BODY COMPOSITION MEASURES OF TYPE 2 DIABETICS

By

R.SARANYA

(11PN13)

A THESIS SUBMITTED TO THE
AVINASHILINGAM INSTITUTE FOR HOME SCIENCE AND HIGHER EDUCATION FOR WOMEN
COIMBATORE - 641 043.

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN FOOD SCIENCE AND NUTRITION

MAY 2013

BODY COMPOSITION MEASURES OF TYPE 2 DIABETICS

By

R.SARANYA

(11PN13)

A THESIS SUBMITTED TO THE
AVINASHILINGAM INSTITUTE FOR HOME SCIENCE AND HIGHER EDUCATION FOR WOMEN
COIMBATORE - 641 043.

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN FOOD SCIENCE AND NUTRITION

CERTIFIED AS BONAFIDE RESEARCH WORK

MAY 2013

Signature of the
Head of the Department

Signature of the Guide

ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

The investigator expresses her deep sense of gratitude to God Almighty who graciously blessed her with good health, strength and wisdom to complete the study.

The investigator expresses her reverential gratitude to **Dr. (Thiru) T. S. K. Meenakshisundaram, M.A., M.Phil., Ph.D.,** Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for providing an opportunity to conduct the study.

The investigator owes her special thanks and gratitude to **Dr. (Mrs.) Sheela Ramachandran, M.Sc., P.G.Dip.Ed., Ph.D., (Avinashilingam),** Vice Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, for her love, support and guidance in carrying out the study smoothly.

The investigator records her sincere gratitude to **Dr. (Mrs.) T. S. Gowri Ramakrishnan, M.Sc., Dip.Ed., M. Phil, Ph.D., (Avinashilingam),** Registrar, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for providing all the help in the smooth conduct of the study.

The investigator records her sincere thanks to **Dr. (Mrs.) K. Thangamani, M.Sc., Dip.Ed., M. Phil., Ph.D.,** Dean, Faculty of Home Science and Professor and Head, Department of Home Science Extension Education, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for the help rendered in the conduct of the study.

The investigator owes her heartfelt thanks and deep sense of gratitude to **Dr. (Mrs.) U. K. Lakshmi, M.Sc., Dip.Ed., M.Phil., (Madras), Ph.D., (Avinashilingam),** Professor and Head, Department of Food Science and Nutrition, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for her valuable help, concern and encouragement which has helped in the successful completion of this study.

With glowing sense of gratitude, the researcher places her sincere and grateful thanks to her most honored guide **Dr. (Mrs.) S. Kowsalya, M.Sc., M.Phil., (Bharathiar), Ph.D., (Avinashilingam),** Professor, Department of Food Science and

Nutrition, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for her excellent, inspiring and ceaseless guidance, valuable suggestions and advice, untiring help and enduring support rendered throughout for the successful completion of the study.

The investigator is thankful to **Dr. (Mr.) S. Ramalingam, Principal PSGIMSR and Dr. (Mrs.) Vijaya, Professor,** Department of Biochemistry, PSGIMSR for their support and help rendered in the conduct of the study.

On the personal note, the investigator is deeply indebted and express her guidance to her ever loving family **(late) Mr. R. M. Natesan, Mr. N. Rajendran, Mrs. R. Ponnalagu, Mr. K. Meganathan, Sister, Brother, friends** and all those who have actively helped and rendered endless inspiration towards the completion of the study.

The investigator takes this opportunity to extend her thanks to all the **Faculty members,** Department of Food Science and Nutrition for their support.

CONTENTS

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

INTRODUCTION

I. INTRODUCTION

Diabetes mellitus (DM) is probably one of the oldest diseases known to man. It was first reported in Egyptian manuscript about 3000 years ago. Diabetes mellitus was first described in India in the ancient texts of Charaka and Sushruta (1500 BCE) (Anjana *et al.*,2011). Since then, the disease has gradually evolved into a major public health problem. In 1936, the distinction between type 1 and type 2 diabetes mellitus was clearly made. Type 2 Diabetes Mellitus also known as non-insulin-dependent or adult-onset diabetes, was first described as a component of metabolic syndrome in 1988.Type 2 Diabetes Mellitus is the most common form of diabetes mellitus characterized by hyperglycemia, insulin resistance, and relative insulin deficiency. Although there is an increase in the prevalence of type 1 diabetes also, the major driver of the epidemic is the more common form of diabetes, namely type 2 diabetes, which accounts for more than 90 per cent of all diabetes cases (Olokoba *et al.,*2012).

Type 2 Diabetes Mellitus is primarily due to lifestyle factors such as physical inactivity, sedentary lifestyle, high calorie intake, cigarette smoking and generous consumption of alcohol. Obesity has been found to contribute to approximately 55 per cent of cases of type 2 diabetes mellitus, central visceral adiposity, genetics (especially having first degree relatives with type 2 diabetes mellitus), behavioral and environmental risk factors (Obateru *et al.,*2012).

According to the WHO, South-east Asia and the Western Pacific region are at the forefront of the current diabetes epidemic, with India and China facing the greatest challenges. In these countries, the incidence and prevalence of type 2 diabetes among children are also increasing at an alarming rate, with potentially devastating consequences.

Diabetes has emerged as a major healthcare problem in India. According to the Fifth Diabetes Atlas published by the International Diabetes Federation (IDF), says India's prevalence of diabetes among 20-79 year olds is 9.2 per cent. India is only

second to China, which has 90 million diabetics (2011) that will increase to about 130 million by 2030. The country is also the largest contributor to regional mortality with 983,000 deaths caused due to diabetes this year. The countries with the largest number of diabetic people will be India, China and USA by 2030. It is estimated that every fifth person with diabetes will be an Indian (IDF,2011).

In 2004, the prevalence. of diabetes averaged 16 per cent in urban India and only three per cent in rural India. Prevalence is only 0.7 per cent for non-obese, physically active, rural Indians. It reaches 11 per cent for obese, sedentary and urban Indians (Diamond,2011).

The National Urban Diabetes Survey (NUDS), a population based study revealed that the prevalence in the southern part of India to be higher-13.5 per cent in Chennai, 12.4 per cent, in Bangalore, and 16.6 per cent in Hyderabad; compared to eastern India (Kolkata), 11.7 per cent; northern India (New Delhi), 11.6 per cent; and western India (Mumbai), 9.3 per cent (Mohan *et al.,*2007).

In developing countries, most people with diabetes are aged between 45 and 65 years, the prevalence of type 2 diabetes in those aged between 30 and 50 years in developing countries is also high in comparison with other countries (Kun-Ho-Yoon *et al.,*2006).

The so called “Asian Indian Phenotype” for diabetes refers to certain unique clinical and biochemical abnormalities in Indians which include increased insulin resistance, greater abdominal adiposity *i.e.*, higher waist circumference despite lower body mass index, lower adiponectin and higher high sensitive C-reactive protein levels. This phenotype makes Asian Indians more prone to diabetes and premature coronary artery disease(Mohan *et al.,*2007).

Madras Diabetes Research Foundation has published that diabetes in India is no longer a disease of the affluent or a rich man’s disease. It is becoming a problem even among the middle income and poorer sections of the society. Studies have shown that poor diabetic subjects are more prone to complications as they have less access to

quality health care (Sandeep *et al.,*2010).

Obesity is a serious social problem, one of the most important health issues of the modern world, especially in industrialized countries (Ostrowska *et al.,*2008). The health problems associated with an increase in the proportion of elderly in the population are further compounded by the increasing prevalence of obesity and overweight in older people. It is now well established that overweight and obesity are associated with an increased burden of hypertension, type 2 diabetes mellitus, coronary heart disease, gall stones or cancers(Ramsay *et al.,*2006).

Type 2 diabetes is a polygenetic disease and that environmental factors such as sedentary lifestyle, a high calorie intake, and consequent obesity play a major role in disease development. The term “diabesity” has been created to express that type 2 diabetes is obesity dependent and that obesity is the main etiologic cause of type 2 diabetes(Meisinger *et al.,*2006).

More than 1.1 billion adults worldwide are overweight, and 312 million of them are obese, according to the International Obesity Task Force. In the past 20 years, the rates of obesity have tripled in developing countries that have been adopting a Western lifestyle involving decreased physical activity and overconsumption of energy-dense foods. The growing prevalence of type 2 diabetes, cardiovascular disease, and some cancers is tied to excess weight. The burden of these diseases is particularly high in the middle-income countries of Eastern Europe, Latin America, and Asia, where obesity is the fifth-most-common cause of the disease burden — ranking just below underweight. Indeed, 90 per cent of individuals with type 2 diabetes are either overweight or obese (Hossain *et al.,*2007).

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 (Vazquez *et al.,*2007).

The Gothenburg study found various measures of central fat distribution and BMI to be independently and simultaneously correlated with NIDDM risk. Strong positive associations are revealed between all of the obesity measures (BMI, waist circumference, and WHR) and NIDDM risk, with waist circumference yielding the sharpest risk gradient (Carey,1997).

Interest in the study of human body composition spans at least a hundred years. The importance of body composition research as a distinct science is evident during at least two main periods during this century. The first period occurred immediately following World War II with the investigation of human semi-starvation and proceeded to early studies of body composition in disease. Many techniques for evaluating body composition were developed during this period, particularly tracer methods for quantifying specific components such as total-body water and fluid volumes.

The second major era in body composition research began during the mid-1980s with the recognition that many chronic and acute illnesses involved alterations in body composition, that these changes were linked with morbidity and mortality, and that nutritional treatments could affect patient outcome. Many body composition techniques were either introduced or fully appreciated during this era.

The measurement of body composition occurs in many branches of biology and medicine. It is measured by the human biologist studying human variation and adaptation and it is being used increasingly in the assessment of nutritional and growth status, fitness, work capacity, disease and its treatment. In human energetics, it is widely used for the standardization of variables such as basal metabolic rate or physical work capacity, for example, the investigation of the types and scope of adaptation to chronic energy and nutrient deficiency or excess.

Body composition can be assessed at the molecular, cellular, and tissue levels using several different methods. Evaluating body composition of obese individuals is necessary both in research and clinical practice to determine health as well as disease risk. It is well known that high amounts of body fat are associated with a greater risk of developing type 2 diabetes, cardiovascular disease, cancer, and renal failure. However, assessing body composition in the obese is challenging because obesity is marked by an increase in body fat and changes in body composition different from that of a non-obese person. There is an increase in total body hydration and a relative expansion of the extracellular water (ECW) component compared to intracellular water(ICW) (Kilates, 2000).

Type 2 diabetes is a metabolic disorder and as such should affect the components of body composition of diabetics. The changes it induces in patients complement the anthropological characteristics of this disease (Bournat *et al.,*2010).

At the simplest level, techniques for measuring body composition can assume that the body is divided into two compartments, fat mass (FM) and fat-free mass (FFM). The fat component is of relatively homogeneous composition, but FFM consists of a heterogeneous mix of water, mineral, protein and additional minor constituents. In order to quantify the amount of FM and FFM, using a two-compartment model, one must assume that these components exist in a known relationship to each other (Minderico *et al.,*2007).

Body composition can be assessed at the atomic level with the basic elements of carbon, calcium, potassium, and hydrogen; at the molecular level by amounts of water, protein, and fat; at the cellular level with extracellular fluid and body cell mass; and at the tissue level for amounts and distributions of adipose, skeletal, and muscle tissues. Analysis from the atomic through the cellular levels is with direct body composition methods such as neutron activation, isotope dilution, and total body counting. Criterion methods measure a property of the body, such as its density, or describe amounts and distributions of skeletal, muscle, and adipose tissues via X-ray or magnetic imaging

techniques. Criterion methods include densitometry, computed X-ray tomography (CT), magnetic resonance imaging (MRI), and DXA. Indirect methods, including anthropometry and Bioelectrical Impedance Analysis (BIA), provide estimates or indices of body composition based on results from direct or criterion methods **(**Duren *et al.,*2008).

Simple, rapid, and accurate measurement of body composition is frequently required for the medical and nutritional follow-up of obese individuals, especially during a weight-reduction period. For this reason, Bioelectrical Impedance Analysis (BIA) has become a popular method in research laboratories, hospitals, private clinics and wellness centers to assess body composition across a spectrum of ages and body weights. BIA is a safe, non-invasive and easy to handle method used for assessing body composition. BIA measures the body's impedance and the technique is based on the differing electrical conductivities (water content) of various components of the body (Kyle *et al.,* 2004).

Impedance measurements were first suggested by Thomasset (1962) but it was Hoffer (1969) who realized its potential as the basis of a simple field technique to measure total body water(Coward *et al.,*1988).

BIA using bipolar foot electrodes provides a valid estimate of percent body fat in subjects with type 2 diabetes mellitus. It does not require examiner skill, is rapid, and free from discomfort, and is a reliable technique for determination of body composition in type 2 diabetic subjects in clinical and investigative studies. Few studies have been done in special populations (e.g. diabetes, renal failure,etc.). Studies in insulin-dependent (type 1) diabetic patients have recently been published, confirming the validity of BIA in this group. However a vast majority of diabetic patients have type 2 non-insulin-dependent diabetes (NIDDM), which is associated with obesity in 85 per cent of individuals. As a consequence, the use of BIA for the measurement of body composition in type 2 diabetes would be of interest both for clinical and investigative purposes.

In recent years, many investigations are being conducted to assess the prevalence or incidence of overweight and obesity among diabetic individuals using simple anthropometric measures. Not much studies are available on body composition using Bioelectrical Impedance Analysis method in India. Hence, the need for the present study. Since there is a paucity of data regarding body composition measures in type 2 diabetic adults, this study was an effort to provide data on the body composition of normal, overweight and obese diabetic adults (30-60 years) and comparing them with those of non-diabetic adults of the same age group.

The specific objectives of the study were: To,

- assess the epidemiological factors associated with type 2 diabetics.
- assess the nutritional status of the selected diabetics.
- assess the body composition measures of the selected adults.
- find the association between anthropometric measures, energy balance and body composition and
- compare these parameters of the normal, overweight and obese type 2 diabetic adults with those of non-diabetic adults.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The literature pertaining to the study entitled **"Body Composition Measures of Type 2 Diabetics"** is reviewed under the following headings:

A. Diabetes Mellitus
B. Obesity and Diabetes
C. Body Composition Analysis and its Importance
D. Bioelectrical Impedance Analysis (BIA) – a promising technique
E. Diet and Diabetes

A. DIABETES MELLLITUS

The Expert Committee on the Diagnosis and Classification of diabetes mellitus defines diabetes as "a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both"(Williams,2005).

1. Classification of Diabetes Mellitus:

Diabetes has been recently reclassified by World Health Organization into four distinct types: (Geissler,2005)

I) TYPE 1 DIABETES:

a) Immune-mediated

b) Idiopathic

II) TYPE 2 DIABETES

III) GESTATIONAL DIABETES

IV) OTHER SPECIFIC TYPES:

a) Genetic defects in β-cell function(MODY)

b) Genetic defects in insulin action

c) Disease of the Endocrine Pancreas

d) Endocrinopathies

e) Drug or Chemical Induced

f) Infections

g) Uncommon forms of immune-mediated diabetes

h) Other genetic syndromes associated with diabetes

2. Type 2 Diabetes Mellitus(T2DM):

Type 2 Diabetes Mellitus, once referred to as Adult Onset Diabetes, may account for about 90 per cent to 95 per cent of all diagnosed cases of diabetes(NIH,2004).

Type 2 Diabetes Mellitus is a non-autoimmune, complex, heterogeneous and polygenic metabolic disease condition in which the body fails to produce enough insulin, characterized by abnormal glucose homeostasis .Its pathogenesis appears to involve complex interactions between genetic and environmental factors (Gupta *et al.,*2008). Type 2 Diabetes Mellitus occurs when impaired insulin effectiveness (insulin resistance) is accompanied by the failure to produce sufficient cell insulin (Permutt *et al.,*2005).

Type 2 Diabetes Mellitus is reaching epidemic proportions worldwide. This is related to changing lifestyles and diets with increased rates of obesity and decreased physical activity. Type 2 Diabetes is occurring in all population groups, especially in ethnic minorities and among youth, is an emerging public health problem(Campagnal *et al.,*2000).

Figure I shows the resistance of insulin towards type 2 diabetes.

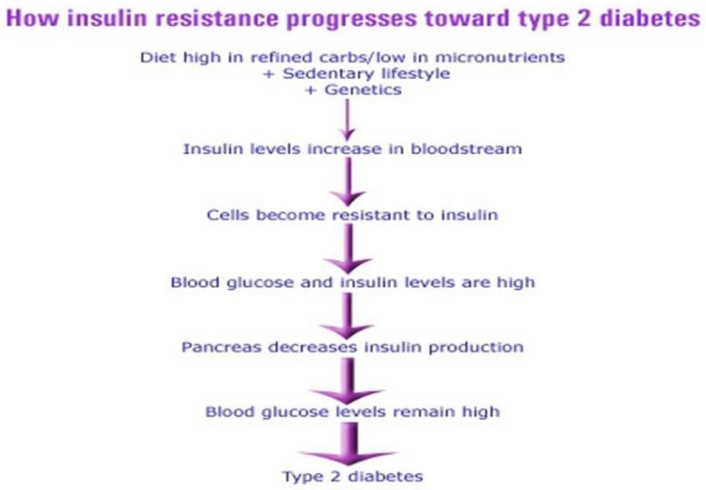


FIGURE I.RESISTANCE OF INSULIN TOWARDS TYPE 2 DIABETES

3. Prevalence of Type 2 Diabetes Mellitus:

It has been estimated that the global burden of type 2 diabetes mellitus (T2DM) for 2010 would be 285 million people (2010) which is projected to increase to 438 million in 2030; a 65 per cent increase. Similarly, for India this increase is estimated to be 58 per cent, from 51 million people in 2010 to 87 million in 2030 (Snehalatha *et al.,*2009).

Global Prevalence: The number of cases of diabetes worldwide in the year 2000 among adults (20years) was estimated to be 171 million and will rise to 366 million by 2030. In terms of rank of countries for T2DM prevalence, Ukraine (3.2 million) is at the bottom of the list, Pakistan (5.2million) comes at number six, China is second with 20.8 million people and India has the highest number (31.7 million) of people with rate of three per cent for T2DM(Wild *et al.,* 2009).

Prevalence of Type 2 Diabetes Mellitus in India: Estimated prevalence rates in urban and rural India are based on national surveys and individual studies:

Urban India: More recently, Mohan *et al.,* (2008) provided estimates from a nationwide surveillance study of T2DM and found that in urban areas there was a prevalence of 7.3 per cent of known T2DM and a prevalence of 3.2 per cent in peri-urban/slum areas (urban fringes).

Rural India: The prevalence for known T2DM was of 6.4 per cent, for undiagnosed T2DM 6.8 per cent, and that 15.5 per cent had impaired fasting glucose. Figures based on National Family Health Survey (NFHS) in 2005-06 suggest the prevalence of T2DM in rural India are highest in Kerala, Tripura, West Bengal, Goa and Sikkim, and least in central India.

4. Causes of T2DM:

T2DM as a common and complex disease has been characterized by the following causes:

• Obesity: Obesity is also considered a key risk factor for T2DM. The association between increasing body mass index (BMI) and greater weight gain and risk of diabetes is most pronounced among Asians, suggesting that lower cut off BMI values are needed to identify Asians at a higher risk of diabetes (Shai *et al.,* 2006).

• Abdominal adiposity: There is also a probable indication that there is a preferential abdominal adiposity in Indians irrespective of the degree of general adiposity (Ramachandran *et al.,* 2002).

• Imbalance of human metabolism is associated with T2DM: Changes in work patterns from heavy labour to sedentary, the increase in computerization and mechanization, and improved transport are just a few of the changes that have had an impact on human metabolism (Zimmet *et al.,* 2001).

• Genes: Since 2007, genome-wide association studies has catalogued around 20 genes (like TCF7L2, HHEX, CDKAL1, SLC30A8 etc.) showing a strong evidence associated with T2DM (Sladek *et al.,* 2007).

• Ethnicity: The interethnic differences (like differences in prevalence of T2DM among Europeans, Americans, Chinese, and Asian Indians) in insulin resistance may have an environmental or genetic explanation. The main acquired factors that seemingly increase insulin resistance in all ethnic groups include obesity, sedentary lifestyle, diet rich in animal products, and aging (Abate, 2001).

5. Risk Factors of Diabetes:

The known risks factors of T2DM embedded in nature (genetic) as well as nurture (i.e. environmental factors including intrauterine environment) are as follows:

Table I

Modifiable Risk Factors	**Studies**
Obesity (via BMI and WHR)	Meta-analysis done by Vazquez *et al.,* (2007) proves that Body mass index, waist circumference, and waist/hip ratio, respectively are the three obesity indicators which are the important risk factor for diabetes.
Physical Inactivity	The protective effect of physical activity in subjects with an excessive BMI and elevated glucose levels; physical activity and weight control are critical factors in diabetes prevention in subjects with both normal and impaired blood glucose regulation **(**Hu *et al.,* 2004**).**
Plasma Lipids and Lipoproteins Level	It has been reported by various workers that T2DM patients have elevated levels of total cholesterol, LDL-Cholesterol, VLDL-Cholesterol, hypertriglyceridemia and reduced levels of HDL-Cholesterol(Eschwege, 2003).
Hypertension	The prospective cohort study found that T2DM was almost 2.5 times as likely to develop in subjects with hypertension as in subjects with normal blood pressure (Gress *et al.,* 2000).
Dietary Habits	Misra *et al.,* (2009) suggested that whole grains are rich in components like dietary fiber, starch, fat, antioxidant nutrients, minerals, vitamin, lignans, and phenolic compounds that

	have been linked to the reduced risk of obesity, insulin resistance, dyslipidemia, T2DM, heart diseases. Intervention study of Stanhope *et al.,* (2009) found dietary fructose specifically increases de novo lipogenesis, promotes dyslipidemia, decreases insulin sensitivity, and increases visceral adiposity in overweight/obese adults. This study proves fasting plasma glucose and insulin levels increases during fructose but not glucose consumption.
Non-modifiable Risk Factors	**Studies**
Family History	Viswanathan *et al.,* (1996) in their study found nearly 75 per cent of the T2DM patients have first degree family history of diabetes. The prevalence among offspring with one diabetic parent to be 36 per cent, which increased to 54 per cent when there, was a positive family history of diabetes on the non-diabetic parental side also. When both parents had diabetes, the prevalence rate increased. (Stumvell *et al.,* 2005).
Genetic factors	Since 2007, genome-wide association studies have catalogued around 20 genes showing strong association with type2 diabetes (Zeggini *et al.,* 2007).
Low/High Birth Weight (Intra-uterine Environment exposure)	Harder *et al.,* (2006) found that low birth weight was associated with increased risk of T2DM. High birth weight was associated with increased risk to the same extent. This finding

	indicate that there exists a relation between birth weight and later-life risk of T2DM

6. Complications Associated with Diabetes:

Both type 1 and type 2 diabetes ultimately lead to high blood sugar levels, a condition called hyperglycemia. Over a long period of time, hyperglycemia damages the retina of the eye, the blood vessels of the kidneys, the nerves, and other blood vessels.

- Damage to the retina from diabetes (diabetic retinopathy) is a leading cause of blindness.
- Damage to the kidneys from diabetes (diabetic nephropathy) is a leading cause of kidney failure.
- Damage to the nerves from diabetes (diabetic neuropathy) is a leading cause of foot wounds and ulcers, which frequently lead to foot and leg amputations.
- Damage to the nerves in the autonomic nervous system can lead to paralysis of the stomach (gastroparesis), chronic diarrhea, and an inability to control heart rate and blood pressure during postural changes.
- Diabetes accelerates atherosclerosis, (the formation of fatty plaques inside the arteries), which can lead to blockages or a clot (thrombus). Such changes can then lead to heart attack, stroke, and decreased circulation in the arms and legs (peripheral vascular disease).
- Diabetes predisposes people to elevated blood pressure, high levels of cholesterol and triglycerides. These conditions typically occurs in people with type 2 diabetes who are not controlling their blood sugar levels, who have become dehydrated, or who have stress, injury, stroke, or are taking certain medications, like steroids.(Bhowmik *et al.,*2012).

B. OBESITY AND DIABETES:

The proportions of people with type 2 diabetes and obesity have increased throughout Asia, and the rate of increase shows no sign of slowing. People in Asia tend to develop diabetes with a lesser degree of obesity at younger ages, suffer longer with complications of diabetes, and die sooner than people in other regions(Yoon *et al.,*2006).

The prevalence of obesity is over 25 per cent in many developed countries. Obesity is strongly associated with an increased risk of fatal and chronic conditions such as cardiovascular disease and T2DM. Therefore it has become a major public health concern for many economics(Miners *et al.,*2012).

T2DM is 3 times more likely to develop in an obese person than in a non-obese person. Furthermore, the person with T2DM often has central obesity. Central-body fat cells appear to be larger and more insulin-resistant than lower-body fat cells, and insulin resistance is a major risk factor for the development of T2DM(James,2000).

The increase in the prevalence of type 2 diabetes is closely linked to the upsurge in obesity. About 90 per cent of type 2 diabetes is attributable to excess weight. Furthermore, approximately 197 million people worldwide have impaired glucose tolerance, most commonly because of obesity and the associated metabolic syndrome. This number is expected to increase to 420 million by 2025(Hossain *et al.,*2007)

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 (Bjo¨ rntorp,1991).

Adult humans have limited and variable numbers of brown fat cells (Cypess *et al.,*2009), which play a role in thermogenesis and potentially influence energy expenditure and obesity susceptibility (Frontini *et al.,*2010).

The link between obesity and hyperinsulinemia, first identified 50 years ago, 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 cell mass and function (Eckel *et al.,*2011).

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(Rampersaud *et al.,*2007).

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-resistin, and retinol-binding protein, that contribute to insulin resistance as well as reduced levels of adiponectin (Deng *et al.,*2010);

2) Ectopic fat deposition, particularly in the liver and perhaps also in skeletal muscle, and the dysmetabolic sequelae (Larson *et al.,*2011); 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 cell function(Bournat *et al.,*2010).

Substantial weight gain (10 per cent) was significantly associated with an increased risk of diabetes. Men with below-average BMI who gained a substantial amount of weight showed a significant threefold increase in risk compared with subjects whose weight remained stable, and the risk was twofold in subjects who were already overweight. This is consistent with the findings that weight gain is associated with an increase in insulin resistance and deterioration in glucose tolerance, factors that are strongly associated with the development of diabetes(Wannamethee *et al.,*1999).

C. BODY COMPOSITION ANALYSIS AND ITS IMPORTANCE:

In terms of health risks, body composition is more important than body weight. Body composition is the relative amount of fat and lean body mass(Insel,2010).An innate characteristic of maturation and aging is a change in body composition that occur

throughout life cycle, beginning with the embryo and extending through old age. Rapid growth entails not only an increase in body mass but also a change in the proportions of components making up this mass(Groff,2000).

The human body is composed of fat and fat free compartments and body composition assessment involves the accurate measurement of one or many of these compartments. Body composition can be assessed at the molecular, cellular, and tissue levels(Beechy *et al.,*2012).

1. Levels of Body Composition:

Body Composition can be approached at a variety of levels:

a. Atomic level: Basic chemical elements compose the atomic level. O2, C, H and N account for greater than 95 per cent of body mass and the addition of 7 other elements – Na, K, P, Cl, Ca, Mg and S accounts for 99.5 per cent of body mass.

b. Molecular level: Water, Lipid, Protein, Minerals, and Carbohydrate. Carbohydrate occurs in small amounts and not usually considered in the estimates of body composition.

c. Cellular level: The Body Cell Mass is defined by intracellular fluids and intracellular solids and is the metabolically active component of the body. Adipocytes store lipids and comprise fat mass(FM).

d. Tissue level: Skeletal muscle, adipose, bone, blood, viscera and brain.

e. The fifth level of body composition is the whole body, its size, shape, physique, and proportions.

1. Models of Body Composition:

a. Two Components: It partitions body mass into lean(Fat Free Mass[FFM]) and Fat Mass(FM) compartments. FM is more labile as it is readily influenced by diet and training.

b. Three Components: It includes FM and partitions FFM into Total Body Water(TBW) and Fat Free Dry Mass(FFDM). FFDM includes protein, glycogen, and minerals in bone and soft tissues.

c. Four Components: It includes TBW, FM and partitions FFDM into Bone Mineral(BM) and the residue.

d. Multi compartment models: It is assumed that the separately measured properties can be summed to provide an estimate of the whole (Arora,2011).

Changes in body composition that accompany the onset and progression of obesity have a dramatic impact on metabolism and insulin sensitivity. Adipose tissue is postulated to be a key factor in regulating whole body lipid flux, thus modulating lipid and glucose homeostasis. Given the role of fat and lean tissue in lipid metabolism and insulin resistance, it is clear that assessing the body's tissue composition is an important part of the management of the diabetic patient (Duren *et al.,*2008).

The presence of type 2 diabetes has been associated with a reduction in cardiovascular function and diminished levels of general fitness(Katoh *et al.,*1996). This diminished fitness may reflect physiological changes, such as change in skeletal muscle fiber type(Marin *et al.,*1994), increased width of skeletal muscle capillary basement membrane(Williamson *et al.,*1996), and increased skeletal muscle fat content(Goodpaster *et al.,*1997).

Diabetes was associated with higher body mass loss and appendicular lean mass loss in older Chinese adults. In men, diabetes was also associated with higher total body fat loss. Diabetes-associated muscle loss may contribute to diabetes-related frailty in older adults (Lee *et al.,*2012)

D. BIOELECTRICAL IMPEDANCE ANALYSIS (BIA) – A PROMISING TECHNIQUE:

Bioelectrical Impedance Analysis (BIA) is another non-invasive method of body composition and it is considered to be highly useful to monitor body compartment changes in various clinical situations (Kamimura *et al.,*2003).

BIA has gained wide acceptance as a field and bedside body composition technique. This is related more to its ease of use and acceptability of the technique and less to an obvious superiority to other field methods. It is quick, simple to use and involves minimum contact with the subject or undressing. BIA has better reproducibility than skin folds, which makes it more suitable for large studies with multiple measurers. It has proven reliability in interlaboratory comparisons. The procedure has become

simpler and faster still with the development of analyzers that require only that the subject stand bare footed on metal plates that contain the electrodes (Deurenberg *et al.,*1994).

BIA measures the body impedance using electrodes that are connected from one leg to the other, or to the arm, to form a circuit for the current to pass through. The impedance measure is used to predict Total Body Water (TBW) and Fat-Free Mass (FFM) and fat mass is calculated from the difference between weight and FFM. Different tissues offer varying resistance, with adipose tissue a poor conductor of the current because of its low water content. Muscle tissue, which has higher water content, offers less resistance and is able to better conduct the current(Kushner,1992).

Bioelectrical Impedance Analyzers do not measure any biological quantity or describe any biophysical model related to obesity. Rather, the impedance index [stature squared divided by resistance (S**2**/R) at a frequency, most often 50 kHz] is proportional to the volume of total water and is an independent variable in regression equations to predict body composition **(**Sun *et al.,*2005).

Single Frequency BIA (SF-BIA) should not be used for body composition assessment in the obese because the theory that the human body is a single cylinder with constant resistivity cannot be applied to the obese. In addition, the frequency of the current applied (50 kHz) in SF-BIA is not high enough to penetrate all tissues. Segmental BIA (tetra- and eight-polar-BIA) recognizes the human body as complex in shape and combines several impedance measures together for a more accurate assessment. However, segmental-BIA has been found to significantly overestimate percent body fat in obese adults (Shafer *et al.,*2009). Multi Frequency-BIA (MF-BIA) allows multiple frequencies to assess fluid distribution; low electric frequencies (e.g. 1 or 5 kHz) measure Extra Cellular Water(ECW) and high frequencies (e.g. 100, 200, or 500 kHz) measure Total Body Water(TBW)(Mager *et al.,*2008). MF-BIA has been found to overestimate percent body fat in the overweight and obese groups, significantly underestimate both total and truncal fat in obese women (Neovius *et al.,*2006), and offer accurate estimates of TBW and ECW in women with a BMI up to 48.2 kg/m^2 (Sartorio *et al.,*2005).

In the study conducted by Hosking *et al.*,(2006) in young children (boys and girls aged about 9 years), the foot-to-foot BIA device may be suitable for use in large-scale epidemiological studies due to the high correlation and small mean differences when compared with dual-energy X-ray absorptiometry (DEXA), and its simplicity and its speed may offer particular advantage to children.

According to the study conducted by Stewart *et al.,* (1993) BIA can be applied to study the distribution of body water between the intracellular (ICW) and extracellular (ECW) phases by the use of multiple frequencies in place of a single frequency as at present. This approach has been validated in healthy male subjects by Segal *et al.,* (1991).

BIA using bipolar foot electrodes provides a valid estimate of percent body fat in subjects with type 2 diabetes mellitus. It does not require examiner skill, is rapid, and free from discomfort, and is a reliable technique for determination of body composition in type 2 diabetic subjects in clinical and investigative studies(Leiter *et al.,*1994).

E. DIET AND DIABETES:

Health behaviors of individuals with or at risk for type 2 diabetes mellitus and those with a high Body Mass Index (BMI) continue to be important drivers of health outcomes from a public health perspective(Thom *et al.,*2006).

High body mass index and weight gain, reflecting a positive energy balance, are associated with a higher risk of type 2 diabetes (Colditz *et al.,*1995).

The increased prevalence of obesity and type 2 diabetes in affluent societies is largely linked to excessive caloric intake and decreased physical activity (Hill *et al.,*2003).

Insulin resistance is regarded as a cardinal feature of the metabolic defects associated with weight gain, and it is postulated to develop as an adaptation to increased nutrients' availability. Energy balance and metabolic homeostasis are maintained by complex regulatory systems. In this regard, changes in nutrient availability and body weight induce adaptive responses in feeding behavior and in metabolic processes that are designed to preserve each individual's set point. Thus,

increased food intake tends to promote weight gain and insulin resistance. Nutrient excess activates biochemical pathways that initiate cellular responses designed to limit the oxidation of excess energy (insulin resistance) and favor weight gain. Simultaneously, the activation of the same pathways either directly or indirectly (by increasing the expression and release of counterregulatory hormones such as leptin and insulin) induces hypothalamic efferent signals that attempt to limit further intake of energy and favor dissipation of excess energy via thermogenesis (Obici *et al.,*2003).

Rapid economic developments have improved the availability of nutrients, together with socioeconomic and health conditions, in many countries(WHO,2003).These improvements have led to lower morbidity and mortality and to a pronounced decrease in nutritional deficiencies. However, high nutrient availability, and specifically an energy dense diet, can predispose people to both obesity and type 2 diabetes(Prentice *et al.,*1995). In Asia, economic factors have had especially apparent effects on the nutrition transition. Obesity has increased concurrently with these nutritional transitions in most Asian countries(Popkin *et al.,*1998).

Carbohydrate intake decreased gradually after 1940, from 81 per cent of total energy intake to 64 per cent in 1995. Total protein intake remained nearly constant throughout that period, whereas fat-derived energy intake increased gradually, from 6·2 per cent to 18·8 per cent (Kim *et al.,*2000).

Deficient expenditure of energy could occur not only from sedentary lifestyles, but also from physiological changes that occur with aging. With increasing age, decreases in muscle mass, resting metabolic rate, and aerobic capacity occur(Taylor *et al.,*2004).Also, sedentary lifestyles may indirectly result in higher energy intakes because of less ability to regulate energy balance, for example,(Prentice *et al.,*2004) more time and opportunity to eat. Low levels of physical activity occur in the context of an automated and automobile-oriented environment that is conducive to a sedentary lifestyle(Epstein *et al.,*2000).

Basal, resting, and 24-h energy expenditure, independently of body composition, sex, and age, were found to be seven to eight per cent higher in overweight and obese Caucasians with type 2 diabetes compared with healthy control subjects. Under a

standardized but low physical activity level, the higher 24-h energy expenditure in type 2 diabetic patients clearly shows that the higher BMR is quantitatively more important than the lower physical activity and postprandial thermogenic response(Bitz *et al.,*2004).

In the large cohort study of middle-aged Chinese women carried out by Villegas *et al.,*(2009) high BMI and weight gain in adulthood, indicating a positive energy balance, were associated with a higher risk of T2D. Participants with the lowest BMI were the least active, while the most obese were among the most active. Reasons for this association could be genetic, reverse causation, or the fact that more active people consume more kcal/day. EI(Energy intake) and PA(Physical activity) interacted with each other in the development of T2D and this interactive effect appeared to be more evident in women with a higher BMI. It was speculated that the EI:PA ratio was only associated with T2D among women with high BMI because the underlying insulin resistance related to obesity makes individuals more vulnerable to a positive energy balance.

METHODOLOGY

III METHODOLOGY

The methodology adopted in the present study entitled, **"Body Composition Measures of Type 2 Diabetics"** is dealt under the following headings.

A. Selection of Area and Subjects.
B. Formulation of Interview Schedule for Data Collection.
C. Assessment of Epidemiological Factors Associated with Type 2 Diabetics.
D. Assessment of Nutritional Status of Selected Subjects.
E. Assessment of Body Composition of the Selected Subjects Using Bioelectrical Impedance Analysis.
F. Computation of Energy Balance.
G. Interpretation and Analysis of Data.

A. SELECTION OF AREA AND SUBJECTS:

The area selected for the study was Coimbatore. For the conduct of the study, diabetic as well as healthy adults irrespective of sex in the age group of 30 to 60 years working at Avinashilingam Institute for Home Science and Higher Education for Women were selected. The university premises was selected mainly because the nature of the study involved in the determination of body composition using Bio-electrical Impedance Analyser early in the morning and also because of the easy accessibility of the investigator to the teaching as well as non-teaching staff members of the Institute.

From the Institute, twenty one non insulin dependent diabetics and twenty one healthy individuals as control were selected. These individuals were screened for overweight and obesity according to WHO standard for Asian-Pacific population. The investigator explained the purpose, method and significance of the study to the Institution authorities, teaching and non-teaching staff members to motivate them to extend their co-operation for the study.

Nutritional anthropometry is measurement of human body at various ages and levels of nutritional status. It is eased on the concept that an appropriate measurement

should reflect any morphological variation occurring due to a significant functional physiological change (Bamji, 2004).

Anthropometry is the study of the measurement of the human body in terms of the dimensions of bone, muscle and adipose (fat) tissue. The word “Anthropometry” is derived from the Greek word “Anthro” meaning “human” and the Greek word “metron” meaning “measure” (Ulajaszah *et al.,*1994).

It is the most commonly used method to assess nutritional status of individuals and population as it is inexpensive, convenient and non-invasive (Vir, 2011).

1. Height or Stature:

It is erect body length from the soles of the feet to the vertex. Vertex is the most superior or the highest point on the head(Retrieved NSI,2010).

The height of an individual is influenced both by genetic and environmental factors. The maximum growth potential of an individual is decided by hereditary factors, while the environmental factors, the most important being nutrition and morbidity, determines the extent of exploitation of the genetic potential, inadequate dietary intake and / or infection reduce nutrients function at cellular level resulting in growth retardation (Bamji, 2004).

A stadiometer (Tanita) was used to measure the stature of the individual. The stadiometer was placed on the ground and the subjects were asked to remove their footwear before standing for measurement. The subjects were asked to stand straight against the stadiometer and a movable meter plank was adjusted according to their respective heights in order to reduce the thickness of hair and to measure the height accurately. The height was measured to the nearest 0.1cm for all the forty two subjects. An average of three measurements was taken as the final measurements.

2. Weight:

Recognition of body weight as an indicator of health status is probably universal and as old as humanity itself (Groff, 2000)

Body weight is the most widely used and the simplest reproducible anthropometric measurement for the evaluation of nutritional status. It indicates the

body mass and is a composite of all body constituents like water, minerals, fat, protein, bone, etc. (Bamji, 2004).

The weight of the subjects were recorded using the stadiometer(Tanita). Subjects were asked to remove footwear, ornaments and heavy clothes and asked not to lean against or hold anything, while the weight was recorded. The weight was recorded for all the selected subjects to the nearest reading and kilograms.

3. Body Mass Index:

Body Mass Index has been used since the 1960's to assess obesity in adults (Shah, 2011).

Body Mass Index (BMI) is calculated as weight in kilograms divided by height in meters squared (kg/m^2). As a measure of relative weight, BMI is easy to obtain. It is an acceptable process for thinness and fatness, and has been directly related to health risks and death rates in many populations (WHO, 2004). According to World Health Organisation (WHO), BMI is calculated using the following formula:

BMI= weight in kg/ height in m^2

According to WHO, obesity is based on BMI as following:

25.0- 29.9	overweight
30.0-34.9	class I obesity
35.0-39.9	class II obesity
Over 40.0	class III obesity

Based on their BMI the subjects were classified as obese and non-obese. The recently published BMI values (WHO Expert Consultations, 2004) are as follows:

Normal	=	18.5-22.9
At risk of Obesity	=	23-26.9,
Grade I	=	27-29.9
Grade II	=	> 30

BMI was computed for all the forty two subjects. Based on the BMI values the twenty one diabetics were divided into three groups. One group consisted of seven subjects with BMI normal (BMI = 18.5- 23.0 according to WHO standard for Asian-Pacific Population), second group of seven subjects with BMI overweight (BMI-23.1-26.9 according to WHO standard for Asian-Pacific Population), third group of seven who's BMI was obese (BMI - ≥ 27, according to WHO standard for Asian-Pacific Population). Similarly, the non diabetic twenty one subjects were divided into three groups (normal, overweight and obese), each group consisted of seven subjects.

B. FORMULATION OF INTERVIEW SCHEDULE FOR DATA COLLECTION:

An interview schedule is an interview with pre-coded question to produce quick, cheap and easy quantitative data which is high in reliability but low in validity (William,2002).

A specially designed interview schedule was used by the investigator to collect information on socio-economic background, health history, life style pattern and dietary pattern of selected individuals (Appendix I).

The socio-economic background included details on hometown, family size, type of family, occupation, literacy level, monthly family income and religion, information on health included family history of diabetes, age of diagnosis of diabetes, regularity of doctor check up, intake of drugs and symptoms they suffering from and lifestyle pattern. The dietary pattern was assessed by included questions regarding number of meals consumed in a day, food consumed out of home, details on habit of skipping meals, food pattern during disease condition, consumption pattern of fast foods, knowledge on usage of food labels and food frequency table. The interview schedule was administrated to all the forty two subjects and data was collected.

C. ASSESSMENT OF EPIDEMIOLOGICAL FACTORS ASSOCIATED WITH TYPE 2 DIABETES:

Epidemiology is a rapidly expanding and essential quantitative tool in the wide science of public health.

The term 'epidemiology' is coined from the Greek word, implying 'study among the population'. It is the study of the distribution and determinants of health related states or events in specified populations, and the application of this study to control of health problems(Zodpey,2011).

The epidemiologic factors associated with type 2 diabetes were assessed using interview schedule through which the background information, dietary pattern, life pattern and health history are collected.

D. ASSESSMENT OF NUTRITIONAL STATUS OF SELECTED SUBJECTS:

Nutritional status refers to the degree of balance between nutrient intake and nutrient requirements. It can be determined by the application of nutritional assessment technique (Jarvis, 1996).

The original term 'Nutritional Assessment' was used by a sub-committee of the League of Nations (1932) referring to a set of medical tasks to determine the nutritional status of a population (Gibbson, 2005).

Today nutrition assessment includes computerized food intake analysis, clinical nutrition body composition assessment (Bio-electrical Impedance), laboratory blood results of applicable, anthropometrics, review of medications, lifestyle and fitness indicators(Blackburn *et al.,* 2005).

1. Biochemical Assessment:

Biochemical tests measure a nutrient or a metabolite in fluids or tissues and are useful in identifying intermediate stages of nutrition deficiencies when the body stores become depleted. These methods can also be used to assess excess of nutrients (*i.e.* cholesterol) or reactions to the intake of a specific nutrient(allergic reactions) (Vir, 2011).

a) Collection of Blood Samples:

Three millilitres of venous blood collected from forty two subjects and stored in polypropylene tubes(Plate I) for estimation of serum total cholesterol, serum triglycerides and High Density Lipoprotein(HDL). The specimens were centrifuged at 3000rpm for 10minutes to obtain serum(Plate II). The isolated sera were stored at -20°C until use.

b) Blood Glucose:

Blood samples were collected using finger prick method from all the subjects and analysed for their fasting blood glucose and post prandial blood glucose levels using Glucometer manufactured by Flextronics Industrial co, Ltd.

c) Total cholesterol:

Spectrophotometer(Plate III and IV) was used to analyse the lipid profile of subjects. Total cholesterol was estimated by CHOD-PAP enzymatic colorimetric method using kit manufactured by Crest Biosystems.

d) Serum triglycerides:

Triglycerides kit manufactured by Crest Biosystems was used in the determination of triglycerides in serum by GPO-PAP method.

e) High Density Lipoprotein(HDL) cholesterol:

Direct enzymatic colorimetric method was used for analysing HDL cholesterol with kit obtained from Crest Biosystems.

f) Very Low Density Lipoprotein(VLDL) and Low Density Lipoprotein(LDL):

From these values, very low density lipoprotein(VLDL) and low density lipoprotein were calculated using the formulas:

VLDL= Triglycerides/5

LDL= Total cholesterol-(HDL+VLDL)

2. Dietary Survey: Dietary assessment is defined as the set of methods that measures and/or estimate food intake, which can be converted to nutrient intake by means of food

COLLECTED BLOOD SAMPLES

PLATE I

CENTRIFUGATION OF BLOOD SAMPLES

PLATE II

PREPARATION FOR ANALYSIS OF LIPID PROFILE

PLATE III

ANALYSIS OF LIPID PROFILE USING SPECTROPHOTOMETER

PLATE IV

composition tables(Dwyer,2000).

Twenty four hour recall method was used to obtain details regarding the food intake of the selected subjects. The nutrient intake was calculated for individuals using the 'Nutritive Values of Indian Foods' (ICMR) and compared with Recommended Dietary Allowances(RDA, 2010).

E. ASSESSMENT OF BODY COMPOSITION OF THE SELECTED SUBJECTS USING BIO-ELECTRICAL IMPEDANCE ANALYSIS:

Measurement of body composition is valuable for monitoring many endocrine, metabolic and nutritional calories (Stewart, 1992).

Bio-electrical Impedance is a safe, non-invasive and rapid means to assess body composition and it is considered to be highly useful to monitor body compartment changes in various clinical situations. It is based on the electrical conductive properties of human body(Kaminura, 2003).

The body composition of the selected subjects was assessed using "Bio-space, in Body 720- the precision Body Composition Analyser". It works on the principle of Bio-electrical Impedance Analysis(BIA).

1. Principle:

In BIA, the current is passed through the body by means of the electrodes opposition to the electric flow current is called impedance and is detected and measured by the instrument impedance is the inverse of conductance. The lowest resistance value of an individual is used to calculate conductance and predict lean body mass. Tissues containing little water and electrolytes (such as fat) are poor conductors and have a high resistant to the passage of current(Groffer, 2000).

The measurement is made by Direct Segmental Multifrequency Bio-electrical Impedance Analysis Method (DSM-BIA method). It records the 30 Impedance(Z) measurements by using six different frequencies (1KHz, 5KHz, 50KHz, 250KHz,

500KHz, 1000KHz) at each five segments (right arm, left arm, trunk, right leg, left leg) of the human body.

The subjects were asked to present themselves early daylight without food and water consumption for measuring their body composition. The subject was asked to remove any metal item on the body before getting onto the “Bio-space, in Body 720- the precision Body Composition Analyser” (Plate V) in order to diminish any alteration in the measurements. The subject was given an electrolyte tissue to clean wipe his/her feet and palm before the test. The subject was then asked to stand on the analyser by adjusting his/her foot in such a way that they are placed correctly on the two electrodes provided near the feet and the weight is recorded. The subjects name, age, height(Plate VI) and gender were entered by the user. Two electrodes are provided for the left and the right arm. The subject was asked to hold the electrodes by placing the thumb and the four fingers on the space provided and the subject was asked to stand motionless till the test is done. Once the analysis is complete, the subjects result sheet is printed out(Plate VII).

The four main body components measured in analyser are total body water, protein, fat and mineral mass. Other parameters measured include:

- Skeletal muscle mass
- Percent body fat
- Waist hip ratio
- Lean balance
- Visceral fat area
- Arm circumference
- Bone mineral content
- Bone cell mass
- Basal metabolic rate
- Ratio of extracellular fluid to total body fluid
- Arm muscle circumference
- Obesity degree
- Ratio of extracellular water to total body water

IN BODY 720-BODY COMPOSITION ANALYZER

PLATE V

MEASURING HEIGHT USING STADIOMETER

PLATE VI

BODY COMPOSITION ANALYSIS IN PROGRESS

PLATE VII

F. COMPUTATION OF ENERGY BALANCE:

The regulation of body weight is depended on a balance between nutrient intake and utilization, although there are some other important factors. In the regulation of energy balance, nutrient intake and energy(E) expenditure are related in the formula:

ΔE = E in- E out (Eastwood, 2003)

1. Total Energy Expenditure (TEE):

TEE was estimated through factorial calculations that combined the allocated habitual activities (as obtained from the individual's time motion record) and the energy cost of those activities. The energy cost of activities was calculated as a multiple of BMR per minute, also referred to as the Physical Activity Ratio (PAR), and the 24 hour energy requirement was expressed as a multiple of BMR per 24 hours by using the Physical Activity Level (PAL) value.

PAR= Energy cost of an individual activity per minute.

= Energy cost of BMR per minute.

PAL(for the day) = Total PAR hours/ Total time.

TEE (24 hours) = Predicted BMR X PAL

BMR was calculated using the age and sex specific predictive equations. In the present study, for adults in the age group of 30- 60 years, BMR was calculated using the following formula:

Predicted BMR = 14.0X B.wt(kg)+ 471 (ICMR,1989)

The PAL values proposed by ICMR expert group(2010) was used for calculation of PAL of individuals, sedentary or light activity lifestyle-1.53, active or moderately active lifestyle-1.8, vigorous or vigorously active lifestyle-2.3.

2. Energy Intake:

The actual food intake was determined from twenty four hour recall method. The energy intake was calculated for the individuals after calculating the carbohydrate, protein and fat intake using the nutritive value of Indian foods (ICMR).

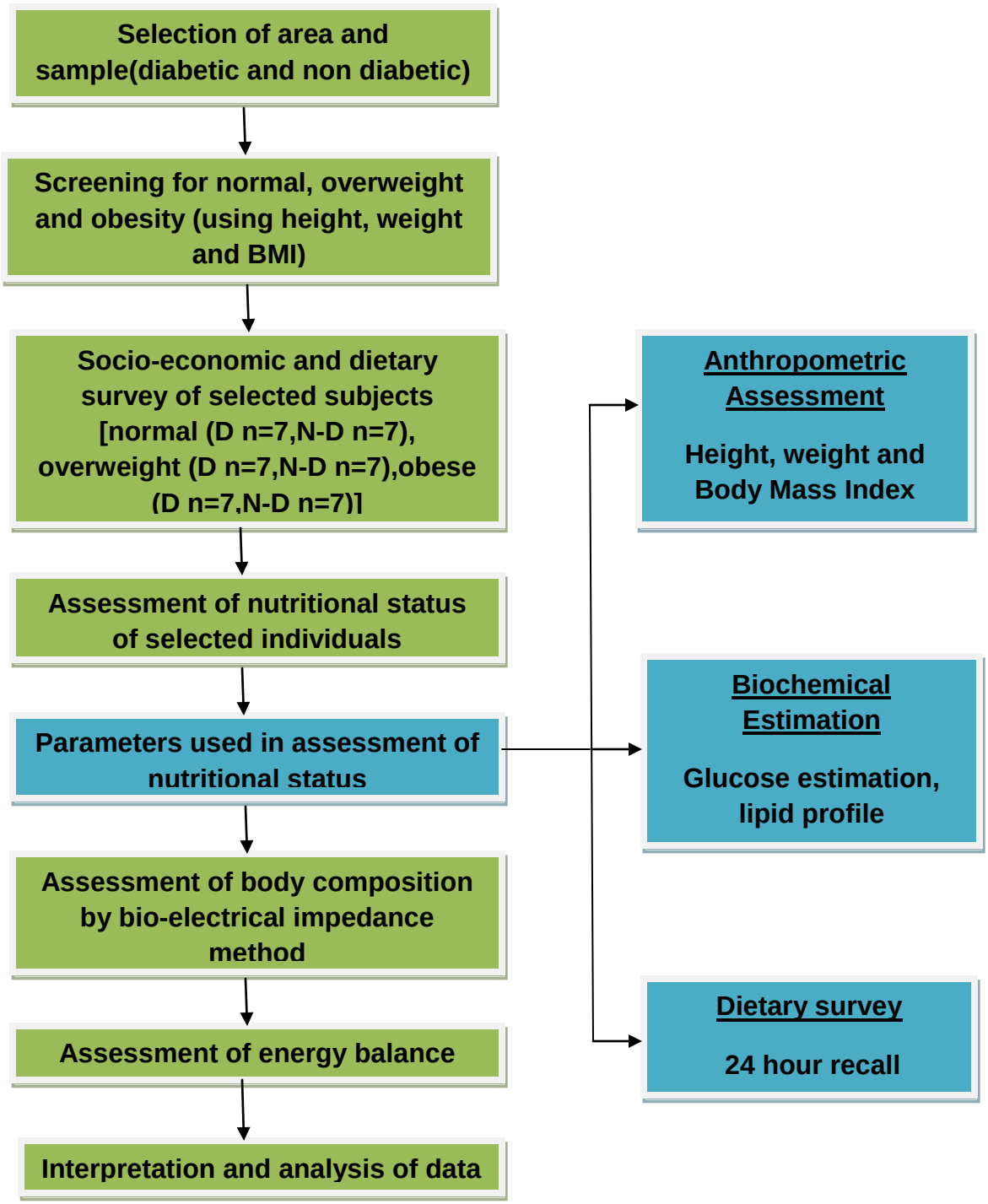
From the above data, the energy balance was calculated by finding the difference in the energy intake and energy expenditure of the individuals.

G. INTERPRETATION AND ANALYSIS OF DATA:

The data was consolidated and tabulated in which mean, standard deviation and percentage were computed. The data was analyzed using the software GraphPad Prism version 6.02 .Comparisons were made between various parameter of three groups using students t-test. Correlation between anthropometric measurements, body composition parameters and biochemical parameters were derived using Karl Persons' co-efficient of correlation. Probability at both 0.05 and 0.01 levels of significance was considered to draw conclusions. Comparison was made between the diabetic and the non diabetic subjects regarding various parameters used.

FIGURE II

EXPERIMENTAL DESIGN



RESULTS AND DISCUSSION

IV. RESULTS AND DISCUSSION

The results of the present study entitled "**Body Composition Measures of Type 2 Diabetics"** are presented and discussed under the following headings:

A. Socio-Economic Background of the Selected Subjects.
B. Health History of the Selected Diabetic Subjects.
C. Lifestyle and Dietary Pattern of the Selected Subjects.
D. Nutritional Status of the Selected Subjects.
E. Body Composition Measures of the Selected Normal, Overweight and Obese Subjects.
F. Energy Balance of the Selected Subjects.

A. SOCIO-ECONOMIC BACKGROUND OF THE SELECTED SUBJECTS

In total, twenty one diabetic and twenty one non diabetic subjects from Coimbatore district were selected for the study. They were divided into normal, overweight and obese as per the BMI cut off 23 and above. Further, their body composition measures were assessed and results interpretated.

As per the categorization mentioned above, the discussions are presented.

1. Socio-economic Background of the Selected Subjects.

Table II shows the socio-economic background of the selected forty two subjects.

TABLE II

SOCIO ECONOMIC BACKGROUND OF THE SELECTED SUBJECTS

Details	Normal(n=14)				Overweight(n=14)				Obese(n=14)				Total(n=42)			
	*D (n=7)		*N-D(n=7)		D (n=7)		N-D (n=7)		D (n=7)		N-D (n=7)		D (n=21)		N-D (n=21)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Religion																
Hindu	6	85.7	7	100	7	100	5	71.4	7	100	6	85.7	20	95.2	18	85.7
Christian	1	14.2	-	-	-	-	2	28.5	-	-	1	14.2	1	4.7	3	14.2
Muslim	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Community																
ST	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SC	2	28.5	1	14.2	2	28.5	1	14.2	2	28.5	1	14.2	6	28.5	3	14.2
OBC	5	71.4	6	85.7	5	71.4	6	85.7	4	57.1	6	85.7	14	66.6	18	85.7
Others	-	-	-	-	-	-	-	-	1	14.2	-	-	1	4.7	-	-
Type of family																
Nuclear	5	71.4	6	85.7	3	42.8	6	85.7	5	71.4	5	71.4	13	61.9	17	80.9
Joint	2	28.5	1	14.2	4	57.1	1	14.2	2	28.5	2	28.5	8	38	4	19
Family Size																
1-4	5	71.4	6	85.7	3	42.8	6	85.7	5	71.4	6	85.7	13	61.9	18	85.7
5-7	2	28.5	-	-	2	28.5	1	14.2	1	14.2	1	14.2	5	23.8	2	9.5
≥8	-	-	1	14.2	2	28.5	-	-	1	14.2	-	-	3	14.2	1	4.7

*D: Diabetic;*N-D: Non diabetic

Health and nutritional status of an individual are affected by an unfavorable socio-economic status of the family like poverty, literacy, over work, ineffective health care service etc. It is seen from Table II that among the selected diabetic subjects, 95.2 per cent were Hindus followed by 4.7per cent Christians and among the non-diabetics, 85.7 per cent were Hindus followed by 14.2 per cent Christians.

Among the selected diabetic subjects, 66.6 per cent belonged to other backward castes, 28.5 per cent scheduled caste and 4.7 per cent to the 'other' category of caste. Among non-diabetics, 85.7 per cent belonged to other backward castes and 14.2 per cent to scheduled caste.

Family size is one of the factors that affect the nutritional status of any population. This is on par with the fact that a majority of the families in India currently are nuclear. Among the diabetics 61.9 per cent belonged to nuclear family, while 38 per cent belonged to joint family. Among non-diabetics, 80.9 per cent belonged to nuclear and 19 per cent belonged to joint family.

2. Personal Details of the Selected Subjects.

Table III provides the data on the personal details of the selected subjects.

TABLE III

PERSONAL DETAILS OF THE SELECTED SUBJECTS

Details	Normal(n=14)				Overweight(n=14)				Obese(n=14)				Total(n=42)			
	*D (n=7)		*N-D(n=7)		D (n=7)		N-D (n=7)		D (n=7)		N-D (n=7)		D (n=21)		N-D (n=21)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Hometown																
Rural	4	57.1	2	28.5	1	14.2	2	28.5	1	14.2	2	28.5	6	28.5	6	28.5
Urban	3	42.8	5	71.4	6	85.7	5	71.4	6	85.7	5	71.4	15	71.4	15	71.4
Literacy status																
No formal education	1	14.2	-	-	1	14.2	-	-	-	-	-	-	2	9.5	-	-
Read & write	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Primary	1	14.2	2	28.5	-	-	1	14.2	-	-	1	14.2	1	4.7	4	19
Secondary	4	57.1	1	14.2	2	28.5	2	28.5	4	57.1	4	57.1	10	47.6	7	33.3
Higher education	1	14.2	3	42.8	1	14.2	3	42.8	1	14.2	2	28.5	3	14.2	8	38
University	-	-	1	14.2	3	42.8	1	14.2	2	28.5	-	-	5	23.8	2	9.5
Type of Work																
Sedentary	3	42.8	3	42.8	5	71.4	5	71.4	4	57.1	5	71.4	12	57.1	13	61.9
Moderate	1	14.2	1	14.2	-	-	1	14.2	-	-	-	-	1	4.7	2	9.5
Heavy	3	42.8	3	42.8	2	28.5	1	14.2	3	42.8	2	28.5	8	38	6	28.5

*D: Diabetic;*N-D: Non diabetic

Among the diabetic subjects, 28.5 per cent were from rural area while 71.4 per cent were from urban area. Among non-diabetic subjects 28.5 per cent were from rural area while 71.4 per cent were from urban area. The literacy status showed that 47.6 per cent had secondary education, 23.8 per cent were graduated, 14.2 per cent had higher education, 9.5 per cent had no formal education while 4.7 per cent had primary education. Among non-diabetic subjects 38 per cent had higher education, 33.3 per cent had secondary education, 19 per cent had primary education while 9.5 per cent were graduates. Higher per cent of diabetics (57.1 per cent) and non-diabetics (61.9 per cent) were involved in sedentary work, while 38 per cent and 28.5 per cent were involved in heavy work and 4.7 per cent of diabetics and 9.5 per cent of non-diabetics were involved in moderate activity.

Increased sedentariness that has resulted from the replacement of manual labour by service jobs, and from the advent of video games, television and computers that keep people seated lethargically watching screens for hours every day is one of the reasons for diabetes prevalence(Verma,2012).

Diabetes is much more prevalent in urban areas than in rural areas. The prevalence of diabetes among those in the highest wealth quintile is far greater than the prevalence among those in the lowest wealth quintile. While the prevalence of diabetes generally increases with increasing wealth quintile, there is no clear pattern by education(NFHS-3,2007).

3. Family History of Diabetes in the Selected Subjects.

Among the diabetics 52.3 per cent had no family history of diabetes, 42.8 per cent had first degree diabetic relatives and 4.7 per cent had second degree diabetic relatives (paternal). Among the non-diabetics 76.1 per cent had no family history of diabetes, 14.2 per cent had first degree diabetic relatives and 9.5 per cent second degree diabetic relatives (paternal).

There is a strong inheritable genetic connection in type 2 diabetes, having relatives (especially first degree) with type 2 diabetes, increases the risks of developing type 2 diabetes substantially. Concordance among monozygotic twins is close to 100 per cent, and about 25 per cent of those with the disease have a family history of diabetes (Rother,2007).

B. HEALTH HISTORY OF THE SELECTED DIABETIC SUBJECTS.

1. Health History of the Selected Diabetic Subjects.

Table IV Provides the data on the health history of the selected subjects.

TABLE IV

HEALTH HISTORY OF THE SELECTED DIABETIC SUBJECTS

Details	Normal		Overweight		Obese	
	No.	%	No.	%	No.	%
Frequency of Doctor's Visit						
Weekly	-	-	-	-	-	-
Monthly	-	-	1	14.2	-	-
>6 times a year	-	-	-	-	-	-
2-6 times a year	3	42.8	4	57.1	5	71.4
Once a year	-	-	-	-	-	-
<1 times a year	4	57.1	2	28.5	2	28.5
Medication prescribed						
Allopathy	3	42.8	3	42.8	5	71.4
Homeopathy	-	-	-	-	-	-
Ayurveda	-	-	1	14.2	-	-
Dietary	4	57.1	3	42.8	2	28.5
Any other	-	-	-	-	-	-

Among normal subjects 42.8 per cent visited Doctor 2- 6 times a year and 57.1 per cent < 1 times a year. In overweight, 14.2 per cent subjects went for a monthly check up, 57.1 per cent 2- 6 times a year and 28.5 per cent < 1 times a year. Among obese subjects 71.4 per cent visited Doctor 2- 6 times a year and 28.5 per cent < 1 times a year.

Among normal and overweight adults, 42.8 per cent took allopathy medication, while 71.4 per cent in case of obese. 14.2 per cent of overweight subjects were dependent on ayurveda medication, while 57.1 per cent in case of normal, 42.8 per cent of overweight and 28.5 per cent of obese were under dietary control.

2. Symptoms Prevalent Among the Diabetics.

Table V gives data on symptoms prevalent among the diabetics.

TABLE V

SYMPTOMS PREVALENT AMONG THE DIABETICS

Symptoms	Yes		No	
	No.	%	No.	%
Polyuria	12	57.1	9	42.8
Polyphagia	14	66.6	7	33.3
Polydipsia	14	66.6	7	33.3
Poor wound healing	3	14.2	18	85.7
Fatigue	12	57.1	9	42.8
Insomnia	7	33.3	14	66.6
Infections	4	19	17	80.9
Blurred vision	8	38	13	61.9
Shortness of breath	10	47.6	11	52.3

From the above Table, it is seen that 57.1 per cent of the subjects had polyuria while 42.8 per cent did not, 66.6 per cent suffered from polyphagia while 33.3 per cent did not. Polydipsia was common among 66.6 per cent of the subjects. 14.2 per cent complained of poor wound healing while 85.7 did not. 57.1 per cent of subjects had fatigue while 42.8 per cent did not. Insomnia was seen among 33.3 per cent of the selected diabetics. 80.9 per cent of subjects did not complain of infections. 38 per cent of subjects had blurred vision while 61.9 per cent did not. Shortness of breath was common among 47.6 per cent of the selected diabetics.

C. LIFESTYLE AND DIETARY PATTERN OF THE SELECTED SUBJECTS.

1. Lifestyle Pattern Adopted by the Selected Subjects.

Data on lifestyle pattern adopted by the selected subjects is shown in Table VI.

TABLE VI

LIFESTYLE PATTERN ADOPTED BY THE SELECTED SUBJECTS

Details	Normal(n=14)				Overweight(n=14)				Obese(n=14)				Total(n=42)			
	*D (n=7)		*N-D(n=7)		D (n=7)		N-D (n=7)		D (n=7)		N-D (n=7)		D (n=21)		N-D (n=21)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Hours of sleep per day																
<6 hours	-	-	2	28.5	-	-	-	-	-	-	-	-	-	-	2	9.5
6-8 hours	7	100	5	71.4	6	85.7	6	85.7	7	100	6	85.7	20	95.2	17	80.9
>8 hours	-	-	-	-	1	14.2	1	14.2	-	-	1	14.2	1	4.7	2	9.5
Sleeping habit in the afternoon																
Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No	7	100	7	100	7	100	7	100	7	100	7	100	21	100	7	100
Habit of snacking													8	38	5	23.8
Yes	3	42.8	1	14.2	3	42.8	4	57.1	2	28.5	-	-	13	61.9	16	76.1
No	4	57.1	6	85.7	4	57.1	3	42.8	5	71.4	7	100				
Regular exercise																
Yes	2	28.5	-	-	4	57.1	2	28.5	3	42.8	1	14.2	9	42.8	3	14.2
No	5	71.4	7	100	3	42.8	5	71.4	4	57.1	6	85.7	12	57.1	18	85.7
Yoga practice																
Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No	7	100	7	100	7	100	7	100	7	100	7	100	21	100	21	100

*D: Diabetic;*N-D: Non diabetic

Among the diabetic individuals, 95.2 per cent had 6-8 hours of sleep per day and 4.7 per cent of >8 hours of sleep per day. Among the non-diabetic subjects 80.9 per cent had 6-8 hours of sleep per day while 9.5 per cent had < 6 hours and 9.5 per cent had > 8 hours of sleep per day. In both the cases no one had the habit of sleeping in the afternoon. 61.9 per cent of the diabetic subjects had no habit of snacking while 38 per cent had the habit of snacking. 76.1 per cent had no habit of snacking while 23.8 per cent had the habit of snacking. 57.1 per cent of the diabetic subjects did not involve in regular exercise while 42.8 per cent did regular exercise. Among non-diabetic subjects 85.7 per cent did not indulge in regular exercise. No diabetic and non-diabetic subjects practiced yoga.

2. Stress Pattern and Management of the Selected Subjects.

Table VII shows a picture on the stress pattern and management of the selected subjects.

TABLE VII

STRESS PATTERN AND MANAGEMENT OF THE SELECTED SUBJECTS

Details	Normal(n=14)				Overweight(n=14)				Obese(n=14)				Total(n=42)			
	*D (n=7)		*N-D(n=7)		D (n=7)		N-D (n=7)		D (n=7)		N-D (n=7)		D (n=21)		N-D (n=21)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Stress pattern																
Relaxed and Calm	1	14.2	4	57.1	4	57.1	4	57.1	2	28.5	3	42.8	7	33.3	11	52.3
Peer pressure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Familial stress	3	42.8	3	42.8	2	28.5	1	14.2	3	42.8	3	42.8	8	38	7	33.3
Environmental stress	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Work stress	3	42.8	-	-	1	14.2	1	14.2	2	28.5	1	14.2	6	28.5	2	9.5
Physiological stress	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stress management																
Music	-	-	-	-	-	-	2	28.5	-	-	1	14.2	-	-	3	14.2
Exercise	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Overeating	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Avoiding food	1	14.2	-	-	-	-	-	-	-	-	-	-	1	4.7	-	-
Meditation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sleep	6	85.7	7	100	7	100	3	42.8	4	57.1	4	57.1	17	80.9	14	66.6
Others	-	-	-	-	-	-	2	28.5	3	42.8	2	28.5	3	14.2	4	19

*D: Diabetic;*N-D: Non diabetic

Among the diabetics, familial stress (38 per cent) and work stress (28.5 per cent) were seen and sleep (80.9 per cent) was chosen by many to manage stress. Among non-diabetics, familial stress (33.3 per cent) and work stress (9.5 per cent) were seen more among the subjects and sleep (66.6 per cent) were chosen by many to manage stress. In both cases, 33.3 per cent and 52.3 per cent were relaxed and calm.

3. Dietary Pattern of the Selected Subjects.

Table VIII provides the dietary pattern data of the selected subjects.

TABLE VIII

DIETARY PATTERN OF THE SELECTED SUBJECTS

Details	Normal(n=14)				Overweight(n=14)				Obese(n=14)				Total(n=42)			
	*D (n=7)		*N-D(n=7)		D (n=7)		N-D (n=7)		D (n=7)		N-D (n=7)		D (n=21)		N-D (n=21)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Dietary pattern																
Vegetarian	-	-	-	-	2	28.5	2	28.5	1	14.2	1	14.2	3	14.2	3	14.2
Non-vegetarian	7	100	7	100	4	57.1	5	71.4	6	85.7	6	85.7	17	80.9	18	85.7
Ova vegetarian	-	-	-	-	1	14.2	-	-	-	-	-	-	1	4.7	-	-
Meal pattern																
2 meals/ day	2	28.5	1	14.2	-	-	-	-	3	42.8	1	14.2	5	23.8	2	9.5
3 meals / day	5	71.4	6	85.7	7	100	7	100	4	57.1	6	85.7	16	76.1	19	90.4
4 meals / day	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
>5 meals / day	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*D: Diabetic;*N-D: Non diabetic

From the above Table VIII, it is seen that 57.1 per cent of the diabetic subjects who were overweight were non-vegetarians, 28.5 per cent were vegetarians, while 14.2 per cent were ova vegetarians. 71.4 per cent of the non-diabetic subjects who were overweight were non-vegetarians, 28.5 per cent were vegetarians. Among the obese 85.7 per cent diabetic and non diabetic subjects were non-vegetarians while 14.2 per cent of the subjects were vegetarians. In case of normal diabetic and non diabetic subjects all were non-vegetarians.

Twenty four per cent of diabetic and 9.5 per cent of the non diabetic subjects consumed two meals per day. While, 71.4 per cent and 85.7 per cent consumed three meals per day. In overweight subjects, in both the cases all consumed three meals per day. In case of obese, 42.8 per cent of the diabetic and 14.2 per cent of the non diabetic subjects consumed two meals per day, while 57.1 per cent and 85.7 per cent consumed three meals per day.

4. Consumption Pattern of Out-of-Home Foods.

It was observed that 14.2 per cent of the diabetic and 28.5 per cent of the non-diabetic normal weight subjects consumed food away from home. Among overweight subjects, 57.1 per cent in both the cases consumed out of home foods. In case of obese, 57.1 per cent diabetics and 28.5 per cent of non- diabetics consumed food away from home.

5. Habit of Skipping Meals.

Around 28.5 per cent and 42.8 per cent of normal and obese diabetic subjects and 14.2 per cent of both normal and overweight non-diabetic subjects said they skip their meals whereas 71.4 per cent, 100 per cent and 57.1 per cent of normal, overweight and obese diabetic subjects said that they do not skip their meals and 85.7 per cent in case of both normal and overweight and 42.8 per cent of the obese non diabetic subjects said they do not skip their meals. Among meals breakfast was skipped more often.

6. Modifications made in Eating Habits.

The modifications made in eating habits during various conditions were recorded from all the forty two subjects. It was found that what so ever be the condition most of the subjects did not change their food habits.

Highest modification was made in overweight condition i.e. 42.8 per cent in diabetic and 23.8 per cent in non diabetic subjects, followed by 28.5 per cent modifications made in case of diabetic subjects in functions and 19 per cent in holidays in case of non diabetic subjects.

7. Details Regarding Food Fads and Taboos.

Hot foods namely papaya, pine apple, chicken, meat, mango were excluded during pregnancy and dysentery. Cold foods like ice cream, cucumber, amla, coconut water, fruits were excluded during common cold and fever. Gas producing foods like potato, plantain, cabbage, yam, tapioca were avoided by most. Bile producing tea and coffee were avoided during ulcers by many. Brinjal, fish, milk, tapioca were certain foods that were avoided by most subjects as it caused allergies.

8. Food Frequency Pattern of the Selected Diabetics.

Table IX represents the food frequency pattern of the selected diabetics.

TABLE IX

FOOD FREQUENCY PATTERN OF THE SELECTED DIABETICS (in per cent)

Foods	Normal					Overweight					Obese				
	Daily	Twice a week	Once a week	Monthly	Never	Daily	Twice a week	Once a week	Monthly	Never	Daily	Twice a week	Once a week	Monthly	Never
Cereals	100	-	-	-	-	100	-	-	-	-	100	-	-	-	-
Pulses	100	-	-	-	-	100	-	-	-	-	100	-	-	-	-
GLV	14.2	28.5	57.1	-	-	57.1	14.2	28.5	-	-	57.1	42.8	-	-	-
Roots & tubers	-	42.8	57.1	-	-	-	57.1	42.8	-	-	-	42.8	57.1	-	-
Other vegetables	-	42.8	57.1	-	-	-	57.1	42.8	-	-	-	42.8	57.1	-	-
Nuts & oilseeds	-	-	100	-	-	-	28.5	42.8	28.5	-	-	42.8	42.8	14.2	-
Fruits	-	-	85.7	14.2	-	14.2	57.1	28.5	-	-	14.2	14.2	42.8	28.5	-
Meat & Fish	14.2	14.2	71.4	-	-	-	28.5	28.5	-	-	-	-	85.7	-	-
Milk & products	100	-	-	-	-	100	-	-	-	-	100	-	-	-	-
Fats	100	-	-	-	-	100	-	-	-	-	100	-	-	-	-
Sugars	100	-	-	-	-	71.4	28.5	-	-	-	100	-	-	-	-

Cereals, pulses, milk and milk products, fats and sugars were consumed daily by the subjects. Among normal (14.2 per cent), the daily consumption of green leafy vegetables was found to be lower when compared to overweight (57.1 per cent) and obese (57.1 per cent). Roots and tubers and other vegetables were not consumed daily by the subjects. The intake of fruits was higher among the overweight (14.2 per cent) and obese (14.2 per cent) daily when compared to normal. Nuts and oil seeds was almost consumed by all the groups once a week. In case of normal subjects, 14.2 per cent consumed meat and fish on daily basis. In case of overweight and obese, the highest range of consumption was once a month 28.5 per cent and 85.7 per cent respectively.

Previous studies have found that a reduced risk of type 2 diabetes is associated with a higher intake of cereal fiber and polyunsaturated fat (Meyer,2000) and that an increased risk is associated with a higher intake of trans fat (formed during the partial hydrogenation of vegetable oils)(Manson,2001) and a higher glycemic load (which reflects the effect of diet on the blood glucose level)(Salmeron,1997).

9. Food Frequency Pattern of the Selected Non- Diabetics.

Table X represents the food frequency pattern of the selected non diabetics.

TABLE X

FOOD FREQUENCY PATTERN OF THE SELECTED NON DIABETICS (in per cent)

Foods	Normal					Overweight					Obese				
	Daily	Twice a week	Once a week	Monthly	Never	Daily	Twice a week	Once a week	Monthly	Never	Daily	Twice a week	Once a week	Monthly	Never
Cereals	100	-	-	-	-	100	-	-	-	-	100	-	-	-	-
Pulses	100	-	-	-	-	100	-	-	-	-	100	-	-	-	-
GLV	-	42.8	57.1	-	-	-	71.4	28.5	-	-	-	71.4	28.5	-	-
Roots & tubers	-	42.8	57.1	-	-	-	57.1	42.8	-	-	-	100	-	-	-
Other vegetables	-	71.4	28.5	-	-	-	57.1	42.8	-	-	-	100		-	-
Nuts & oilseeds	-	42.8	-	57.1	-	-	-	85.7	14.2	-	-	42.8	57.1	-	-
Fruits	-	42.8	-	57.1	-	-	57.1	42.8	-	-	-	57.1	28.5	14.2	-
Meat & Fish	-	-	100	-	-	-	14.2	57.1	-	-	-	85.7	-	-	-
Milk & products	100	-	-	-	-	100	-	-	-	-	100	-	-	-	-
Fats	100	-	-	-	-	100	-	-	-	-	100	-	-	-	-
Sugars	100	-	-	-	-	100	-	-	-	-	100	-	-	-	-

Similar to diabetic subjects, non- diabetic subjects consumed cereals, pulses, milk and milk products, fats and sugars daily. Green leafy vegetables, roots and tubers and other vegetables were not consumed daily by the subjects. The intake of fruits was higher among the overweight (57.1 per cent) and obese (57.1 per cent) twice a week when compared to normal (42.8 per cent) subjects. Nuts and oil seeds were almost consumed by all the groups. Among the non-vegetarian most of them consumed meat and poultry once a week.

10. Information on Labelled Foods.

Among the normal, 57.1 per cent of the diabetic subjects purchased labelled foods whereas 42.8 per cent did not, 71.4 per cent of the non diabetic subjects purchased labelled foods whereas 28.5 per cent did not. Among the overweight, 57.1 per cent of the diabetic subjects purchased labelled foods whereas 28.5 per cent did not, all the non diabetic subjects purchased labelled foods. Among obese, 42.8 per cent of diabetic subjects purchased labelled foods whereas 57.1 per cent did not, 85.7 per cent of non diabetic subjects purchased labelled foods whereas 14.2 per cent did not. The information looked upon while purchasing food products included manufacturing date, expiry date, food additives, ingredients used, price, precautions, nutrition information, and method of preparation, logo of food standards, recommended usage / dosage and nutritional claims.

11. Consumption Pattern of High Energy/ Fat Foods in Diabetics.

Table XI shows the consumption pattern of high energy/fat foods of the selected Diabetics.

12. Consumption Pattern of High Energy/ Fat Foods in Non- Diabetics.

Table XII shows the consumption pattern of high energy/fast foods of the selected non diabetics.

TABLE XI

CONSUMPTION PATTERN OF HIGH ENERGY/FAT FOODS IN DIABETICS (in per cent)

Food Items	Normal				Overweight				Obese			
	Daily	Weekly	Monthly	Never	Daily	Weekly	Monthly	Never	Daily	Weekly	Monthly	Never
Sweets	-	42.8	57.1	-	-	28.5	71.4	-	-	-	100	-
Fried foods	-	42.8	57.1	-	-	28.5	71.4	-	-	-	100	-
Bakery Items	-	28.5	71.4	-	-	28.5	71.4	-	-	-	100	-
Fast foods	-	28.5	71.4	-	-	28.5	28.5	42.8	-	-	100	-
Salted foods	-	42.8	42.8	14.2	-	28.5	28.5	42.8	-	-	100	-
Fleshy foods	-	71.4	28.5	-	-	-	57.1	42.8	-	42.8	42.8	14.2

TABLE XII

CONSUMPTION PATTERN OF HIGH ENERGY/FAT FOODS IN NON DIABETICS (in per cent)

Food Items	Normal				Overweight				Obese			
	Daily	Weekly	Monthly	Never	Daily	Weekly	Monthly	Never	Daily	Weekly	Monthly	Never
Sweets	-	-	100	-	-	14.2	85.7	-	-	-	100	-
Fried foods	-	-	100	-	-	-	100	-	-	-	100	-
Bakery Items	-	-	100	-	-	14.2	85.7	-	-	-	100	-
Fast foods	-	-	100	-	-	14.2	85.7	-	-	-	100	-
Salted foods	-	-	100	-	-	14.2	85.7	-	-	-	100	-
Fleshy foods	-	100	-	-	-	28.5	42.8	28.5	-	42.8	42.8	14.2

From the table XI it is seen that there is no daily consumption of high energy/ fat foods. Among normal subjects weekly and monthly consumption was seen, in case of overweight, weekly and monthly consumption was seen with 42.8 per cent subjects who never consumed fast foods, salted foods and fleshly foods. In obese, highest consumption was seen on monthly basis.

The nutrition transition refers to a shift from consumption of simple, traditional foods to heavily marketed foods High in calories, sugar, and animal fat but low In vitamins and minerals derived from fruits and vegetables(Popkin,2001). Although the nutrition transition has reduced under nutrition, it increases diabetes risk(Narayan,2006).

From the table XII it is seen that there is no daily consumption of high energy/ fat foods. Among normal and obese adults monthly consumption was seen, in overweight weekly and monthly consumption was seen with 28.5 per cent of overweight and 14.2 per cent of obese who never consumed fleshy foods.

D.NUTRITIONAL STATUS OF THE SELECTED SUBJECTS

1. Assessment of Anthropometric Parameters of the Selected Normal, Overweight and Obese Diabetic and Non Diabetic Subjects.

Anthropometry has been widely and successfully applied to the assessment of health and nutritional risk. Data on mean and standard deviation of body measurements of subjects based on their BMI categories is shown in Table XIII.

TABLE XIII

ANTHROPOMETRIC PARAMETERS OF THE SELECTED NORMAL, OVERWEIGHT AND OBESE DIABETIC AND NON-DIABETIC SUBJECTS

Parameters	Standard*	Normal (n=14)		Overweight (n=14)		Obese (n=14)	
		#D (n=7)	#N-D (n=7)	D (n=7)	N-D (n=7)	D (n=7)	N-D (n=7)
Height (cm)	155.5	148.71± 7.63	152.28±5.64	154.28±5.9	154.28±6.15	153.42±4.92	150.14±8.80
Weight (kg)	55.5	48±7.39	48.42±4.46	59.42±4.68	59.14±2.96	76.28±10.06	71.14±12.99
Body Mass Index (kg/m^2)	18.5-22.9	21.64±1.65	21.02±1.52	24.78±0.99	24.92±1.17	32.42±3.61	31.57±4.64
Waist Hip Ratio	0.81-0.90	0.92± 0.02	0.88±0.02	0.94±0.02	0.91±0.02	1±0.04	0.99±0.03
Arm Circumference (cm)	27.9	27.3±2.22	27.4±1.81	30.24±1.10	30.52±1.20	34.35±2.77	36.12±3.17
Arm Muscle Circumference (cm)	20.8	21.3±1.74	21.37±1.53	23.17±1.70	23.21±1.25	24.75±1.40	25.75±2.25

*ICMR standards, 2009 # D: Diabetic; #N-D: Non diabetic

The standard height for the age group 30-60 years was found to be 155.5 cm. The mean height of normal diabetics (148.71 cm), non-diabetics (152.28 cm), overweight diabetics as well as non-diabetics (154.28 cm) and obese diabetics (153.42 cm) and non-diabetics (150.14 cm) was found to be lesser than that of the standard. Mean weight of the normal diabetics was found to be 48 kg and for non-diabetics 48.42 kg, that of overweight diabetics was 59.42 kg and non-diabetics 59.14 kg and that of obese diabetics was 76.28 kg and non-diabetics was 71.14 kg. The standard weight is 55.5 kg and it is clear that the normal subjects had a mean weight lesser than the standard, the overweight and obese subjects had a mean weight greater than the standard value. It is also to be noted that in case of overweight and obese the weight of diabetics was found to be greater than non-diabetics.

The BMI is an indicator of overweight and obesity. The BMI of overweight and obese subjects was greater than the standard BMI where as the normal subjects lie within the normal value. The obese, overweight and normal diabetic subjects had WHR greater than the normal range (0.81-0.90) except in case of normal non diabetic subjects. Arm circumference and arm muscle circumference were seen to be higher with obese when compared to normal or overweight.

Regression analysis revealed age ($p<0.0001$), waist circumference ($p<0.0001$), body mass index ($p<0.0001$), waist-hip ratio ($p< 0.0001$), family history of diabetes ($p<0.0001$), higher Socio economic status ($p<0.0001$), moderate ($p = 0.001$) and light ($p < 0.001$) grade physical activity to be associated with glucose intolerance(Deepa et.al;2003).

Table XIV shows the statistical interpretation for comparison between the anthropometric parameters of the subjects.

TABLE XIV

STATISTICAL INTERPRETATION FOR COMPARISON BETWEEN ANTHROPOMETRIC PARAMETERS OF THE SUBJECTS(t values)

BMI category	Height(cm)		Weight(kg)		WHR		AC(cm)		AMC(cm)	
	#D (n=7)	#N-D (n=7)	D (n=7)	N-D (n=7)	D (n=7)	N-D (n=7)	D (n=7)	N-D (n=7)	D (n=7)	N-D (n=7)
Normal vs. Overweight	1.230^{NS}	1.080^{NS}	2.613*	11.06**	1.081^{NS}	2.976*	4.061**	3.573*	1.583^{NS}	3.236*
Normal vs. Obese	1.598^{NS}	0.866^{NS}	9.751**	5.983**	3.584*	8.521**	4.155**	6.214**	3.615*	4.830**
Overweight vs. Obese	0.2646^{NS}	2.700*	3.142*	2.625*	2.378^{NS}	7.778**	3.406*	3.825**	1.676^{NS}	3.116*

D: Diabetic; #N-D: Non diabetic

Comparison between subjects classified on the basis of BMI was done for height, weight, WHR, arm circumference and arm muscle circumference. In case of diabetics, no significant difference was found in height, WHR and AMC when normal subjects were compared with overweight and five per cent significance in weight and highest positive correlation ($P<0.01$) is seen with AC. In case of non-diabetics, no significant difference was found with height, high positive significant difference ($P<0.01$) with weight and five per cent significance was seen with WHR, AC and AMC. When normal were compared with obese in both diabetic and non-diabetic subjects no significant difference was seen in height, one per cent significance was seen with weight and AC, with WHR and AMC of non-diabetic subjects and five per cent significance with WHR and AMC of diabetic subjects. When overweight subjects were compared with obese subjects no significant difference in height, WHR and AMC, five per cent significance with weight, AC was seen among diabetic subjects. Among non-diabetic subjects, five per cent significance was seen with height, weight and AMC and high positive significant difference ($P<0.01$) with WHR and AC was noticed.

Table XV shows the coefficient correlation within anthropometric parameters of the selected subjects.

TABLE XV

CORRELATION WITHIN ANTHROPOMETRIC PARAMETERS AMONG NORMAL, OVERWEIGHT AND OBESE SUBJECTS(r values)

Parameters	BMI category					
	Normal(n=14)		Overweight(n-=14)		Obese(n=14)	
	#D(n=7)	#N-D(n=7)	D(n=7)	N-D(n=7)	D(n=7)	N-D(n=7)
Weight vs. BMI	0.773*	0.892**	0.686^{NS}	0.834**	-0.165^{NS}	0.032^{NS}
Weight vs.WHR	0.766*	0.888**	0.683^{NS}	0.835**	-0.198^{NS}	-0.0001^{NS}
Weight vs. AC	0.769*	0.887**	0.713*	0.848**	-0.123^{NS}	0.130^{NS}
Weight vs. AMC	0.908**	0.803*	0.910**	0.855**	0.515^{NS}	0.961**
BMI vs. WHR	0.996**	0.888**	0.685^{NS}	-0.354^{NS}	-0.147^{NS}	0.518^{NS}

D: Diabetic; #N-D: Non diabetic

Weight was found to be positively correlated with body circumference's like AMC and AC except in case of obese diabetic and non-diabetic subjects where no significance was found with AC. Weight and WHR when correlated showed no significant difference in overweight and obese diabetic subjects and one per cent significance in normal and overweight non-diabetic subjects five per cent significance(r=0.766) in normal diabetics were seen. BMI and WHR showed a high positive correlation ($P<0.01$) in normal subjects where as not significant in case of overweight and obese subjects.

2. Assessment of Biochemical Parameters.

Table XVI shows the Biochemical parameters of the selected normal, overweight and obese subjects.

.

TABLE XVI

BIOCHEMICAL PARAMETERS OF THE SELECTED NORMAL, OVERWEIGHT AND OBESE SUBJECT

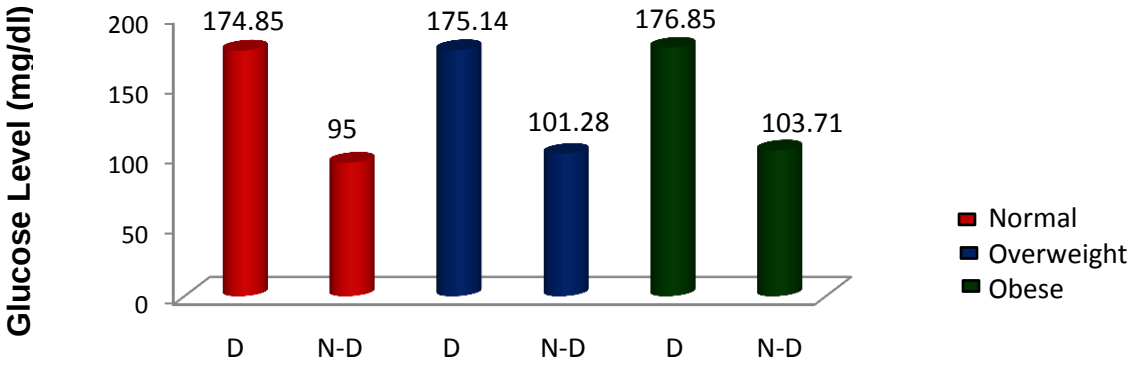
Parameters	Standard*	Normal (n=14)		Overweight (n=14)		Obese (n=14)	
		#D (n=7)	#N-D (n=7)	D (n=7)	N-D (n=7)	D (n=7)	N-D (n=7)
Fasting Glucose(mg/dl)	80-110	174.85±60.70	95±14.96	175.14±49.94	101.28±10.85	176.85±44.44	103.71±10.93
Post prandial Glucose(mg/dl)	<200	254.14±64.50	140.42±26.46	260±70.65	141.85±23.01	261.28±61.91	172.14±25.97
Total cholesterol (mg/dl)	<200	237.28±62.62	200.71±72.49	238.42±58.36	218.71±32.34	244.85±57.62	220.14±62.03
Triglycerides (mg/dl)	50-150	153.42±40.21	127.14±37.49	176.85±58.31	202.57±92.84	158.28±19.16	144.42±49.05
High-density lipoprotein (mg/dl)	>45	56.85±9.97	52.85±5.01	46±12.38	50.57±9.36	53.85±3.76	51.57±10.92
Very low-density lipoprotein (mg/dl)	<40	30.71±7.93	25.28±7.58	35.28±11.67	40.57±18.52	31.57±3.82	28.57±10.01
Low-density lipoprotein(mg/dl)	<100	146.85±56.50	102±36.37	157.14±59.93	127.71±22.12	159.71±54.79	140.14±50.12

*National Cholesterol Programme, 2001 # D: Diabetic ;#N-D: Non diabetic

The mean fasting level was found to be greater than standard (80-110) in normal, overweight and obese diabetics. In India, as in the West, diabetes is ultimately due to chronically high levels of blood glucose, and some of the clinical consequences are similar (Magliano,2010). In case of non-diabetic the fasting blood glucose levels increases from normal to obese subjects supporting many studies that have shown that the blood glucose levels are found to be greater in obese people.(Figure III) Similarly, the mean post prandial glucose level was found to be greater than standard(<200) in normal, overweight and obese diabetics. In non-diabetic subjects the post prandial blood glucose level increases from normal to obese subjects. Total cholesterol was higher in diabetic subjects in all the three groups when compared to non-diabetic with the standard(<200)(Figure IV). The normal range for triglycerides was found to be 50-150 mg/dl and it was found to be higher among the diabetic subjects when compared to non-diabetic subjects. It was found to be highest in overweight category(Figure V). The HDL level was found to be highest in case of normal subjects both diabetic and non-diabetic categories when compared to overweight and obese subjects(Figure VI). The normal VLDL level is <40 and it has been found to be in normal range in all the three groups(Figure VIII). The standard LDL level is <100 and it was found to be higher in all the three groups especially in diabetic normal, overweight and obese subjects(Figure VII).

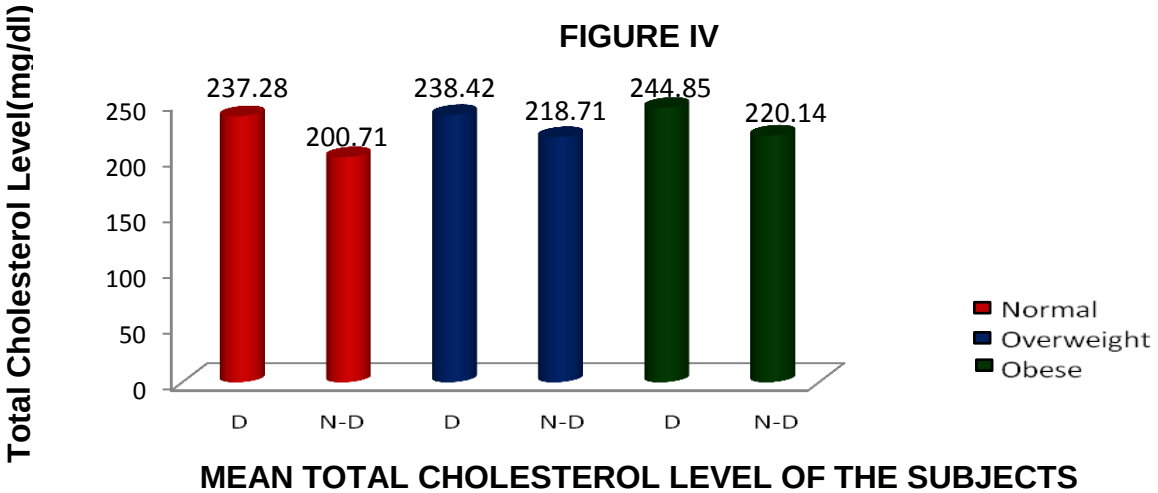
Table XVII shows the statistical interpretation for comparison between biochemical parameters of the subjects.

FIGURE III



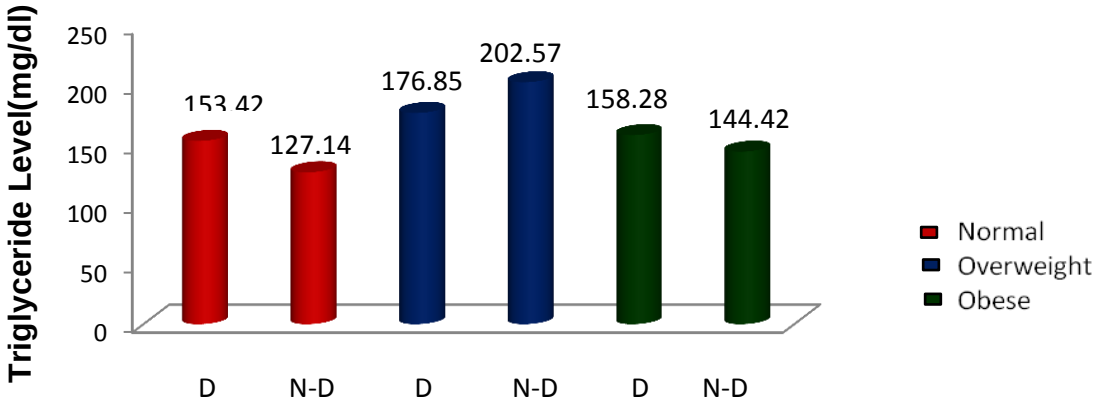
MEAN GLUCOSE LEVEL OF THE SUBJECTS

FIGURE IV



MEAN TOTAL CHOLESTEROL LEVEL OF THE SUBJECTS

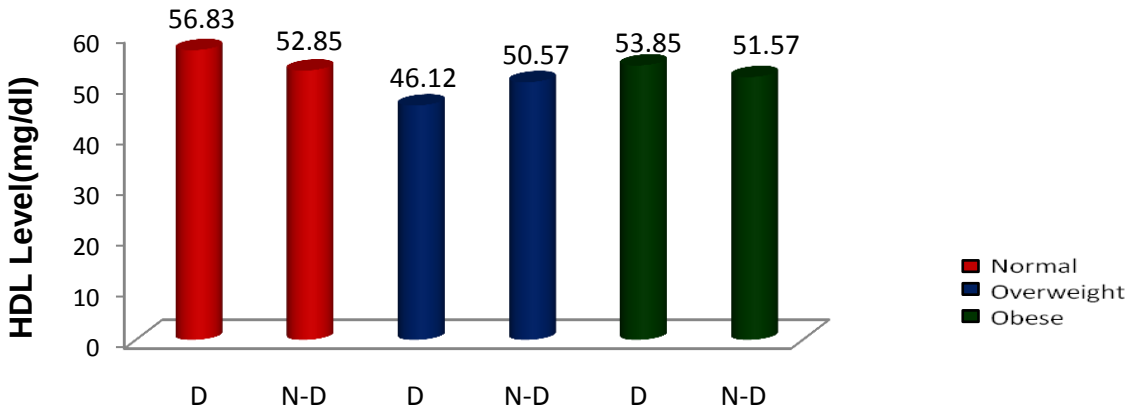
FIGURE V



MEAN

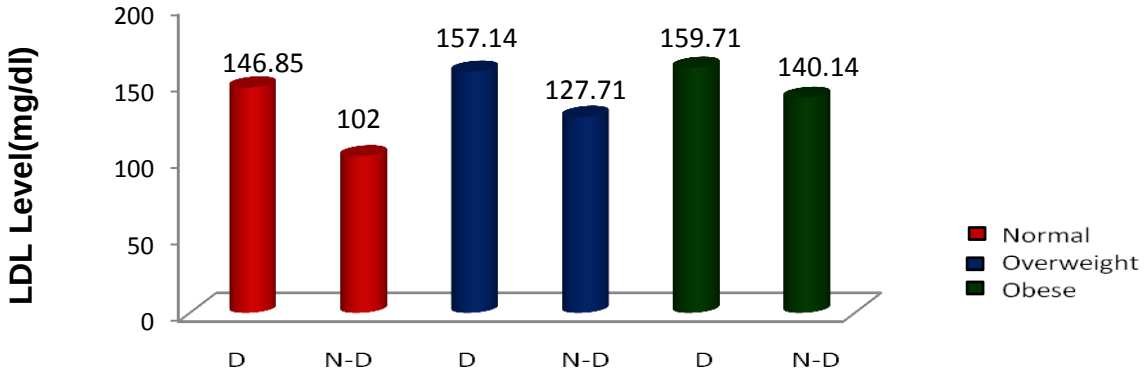
TRIGLYCERIDE LEVEL OF THE SUBJECTS

FIGURE VI



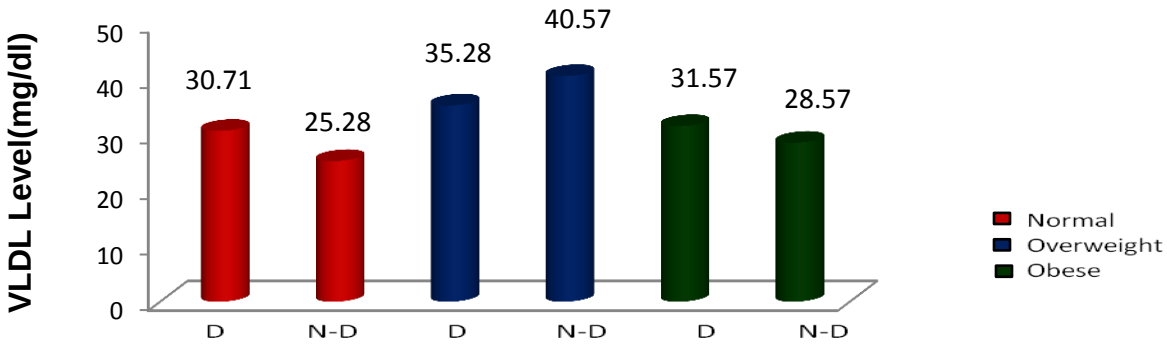
:AN HDL LEVEL OF THE SUBJECT

FIGURE VII



MEAN LDL LEVEL OF THE SUBJECTS

FIGURE VIII



MEAN VLDL LEVEL OF THE SUBJECTS

TABLE XVII

STATISTICAL INTERPRETATION FOR COMPARISON BETWEEN BIOCHEMICAL PARAMETERS OF THE SUBJECTS

BMI category	Fasting Glucose (mg/dl)		Post Prandial Glucose (mg/dl)		Total Cholesterol (mg/dl)		TGL (mg/dl)		HDL (mg/dl)		VLDL (mg/dl)		LDL (mg/dl)	
	#D (n=7)	#N-D (n=7)	D(n=7)	N-D (n=7)	D(n=7)	N-D (n=7)	D(n=7)	N-D (n=7)	D(n=7)	N-D (n=7)	D(n=7)	N-D (n=7)	D(n=7)	N-D (n=7)
Normal vs. Overweight	0.008^{NS}	1.188^{NS}	0.155^{NS}	0.158^{NS}	0.032^{NS}	0.631^{NS}	0.727^{NS}	3.454*	1.447^{NS}	0.657^{NS}	0.714^{NS}	3.576*	0.320^{NS}	1.364^{NS}
Normal vs. Obese	0.084^{NS}	1.008^{NS}	0.274^{NS}	3.664*	0.345^{NS}	0.440^{NS}	0.319^{NS}	0.655^{NS}	0.741^{NS}	0.290^{NS}	0.286^{NS}	0.598^{NS}	0.629^{NS}	1.422^{NS}
Overweight vs. Obese	0.128^{NS}	0.484^{NS}	0.061^{NS}	2.281^{NS}	0.219^{NS}	0.076^{NS}	0.785^{NS}	1.236^{NS}	1.594^{NS}	0.244^{NS}	0.789^{NS}	1.260^{NS}	0.092^{NS}	0.970^{NS}

D: Diabetic ;#N-D: Non diabetic

Comparison between the biochemical parameters like fasting, post prandial blood glucose, total cholesterol, triglycerides, HDL, LDL and VLDL were made. The comparison of TGL and VLDL levels between normal and overweight, post prandial glucose level between normal and obese, among non-diabetic subjects showed five per cent significance, while the comparison of fasting glucose, post prandial glucose, total cholesterol, TGL, HDL, LDL and VLDL between normal and overweight, normal and obese and overweight and obese in other subjects showed no significance.

3. Dietary Pattern of the Selected Individuals.

a. Mean Nutrient Intake of the Selected Subjects.

Mean nutrient intake of the selected subjects are presented in the Table XVIII

TABLE XVIII
MEAN NUTRIENT INTAKE (n=42)

Nutrient	Normal (n=14)		Overweight (n=14)		Obese (n=14)	
	#D (n=7)	#N-D (n=7)	D (n=7)	N-D (n=7)	D (n=7)	N-D (n=7)
Protein (gm)	36.55±12.08	32.93±10.81	46.16±8.22	31.97±11.57	59.01±17.85	46.97±14.79
Fat (gm)	9.41±9.15	7.01±4.59	5.21±0.92	8.45±3.34	7.10±2.09	14.21±10.37
Energy (kcal)	1303.35±163.83	1243±321.23	1478.1±180.64	1341.25±246.91	2204.21±1044.06	1618.64±364.12
Calcium (mg)	253.27±122.04	295.94±101.07	378.21±123.60	590.50±198.58	481.15±225.56	540.30±321.26
Iron (mg)	10.46±9.71	7.57±2.81	11.25±4.15	18.33±12.33	14.68±3.71	26±16.83

D: Diabetic ;#N-D: Non diabetic

From the above Table XVIII, it is seen that the obese subjects especially the diabetic subjects consumed more protein than that of overweight and obese diabetic as well as non-diabetic subjects. The obese subjects especially the non-diabetic subjects consumed more fat when compared to overweight and obese subjects. The mean energy intake was found to be greater in obese especially in diabetic subjects when compared to other two groups.

b. Deficit or Excess Nutrient Consumed by the Subjects.

Table XIX gives the deficit or excess nutrient intake by the subjects from the three groups.

TABLE XIX

NUTRIENT INTAKE COMPARISON WITH RECOMMENDED ALLOWANCE

Nutrient	RDA	Normal				Overweight				Obese			
		#D(n=7)		#N-D(n=7)		D(n=7)		N-D(n=7)		D(n=7)		N-D(n=7)	
		Intake	Deficit/ Excess (%)	Intake	Deficit/ Excess (%)	Intake	Deficit/ Excess (%)	Intake	Deficit/ Excess (%)	Intake	Deficit/ Excess (%)	Intake	Deficit/ Excess (%)
Protein	55	41	-25	42	-24	43	-22	45	-18	53	-4	54	-2
Fat	25	27	+8	26	+4	29	+16	28	+12	32	+28	30	+20
Energy	2230	2018	-9	1872	-16	2335	+5	2313	+4	2561	+15	2476	+11
Calcium	600	439	-27	453	-24	464	-23	476	-21	481	-20	512	-15
Iron	21	17	-19	18	-14	19	-10	19	-10	20	-5	20	-5

D: Diabetic ;#N-D: Non diabetic

Fat was consumed in excess when compared to ICMR recommended values by all the three groups. The energy was found to be deficit among normal diabetic as well as non-diabetic subjects but in case of overweight and obese subjects the energy intake was found to be in excess. Protein, calcium and Iron did not reach the recommended ICMR levels in all the three groups.

Some genes lead to obesity and type 2 diabetes when exposed to a constant high energy diet. In virtually all populations, higher fat diets and decreased physical activity and sedentary occupational habits have accompanied the process of modernization which has resulted in the doubling of the prevalence of obesity and type 2 diabetes in less than a generation(Mohan *et al.,*2007).

E. BODY COMPOSITION MEASURES OF THE SELECTED NORMAL, OVERWEIGHT AND OBESE SUBJECTS.

The mean of the various body composition measures are given in Table XX.

TABLE XX

BODY COMPOSITION PARAMETERS OF THE SELECTED NORMAL, OVERWEIGHT AND OBESE SUBJECTS

Parameters	Standard*	Normal(n=14)		Overweight(n=7)		Obese(n=7)	
		D(n=7)	N-D(n=7)	D(n=7)	N-D(n=7)	D(n=7)	N-D(n=7)
Body Fat Mass(kg)	10.5-16.8	15.48±4.07	14.71±3.27	20.12±5.15	21.78±4.08	37.85±8.06	33.04±8.17
Percent Body Fat(%)	18-28	32.37±7.14	30.57±6.34	34.4±9.77	36.85±7.42	49.22±5.01	45.94±3.99
Fat Free Mass(kg)	36.2-44.5	32.2±6.21	33.54±4.80	39.04±7.92	37.47±5.34	38.32±3.82	38.41±6.19
Total Body Water(l)	26.5-32.7	23.61±4.58	24.6±3.55	28.67±5.83	27.45±3.91	28.18±2.82	28.18±4.60
Intra Cellular Water(l)	16.3-20.3	14.55±2.78	15.25±2.29	17.68±3.79	17.02±2.45	17.58±1.71	17.35±2.76
Extra Cellular Water(l)	10.2-12.4	9.04±1.82	9.34±1.30	10.98±2.03	10.42±1.47	10.6±1.58	10.82±1.86
Protein(kg)	7.2-8.8	6.3±1.20	6.58±0.98	7.65±1.64	7.37±1.07	7.61±0.74	7.5±1.19
Skeletal Muscle Mass(kg)	19.9-24.3	17±3.64	17.88±2.96	21.05±4.95	20.24±3.21	20.91±2.21	20.62±3.59
Mineral(kg)	2.5-3.0	2.25±0.42	2.36±0.25	2.72±0.44	2.64±0.35	2.68±0.32	2.54±0.40
Bone Mineral Content(kg)	2.0-2.5	1.86±0.35	1.96±0.20	2.25±0.35	2.19±0.29	2.22±0.28	2.08±0.33
Body Cell Mass(kg)	23.8-29.1	20.87±4.01	21.85±3.25	25.34±5.45	24.4±3.53	25.2±2.42	24.88±3.95
Visceral Fat Area(cm^2)	<100	100.3±15.92	84.25±3.62	108.45±15.94	102.75±9.88	159.61±26.16	135.1±16.62
ECF/TBF	0.36-0.39	0.33±0.008	0.33±0.005	0.33±0.007	0.33±0	0.33±0.01	0.33±0.01
ECW/TBW	0.31-0.34	0.38±0.008	0.37±0.005	0.38±0.008	0.37±0.005	0.38±0.01	0.37±0.006

*Reference range as per In Body body composition analysis data for normal subjects

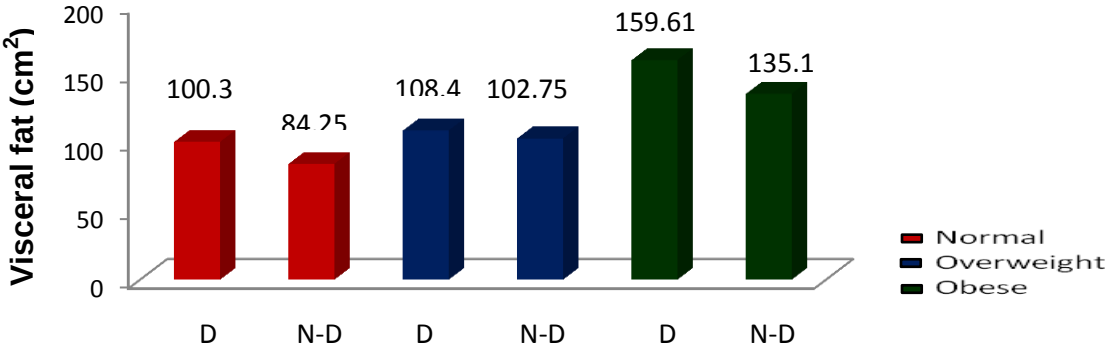
Bioelectrical Impedance Analysis(BIA) is based on the principle that the resistance to an applied electric current is inversely related to the amount of fat free mass within the body. Measurements of body fat, FFM, TBW, protein, mineral was done.

The normal range for total body fat is said to be 10.5-16.8kg for the adults. From the findings, it is seen that the body fat mass of normal diabetic as well as non-diabetic subjects come within standard range, while that of overweight and obese both diabetic and non-diabetic subjects vary largely. This indicates that a major portion of weight for the obese subjects was their fat content(Figure XI).

The percent body fat had a normal range of 18-28 per cent for adults. The normal diabetic subjects had 32.37 per cent, non-diabetics had 30.57 per cent, 34.4 per cent in case of overweight diabetics, non-diabetic 36.85 per cent and obese diabetic subjects had 49.22 per cent and non-diabetic had 45.94 per cent and it was seen that even the normal subjects of both the categories did not fall under the normal range and hence it shows that BMI defines the condition of a person in predetermined values of overweight and obesity but composition specifies the fat content values.

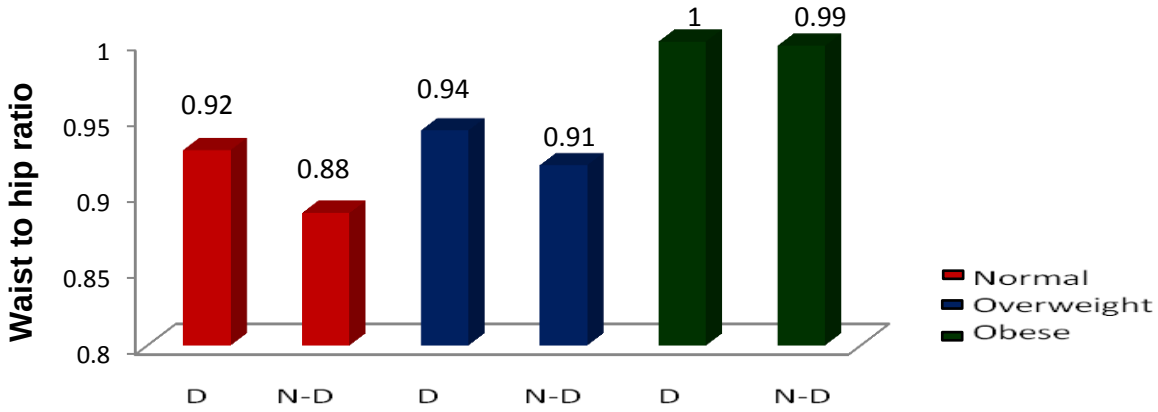
Visceral fat area is the fat content found in the abdomen region and the normal value is found to be less than 100$cm^{2.}$ The normal diabetic subjects had a mean VFA of 100.3 cm^2 and non-diabetics had 84.25 cm^2 and overweight diabetics had a mean VFA of 108.45 cm^2 and non-diabetics of 102.75 cm^2 whereas obese diabetic subjects had a VFA of 159.61 cm^2 and non-diabetics had 135.1 cm^2 which clearly shows that only normal non-diabetics fall in the normal category where as overweight and obese subjects especially the diabetics along with normal diabetics exceed the normal range showing central obesity(Figure IX).

FIGURE IX



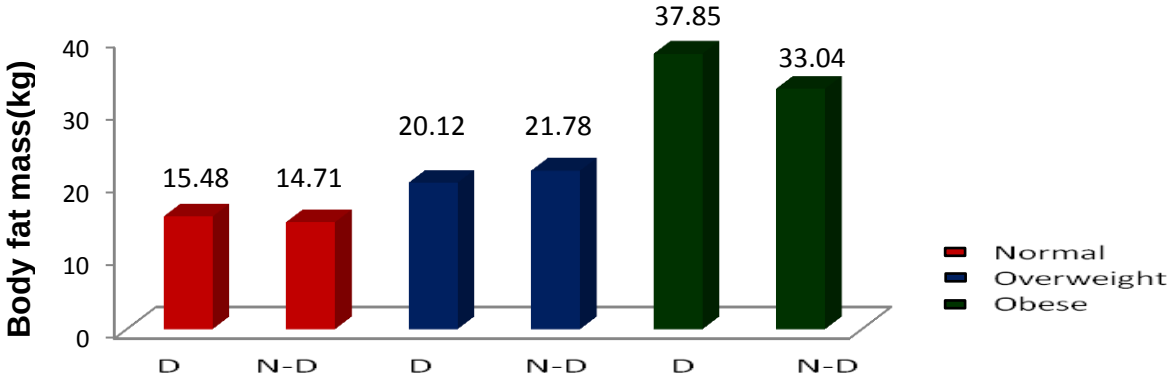
MEAN VISCERAL FAT AREA OF THE SUBJECTS

FIGURE X



MEAN WAIST TO HIP RATIO OF THE SUBJECTS

FIGURE XI



MEAN BODY FAT MASS OF THE SUBJECTS

Obesity is a cause of insulin resistance. Android obesity, which is characterized by a gross excess of adipose tissue within and around the abdomen, is the main type of obesity associated with type 2 diabetes and increased vascular risk (Kopelman *et al.,*1997).

The FFM had a normal range of 36.2-44.5kg and was found to be below normal in normal BMI subjects of both the categories and the FFM of overweight and obese diabetic as well as non-diabetic subjects were within the normal range.

Despite having lower prevalence of obesity as defined by body mass index (BMI), Asian Indians tend to have greater waist circumference and waist to hip ratios(Ramachandran *et al.,*1997) thus having a greater degree of central obesity. Again, Asian Indians have more total abdominal and visceral fat for any given BMI(Raji *et al.,*2001) and for any given body fat they have increased insulin resistance(Chandalia *et al.,*1999).

Insulin resistance which was found to be a characteristic feature of the Asian Indians, despite their lean body mass, could be adversely affected by even small increments in the body mass. In other words higher BMI, rather than obesity seems to be a risk factor in Indians(Snehalatha *et al.,*1999).

The increase in total body fat in asian indians results in an increase in visceral fat and an expected increase in insulin resistance(Banerji *et al.,*1999).

Normal diabetic subjects had a TBW of 23.61L, non-diabetic had 24.6L, overweight diabetic 28.67L, non-diabetic 27.45L and obese diabetic and non-diabetic had 28.18L. The water content of normal subjects were found to be less than the normal range(26.5-32.71) where as the overweight and obese subjects were within this range.

The protein content of overweight and obese diabetic as well as non diabetic subjects were found to be within the normal range but the normal diabetic and non-diabetic subjects had a mean protein level less than the normal range which directly reflects on the SMM which showed similar results.

Minerals and BCM was found to be below the normal range in normal subjects and was found to be normal in overweight and obese subjects.

Table XXI provide the statistical interpretation for comparison between body composition parameters of the subjects.

TABLE XXI

STATISTICAL INTERPRETATION FOR COMPARISON BETWEEN BODY COMPOSITION PARAMETERS OF THE SUBJECTS(t values)

Parameters	Normal vs. Overweight		Normal vs. Obese		Overweight vs. Obese	
	D(n=7)	N-D(n=7)	D(n=7)	N-D(n=7)	D(n=7)	N-D(n=7)
BFM (kg)	2.458*	3.370*	10.33**	6.215**	6.864**	2.659*
PBF (%)	0.535^{NS}	1.781^{NS}	7.020**	5.622**	5.579**	2.794*
VFA (cm^2)	1.764^{NS}	4.613**	6.917**	7.665**	5.440**	5.712**
FMM (kg)	1.483^{NS}	2.380^{NS}	2.337^{NS}	2.216^{NS}	0.201^{NS}	0.960^{NS}
TBW (l)	1.490^{NS}	2.314^{NS}	2.377^{NS}	2.229^{NS}	0.186^{NS}	0.977^{NS}
Protein (kg)	1.496^{NS}	2.393^{NS}	2.416^{NS}	2.183^{NS}	0.064^{NS}	0.726^{NS}
SMM (kg)	1.473^{NS}	2.405^{NS}	2.428^{NS}	2.132^{NS}	0.070^{NS}	0.701^{NS}
Mineral (kg)	1.578^{NS}	2.976*	2.568*	1.440^{NS}	0.179^{NS}	1.943^{NS}
BMC (kg)	1.590^{NS}	3.001*	2.552*	1.240^{NS}	0.181^{NS}	2.496*
BCM (kg)	1.474^{NS}	2.352^{NS}	2.438^{NS}	2.134^{NS}	0.063^{NS}	0.800^{NS}
ICW (l)	1.484^{NS}	2.355^{NS}	2.453*	2.113^{NS}	0.064^{NS}	0.776^{NS}
ECW (l)	1.505^{NS}	2.254^{NS}	1.934^{NS}	2.342^{NS}	0.341^{NS}	1.241^{NS}

A high positive and significant difference ($P<0.01$) was seen in parameters like BFM, PBF and VFA among the normal versus obese in both diabetic and non-diabetic subjects, VFA in non-diabetic normal versus overweight and in both diabetic and non-diabetic in case of overweight and obese. Comparison of FFM, TBW, protein, SMM, BCM among normal and overweight, normal and obese and overweight and obese was found to be not significant in both diabetic and non-diabetic subjects. The mineral content among normal and overweight diabetic subjects, normal and obese non-diabetic subjects and overweight and obese diabetic as well as non-diabetic subjects when compared was found to be not significant, normal and overweight non-diabetic and normal and obese diabetic subjects were found to be at five per cent significance. Significant difference was noticed between body fat content when groups were compared against each other.

Table XXII shows the correlation between anthropometric and body composition parameters of normal, overweight and obese subjects.

TABLE XXII

CORRELATION BETWEEN ANTHROPOMETRIC AND BODY COMPOSITION PARAMETERS OF NORMAL, OVERWEIGHT AND OBESE SUBJECTS(r values)

Parameters	BMI category					
	Normal(n=14)		Overweight(n=7)		Obese(n=7)	
	D(n=7)	N-D(n=7)	D(n=7)	N-D(n=7)	D(n=7)	N-D(n=7)
Weight vs. BFM	0.779*	0.891**	0.672^{NS}	0.829*	-0.119^{NS}	0.074^{NS}
Weight vs. %BF	-0.512^{NS}	-0.674^{NS}	-0.785^{*}	-0.827*	0.392^{NS}	0.190^{NS}
Weight vs. FFM	0.893**	0.942**	0.863**	0.919**	-0.060^{NS}	0.266^{NS}
Weight vs. TBW	0.896**	0.764*	0.830*	0.785*	0.715^{NS}	0.917**
Weight vs. Protein	0.868*	0.782*	0.820*	0.801*	0.525^{NS}	0.887**
Weight vs. SMM	0.869*	0.773*	0.828*	0.800*	0.553^{NS}	0.889**
Weight vs. Mineral	0.960**	0.743^{NS}	0.844*	0.753^{NS}	0.828*	0.776*
Weight vs. VFA	0.624^{NS}	0.0476^{NS}	-0.407^{NS}	-0.135^{NS}	0.808*	0.907**
Weight vs. BCM	0.868*	0.770*	0.830*	0.801*	0.559^{NS}	0.891**
BMI vs. BFM	0.998**	0.998**	0.995**	0.999**	0.985**	0.974**
BMI vs. %BF	-0.673^{NS}	-0.685^{NS}	-0.644^{NS}	-0.724*	-0.849**	-0.822*
BMI vs. FFM	0.972**	0.977**	0.930**	0.951**	0.972**	0.952**
BMI vs. TBW	0.564^{NS}	0.245^{NS}	0.280^{NS}	-0.754^{NS}	0.455^{NS}	0.489^{NS}
BMI vs. Protein	0.549^{NS}	0.275^{NS}	0.294^{NS}	-0.745^{NS}	0.150^{NS}	0.427^{NS}
BMI vs. SMM	0.544^{NS}	0.264^{NS}	0.284^{NS}	-0.751^{NS}	0.174^{NS}	0.434^{NS}
BMI vs. Mineral	0.659^{NS}	0.138^{NS}	0.358^{NS}	-0.823*	0.583^{NS}	0.228^{NS}
BMI vs. VFA	0.787*	0.080^{NS}	-0.309^{NS}	0.098^{NS}	0.782*	0.945**
BMI vs. BCM	0.547^{NS}	0.261^{NS}	0.284^{NS}	-0.748^{NS}	0.179^{NS}	0.438^{NS}
WHR vs. BFM	0.999**	0.999**	0.998**	0.999**	0.996**	0.996**
WHR vs. %BF	-0.703^{NS}	-0.710^{*}	-0.626^{NS}	-0.764*	-0.937**	-0.950**
WHR vs. FFM	0.962**	0.976**	0.925**	0.966**	0.981**	0.954**
WHR vs. TBW	0.069^{NS}	0.100^{NS}	0.925**	-0.300^{NS}	-0.086^{NS}	0.202^{NS}
WHR vs. Protein	0.028^{NS}	0.095^{NS}	-0.665^{NS}	-0.327^{NS}	-0.171^{NS}	0.139^{NS}
WHR vs. SMM	0.026^{NS}	0.092^{NS}	-0.664^{NS}	-0.331^{NS}	-0.193^{NS}	0.151^{NS}
WHR vs. Mineral	0.256^{NS}	-0.085^{NS}	-0.732^{NS}	-0.392^{NS}	-0.176^{NS}	-0.091^{NS}
WHR vs. VFA	0.945**	0.753^{NS}	0.746^{NS}	0.880**	0.337^{NS}	0.792*
WHR vs. BCM	0.027^{NS}	0.097^{NS}	-0.664^{NS}	-0.330^{NS}	-0.194^{NS}	0.156^{NS}
AC vs. BFM	0.988**	0.993**	0.996**	0.998**	0.986**	0.987**
AC vs. FFM	0.967**	0.972**	0.937**	0.962**	0.979**	0.976**
AC vs. Protein	0.393^{NS}	0.103^{NS}	0.511^{NS}	-0.023^{NS}	0.253^{NS}	0.671^{NS}
AC vs. SMM	0.391^{NS}	0.105^{NS}	0.520^{NS}	-0.031^{NS}	0.255^{NS}	0.678^{NS}
AC vs. Mineral	0.237^{NS}	-0.049^{NS}	0.494^{NS}	-0.122^{NS}	0.440^{NS}	0.474^{NS}
AMC vs. BFM	0.996**	0.995**	0.991**	0.996**	0.995**	0.998**
AMC vs. FFM	0.981**	0.988**	0.955**	0.975**	0.988**	0.979**
AMC vs. Protein	0.927**	0.918**	0.951**	0.666^{NS}	0.353^{NS}	0.851*
AMC vs. SMM	0.924**	0.916**	0.955**	0.660^{NS}	0.351^{NS}	0.853*
AMC vs. Mineral	0.897**	0.802*	0.923**	0.575^{NS}	0.633^{NS}	0.698^{NS}

- **Weight and Body Composition Parameters**

Weight when correlated with BFM showed one percent significance in normal non diabetic subjects, five percent significance in normal diabetic and overweight non diabetic subjects and no significance was found in overweight diabetic and in both the cases in obese subjects, with percent body fat, five percent significance in overweight subjects and no significance in normal and obese subject, with TBW, protein, SMM and BCM five percent significance in normal and overweight subjects. With FFM five percent significance in normal and overweight subjects and no significance in obese subjects, no significance was found with VFA in normal and overweight subjects while one percent significance in non diabetic and five percent significance in diabetic obese subjects were noticed.

- **BMI and Body Composition Parameters**

BMI correlated with BFM and FFM was found to have one percent significance in all the three groups. BMI with TBW, protein, SMM, mineral and BCM showed no significant difference in all three groups. With percent BF showed no significance in normal diabetic and non diabetic subjects and overweight diabetic subjects and five percent significance in overweight and obese non diabetic subjects and one percent significance in obese diabetic subjects. With VFA five percent significance was found in normal and obese diabetic subjects, one percent significance in obese non diabetics and no significance in case of normal non diabetics and overweight diabetic as well as non diabetic subjects.

- **WHR and Body Composition Parameters**

WHR correlated with BFM and FFM showed one percent significance in all the three cases. No significance was found with TBW, protein, SSM, mineral and BCM in all the three groups. With VFA five percent significance was found in obese non diabetics and one percent significance in normal diabetics and

overweight non diabetics and no significance was found in normal non diabetics, overweight and obese diabetic subjects. With percent BF one percent significance was found in obese subjects, five percent significance in normal and overweight non diabetics and no significant difference among normal and overweight diabetic subjects.

- **AC and Body Composition Parameters**

AC when correlated with BFM and FFM showed a high positive significance ($p<0.01$) in all the three groups. With protein, SSM and mineral showed no significant difference.

- **AMC and Body Composition Parameters**

AMC when correlated with BFM and FFM showed a high positive significance ($p<0.01$) in all the three groups. With protein, SSM and mineral one per cent significance was seen in case of normal diabetic and non diabetic subjects and overweight diabetic subjects, while no significance was found in case of overweight non diabetics and obese diabetic subjects and five per cent significance in obese non diabetic subjects.

Table XXIII shows the data on correlation within body composition parameters in the selected subjects.

TABLE XXIII

CORRELATION BETWEEN ANTHROPOMETRIC AND BODY COMPOSITION PARAMETERS OF NORMAL, OVERWEIGHT AND OBESE SUBJECTS(r values)

Parameters	BMI category					
	Normal(n=14)		Overweight(n=7)		Obese(n=7)	
	#D(n=7)	#N-D(n=7)	D(n=7)	N-D(n=7)	D(n=7)	N-D(n=7)
BFM vs. %BF	-0.579^{NS}	-0.605^{NS}	-0.415^{NS}	-0.615^{NS}	-0.631^{NS}	-0.704^{NS}
BFM vs. FFM	0.954**	0.951**	0.816*	0.900**	0.870**	0.939**
BFM vs. TBW	0.176^{NS}	-0.406^{NS}	-0.818*	-0.803*	0.422^{NS}	0.758*
BFM vs. Protein	0.124^{NS}	-0.377^{NS}	-0.827*	-0.785*	0.213^{NS}	0.709^{NS}
BFM vs. SMM	0.123^{NS}	-0.389^{NS}	-0.819*	-0.783*	0.247^{NS}	0.713^{NS}
BFM vs. Mineral	0.373^{NS}	-0.408^{NS}	-0.774*	-0.815*	0.589^{NS}	0.553^{NS}
BFM vs. VFA	0.940**	-0.375^{NS}	0.706^{NS}	-0.197^{NS}	0.850*	0.965**
BFM vs. BCM	0.124^{NS}	-0.396^{NS}	-0.817*	-0.785*	0.252^{NS}	0.715^{NS}
FFM vs. BFM	0.924**	0.943**	0.815*	0.909**	0.962**	0.919**
FFM vs. %BF	-0.754*	-0.839**	-0.928**	-0.937**	-0.908**	-0.823*
FFM vs. TBW	1.000**	0.999**	0.999**	0.999**	0.991**	0.998**
FFM vs. Protein	0.996**	0.999**	0.999**	0.999**	0.910**	0.998**
FFM vs. SMM	0.997**	0.999**	0.999**	0.999**	0.918**	0.998**
FFM vs. Mineral	0.969**	0.976**	0.986**	0.988**	0.947**	0.951**
FFM vs. VFA	0.252^{NS}	0.301^{NS}	-0.644^{NS}	-0.060^{NS}	0.398^{NS}	0.683^{NS}
FFM vs. BCM	0.996**	0.999**	0.999^{NS}	0.999**	0.920**	0.998**
TBW vs. ICW	0.975**	0.984**	0.952^{NS}	0.978**	0.987**	0.999**
TBW vs. ECW	0.856**	0.897**	0.739*	0.812*	0.714*	0.999**
Protein vs. SMM	0.999**	0.999**	0.999**	0.999**	1.000**	0.969**
Mineral vs. BMC	0.999**	1.000**	0.999**	0.999**	0.999**	0.730*

D: Diabetic ;#N-D: Non diabetic

No significant correlation was found between BFM and percent body fat in all the three groups. A high positive correlation ($p<0.01$) was found with FFM in all the three groups. BFM when correlated with TBW , protein, SSM and mineral showed five per cent significance in overweight subjects and no significance in case of normal and obese subjects. FFM with VFA showed no significant difference in all the three groups, with BCM showed no significance in overweight diabetic subjects while showed one per cent significance in other subjects. With BFM, TBW, percent BF, protein, SSM and mineral showed one per cent significance in all the three groups. TBW when correlated with ICW showed no

significance in overweight diabetic subjects, where as one per cent significance in other subjects. TBW with ECW showed one per cent significance in normal subjects and obese non diabetic subjects and five per cent significance in case of overweight subjects and obese diabetic subjects. Protein with SMM and mineral with BMC showed high positive correlation ($p<0.01$) in all the three groups.

Table XXIV presents the data on correlation between biochemical parameters and body composition parameters.

TABLE XXIV

CORRELATION BETWEEN BIOCHEMICAL PARAMETERS AND BODY COMPOSITION

Parameters	BMI category					
	Normal(n=14)		Overweight(n=7)		Obese(n=7)	
	#D(n=7)	#N-D(n=7)	D(n=7)	N-D(n=7)	D(n=7)	N-D(n=7)
Glucose vs. Weight	-0.557^{NS}	-0.532^{NS}	-0.616^{NS}	-0.732*	-0.709*	-0.717*
Glucose vs. BMI	0.217^{NS}	0.297^{NS}	0.622^{NS}	0.768*	0.576^{NS}	0.578^{NS}
Glucose vs. BFM	-0.640^{NS}	-0.499^{NS}	-0.536^{NS}	-0.680^{NS}	-0.730*	-0.680^{NS}
Glucose vs. %BF	-0.927**	0.335^{NS}	0.378^{NS}	0.337^{NS}	-0.182^{NS}	-0.184^{NS}
Glucose vs. VFA	-0.774*	-0.052^{NS}	0.327^{NS}	-0.651^{NS}	-0.297^{NS}	0.044^{NS}
Cholesterol vs. Weight	-0.730*	-0.547^{NS}	-0.542^{NS}	-0.856**	-0.802*	-0.608^{NS}
Cholesterol vs. BMI	0.420^{NS}	0.731*	0.545^{NS}	0.816*	0.509^{NS}	0.694^{NS}
Cholesterol vs. BFM	-0.764*	-0.520^{NS}	-0.620^{NS}	-0.891**	-0.805*	-0.510^{NS}
Cholesterol vs. %BF	-0.461^{NS}	0.278^{NS}	-0.524^{NS}	-0.546^{NS}	0.010^{NS}	0.171^{NS}
Cholesterol vs. VFA	-0.343^{NS}	0.480^{NS}	-0.318^{NS}	0.458^{NS}	-0.357^{NS}	0.345^{NS}
TLG vs. Weight	-0.647^{NS}	-0.474^{NS}	-0.553^{NS}	-0.454^{NS}	-0.863**	-0.450^{NS}
TLG vs. BMI	0.344^{NS}	0.521^{NS}	0.660^{NS}	0.462^{NS}	0.744*	0.428^{NS}
TLG vs. BFM	-0.689^{NS}	-0.492^{NS}	-0.550^{NS}	-0.470^{NS}	-0.843**	-0.410^{NS}
TLG vs. %BF	-0.496^{NS}	-0.194^{NS}	-0.070^{NS}	-0.207^{NS}	-0.402^{NS}	-0.155^{NS}
TLG vs. VFA	-0.499^{NS}	0.578^{NS}	0.316^{NS}	0.021^{NS}	-0.096^{NS}	0.113^{NS}
HDL vs. Weight	0.514^{NS}	0.809*	0.617^{NS}	0.657^{NS}	0.841**	0.652^{NS}
HDL vs. BMI	-0.046^{NS}	-0.766*	-0.759*	-0.600^{NS}	-0.759*	-0.175^{NS}
HDL vs. BFM	0.580^{NS}	0.795*	0.687^{NS}	0.618^{NS}	0.802*	0.735*
HDL vs. %BF	0.700^{NS}	-0.151^{NS}	0.434^{NS}	-0.242^{NS}	0.414^{NS}	0.414^{NS}
HDL vs. VFA	0.923**	-0.476^{NS}	0.200^{NS}	0.549^{NS}	0.194^{NS}	0.735^{NS}
LDL vs. Weight	-0.478^{NS}	-0.280^{NS}	-0.507^{NS}	-0.699^{NS}	-0.591^{NS}	-0.399^{NS}
LDL vs. BMI	0.143^{NS}	0.417^{NS}	0.462^{NS}	0.622^{NS}	0.246^{NS}	0.522^{NS}
LDL vs. BFM	-0.522^{NS}	-0.323^{NS}	-0.401^{NS}	-0.758*	-0.626^{NS}	-0.309^{NS}
LDL vs. %BF	-0.435^{NS}	-0.415^{NS}	0.539^{NS}	-0.525^{NS}	0.006^{NS}	0.160^{NS}
LDL vs. VFA	-0.322^{NS}	0.550^{NS}	0.415^{NS}	0.410^{NS}	-0.382^{NS}	0.259^{NS}
VLDL vs. Weight	0.867**	0.925**	0.770*	0.551^{NS}	0.958**	0.860**
VLDL vs. BMI	-0.888**	-0.761*	-0.655^{NS}	-0.507^{NS}	-0.882**	-0.704^{NS}
VLDL vs. BFM	0.834*	0.911**	0.753*	0.525^{NS}	0.874**	0.818*
VLDL vs. %BF	-0.497^{NS}	-0.184^{NS}	-0.068^{NS}	-0.204^{NS}	-0.427^{NS}	-0.190^{NS}
VLDL vs. VFA	-0.493^{NS}	0.611^{NS}	0.324^{NS}	0.021^{NS}	-0.137^{NS}	0.058^{NS}

D: Diabetic ;#N-D: Non diabetic

Glucose when correlated with weight showed no significance in case of normal subjects and overweight diabetic subjects while five per cent significance in non diabetic overweight subjects and obese subjects. With BMI five per cent significance in non diabetic overweight subjects, with BFM five per cent significance in diabetic obese subjects, with percent BF one per cent significance in diabetic normal subjects and with VFA five per cent significance in diabetic normal subjects. Other cases showed no

significance. Cholesterol with percent BF and VFA showed no significance in all the three groups. One per cent significance was found with weight and BFM in case of overweight non diabetic subjects, while five per cent significance in case of normal and obese diabetic subjects. Triglyceride with weight, BMI, BFM, percent BF and VFA showed no significance difference in all the three groups except in case of obese diabetic subjects that too with weight, BMI and BFM. Correlation of HDL with weight, BMI and BFM, percent BF and VFA was given in Table XXIV. LDL showed no significant differences in all the three groups when correlated with weight, BMI, BFM, percent BF and VFA. VLDL with percent BF and VFA showed no significance in all the three groups. One per cent significance was found with weight and BMI of normal and obese diabetic subjects and no significance in case of overweight non diabetics, with weight showed one per cent significance in normal and obese non diabetic subjects.

D. ENERGY BALANCE OF THE SELECTED SUBJECTS.

From the data collected, BMR was calculated using the prediction equation. The total energy expenditure was calculated using the physical activity expenditure and BMR.

Table XXV presents the energy balance data of the selected subjects.

TABLE XXV

MEAN ENERGY BALANCE OF THE SELECTED INDIVIDUALS

BMI Category	Energy Intake (kcal)		Energy Expenditure (kcal)		Energy Balance (kcal)	
	#D(n=7)	#N-D(n=7)	D(n=7)	N-D(n=7)	D(n=7)	N-D(n=7)
Normal(n=14)	1303.35±163.83	1243±321.23	1500.57±319.09	1645.4±275.58	517.06±393.20	226.17±122.34
Overweight (n=14)	1478.1±180.64	1341.25±246.91	1847.57±191.74	1820.54±340.11	487.67±481.96	492.13±384.94
Obese(n=14)	2204.21±1044.06	1618.64±364.12	1978.17±725.25	2002.2±531.08	583.19±476.78	473.58±635.33

D: Diabetic ;#N-D: Non diabetic

Positive energy balance was seen among all the three groups which indicates that their energy intake was greater than their energy expenditure. Especially higher in case of diabetic normal and obese subjects and non-diabetic overweight subjects. High BMI and weight gain in adulthood, indicating a positive energy balance, were associated with a higher risk of type 2 diabetes. The components of energy balance, energy intake and physical activity, have an interactive effect on the incidence of type 2 diabetes(Villegas et al.2009).

Table XXVI shows the statistical interpretation for comparison of energy balance of the subjects.

TABLE XXVI

STATISTICAL INTERPRETATION FOR COMPARISON OF ENERGY BALANCE OF THE SUBJECTS

BMI Category	Energy Intake		Energy Expenditure		Energy Balance	
	D(n=7)	N-D(n=7)	D(n=7)	N-D(n=7)	D(n=7)	N-D(n=7)
Normal vs. Overweight	0.849^{NS}	1.938^{NS}	2.312^{NS}	1.757^{NS}	0.109^{NS}	1.962^{NS}
Normal vs. Obese	1.366^{NS}	1.319^{NS}	2.099^{NS}	1.343^{NS}	0.291^{NS}	1.063^{NS}
Overweight vs. Obese	0.398^{NS}	0.395^{NS}	0.405^{NS}	0.703^{NS}	0.299^{NS}	0.104^{NS}

No significant difference was noticed in energy intake, energy expenditure and energy balance among all the three groups irrespective of diabetic and non-diabetic subjects.

From the foregoing results, it is evident that body composition measures of diabetes were found to be high compared to non diabetics. Positive correlation existed among anthropometry, biochemistry and body composition measures. It is interesting to note that diabetics with normal BMI showed a higher WHR, depicting that WHR is a good indicator of obesity. Visceral fat area was found to be higher in normal, overweight and obese diabetics. Further in depth studies on body composition on larger samples of diabetics are recommended to throw more light on this field.

SUMMARY AND CONCLUSION

V. SUMMARY AND CONCLUSION

The present study entitled **"Body Composition Measures of Type 2 Diabetics"** aimed at assessing the epidemiological factors associated with type 2 diabetics, determining the body composition of selected subjects and finding the association between body composition measures, anthropometry and energy balance. In the methodology, initially twenty one type 2 diabetics and twenty one non diabetics working at Avinashilingam Institute for Home Science and Higher Education for Women were selected. They were screened for overweight and obesity using height, weight and Body Mass Index (BMI) as parameters. They were classified as normal, overweight and obese based on their BMI cut off for Asians.

An interview schedule was formulated and given to the selected forty two subjects to collect information on socio-economic background, health history, lifestyle and their dietary pattern. Further, the nutritional status of the forty two subjects was assessed through biochemical assessment and diet survey. Biochemical estimation of blood glucose, total cholesterol, serum triglycerides and HDL cholesterol were performed. Three millilitres of blood samples were collected from the subjects for analysis. The glucose level was estimated using Glucometer (Glucose oxidase), total cholesterol was estimated using the CHOD- PAP enzymatic colorimetric method, GPO-PAP method was used to estimate the serum triglycerides and the HDL cholesterol level was estimated using the direct enzymatic colorimetric method. The LDL and VLDL cholesterol was calculated using Friedewald's formulae. A twenty four hour recall method was used to assess the food and nutrient intake from the subjects. The intake of macronutrients namely fat, protein and energy intake were calculated and the micronutrient intake in terms of calcium and iron was also calculated. Later, the body composition of the selected subjects was assessed, using 'Bio space, In body 720- the precision body composition analyser'. The body composition analyser is a four compartment model and the four main compartments include total body water, protein, fat and mineral mass. The other parameters assessed include skeletal muscle mass, per cent body fat, waist hip ratio, lean balance, visceral fat area, arm circumferences,

arm muscle circumference, obesity degree, bone mineral content, body cell mass, basal metabolic rate, ratio of extracellular fluid to total body fluid, ratio of extracellular water to total body water. The Total Energy Expenditure (TEE) was estimated through fractional calculations that combined allocated habitual activities (as obtained from the individual's time motion record) and the energy cost of those activities. The energy cost of activities was calculated as a multiple of BMR per minute, also referred to as the Physical Activity Ratio (PAR), and the 24-hour energy requirement was expressed as a multiple of BMR per 24 hours by using the Physical Activity Level (PAL) value. BMR per 24 hours using the age and sex specific predictive equations. The PAL values proposed by ICMR expert group (2010) was used for calculation of PAL of individuals, sedentary or light active lifestyle- 1.53, active or moderately active lifestyle- 1.8, vigorous or vigorously active lifestyle- 2.3. The energy balance was calculated from the computed energy intake and energy expenditure data. The data was consolidated in which mean, standard deviation and percentage were computed. The data was analyzed using the software GraphPad prism version 6.02. Comparisons were made between various parameters of three groups using student's t-test. Correlation between anthropometric measurements, body composition parameters, and biochemical parameters were derived using Karl Pearson's co-efficient of correlation.

The salient findings of the study are given below:

- It is seen that nearly 62 per cent of the diabetics and 81 per cent of non diabetics lived in nuclear family and 38 per cent of diabetics and 19 per cent of non diabetics lived in joint family.
- Around 28.5 per cent of diabetic and non diabetic subjects were from rural area whereas 71.4 per cent of the diabetic and non diabetic subjects were from urban area.
- About 57.1 per cent of the diabetic and 61.9 per cent of non diabetic subjects were involved in sedentary work, 38 per cent and 28.5 per cent were involved in heavy work and 4.7 per cent and 9.5 per cent of the respective subjects were involved in moderate work respectively.

- About 71.4 per cent of the diabetic and 57.1 per cent of the non diabetic subjects had a family income between the range of Rs.4610.83- Rs.18218.75 (low income grade) and 28.5 per cent of diabetic subjects and 42.8 per cent of non diabetic subjects between the range of Rs.18223.33- Rs.56260.41(upper middle income grade).
- It is seen that 42.8 per cent of diabetic and 14.2 per cent of non diabetic subjects had first degree relations with diabetes and 4.7 per cent of diabetic subjects and 9.5 per cent of non diabetic subjects had second degree relatives (paternal) with diabetes, others with no family history of diabetes.
- Familial stress (38 per cent in diabetic and 33.3 per cent in non diabetic) was seen more among subjects and sleep (80.9 per cent in diabetic and 66.6 per cent in non diabetic) was chosen by many to manage stress.
- The study has shown that 14.2 per cent of diabetic and non diabetic subjects were vegetarians, 80.9 per cent of diabetic and 85.7 per cent of non diabetic subjects were non-vegetarians and 4.7 per cent of diabetic subjects were ova vegetarians.
- Cereals and cereal products, pulses, milk and milk products, fats, sugars were consumed daily by all the subjects. Among the non-vegetarians, most of them consumed meat, poultry and fish once a week in both diabetic and non-diabetic subjects. The daily intake of fruits was higher among overweight(14.2 per cent) and obese (14.2 per cent) in diabetic subjects. Among non-diabetic subjects no daily consumption of fruits was found, most of them consumed twice a week in all the three groups. Similarly it is for green leafy vegetables.
- Among the selected subjects, 42.8 per cent of the obese diabetic subjects purchased labelled foods while 57.1 per cent did not. While 85.7 per cent of obese non diabetic subjects purchased labelled foods while 14.2per cent did not. The information looked upon while purchasing food products included manufacturing date, expiry date, food additives, price, nutritional information, logo of food standard and nutritional claims.
- High energy/ fat foods like sweets, fried foods, bakery items, fast foods, salted foods are mostly consumed once a month by the diabetic subjects, while flesh food consumption was most common on weekly basis in case of normal and obese subjects and monthly

once in case of overweight subjects. Among non diabetic subjects most of them consumed these high energy foods on monthly basis, while fleshy food was consumed weekly once in all the three groups.

- With regard to anthropometric measurements, the obese diabetic subjects had a greater weight (76.28 kg), BMI (32.42) and WHR (1) when compared to non diabetic subjects but the arm circumference (36.12 cm) and arm muscle circumference (25.75) were found to be greater in case of non diabetic when compared to diabetic subjects.
- When weight was correlated with other anthropometric measures, showed no significant difference in case of diabetic and non diabetic obese subjects. When the obese subjects were considered, it was found that total cholesterol, triglycerides, HDL, LDL and VLDL levels were higher in case of diabetic subjects when compared to non diabetic adults. But triglycerides levels in case of both diabetic and non diabetic subjects were found to be higher in case of overweight when compared to normal and obese, which needs to be studied in depth.
- The mean nutrient intake of the obese diabetic as well as non diabetic subjects showed that they had a deficit intake of protein, calcium and iron, but excess intake of fat and energy was noted.
- All the body composition parameters were found to be higher in obese subjects when compared to that of the normal but almost similar to overweight except in case of body fat mass, percent body fat, fat free mass and visceral fat area. It was found that the fat content and percent body fat of the normal subjects in both diabetic and non diabetic subjects were found to be greater than the normal range.
- The visceral fat area was found to be normal in normal subjects, close to normal in overweight subjects, but was found to be beyond the normal value in obese subjects in both diabetic and non diabetic categories.
- Fat free mass, total body water, protein, skeletal muscle mass, mineral, bone mineral content and body cell mass was found to be deficit in normal diabetic and non diabetic subjects but considerably normal in overweight and obese diabetic and non diabetic subjects.
- A high positive and significant difference was seen among the normal versus obese and

overweight and obese in diabetic as well as in non diabetic subjects in BFM, PBF and VFA. In case of normal versus overweight five per cent significance was found in BFM and no significance in PBF and VFA. The others like FMM, TBW, protein, SMM, mineral, BMC and BCM showed no significant difference in both diabetic and non diabetic cases in all the three groups.

- Weight showed no significant difference with VFA in normal and overweight categories in both diabetic and non diabetic subjects and less significance with BFM, protein, SMM and mineral and high significance with FFM except in case of obese. BMI with BFM and FFM showed high positive correlation, with other body composition parameters showed no or less significant difference. Similar, is in the case of WHR with the body composition parameters. BFM with the parameters showed no significant difference in normal and obese subjects while less significance in overweight subjects. FFM showed high positive correlation with all the parameters in all the three groups.
- All the biochemical parameters when correlated with body composition measures were not found to be significant except in four cases which showed a lesser significance.
- No significant difference was seen among all the three groups in both diabetic and non diabetic subjects for energy intake, energy expenditure and energy balance.

From the results, it may be concluded that though the study was carried out with small sample size, the findings revealed the importance of body composition measurements in diabetic subjects and the association between body composition measures, biochemical parameters, energy balance and anthropometry and how these values differed from that of non diabetic subjects.

The recommendations that emerge from the study are:

RECOMMENDATIONS:

- Body composition studies on larger samples of diabetics for database generation.
- Obtain the body composition data on different age groups which include childhood, older adults, late adolescents, pregnant women and lactating mothers.
- Studies on association between diet and body composition and diabetes.
- Assessing body composition in other chronic degenerative disorders such as cancer and cardiovascular disease.
- Studies on metabolic syndrome and body composition measures.
- Studies on awareness on body composition and its relation to diabetes and development of suitable education modules and imparting health education.

BIBLIOGRAPHY

BIBLIOGRAPHY

- . Marin P, Andersson B, Krotkiewski M, B J Ö Rntorp P: Muscle Fiber Composition And Capillary Density In Men And Women With NIDDM. Diabetes Care 17:282–286, 1994
- A Ramachandran, AK Das, SR Joshi, CS Yajnik, S Shah, KM Prasanna Kumar, Current Status Of Diabetes In India And Need For Novel Therapeutic Agents, Supplement To Japi , June 2010 •Vol. 58.
- A Ramachandran,C Snehalatha, Type 2 Diabetes Mellitus – The Epidemic Of The 21st Century:The Indian Scenario, Int. J. Diab. Dev. Countries (1999), Vol. 19.
- A. Sartorio, M. Malavolti, F. Agosti, P.G. Marinone, O. Caiti, N. Battistini Et Al. Body Water Distribution In Severe Obesity And Its Assessment From Eight-Polar Bioelectrical Impedance Analysis Eur J Clin Nutr, 59 (2005), Pp. 155–160
- Abate N, Chandalia M. Ethnicity And Type 2 Diabetes - Focus On Asian Indians. Journal Of Diabetes And Its Complications, 2001, 15: 320–327.
- Abdulfatai B. Olokoba, Olusegun A. Obateru, Lateefat B. Olokoba, Type 2 Diabetes Mellitus: A Review Of Current Trends, Oman Medical Journal (2012) Vol. 27.
- Baumgartner RN, Chumlea WC, Roche AF. Bioelectric Impedance For Body Composition. In: Pandolf KB, Editor. Exercise And Sports Sciences Reviews. New York: Macmillan, 1990. P 193-224.
- Bioelectrical Impedance Analysis In Body Composition Measurement. Rroceeding Of A National Institutes Of Health Technology Assessment Conference, Bethesda, MD, December 12–14, 1994. Am J Clin Nutr 1996; 64 [Suppl]: S524–S532
- Bjo¨ Rntorp P. Metabolic Implications Of Body Fat Distribution. Diabetes Care 1991;14:1132–1143
- Bournat JC, Browncw.Mitochondrial Dysfunction In Obesity. Curr Opin Endocrinol Diabetes Obes 2010;17:446–452
- Brajendra Kumar Tripathi, Arvind Kumar Srivastava, Diabetes Mellitus: Complications And Therapeutics, Med Sci Monit, 2006.
- Carolyn Jarvis, Physical Examination And Health Assessment, W.B. Saunders Company, 2nd Edition,1996.
- Catherine Geisser And Hilary Powers, Human Nutrition, 11th Edition, Elsevier Churchill Livingstone, 2005, Pg402.
- Centers For Disease Control And Prevention. National Diabetes Fact Sheet: General Information And National Estimates On Diabetes In The United States, 2005. Atlanta, GA: US Department Of Health And Human Services, Centers For Disease Control And Prevention; 2005.
- 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(9):961–9. [Pubmed: 7988316]
- Chandalia M, Abate N, Garg A, Stray-Gunderson J, Grundy SM. Relationship Between Generalized And Upper Body Obesity To Insulin Resistance In Asian Indian Men. J Clin Endocrinol Metab 1999; 84 : 2329-35.
- Christian Bitz, Msc,Søren Toubro, Md, Drmedsci, Thomas M. Larsen, Msc, Helle Harder, Msc,Kirsten L., Rennie, Phd,Susan A. Jebb, Phd,Arne Astrup, Md, Drmedsci, Increased 24-H Energy Expenditure In Type 2 Diabetes, Diabetes Care, Volume 27, Number 10, October 2004.
- Chumlea WC, Sun SS. Bioelectrical Impedance Analysis. In: Heymsfield SB, Lohman TG, Wang Z, Going SB, Editors. Human Body Composition. Champaign, IL: Human Kinetics Books; 2005.
- Colditz GA, Willett WC, Rotnitzky A, Manson JE. Weight Gain As A Risk Factor For Clinical Diabetes Mellitus In Women. Ann Intern Med 1995;122(7):481–6. [Pubmed: 7872581]

- Cypess AM, Lehman S, Williams G, Et Al. Identification And Importance Of Brown Adipose Tissue In Adult Humans.Nengl J Med 2009; 360:1509–1517
- Dana L. Duren, Ph.D., Richard J. Sherwood, Ph.D., Stefan A. Czerwinski, Ph.D.,Miryoung Lee, Ph.D., Audrey C. Choh, Ph.D.,1 Roger M. Siervogel, Ph.D.,And Wm. Cameron Chumlea, Ph.D. Body Composition Methods: Comparisons And Interpretation, **Journal Of Diabetes Science And Technology** Volume 2, Issue 6, November 2008
- David A.Bender, Introduction To Nutrition And Metabolism, 2nd Taylor And Francis Publishing, 1997.Pg179.
- Deng Y, Scherer PE. Adipokines As Novel Biomarkers And Regulators Of The Metabolic Syndrome. Ann N Y Acad Sci 2010;1212:E1–E19
- Deurenberg P, Westerterp KR, Velhuis-Te Wierk EJM. Between-Laboratory Comparison Of Densitometry And Bioelectrical Impedance Measurements. British Journal Of Nutrition 1994; 71: 309–16.
- Dr.H.K.Bakhru, The Complete Handbook Of Nature Cure, 5th Revised Edition, Jaico Publishing House,2011, Pg351-353.
- Drewnowski A, BM. P. The Nutrition Transition: New Trends In The Global Diet. Nutr Rev 1997; 55: 31–43.
- E, Damcott CM, Fu M, Et Al. Identification Of Novel Candidate Genes For Type 2 Diabetes From A Genome-Wide Association Scan In The Old Order Amish: Evidence For Replication From Diabetesrelated Quantitative Traits And From Independent Populations. Diabetes 2007;56:3053–3062
- Eleanor Noss Whitney Sharon Raddy Rolfes, Understanding Nutrition, West/Wadsworth, 8th Edition, 1999 Pg17, 247.
- Epstein LH, Saelens BE. Behavioral Economics Of Obesity: Food Intake And Energy Expenditure. In: Bickel WK, Vuchinich RE, Eds. Reframing Health Behavior Change With Behavioral Economics. Mahwah, NJ: Lawrence Erlbaum Associates; 2000.
- Eschwege E. The Dysmetabolic Syndrome, Insulin Resistance And Increased Cardiovascular (CV) Morbidity And Mortality In Type 2 Diabetes: Aetiological Factors In The Development Of CV Complications. Diabetes Metabolism, 2003, 29:6S19–6S27.
- Executive Summary Of The 3rd Report Of The National Cholesterol Programme (NCEP,2001), Expert Panel On Detection, Evaluation And Treatment Of High Blood Cholesterol In Adults(Adult Treatment Panel III), JAMA 285(19), 2486.
- Frank B. Hu, M.D., Joann E. Manson, M.D., Meir J. Stampfer, M.D., Graham Colditz, M.D., Simin Liu, M.D., Caren G.Solomon, M.D., And Walter C. Willett, M.D, Diet, Lifestyle, And The Risk Of Type 2 Diabetes Mellitus In Women, N Engl J Med, Vol. 345,11 September 13, 2001, Www.Nejm.Org.
- Friedman JM0 2003 A War On Obesity, Not The Obese. Science 299:856–858
- Frontini A, Cinti S. Distribution And Development Of Brown Adipocytes In The Murine And Human Adipose Organ. Cell Metab 2010; 11:253–256
- G.W. Strain, J. Wang, M. Gagner, A. Pomp, W.B. Inabnet, S.B. Heymsfield Bioimpedance For Severe Obesity: Comparing Research Methods For Total Body Water And Resting Energy Expenditure Obesity (Silver Spring), 16 (2008), Pp. 1953–1956
- Gabriela Vazquez, Sue Duval1, David R. Jacobs Jr.1 And Karri Silventoinen, Comparison Of Body Mass Index, Waist Circumference, And Waist/Hip Ratio In Predicting Incident Diabetes: A Meta-Analysis, Epidemiol Rev (2007) 29 (1): 115-128. Doi: 10.1093/Epirev/Mxm008 First Published Online: May 10, 2007
- Goodpaster BH, Thaete FL, Simoneau JA, Kelley DE: Subcutaneous Abdominal Fat And Thigh Muscle Composition Pre D I C T Insulin Sensitivity Independently Of Visceral Fat. D I A B E T E S 46:1579–1585, 1997
- Gress TW, Nieto FJ, Shahar E, Wofford MR, Brancati FL. Hypertension And Antihypertensive Therapy As Risk Factors For Type 2 Diabetes Mellitus. New England Medical Journal Of Medicine 2000, 342(13):905–912.

- Gupta V, Khadgawat R, Saraswathy KN, Sachdeva MP And Kalla AK. Emergence Of TCF7L2 As A Most Promising Gene In Predisposition Of Diabetes Type II. Int J Hum Genet, 2008, 8(1-2): 199-215.
- Harder T, Rodekamp E, Schellong K, Dudenhausen JW, Plagemann A. Birth Weight And Subsequentrisk Of Type 2 Diabetes: A Meta-Analysis. American.
- Hill JO, Wyatt HR, Reed GW, Peters JC 2003 Obesity And The Environment: Where Do We Go From Here? Science 299:853–855
- Hodge A, Dowse G, Zimmet P. Diet Does Not Predict Incidence Or Prevalence Of Non-Insulin-Dependent Diabetes In Nauruans. Asia Pac J Clin Nutr 1993; 2: 35–42.
- India, National Family Health Survey(NFHS-3) Volume 1, Minestry Of Health And Family Welfare Government Of India, 2005-06, September 2007.
- Indian Council For Medical Research, 2010, Nutrition Requirement And Recommended Dietary Allowances For Indians, A Report Of The Expert Group Of The Indian Concil Of Medical Research, AP, Hyderabad, Pg40,41.
- Insel, R.Elaine Turner, Don Ross, Discovering Nutrition 3rd Edition Paul Jones And Bartlett Publishers 2010, Pg.284.
- International Diabetes Federation. Diabetes Atlas. 3rd Ed. 2006. Brussels, Belgium: International Diabetes Federation.
- J. J. Reilly, L. A. Murray, J. Wilson And J. V. G. A. Durnin, Measuring The Body Composition Of Elderly Subjects: A Comparison Of Methods, British Journal Of Nutrition (1994) 12, 33-44
- J. S. W. Lee, T. W. Auyeung, J. Leung, T. Kwok, P. C. Leung, And J. Woo, The Effect Of Diabetes Mellitus On Age-Associated Lean Mass Loss In 3153 Older Adults, Diabet Med, 2012
- J.R. Mager, S.D. Sibley, T.R. Beckman, T.A. Kellogg, C.P. Earthman Multifrequency Bioelectrical Impedance Analysis And Bioimpedance Spectroscopy For Monitoring Fluid And Body Cell Mass Changes After Gastric Bypass Surgery Clin Nutr, 27 (2008), Pp. 832–841
- James L. Groff,Sareen S. Gropper, Advanced Nutrition And Human Metabolism ,Wadsworth, 3rd Edition, 2000, Pg 502,513-514.
- Jared Diamond, Nature , Vol 469 ,27 January 2011.
- Joanne Hosking, Brad S. Metcalf, Alison N. Jeffery, Linda D. Voss And Terence J. Wilkin, Validation Of Foot-To-Foot Bioelectrical Impedance Analysis With Dual-Energy X-Ray Absorptiometry In The Assessment Of Body Composition In Young Children: The Earlybird Cohort, British Journal Of Nutrition (2006), 96, 1163–1168
- Journal Of Epidemiology, 2007, 165:849–857. Viswanathan, M., Mccarthy, M. I., Snehalatha, C, Hitman GA, Ramachandran A. Diabetic Medicine,1996, 13:232–237
- K.J. Shafer, W.A. Siders, L.K. Johnson, H.C. Lukaski Validity Of Segmental Multiple-Frequency Bioelectrical Impedance Analysis To Estimate Body Composition Of Adults Across A Range Of Body Mass Indexes Nutrition, 25 (2009), Pp. 25–32
- K.P. Sampath Kumar, Debjit Bhowmik, Shweta Srivastava, Shravan Paswan, Amit Sankar Dutta, Diabetes Epidemic In India-- A Comprehensive Review Of Clinical Features, Management And Remedies, The Pharma Innovation, Vol. 1 No. 2 2012.
- Katoh J, Hara Y, Kurusu M, Miyaji J, Narutaki K: cardiorespiratory Function As Assessed By Exercise Testing In Patients With Non-Insulin-Dependent Diabetes Mellitus. J Int Med Res 24:209–213, 1996
- Kim S, Moon S, Popkin BM. The Nutrition Transition In South Korea. Am J Clin Nutr 2000; 71: 44–53.
- Kopelman PG, Albon L: Obesity, Non-Insulin Dependent Diabetes Mellitus And The Metabolic Syndrome. Br Med Bull, 1997; 53: 322–40
- Larson-Meyer DE, Newcomer BR, Ravussin E, Et Al. Intrahepatic And Intramyocellular Lipids Are Determinants Of Insulin Resistance In

- Laura Beechy, Jennie Galpern, Andrew Petrone, Sai Krupa Das Assessment Tools In Obesity — Psychological Measures, Diet, Activity, And Body Composition, Physiology & Behavior, Volume 107, Issue 1,Elsevier, 20 August 2012, Pages 154–171
- Leiter L, Lukaski H, Kenny D, Basnie A, Camelon K, Ferguson R, Et Al. The Use Of Bioelectrical Impedance Analysis To Estimate Body Composition In The Diabetes Control And Complications Trial (DCCT). Int J Obesity 1994; 18: 829-835.
- M. Neovius, E. Hemmingsson, B. Freyschuss, J. Udden Bioelectrical Impedance Underestimates Total And Truncal Fatness In Abdominally Obese Women Obesity, 14 (2006), Pp. 1731–1738
- Magliano, D. J. Et Al. Diabetes Care 33, 1983–1989 (2010).
- Mahtab. S. Bamji, N. Prashad Rao, Vinodini Reddy, Textbook Of Human Nutrition, 2nd Edition, Oxford And IBH Publishing Co. Pvt. LTD. 2004, Pg. 129,154,155,166.
- Maria Ayako Kamimura, Carla Maria Avesani, Miguel Cendoroglo, Maria Eugeˆnia Fernandes Canziani, Se´Rgio Antoˆ Nio Draibe And Lilian Cuppari, Comparison Of Skinfold Thicknesses And Bioelectrical Impedance Analysis With Dual-Energy X-Ray Absorptiometry For The Assessment Of Body Fat In Patients On Long-Term Haemodialysis Therapy, Nephrol Dial Transplant (2003) 18: 101–105
- Martin,Principles Of Human Nutrition, 2nd Edition, Eastwood Blackwell Publishing, 2003 Pg146.
- Meyer KA, Kushi LH, Jacobs DR Jr, Slavin J, Sellers TA, Folsom AR. Carbohydrates, Dietary Fiber, And Incident Type 2 Diabetes In Older Women. Am J Clin Nutr 2000;71:921-30.
- Michael J. Gibney, Barrie M. Margetts, John M. Kearney And Lenore Arab, The Nutrition Society Textbook Series, Public Health Nutrition, Blackwell Publishing, 2005, Pg.332-334.
- Micheal J. Gibney, Lan A. Macdonald And Helen M. Roche,Nutrition And Metabolism Blackwell Publishing, 2004, Pg.131,245.
- Misra A, Chowbey P, Makkar BM, Vikram NK, Wasir JS, Et Al. Concensus Group. Consensus Statement For Diagnosis Of Obesity, Abdominal Obesity And The Metabolic Syndrome For Asian Indians And Recommendations For Physical Activity, Medical And Surgical Management. Journal Of Association Of Physicians Of India, 2009a, 57:163–170.
- Narayan KMV, Williams D, Gregg EW. Diabetes: The Pandemic And Potential Solutions. Disease Control Priorities In Developing Countries; 2006; 591–603.
- National Institute Of Health(NIH) And National Institute Of Diabetes And Digestive And Kidney Diseases(2004). Diabetes Prevention Program, Retrived July 9, 2004, From U.S. Department Of Health And Human Services(USDHHS) (2004). The Health Consequences Of Smoking. A Report Of The Surgeon General. Atlanta, GA: CDC, National Centre For Chronic Disease Prevention And Health Promotion, Office On Smoking And Health.
- Paul Deurenberg, Klaas R. Westerterp And Erica J. M. Velthuis-Te Wierik, Between-Laboratory Comparison Of Densitometry And Bio-Electrical Impedance Measurements, British Journal Of Nutrition (1994), 71, 309-316
- Paul Insel, R. Elaine Turner, Don Ross, Discovering Nutrition, 3rd Edition Jones And Bartlett Publishers, 2011, Pg-284.
- Permutt MA, Wasson J, Cox N. Genetic Epidemiology Of Diabetes. Journal Of Clinical Investigation, 2005, 115:1431–1439.
- Popkin B M. The Nutrition Transition And Obesity In The Developing World. J Nutr 2001; 131(3): 871S–73S.
- Popkin B. Nutritional Patterns And Transitions. Popul Dev Rev 1993; 19: 138–57.
- Popkin B. The Nutrition Transition And Its Health Implications In Lower-Income Countries. Public Health Nutr 1998; 1: 5–21.
- Prentice A, Jebb S. Energy Intake/Physical Activity Interactions In The Homeostasis Of Body Weight Regulation. Nutr Rev. 2004;62:S98 –S104.
- Prentice AM, Jebb SA. Obesity In Britain: Gluttony Or Sloth? BMJ 1995; 311: 437–39.
- Prepubertal Children. Diabetologia 2011;54:869–875

- R.F. Kushner Bioelectrical Impedance Analysis: A Review Of Principles And Applications J Am Coll Nutr, 11 (2) (April 1992), Pp. 199–209
- Rajeev Gupta And Anoop Misra Type 2 Diabetes In India: Regional Disparities British Journal Of Diabetes & Vascular Disease 2007.
- Raji A, Seely EW, Arky RA, Simonson DC. Body Fat Distribution And Insulin Resistance In Healthy Asian Indians And Caucasians. J Clin Endocrinol Metab 2001; 86 : 5366-71.
- Ramachandran A, Snehalatha C, Viswanathan V, Viswanatha M, Haffner SM. Risk Of Non Insulin Dependent Diabetes Mellitus Conferred By Obesity And Central Adiposity In Different Ethnic Groups: A Comparative Analysis Between Asian Indians, Mexican Americans And Whites. Diabetes Res Clin Pract 1997; 36 : 121-5.
- Ranjit Mohan Anjana, M.D., Rajendra Pradeepa, Ph.D.,1 Mohan Deepa, Ph.D.,1 Manjula Datta, M.D.,Vasudevan Sudha, M.Sc., Ranjit Unnikrishnan, M.D., Lalith M. Nath, M.D.,Ashok Kumar Das, M.D., Ph.D., FAMS, Sri Venkata Madhu, D.M.,Paturi Vishnupriya Rao, M.D., Ph.D.,Deepak Kumar Shukla, Ph.D.,Tanvir Kaur, Ph.D.,Mohammed K. Ali, M.D.,And Viswanathan Mohan, M.D., Ph.D., D.Sc., FRCP, FNAS, The Indian Council Of Medical Research–India Diabetes (ICMR–INDIAB) Study: Methodological Details, Journal Of Diabetes Science And Technology Volume 5, Issue 4, July 2011.
- Raquel Villegasa, Xiao Ou Shua, Gong Yanga, Charles E. Matthewsa, Honglan Lib, Hui Caia, Yu-Tang Gaob, And Wei Zhenga, Energy Balance And Type 2 Diabetes: A Report From The Shanghai Women's Health Study, Nutr Metab Cardiovasc Dis. 2009 March ; 19(3): 190–197.
- Researchw. A. Coward, Susan A. Parkinson And P. R. Murgatroyd Nutrition Research Reviews (1988), 1, 115-124 115body Composition Measurements For Nutrition Medical Research Council, Dunn Nutrition Laboratory, Downham's Lane, Milton Road, Cambridge Cb4 1xj
- Rother KI. Diabetes Treatment–Bridging The Divide. N Engl J Med 2007 Apr;356(15):1499-1501.
- S. P. Stewart, P. N. Bramley, R. Heighton, J. H. Green,A. Horsman, M. S. Losowsky And M. A. Smith, Estimation Of Body Composition From Bioelectrical Impedance Of Body Segments : Comparison With Dual-Energy X-Ray Absorptiometry, British Journal Of Nutrition (1993), 69, 645-655
- S.L. Arora, Suresh Gopapalni,Methods For Estimating Body Composition, Sports Nutrition, Cyber Tech Publications, 2011, Pg.32-36.
- Salmeron J, Ascherio A, Rimm EB, Et Al. Dietary Fiber, Glycemic Load, And Risk Of NIDDM In Men. Diabetes Care 1997;20:545-50
- Salmeron J, Hu FB, Manson JE, Et Al. Dietary Fat Intake And Risk Of Type 2 Diabetes In Women. Am J Clin Nutr 2001;73:1019-26.
- Salmeron J, Manson JE, Stampfer MJ, Colditz GA, Wing AL, Willett WC. Dietary Fiber, Glycemic Load, And Risk Of Non-Insulin-Dependent Diabetes Mellitus In Women. JAMA 1997;277:472-7.
- Sari Edelstein, Judith Sharlin,Life Style Nutrition An Evidence Based Approach, Jones And Bartlett Publishers, 2009.
- Segal, K. R., Burastero, S., Chun, A,, Coronel, P., Pierson, R. N. & Wang, J. (1991). Estimation Of Extracellular And Total Body Water By Multiple-Frequency Bioelectrical-Impedance Measurement. American Journal Of Clinical Nutrition 54, 2629.
- Shai I, Jiang R, Manson JE, Stampfer MJ, Willett WC, Colditz GA, Hu FB. Ethnicity, Obesity, And Risk Of Type 2 Diabetes In Women. Diabetes Care, 2006, 29:1585–1590.
- Sheena E. Ramsay, Peter H. Whincup, A. G. Shaper, And S. G. Wannamethee, The Relations Of Body Composition And Adiposity Measures To Ill Health And Physical Disability In Elderly Men, American Journal Of Epidemiology ,Vol. 164, No. 5,2006;164:459–469
- Sheila Chandra Vir, Public Health Nutrition In Developing Countries Part1, Woodhead Publishing India Pvt. LTD, 2011 Pg.1-2,131,35-36.

- Silvana Obici And Luciano Rossetti, Minireview: Nutrient Sensing And The Regulation Of Insulin Action And Energy Balance, Endocrinology, December 2003, 144(12):5172–5178.
- Sir Stanley Davidson, R. Passmore, J.F.Brock, Human Nutrition And Dietetics, 5th Edition, The English Language Book Society And Churchill Livingstone, 1973, Pg1-2.
- Snehalatha And Ramachnadaran 2009, Insight Into The Mechanism Of Primary Prevention Of Type 2Diabetes: Improvement In Insulin Sensitivity And Beta Cell Function. "Genetic And Epigenetic Basis Ofcomplex Diseases " Conference In Centre For Cellular And Molecular Biology; December, 2009.
- Stanhope KL, Schwarz JM, Keim NL, Griffen SC, Bremer AA Et Al. Consuming Fructose-Sweetened, Not Glucose-Sweetened, Beverages Increases Visceral Adiposity And Lipids And Decreases Insulin Sensitivity In Overweight/Obese Humans. Journal Of Clinical Investigation, 2009, 119(5):1322–1334.
- Stumvoll M, Goldstein BJ, Van Haeften TW. Type 2 Diabetes: Principles Of Pathogenesis And Therapy. Lancet. 2005, 365:1333–1346.
- Sun SS, Chumlea WC. Statistical Methods For The Development And Testing Of Body Composition Prediction Equations. In: Heymsfield SB, Lohman TG, Editors. Human Body Composition. Champaign, IL: Human Kinetics Books; 2005.
- Taylor AH, Cable NT, Faulkner G, Hillsdon M, Narici M, Van Der Biz AK. Physical Activity And Older Adults: A Review Of Health Benefits And The Effectiveness Of Interventions. J Sports Sci. 2004;22:703–725.
- Thom T, Haase N, Rosamond W, Et Al. Heart Disease And Stroke Statistics – 2006 Update. A Report From The American Heart Association Statistics Committee And Stroke Statistics Subcommittee. Circulation. 2006;113: E85–E151.
- V Mohan, CS Shanthirani, R Deepa, Glucose Intolerance (Diabetes And IGT) In A Selected South Indian Population With Special Reference To Family History, Obesity And Lifestyle Factors – The Chennai Urban Population Study (CUPS 14), Japi, Vol. 51, August 2003.
- V. Mohan, S. Sandeep, R. Deepa, B. Shah & C. Varghese Madras, Epidemiology Of Type 2 Diabetes: Indian Scenario, Indian J Med Res 125, March 2007, Pp 217-230.
- Vazquez G, Duval S, Jacobs DR, Silventoinen K. Comparison Of Body Mass Index, Waist Circumference, And Waist ⁄ Hip Ratio In Predicting Incident Diabetes: A Meta Analysis. Epidemiological Reviews, 2007, 29:115–128
- Verma R, Khanna P, Bharti. National Programme On Prevention And Control Of Diabetes In India:Need To Focus. AMJ 2012, 5, 6, 310---315. Http//Dx.Doi.Org/10.4066/AMJ.2012.1340.
- Vipin Gupta, Type 2 Diabetes Mellitus In India, South Asia Network For Chronic Disease, New Delhi
- W. A. Coward, Susan A. Parkinson And P. R. Murgatroyd, Body Composition Measurements For Nutrition Research, Nutrition Research Reviews (1988), 1, 115-124
- Weyer C, Bogardus C, Pratley RE: Metabolic Factors Contributing To Increased Resting Metabolic Rate And Decreased Insulin- Induced Thermogenesis During The Development Of Type 2 Diabetes. Diabetes 48: 1607–1614, 1999
- WHO Expert Consultation, 2004. Appropriate Body Mass Index For Asian Populations And Its Implications For Policy And Intervention Stratergies. The Lancet.363,157-163.
- WHO. Diet, Nutrition And The Prevention Of Chronic Diseases. Geneva, Switzerland: World Health Organization, 2003.
- Williams' Basic Nutrition Amd Diet Therapy 12th Edition, Staci Nix Mosby, An Imprint Of Elsevier, Pg367-369.
- Williamson JR, Hoffman PL, Kohrt WM, Spina RJ, Coggan AR, Holloszy O: Endurance Exercise Training Decreases Capillary Basement Membrane Width In Older Nondiabetic And Diabetic Adults. J Appl Phys -I O L 80:747–753, 1996
- World Health Organization, Definition, Diagnosis And Classification Of Diabetes Mellitus And Its Complications,1999.

WEBSITE:

- http://www.censusindia.net/census of India
- http://www.sitesources.worldbank.org
- http://www.nejm.org/doi/full10.1056/nejm199704033361404
- http://www.ajcn.org/content/81511425.abstract
- http://www.questia.com/googlescholar.qsdoc1D=5000241437
- http://www.icmr.nic.in/icmrsql/reportpub.asp?expno=00011393
- http://www.ncbi.nlm.nih.gov/pubmed/6627412

APPENDIX

INTERVIEW SCHEDULE TO ELICIT THE BACKGROUND INFORMATION, DIETARY PATTERN AND LIFE STYLE PATTERN OF TYPE II DIABETIC INDIVIDUALS

I. Background Information:

1. Name :

2. Age :

3. Sex :

4. Contact no :

5. Address :

6.Hometown :

Rural ☐ Urban ☐

7.Religion :

Hindu ☐ Christian ☐ Muslim ☐ Others ☐

8.Highest level of education:

i)No formal education ☐ ii)Read and write ☐ iii)Primary education ☐

iv)secondary education ☐ v)Higher education ☐ vi)University ☐

9. Occupation :

10.Community :

Scheduled Tribe ☐ Schedule Caste ☐

Other backward Castes ☐ Others ☐

11. No. of family Members:

1-4 ☐ 5-7 ☐ >8 ☐

12. Type of family:

Nuclear ☐ Joint ☐ Extended Nuclear ☐

13.Total family income (World Bank Group, 2011)

Below Rs.4606.25 (economical weak section) ☐

Rs.4610.83-Rs.18218.75(low income grade) ☐

Rs.18223.33-Rs.56260.48(upper middle income grade) ☐

Above Rs.56,000(high income grade) ☐

II.DIETARY PATTERN:

14. Dietary habit:

Vegetarian ☐ Ova-vegetarian ☐ Non-Vegetarian ☐

15. Daily meal pattern:

2 ☐ 3 ☐ 4 ☐ >5 ☐

16. How often do you eat out in a restaurant/hotel?

Daily ☐ Weekly ☐ occasionally ☐ Never ☐

17. Do you skip meals?

Yes ☐ No ☐

If yes,

MEALS MISSED	FREQUENCY
Breakfast	
Lunch	
Tea and Snacks	
Dinner	

19.Do you suffer from any food allergy/food intolerance?

Yes ☐ No ☐

If yes,

Which food makes you allergic?

20.Do you have any eating problems?

Yes ☐ No ☐

If yes,

Dental ☐ Gastrointestinal ☐ Others ☐

21.Do you have the habit of snacking?

Yes ☐ No ☐

If yes,

Junk foods ☐ Carbonated beverages ☐ Healthy foods ☐

22.Do you use artificial sweetener?

Yes ☐ No ☐

23.While selecting foods what aspects do you look into?

Nutritive value ☐ Cost ☐ Taste ☐ Availability ☐

Hygiene ☐ Brand ☐ Peer influence ☐ Mass media ☐

24.Do you look at the information that appears on food labels?

Yes ☐ No ☐

If yes, what do you look for?

Manufacturing date ☐ Expiry date ☐ Food additives ☐

Ingredients used ☐ Price ☐ Precautions ☐

Nutrition information ☐ Preparation methods ☐ Logo of food standards ☐

Recommended usage ☐ Nutritional claims ☐

25.Do you modify your eating habits according to the body condition?

CONDITIONS	YES	NO	MODIFICATIONS
Ailments			
Heavy physical work			
Overweight			
Underweight			
Holidays			
Functions			
Seasons/Climate			

26.Details regarding food fads and taboos:

REASONS	FOOD STUFF	CONDITIONS WHEN AVOIDED	CONDITIONS WHEN INCLUDED
Hot foods			
Cold foods			
Gas producing			
Bile producing			
Food causing skin diseases			

19. Daily Meal Pattern (24 hrs)

MEAL	MENU	INGEDIENTS	COOKED AMOUNT	RAW EQUIVALENT
Break fast				
Mid morning				
Lunch				
Tea time				
Dinner				

28.Frequency of consumption of high energy/fat foods:

FOOD ITEMS	DAILY	WEEKLY	MONTHLY/OCCASSIONALLY	NEVER
Sweets				
Fried foods				
Bakery items				
Fast foods				
Salted foods				
Fleshy foods				

20. Details of food consumption

S.no	Food items	Daily	2-4 times a week	Once a week	Once a month	Never
1	**Cereals and millets**					
2	**Pulses and legumes**					
3	**Vegetables** i)Leafy					

	ii)Roots and tubers iii)others					
4	**Nuts and oil seeds**					
5	**Spices and condiments**					
6	**Fruits**					
7	**Non Vegetarian** i)Fish and other sea foods ii)meat and poultry products					
8	**Milk and milk products**					
9	**Sugar and Jaggery**					
10	**Fats oils and edible**					

III. LIFE STYLE PATTERN

27. Do you have the habit of doing exercise?

Yes ☐ No ☐

If yes,

Daily ☐ Weekly once ☐ Weekly twice ☐ Infrequent ☐

Types of exercise involved:

Walking ☐ Jogging ☐

Gardening ☐ Cycling ☐

Swimming ☐ Any other ☐

31. Do you practicing any yoga regularly?

Yes ☐ No ☐

32.How long do you indulge in these activities?

15mins ☐ 30mins ☐ >30mins ☐

33.How long do you sleep in a day?

<6hours ☐ 6-8hours ☐ >8hours ☐

34.Do you sleep soon after lunch?

Yes ☐ No ☐

35.Stress pattern:

Relaxed and calm ☐ Peer pressure ☐ Familial stress ☐

Environmental stress ☐ Work stress ☐ Physiological stress ☐

36.How do you manage stress?

Music ☐ Exercise ☐ Overeating ☐ Avoiding food ☐

Meditation ☐ Sleep ☐ Others ☐

37. Do you have the habit of smoking cigarettes/beedi?

Regularly ☐ Occasionally ☐ Not at all ☐

38. Do you have the habit of drinking alcohol?

Regularly ☐ Occasionally ☐ Not at all ☐

39. Other habits (do you have the habit of chewing)

NON FOOD ITEMS	DAILY	OCCASIONALLY	NOT AT ALL
Tobacco			
Pan masala			
Betal leaves			

IV. HEALTH HISTORY :

40. How long have you been suffering from this disorder?

Duration : Years _____ Months _____ Days _____

41.How often do you see doctor for a checkup?

Weekly ☐ Monthly ☐ More than 6 times a year ☐

2-6 times a year ☐ Once a year ☐ Less than once a year ☐

42. Are you currently on any form of prescribed medication:

Yes ☐ No ☐

If yes, specify the drug:

ALLOPATHY	HOMEOPATHY	AYURVEDA	DIETARY	ANY OTHER

43.Have you ever been told that you have pre-diabetes?

Yes ☐ No ☐

44. Do you have any family history of diabetes mellitus?

Yes ☐ No ☐

If yes,

FAMILY HISTORY	YES	NO
I Degree relatives		
Father		
Mother		
Siblings		
II Degree relatives(paternal)		
Grandfather		
Grandmother		
Uncle		
Aunt		
II Degree relatives(maternal)		
Grandfather		
Grandmother		
Uncle		
Aunt		

45.At present, do you suffer from any of these symptoms?

Symptoms	YES	NO
Polyuria		
Polyphagia		
polydipsia		
Poor wound healing		
Fatigue		
Insomnia		
Infections		
Blurred vision		
Shortness of breath		