type II diabetes with waist circumference or waist-to-hip ratio stronger than that with body mass index? Eur J Clin Nutr 2010;64(1):30-4.

65. Fox CS, Massaro JM, Hoffmann U, Pou KM, Maurovich-Horvat P, Liu CY, et al. Abdominal visceral and subcutaneous adipose tissue compartments:association with metabolic risk factors in the Framingham Heart Study. Circulation. 2007;116(1):39-48.

66. Preis SR, Massaro JM, Hoffmann U, D'Agostino RB Sr, Levy D, Robins SJ, et al. Neck circumference as a novel measure of cardiometabolic risk:the Framingham Heart study. J Clin Endocrinol Metab. 2010;95(8):3701-10

67. Jensen MD. Role of body fat distribution and the metabolic complications of obesity. J Clin Endocrinol Metab 2008;93(11 Suppl 1):S57–63.

68. Vague J. The degree of masculine differentiation of obesities:a factor determining predisposition to diabetes, atherosclerosis, gout, and uric calculous disease. Am J Clin Nutr 1956;4:20–34.

69. Ben-Noun LL, Laor A. Relationship between changes in neck circumference and cardiovascular risk factors. Exp Clin Cardiol 2006;11(1):14-20.

70. Ben-Noun L, Sohar E, Laor A. Neck circumference as a simple screening measure for identifying overweight and obese patients. Obes Res 2001;9:470–7.

71. Ben-Noun L, Laor A. Relationship of neck circumference to cardiovascular risk factors. Obes Res 2003;11:226–31.

72. Ben-Noun LL, Laor A. Relationship between changes in neck circumference and changes in blood pressure. Am J Hypertens 2004;17:409–14.

73. Freedman DS, Rimm AA. The relation of body fat distribution, as assessed by six girth measurements, to diabetes mellitus in women. Am J Public Health 1989;79:715–20

74. Laakso M, Matilainen V, Keinänen-Kiukaanniemi S. Association of neck circumference with insulin resistance-related factors. Int J Obes Relat Metab Disord 2002;26:873–5.

75. Grunfeld C, Rimland D, Gibert CL, Powderly WG, Sidney S, Shlipak MG, et al. Association of upper trunk and visceral adipose tissue volume with insulin resistance in control and HIV-infected subjects in the FRAM study. J Acquir Immune Defic Syndr 2007;46:283–90.

76. Wohl D, Scherzer R, Heymsfield S, Simberkoff M, Sidney S, Bacchetti P, et al. The associations of regional adipose tissue with lipid and lipoprotein levels in HIV-infected men. J Acquir Immune Defic Syndr 2008;48:44–52.

77. Guo ZK, Hensrud DD, Johnson CM, Jensen MD. Regional postprandial fatty acid metabolism in different obesity phenotypes. diabetes. 1999;48:1586–92

78. Yang GR, Yuan SY, Fu HJ, Wan G, Zhu LX, Bu XL. Neck circumference positively related with central obesity, overweight, and metabolic syndrome in chinese subjects with type 2 diabetes: Beijing community diabetes study 4. Diabetes Care. 2010;33:2465–7.

79. Li HX, Zhang F, Zhao D, Xin Z, Guo SQ, Wang SM, et al. Neck circumference as a measure of neck fat and abdominal visceral fat in Chinese adults. BMC Public Health. 2014;14:311.

80. Freedman DS, Rimm AA. The relation of body fat distribution, as assessed by six girth measurements, to diabetes mellitus in women. Am J Public Health. 1989 June; 79(6): 715–720.

81. World Health Organisation. The Asia-Pacific perspective: Redifining obesity and its treatment. Australia: International Diabetes Institute Health Communications Australia Pty Ltd; 2000.

82. Snehalatha C, Viswanathan V, Ramachandran A. Cutoff values for normal anthropometric variables in asian Indian adults. Diabetes Care. 2003;26(5):1380-4.

83. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive Summary of the Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). JAMA 2001; 285: 2486–97.

84. Momin AA, Bankar MP, Bhoite GM. Determination of HOMA IR cut off value, and efficiency of lipids and lipoprotein ratios as discriminator of insulin

resistance in type 2 Diabetes Mellitus patients. IOSR J Pharm 2014;4 (6):9-14.

85. Chan DC, Watts GF, Barrett PH, Burke V. Waist circumference, waist-to-hip ratio and body mass index as predictors of adipose tissue compartments in men. QJM 2003; 96: 441-7.
86. Kopelman PG, Hitman GA. Naturally occurring antihyper glycemic and antidyslipedimic agents. The Lancet 1998;5:352.
87. Shi Y, Frank B. The global implications of diabetes and cancer. The Lancet 1947;9933:383.
88. Henry M, Kronenberg MD, Shlomo Melmed MD, Kenneth S. Polonsky MD. 'Williams's textbook of endocrinology. 12th ed., Philadelphia: Elsevier/ Saunders; 2011.
89. Vos T, Flaxman AD, Nghavi M, Lozano R, Michaud C, Ezzati M, et al. A systemic analysis for the global burden of disease study, The Lancet 2010;380 (9859):2163.
90. Mathers CD, Loncar D. Projections of global mortality and burden of disease from 2002 to 2030. PLOS Med 2006;3(11):442.
91. Shaw JE, Sicree RA, Zimmet PZ. Global estimates of the prevalence of diabetes for 2010 and 2030. Diabetes Res Clin Pract 2010;87:4-14.
92. Diabetes Atlas. 6th ed., Brusels: International Diabetes Federation; 2013.
93. Ramachandran A, Das AK, Joshi SR, Yajnik CS, Shah S, Prasanna Kumar KM. Current status of diabetes in India and need for novel therapeutic agents. J Assoc Physicians India. 2010;58:7–9.
94. Janssen I, Heymsfield SB, Allison DB, Kotler DP, Ross R. Body mass index and waist circumference independently contribute to the prediction of

nonabdominal, abdominal subcutaneous, and visceral fat. Am J Clin Nutr 2002; 75: 683-8.

95. Carr ME. Diabetes mellitus:A hypercoagulable state. J Diabetes Complications 2001;15:44-54.
96. Mooradian AD. Dyslipidemia in type 2 diabetes mellitus. Nature Clinical Practice Endocrinology & Metabolism 2009;5:150-9.
97. Stamler J, Vaccaro O, Neaton JD, Wentworth D. Diabetes, other risk factors, and 12-yr cardiovascular mortality for men screened in the Multiple Risk Factor Intervention Trial. Diabetes Care 1993;16:434–44
98. Sadeghi M, Raza H. Serum lipid distribution and prevalence of Dyslipidemia in urban and rural communities in Iran - IHHP study. Pak J Cardiol 2004;15(2): 88-94.
99. Wei M, Mitchell BD, Haffner SM. Effects of cigarette smoking, diabetes, high cholesterol, and hypertension on all-cause mortality and cardiovascular disease mortality in Mexican Americans: The San Antonio Heart Study. Am J Epidemiol 1996;144:1058-65.
100. Alaettin A, Abdullah D, Murat S. The predictive and discriminative value of serum lipoproteins in atherosclerotic coronary artery disease. Pak Heart J 1998;31:23-30.
101. Bhatti SM, Dhakam S, Khan MA. Trends of lipid abnormalities in Pakistani Type-2 Diabetes Mellitus patients: A tertiary care centre data. Pak J Med Sci 2009;25(6):883-9.
102. Khalil AM, Rehman S. Prevalence of diabetic dyslipidemia in 120 patients of type 2 Diabetes Mellitus. J Med Sci 2005;13(2):128-31.

103. Hannan F, Abdullatif H, Nahida H. The metabolic syndrome in west bank population, an urban-rural comparison. Diabetes Care 2001;24:275-9.

104. DeFronzo RA, Sherwin RS, Kraemer N. Effect of physical training on insulin action in obesity. Diabetes. 1987;36:1379-85.

105. Guo X, Li Y, Sun G, Yang Y, Zheng L, Zhang X, et al. Prehypertension in children and adolescents: association with body weight and neck circumference. Intern Med. 2012;51:23–27.

106. Kurtoglu S, Hatipoglu N, Mazicioglu MM, Kondolot M. Neck circumference as a novel parameter to determine metabolic risk factors in obese children. Eur J Clin Invest. 2012;42:623–630.

107. Onat A, Hergenc G, Yuksel H, Can G, Ayhan E, Kaya Z, Dursunoglu D. Neck circumference as a measure of central obesity: associations with metabolic syndrome and obstructive sleep apnea syndrome beyond waist circumference. Clin Nutr 2009; 28: 46-51.

108. Hatipoglu N, Mazicioglu MM, Kurtoglu S, Kendirci M. Neck circumference: an additional tool of screening overweight and obesity in childhood. Eur J Pediatr 2010; 169: 733-9.

109. Nafiu OO, Burke C, Lee J, Voepel-Lewis T, Malviya S, Tremper KK. Neck circumference as a screening measure for identifying children with high body mass index. Pediatrics 2010; 126: e306-10.

110. Mazicioglu MM, Kurtoglu S, Ozturk A, Hatipoglu N, Cicek B, Ustunbas HB. Percentiles and mean values for neck circumference in Turkish children aged 618 years. Acta Paediatr 2010; 99: 1847-53.

111. Samuel VT, Shulman GI. Mechanisms for insulin resistance: common threads and missing links. Cell. 2012;148(5):852-71.

112. da Silva Cde C, Zambon MP, Vasques AC, Rodrigues AM, Camilo DF[1], Antonio MÂ, et al. Neck circumference as a new anthropometric indicator for prediction of insulin resistance and components of metabolic syndrome in adolescents: Brazilian Metabolic Syndrome Study. Rev Paul Pediatr. 2014;32(2):221-9.

113. Androutsos O, Grammatikaki E, Moschonis G, Roma-Giannikou E, Chrousos GP, Manios Y, et al. Neck circumference: a useful screening tool of cardiovascular risk in children. Pediatr Obes. 2012;7:187–195.

114. LaBerge RC, Vaccani JP, Gow RM, Gaboury I, Hoey L, Katz SL. Inter- and intra-rater reliability of neck circumference measurements in children. Pediatr Pulmonol. 2009;44:64–69.

ANNEXURE I – CONSENT FORM

Title of research study: "ESTIMATION OF SUBCUTANEOUS FAT THICKNESS USING VARIOUS ANTHROPOMETRIC MEASURES AND THEIR CORRELATION IN TYPE 2 DIABETES MELLITUS-A ONE YEAR CROSS SECTIONAL STUDY"

Principal investigator:

Dr. _____

Post-graduate student,

Department of General Medicine,

Jawaharlal Nehru Medical College,

Belagavi – 590 010

Introduction and purpose

Diabetes mellitus (DM) is a syndrome of impaired carbohydrate, fat, and protein metabolism either by lack of insulin secretion (DM type I) or by decrease in sensitivity of tissues to insulin (DM type II). There has been a dramatic increase in the prevalence of DM type II in India in recent times. Insulin resistance is also associated with visceral and subcutaneous fat content. Neck circumference (NC) is a relatively new method of differentiating between normal and abnormal and abnormal fat distribution. It has been scapular skin thickness (ISST) is also associated with metabolic traits related to insulin resistance so is subcutaneous abdominal fat (SAF) thickness. These parameters have correlated individually in various studies, but no study till date has taken all these anthropometric measures and compared with each other in patients of type II diabetes mellitus.

Procedure

If you agree to be part of the research study, you will be asked the relevant history and will be subjected to relevant clinical examination and investigations. You will also have to give blood samples for the investigations as follows Fasting blood sugar, Post-Prandial blood sugar, HbA1c, Lipid profile, Serum Insulin level.

Risks and benefits

The only risk and possible discomfort you might get is while taking blood samples for the investigations. It may cause swelling, pain. Redness bruising or infection (rarely happens) at the site from where the samples are drawn.

By participating in this study you may not get any benefits from this but the data collected will be helpful in understand diabetes mellitus better.

Alternatives

Taking part in this study is voluntary. You may choose not to be take part in this study, or if you decide to take part you can later change your mind and withdraw from the study. Your decision will not change the present or future health care or other services that you receive. The study doctor or sponsor may stop your participation in this study at any time. If you choose not to take part in the study, you will receive the standard treatment for patients with your condition.

Privacy and confidentiality

All information collected about you during the course of this study will be kept confidential to the extent permitted by law. The code numbers will identify you in this research record. Information from this study may be published but your identity will be confidential in any publication.

Institution/sponsors/compensation

In case of any injury related to the study, treatment will be made available at KLES Dr. Prabhakar Kore Hospital and Medical Research Centre, Belgaum. There is no compensation or payment for such medical treatment by law.

Financial incentives for participants

You will not be paid/offered any gifts/incentives for participating in the study.

Authorisation to publish the results

The results of the study would be forwarded to the KLE University, Belgaum as part of requirement towards the completion of MD degree, review and publishing.

Questions/contact details

In case of the queries during study you may contact following persons.

In case of any queries, regarding right as a part

3) Dr. Ganga Pilli,
Chairman,
Jawaharlal Nehru Medical College,
Ethical committee for human research
Phone Number: 08312471350
Extension: 1527

CONSENT STATEMENT

I voluntarily agree to take part in this study by signing below. I may withdraw at any time. I am not giving up any of my legal rights by signing this form. My signature below indicated that I have read, or it has been read to me, this consent form, and have had all the questions answered.

Name of the participant : _____

Signature/Thumb print : _____

Name of guardian : _____

Signature/Thumb print : _____

Name of the witness : _____

Signature/Thumb print : _____

Investigator name : _____

Signature : _____

Date:

Place:

ANNEXURE II – PROFORMA

Case Number :

Name :

Age/Sex :

Address :

Occupation :

Chief complaints

History of present illness

Past history

Treatment history

Family history

Personal history

On Examination

Physical Examination

General Condition

Pallor:	Yes/No	Icterus	:	Yes/No
Lymphadenopathy:	Yes/No	Cyanosis	:	Yes/No
Clubbing:	Yes/No	Edema	:	Yes/No

Vitals

Temperature	:	Respiratory rate	:
Pulse	:	Blood pressure	:

Systemic Examination

Cardiovascular system :

Respiratory system :

Per abdomen :

Central nervous system :

Investigations

ANNEXURE- III MASTER CHART

Serial number	IP/OP number	Age	Sex	T2 DM HISTORY			Height (Cms)	Weight (Kgs)	Body mass index (kg/m2)	Waist circumference (Cms)	Hip circumference (Cms)	Waist hip ratio	General condition						Vitals					Systemic Examination			FBS	PPBS	HBA1C	TOTAL CHOLESTEROL	HDL	ldl	TRIGLYCERIDES	serum insulin	Neck circumference (Cms)	Intrascapular skin thickness (Cm)	HOMA IR
																					BP (mmHg)															
				history	duration	on treatment							Pallor	Icterus	Lymphadenopathy	Cyanosis	Clubbing	Edema	Temperature	Respiratory rate	Pulse	Systolic	Diastolic	Cardiovascular system	Per abdomen	Central nervous system										
1	3577984	55	F	Y	4	Y	168	70	24.8	87	76	1.14	N	N	N	N	N	N	N	14	70	130	70	N	N	N	125	101	7.2	186	36	102	188	12	36	2	3.7
2	1132545	62	M	Y	8	Y	170	84	29.1	90	78	1.15	N	N	N	N	N	N	N	12	84	140	90	N	N	N	166	256	14.9	200	30	142	224	10	40	1.8	4.1
3	2515059	70	F	Y	3	Y	180	79	24.4	104	83	1.25	Y	N	N	N	N	N	N	14	68	150	80	N	N	N	88	193	6.9	184	37	122	127	4.4	38	1.2	1
4	649404	61	F	Y	5	Y	159	68	26.9	103	87	1.18	N	N	N	N	N	N	N	12	78	136	78	N	N	N	160	315	10.7	133	28	84	105	7.6	37	2	3
5	3332281	55	M	Y	3	Y	170	88	30.5	100	76	1.31	N	N	N	N	N	N	N	14	80	140	90	N	N	N	163	305	8.2	147	32	110	180	9.8	40	1.8	3.9
6	3547784	75	M	Y	1	Y	166	69	25.2	88	71	1.23	Y	N	N	N	N	N	N	16	74	144	78	N	N	N	130	303	9	178	33	111	169	4.2	39	1	1.3
7	3562589	45	M	Y	2	Y	161	68	26.2	88	89	0.88	N	N	N	N	N	N	N	16	68	138	80	N	N	N	83	173	7	170	28	128	111	3.2	39.5	1.1	0.7
8	3408229	57	M	Y	7	Y	169	76	26.6	100	90	1.1	N	N	N	N	N	N	N	16	70	146	82	N	N	N	177	267	8.7	190	35	125	164	6	40	1.3	2.6
9	3549464	50	M	Y	3	Y	174	78	25.8	104	78	1.33	N	N	N	N	N	N	N	12	76	150	90	N	N	N	100	162	6.1	79	23	27	144	5.6	41.2	2	1.4
10	1193116	56	M	Y	8	Y	158	66	26.4	94	79	1.1	N	N	N	N	N	N	N	12	82	142	90	N	N	N	146	237	14.1	148	30	96	109	6.8	41.5	1.5	2.5
11	750293	74	M	Y	5	Y	161	69	26.6	92	82	1.12	Y	N	N	N	N	Y	N	18	70	136	88	N	N	N	172	284	8	136	46	41	244	5.6	38.6	1.7	2.4
12	666517	73	M	Y	12	Y	168	76	26.9	90	88	1.02	Y	N	N	N	N	N	N	16	60	138	90	N	N	N	168	246	11.6	108	24	74	54	6.9	42.2	2.2	2.9
13	1259265	60	M	Y	14	Y	167	69	24.9	104	86	1.2	N	N	N	N	N	N	N	12	66	142	80	N	N	N	127	114	6.7	191	38	114	195	4.5	38.6	1.5	1.4
14	3361510	56	M	Y	8	Y	163	68	25.6	99	90	1.1	N	N	N	N	N	N	N	14	78	148	86	N	N	N	156	225	10.7	185	34	120	178	4.8	38	1.9	1.8
15	3488763	45	F	Y	4	Y	162	69	26.3	87.5	76	1.2	N	N	N	N	N	N	N	14	88	132	78	N	N	N	213	156	8.5	162	37	102	116	8.9	36.5	2.1	4.7
16	3364389	70	F	Y	16	Y	176	79	25.5	104	71	1.46	N	N	N	N	N	N	N	16	74	136	80	N	N	N	152	207	8.3	130	30	88	187	6	42	2.3	2.3
17	2686217	66	M	Y	10	Y	165	69	25.3	88	77	1.1	N	N	N	N	N	N	N	14	78	150	88	N	N	N	195	288	10.2	136	31	65	199	4.8	41	1.5	2.3
18	3789762	71	M	Y	9	Y	165	68	25.2	88.5	74	1.12	Y	N	N	N	N	N	N	14	92	132	78	N	N	N	486	539	12.5	178	28	117	254	22	40	1.3	26.4
19	3522773	55	F	Y	6	Y	164	64	23.8	92	81	1.13	N	N	N	N	N	N	N	12	80	134	90	N	N	N	170	249	8	200	29	107	323	5.8	38	1.3	2.4
20	571639	57	M	Y	3	Y	160	67	26.4	86.5	80	1.07	N	N	N	N	N	N	N	18	74	142	86	N	N	N	82	164	7.5	206	25	146	267	6	37	1.1	1.2
21	700772	38	M	Y	1	Y	172	69	23.3	92	80.4	1.1	N	N	N	N	N	N	N	16	70	134	78	N	N	N	189	287	15.4	174	32	107	308	7.8	39.4	1.5	3.6
22	3541863	54	M	Y	6	Y	177	88	28.1	96	75	1.27	N	N	N	N	N	N	N	14	80	138	90	N	N	N	118	203	10.7	168	36	102	198	5.7	40	2.2	1.7
23	693728	42	M	Y	3	Y	176	80	25.8	103	77	1.33	N	N	N	N	N	N	N	16	78	154	94	N	N	N	165	247	7.9	136	25	74	182	4.9	41	2.4	2
24	667626	64	M	Y	5	Y	160	74	28.9	101	76	1.3	N	N	N	N	N	N	N	18	84	138	90	N	N	N	110	191	7.8	132	25	68	196	4.1	40.2	3	1.1
25	1158726	50	M	Y	9	Y	162	60	23	89	79	1.12	N	N	N	N	N	N	N	14	78	142	88	N	N	N	132	201	7.9	175	37	118	103	3.9	38.6	1.5	1.3
26	3321263	54	M	Y	5	Y	175	78	25.6	87	81	1.07	N	N	N	N	N	N	N	16	70	152	80	N	N	N	143	261	9	190	26	140	302	5.2	40	1.4	1.8

27	689068	59	F	Y	4	Y	168	70	24.8	90	82	1.09	N	N	N	N	N	N	N	12	80	130	80	N	N	N	145	220	8.1	198	54	121	114	13	38	1.2	4.8
28	685202	68	F	Y	12	Y	167	69	24.9	92	86	1.06	N	N	N	N	N	N	N	16	88	146	90	N	N	N	125	168	7.6	204	32	70	124	12	39	1.5	3.7
29	703774	71	M	Y	8	Y	170	84	26	99	80	1.2	N	N	N	N	N	N	N	15	84	123	80	N	N	N	122	179	7.3	108	47	48	63	25	40	2.3	7.4
30	3541863	54	M	Y	6	Y	166	80	29	96	89	1.07	N	N	N	N	N	N	N	18	76	130	90	N	N	N	118	203	10.7	160	24	102	134	10	39	2.2	3
31	585602	63	M	Y	5	Y	174	78	25.7	101	78	1.3	N	N	N	N	N	N	N	16	78	160	100	N	N	N	141	256	9.7	178	29	104	224	9.8	37.4	2	3.4
32	3549464	50	M	Y	4	Y	160	69	27	104	78	1.33	N	N	N	N	N	N	N	13	84	126	80	N	N	N	98	175	7	79	23	27	144	3.4	37	2.5	0.8
33	1429413	55	F	Y	9	Y	164	80	29.7	102	98	1.04	N	N	N	N	N	N	N	14	76	130	80	N	N	N	115	152	6.8	172	45	106	106	3.8	34	2.6	1.1
34	2395022	76	M	Y	6	Y	170	88	30.5	87.5	99	0.87	N	N	N	N	N	N	N	16	82	156	100	N	N	N	164	214	7.5	148	30	98	334	7.8	37.3	1.4	3.2
35	1556328	38	M	Y	4	Y	164	78	29	102	90	1.13	N	N	N	N	N	N	N	12	90	140	90	N	N	N	271	271	9.6	202	32	120	229	15	39.4	1.6	9.8
36	3631502	54	F	Y	12	Y	156	67	27.5	100	76	1.31	N	N	N	N	N	N	N	14	98	150	90	N	N	N	218	320	8.4	135	27	85	118	12	36.4	1.3	6.5
37	742189	60	M	Y	5	Y	165	63	23.1	104	70	1.48	N	N	N	N	N	N	N	17	86	156	90	N	N	N	243	273	11.4	252	43	149	303	16	40	1.9	9.6
38	2047786	57	F	Y	7	Y	170	86	29.8	88	68	1.29	N	N	N	N	N	N	N	12	84	170	110	N	N	N	176	268	8.3	188	42	120	222	8.8	34	1.8	3.8
39	1059471	55	F	Y	8	Y	164	82	30.5	90	72	1.25	N	N	N	N	N	N	N	14	76	126	90	N	N	N	109	218	7.2	215	46	133	181	6.7	33	1.4	1.8
40	926078	75	M	Y	9	Y	167	89	31.9	104	75	1.38	N	N	N	N	N	N	N	16	78	148	90	N	N	N	134	198	6.7	234	34	134	254	4.7	36.8	1.6	1.6
41	2422054	52	F	Y	7	Y	143	76	37.2	105	74	1.41	N	N	N	N	N	N	N	12	92	150	80	N	N	N	317	447	12.8	156	25	100	256	18	40.3	1.5	14.1
42	662635	74	M	Y	5	Y	168	86	94	93	92	1.01	N	N	N	N	N	N	N	16	88	130	70	N	N	N	112	243	7.4	194	33	146	75	4.8	36.4	1.6	1.3
43	3297044	45	F	Y	2	Y	174	98	32.4	94	101	0.93	N	N	N	N	N	N	N	12	76	140	90	N	N	N	284	450	12.7	258	39	184	242	20	39	1.7	14
44	3619132	55	M	Y	5	Y	170	90	31.1	108	98	1.1	N	N	N	N	N	N	N	12	87	160	98	N	N	N	359	404	13.2	204	65	121	87	24	43	1.5	21.3
45	2357426	63	F	Y	7	Y	156	83	34	98	88	1.1	N	N	N	N	N	N	N	14	90	120	80	N	N	N	130	163	10.1	151	49	80	106	5.8	35	2.2	1.9
46	3332281	55	M	Y	4	Y	154	80	33.7	87.6	82	1.06	N	N	N	N	N	N	N	12	100	120	90	N	N	N	163	305	8.2	154	34	88	278	7.5	38.5	2.6	3
47	3621793	58	F	Y	6	Y	160	82	32	106	85	1.24	N	N	N	N	N	N	N	12	68	110	70	N	N	N	111	138	6.8	160	30	90	321	6.4	34	2.8	1.8
48	3323287	52	F	Y	4	Y	178	89	28.1	89	86	1.04	N	N	N	N	N	N	N	12	66	120	80	N	N	N	179	272	9.4	133	38	73	108	8.9	36	3	3.9
49	2991128	59	M	Y	8	Y	180	90	27.8	86	90	0.96	N	N	N	N	N	N	N	14	79	134	80	N	N	N	154	254	9.2	185	34	110	202	9.6	39.6	2.9	3.7
50	3177618	32	M	Y	1	Y	168	76	26.9	96	99	0.96	N	N	N	N	N	N	N	18	56	140	90	N	N	N	174	306	8.6	196	42	134	245	7.8	39	2.4	3.4
51	3607220	48	M	Y	4	Y	178	88	27.8	106	64	1.65	N	N	N	N	N	N	N	16	66	130	80	N	N	N	144	173	7.4	224	46	150	234	6.8	38.8	1.9	2.4
52	3092841	53	M	Y	6	Y	169	98	34.3	110	78	1.41	N	N	N	N	N	N	N	12	68	140	90	N	N	N	110	248	8.3	202	35	168	345	7.8	39.2	1.5	2.1
53	2686217	66	M	Y	10	Y	160	62	24.2	106	98	1.09	N	N	N	N	N	N	N	15	96	136	80	N	N	N	195	288	10.2	136	31	65	199	11	40	1.4	5.3
54	3559347	51	M	Y	6	Y	170	92	31.8	100	88	1.02	N	N	N	N	N	N	N	12	96	124	80	N	N	N	108	185	7.3	126	24	74	258	7.9	38.9	1.9	2.1
55	3164404	57	M	Y	8	Y	158	92	36.8	104	78	1.33	N	N	N	N	N	N	N	17	67	130	90	N	N	N	148	240	7.9	155	40	57	289	6.2	37.6	1.4	2.3
56	3469265	71	M	Y	15	Y	180	90	27.8	84	76	1.1	N	N	N	N	N	N	N	18	65	110	80	N	N	N	172	292	9.7	130	38	68	290	8.5	40	1.4	3.6
57	3203790	48	M	Y	2	Y	162	71	27.1	92	71.5	1.29	N	N	N	N	N	N	N	14	56	120	78	N	N	N	132	187	7.9	226	45	136	236	7.3	38	1.3	2.4
58	682418	64	M	Y	7	Y	170	80	27.7	90	78	1.15	N	N	N	N	N	N	N	12	60	134	90	N	N	N	136	281	7.6	196	36	140	102	5	39	1.9	1.7
59	3183809	58	M	Y	3	Y	162	76	29	88	77	1.1	N	N	N	N	N	N	N	12	61	144	88	N	N	N	262	359	8.2	191	48	126	85	14	41	2.2	9.1
60	3509661	70	M	Y	12	Y	167	80	28.7	96	72	1.33	N	N	N	N	N	N	N	14	70	156	86	N	N	N	240	332	8.5	134	34	87	66	17	43	2.5	10
61	3581142	46	M	Y	1	Y	166	72	26.1	89	75	1.18	N	N	N	N	N	N	N	16	80	166	100	N	N	N	120	175	6.4	156	30	68	90	8.4	38	2.6	2.5
62	743486	63	M	Y	6	Y	182	88	26.6	110	82	1.34	N	N	N	N	N	N	N	16	88	124	80	N	N	N	148	257	6.9	121	43	26	261	7.4	37.6	2.7	2.7
63	3582379	60	M	Y	8	Y	170	88	30.5	106	83	1.27	N	N	N	N	N	N	N	14	79	110	80	N	N	N	212	437	7.8	142	26	78	168	17	41.3	2.4	8.8
64	1805954	51	M	Y	4	Y	164	79	29.6	90	86	1.04	N	N	N	N	N	N	N	12	78	112	60	N	N	N	184	220	9.5	105	26	52	142	11	39	2.3	5.1
65	3559347	51	M	Y	2	Y	164	78	29	94	97	0.9	N	N	N	N	N	N	N	14	59	120	80	N	N	N	108	185	7.3	168	24	110	128	3.6	37	1.4	1
66	3200958	60	M	Y	6	Y	165	72	26.6	106	99	1.07	N	N	N	N	N	N	N	16	50	146	90	N	N	N	133	283	8.4	190	28	98	164	7.9	39.9	1.6	2.6

67	3124697	31	M	Y	1	Y	170	80	27.7	102	78	1.3	N	N	N	N	N	N	N	18	56	126	70	N	N	N	536	625	14.9	240	26	180	179	26	44	2	34.4
68	2165658	55	F	Y	4	Y	170	88	30.5	96	67	1.43	N	N	N	N	N	N	N	13	68	138	60	N	N	N	242	465	10.2	234	30	178	154	10	38.3	2.2	6
69	3412736	66	M	Y	4	Y	168	74	26.2	92	60	1.53	N	N	N	N	N	N	N	12	63	150	90	N	N	N	135	133	6.6	220	38	164	278	6.7	37.4	1.4	2.2
70	2783038	67	M	Y	8	Y	166	80	29	84	76	1.1	N	N	N	N	N	N	N	14	78	178	114	N	N	N	102	117	6.5	75	32	26	82	6.3	37.2	1.3	1.6
71	2047786	57	F	Y	9	Y	164	74	27.5	87	78	1.11	N	N	N	N	N	N	N	14	78	120	70	N	N	N	176	268	8.3	314	49	214	255	7.8	35.7	1.1	3.4
72	3537639	50	F	Y	5	Y	170	76	26.4	100	89	1.12	N	N	N	N	N	N	N	16	55	110	62	N	N	N	276	294	12	190	32	112	225	18	36.6	2	12.1
73	757544	65	F	Y	9	Y	169	80	28	102	95	1.07	N	N	N	N	N	N	N	14	70	124	70	N	N	N	198	278	10.4	219	35	148	237	12	37	1.6	5.9
74	2003472	63	M	Y	10	Y	176	90	29	104	68	1.52	N	N	N	N	N	N	N	12	54	114	80	N	N	N	120	202	6.6	228	32	165	345	4.8	36.5	1.3	1.4
75	3366613	53	F	Y	3	Y	164	78	29	105	73	1.43	N	N	N	N	N	N	N	12	66	144	80	N	N	N	124	143	6.4	128	47	61	101	7.2	35.8	1.54	2.2
76	3589824	50	M	Y	2	Y	170	88	30.5	98	71	1.3	N	N	N	N	N	N	N	14	80	156	90	N	N	N	186	288	11.2	156	23	67	330	6.7	38.6	1.7	3.1
77	700194	65	F	Y	5	Y	166	80	29	109	75.6	1.45	N	N	N	N	N	N	N	16	90	130	88	N	N	N	192	222	9.4	154	30	50	367	8	38	0.8	3.8
78	3494362	62	M	Y	8	Y	178	80	25.3	110	77	1.42	N	N	N	N	N	N	N	14	76	120	70	N	N	N	91	123	6.8	178	42	74	134	3.8	35	1.4	0.9
79	3523035	55	M	Y	4	Y	166	60	21.8	98	76	1.28	N	N	N	N	N	N	N	18	58	164	90	N	N	N	153	187	9.1	143	23	46	369	8.4	40.5	1.4	3.2
80	3412736	66	M	Y	10	Y	165	63	23.1	88	74	1.2	N	N	N	N	N	N	N	12	70	144	80	N	N	N	96	133	6.6	184	38	64	202	4	37.2	1.8	0.9
81	3290627	50	M	Y	6	Y	166	65	23.6	109	83	1.32	N	N	N	N	N	N	N	12	87	160	100	N	N	N	124	229	6.4	126	28	70	143	5.7	37.6	2.1	1.7
82	727994	58	F	Y	8	Y	167	68	24.4	86	85	1.03	N	N	N	N	N	N	N	14	68	120	80	N	N	N	93	153	6.9	162	36	106	104	3.5	33	2.2	0.8
83	3608528	50	M	Y	5	Y	164	68	25.3	105	75	1.4	N	N	N	N	N	N	N	12	70	90	60	N	N	N	172	362	11.6	122	40	61	107	12	42	2.7	5.1
84	3541863	54	M	Y	7	Y	158	60	24	100	89	1.12	N	N	N	N	N	N	N	12	80	100	60	N	N	N	118	203	10.7	156	36	68	222	4.8	38	2.7	1.4
85	3441410	56	M	Y	8	Y	160	68	26.7	102	80	1.27	N	N	N	N	N	N	N	14	54	120	90	N	N	N	176	245	8.2	178	40	122	198	12	41.1	2.4	5.2
86	3632204	67	F	Y	6	Y	158	66	26.4	98	81	1.2	N	N	N	N	N	N	N	12	62	110	80	N	N	N	190	258	9	122	25	68	142	9.8	39	1.6	4.6
87	162625	68	M	Y	10	Y	166	65	23.6	89	62	1.42	N	N	N	N	N	N	N	14	64	114	62	N	N	N	197	280	7.2	100	28	46	120	14	40.4	1.2	6.8
88	742589	80	F	Y	12	Y	169	65	22.7	87	70	1.2	N	N	N	N	N	N	N	15	68	164	90	N	N	N	176	278	7	162	46	64	154	8.9	39.7	1.9	3.9
89	598872	57	M	Y	5	Y	170	86	29.8	88	79	1.25	N	N	N	N	N	N	N	15	70	110	60	N	N	N	145	198	6.8	100	38	36	120	7.8	38	2.6	2.8
90	656962	66	F	Y	8	Y	157	69	27.6	80	80	1	N	N	N	N	N	N	N	13	58	126	82	N	N	N	132	200	6.7	128	37	48	98	8.4	35	2.9	2.7
91	688822	78	F	Y	9	Y	170	80	26.8	90	81	1.11	N	N	N	N	N	N	N	16	72	144	70	N	N	N	162	212	7.1	158	28	58	178	9.7	36.7	3	3.9
92	716987	68	M	Y	12	Y	164	89	33.1	101	88	1.14	N	N	N	N	N	N	N	17	70	124	70	N	N	N	122	224	7.4	162	27	70	134	6.7	38.6	2.2	2
93	3541933	71	F	Y	12	Y	170	80	27.2	110	98	1.12	N	N	N	N	N	N	N	18	58	110	70	N	N	N	148	198	8.4	178	28	84	158	7.4	39	2.4	2.7
94	1215217	64	M	Y	10	Y	166	60	29	98	67	1.46	N	N	N	N	N	N	N	12	68	150	90	N	N	N	170	224	8.6	132	39	56	142	12	37	1.4	4.8
95	2203899	55	F	Y	5	Y	164	89	33.1	97	77	1.24	N	N	N	N	N	N	N	14	79	164	90	N	N	N	124	178	10.2	140	37	60	178	9.3	33	1.4	2.8
96	3040334	73	M	Y	8	Y	165	76	27.9	99	112	0.87	N	N	N	N	N	N	N	11	80	124	70	N	N	N	165	236	9	172	34	78	180	8.3	38.8	2.2	3.4
97	665433	65	F	Y	9	Y	168	82	29.1	105	110	0.95	N	N	N	N	N	N	N	16	81	156	94	N	N	N	126	199	7.8	158	29	43	120	7	34	1.6	2.2
98	678955	77	M	Y	6	Y	164	70	26	110	112	0.98	N	N	N	N	N	N	N	15	74	124	80	N	N	N	134	186	6.8	132	30	48	165	6.8	37.8	1.8	2.2
99	685202	67	F	Y	8	Y	168	76	27.1	112	84	1.27	N	N	N	N	N	N	N	12	79	112	80	N	N	N	124	174	6.6	108	32	40	168	8	36	2.2	2.4
100	689068	57	M	Y	6	Y	170	88	30.5	98	88	1.11	N	N	N	N	N	N	N	14	58	100	56	N	N	N	112	188	7.2	120	28	62	100	6	37	1.76	1.7

ANNEXURE III – KEY TO MASTER CHART

BP	-	Blood pressure
Cms	-	Centimeters
F	-	Female
FBS	-	Fasting blood sugar
HbA1c	-	Glycosylated haemoglobin
HDL	-	High density lipoprotein
IP/OP	-	In patient/Out patient
Kg/m^2	-	Kilograms per square meter
Kgs	-	Kilograms
LDL	-	Low density lipoprotein
M	-	Male
mmHg	-	millimeters of mercury
N	-	Normal
PPBS	-	Post prandial blood sugar
T2 DM	-	Type 2 diabetes mellitus
Y	-	Yes