INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

UMI®

DIABETES AND OBESITY IN ADULT SAUDI POPULATION

by

Mohammed A. Alsaif

Copyright © Mohammed A. Alsaif 2 0 0 1

A Dissertation Submitted to the Faculty of the

COMMITTEE ON NUTRITIONAL SCIENCES

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

2 0 0 1

UMI Number: 3026586

Copyright 2001 by
Alsaif, Mohammed A.

All rights reserved.

UMI®

UMI Microform 3026586

Copyright 2001 by Bell & Howell Information and Learning Company.
All rights reserved. This microform edition is protected against
unauthorized copying under Title 17, United States Code.

Bell & Howell Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

THE UNIVERSITY OF ARIZONA ®
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Mohammed A. Alsaif

entitled Diabetes and Obesity in Adult Saudi Population

and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy

David K. Y. Lei
Dr. David K. Y. Lei — Date 7/6/01

Iman Hakim
Dr. Iman Hakim — Date 7/6/01

Robin B Harris
Dr. Robin Harris — Date 7/6/01

Ralph L Price
Dr. Ralph Price — Date 7/6/01

Jay Winzerling
Dr. Joy Winzerling — Date 7/6/01

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

David K. Y. Lei
Dissertation Director Dr. David K. Y. Lei — Date 7-6-01

STATEMENT BY THE AUTHOR

This dissertation has been submitted in the partial fulfillment of the requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the library.

Brief quotations from this dissertation are allowable without special permission, provided that accurate acknowledgement of the source is made. Requests for permission for extended quotation from or reproduction of this manuscript is whole or in part may be granted by the copyright holder.

SIGNED:

ACKNOWLEDGEMENTS

I wish to express my sincere, profound thanks to my committee members Dr. David Lei, Dr. Iman Hakim, Dr. Robin Harris, Dr. Ralph Price and Dr. Joy Winzerling. Their encouragement and guidance have been a delight experience.

I was fortunate to have Dr. David Lei as my advisor, monitor and friend, with his great knowledge and experience, he made my journey of graduate studies more tolerable. I learned immensely from him.

I am grateful to each of my committee members, Dr. Iman Hakim and Dr. Robin Harris for their help in statistical analysis and writing. I wish also to thank them for their support during the production of this research.

A special thanks is expanded to Dr. Omar S. Al-Attas, for providing the data: without his help and assistance this project would have never started.

Dedicated to my family for their patience and sacrifices.

TABLE OF CONTENTS

TABLE OF CONTENTS - *Continued*

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

In this series of studies, three issues were addressed. First, the prevalence of undiagnosed diabetes (high fasting blood glucose with no prior diagnosis of diabetes) and how different they are from the diagnosed diabetes in risk factors. Second, the prevalence and risk factors of overweight and obesity were described in the general population. Finally, an evaluation of the relationship between obesity and type 2 diabetes were made in Saudi adult men and women. Our study population came from a national cross sectional survey which included 3271 males and females, age 30-70 years old. All participants completed a specifically designed questionnaire, and a comprehensive physical examination which included blood pressure and anthropometric measurements. Fasting serum samples were analyzed for glucose and blood lipids.

A number of compelling findings have resulted from this research. First, the prevalence of diabetes is high with 30% of men and 25% of women diabetics. Undiagnosed diabetes presents a substantial problem; they constitute 41% of the total diabetic population and 11% of the total population. Undiagnosed diabetics are however, similar to diagnosed diabetes with uncontrolled fasting blood glucose level and many of the associated risk factors. Second, the prevalence of obesity is also high with 49.15% in women and 29.94% in men identified as obese and an additional 31.55% of females and 41.91% of males identified as overweight. Third, in this study population, 12% are obese diabetics and in the diabetic population 43% are obese diabetics. Diabetes appears to have a harmful effect on blood lipids, which seem to worsen when diabetes is combined with obesity. Based on these findings, obesity and diabetes appear to have created very serious complications and prevalent health problems in adult Saudi population between the age of 30 - 70 years old. Because about half of the population are under 18 years old, there is a very good chance for the government to successfully implement education and health programs to prevent and control these two conditions from becoming an epidemic in future generations.

CHAPTER 1

INTRODUCTION

Saudi Arabia is a large country, occupying four-fifths [865,000 square miles] of the Arabian Peninsula, which is located in Southwest Asia (1). In the recent past, Saudi Arabia has achieved much - with the help of oil revenues - in a short period of time. In 1980, the total population was 9.3 million, with 45% under 15 years of age; in 2000 the population was estimated to be about 21 million, with about 50% under the age of 18 years old. In 1960, the under five mortality rate was 250 deaths per 1000 and the fertility rate was 7.2. In contrast, in 1999, the figures were 25 and 5.6, respectively. Population growth declined from 5.1% between 1970-90, to 2.9% in the period 1990-99. In addition, life expectancy increased from 52 years in 1970 to 72 years in 1999. In the past 25 years, education has reached all parts of the country.

Between 1980 and 1999, female adult literacy rose to 70% from 32%, while male literacy rose to 91% from 65%. Primary school enrollment in 1999 was 90% for females and 97% for males. In addition, health services have improved and extended to reach the entire population. The percent of fully immunized infants was above 93% in most of the recommended vaccinations (TB, DPT, Polio, Measles) (2,3). Pattern of diseases has also changed in Saudi Arabia with the improvement in the economic status and the standard of living of the general population. Causes of morbidity and mortality have shifted from infectious diseases and malnutrition to chronic diseases, such as type 2 diabetes mellitus, obesity, hypertension, heart disease and stroke (4).

In Saudi Arabia, the prevalence and the risk factors of type 2 diabetes have been major foci of epidemiological studies. According to Ahmed in 1989, 85% of the Saudi diabetic population were type 2 diabetics and 15% had type 1 diabetes (5). In 1996, El-Hazmi et al., studied diabetes mellitus in Saudi Arabia within a population of over 23,000 individuals between

2-70 years of age: they found 88% of the Saudi diabetics had type 2 diabetes (6). In 1995, the Saudi national chronic metabolic diseases survey reported a prevalence of diabetes mellitus (DM) of 11.8% for males and 12.8% for females age 15 years and older. The survey also reported the prevalence of impaired glucose tolerance (IGT) of 10% for males and 9% for females (7). The overall prevalence of 4.4% was found in Riyadh, however for the population over 30 years old the prevalence was 16% for males and 12.3% for females. In each age group males had a significantly higher prevalence of type 2 diabetes than females (8). This is significantly higher than the prevalence (5.4%) reported 20 years ago for the 30 years old and above (9). This increase within the past 20 years suggests that the prevalence of diabetes is increasing in the Saudi population. In General, type 2 diabetes is associated with microvascular and macrovascular disorders. The incidence of diabetes nephropathy among type 2 diabetics is increasing (10). Type 2 diabetics are at greater risk for cardiovascular disease as compared to the general population (11). The most frequent ophthalmic complication in diabetics is retinopathy and its development and severity is related to the duration of the disease (12).

In Saudi Arabia, obesity has also reached epidemic proportions in all segments of the population. In a study of more than 14,000 Saudis, 14 years of age and older, over 27% of males and 25% of females were overweight, (i.e. BMI $\geq$ 25- <30). Furthermore, 13% of males and 20% of females were obese (BMI $\geq$ 30) (13). In a study of 18-74 year old Saudi adults attending primary health care centers, the prevalence of obesity was 31% and the overweight prevalence was 34% (14). Another study of Saudi adult females, reported a prevalence of obesity of 42% and overweight of 27% (15). A study of School children 6-18 years old were surveyed for overweight and obesity used the percentage of BMI of expected BMI at the 50th percentile for each age group and compared it with the 50th percentile of the NCHS/CDC as the reference group. Overweight was defined as weighing between 110% and 120% of the expected median percentile of the reference group and obesity as more than 120%. Results showed the overweight prevalence to be 12% and obesity 16% (5). Obesity has been associated with coronary heart disease. primarily as a factor aggravating or initiating other risk factors of coronary heart disease. such as dyslipidemia. impaired glucose tolerance. type 2 diabetes mellitus and hypertension (16). When obese individuals lose weight they also reduce the other risk factors for heart disease. type 2 diabetes mellitus and osteoarthritis (17).

Considering the demographic profile of the Saudi population. with 60% being young people. the prevalence of type 2 diabetes and obesity are likely to increase in the future (6). Lifestyle and dietary habits are often seen as the major environmental factors behind the development of both diabetes and obesity. The dramatic change that happened in the country during the past 20 years transformed the population to a sedentary lifestyle and introduced to them new foods that were not native to the country (8). Furthermore. the classical Arabic culture view of obesity as a sign of health and wealth has not helped focus the attention towards the problem of obesity and diabetes (14). To avoid health care disaster in the future steps need to be taken. Epidemiological studies to monitor the patterns and progression of these two conditions are needed. as well as the related risk factors. This dissertation will aid in the task of monitoring prevalence and associated risk factors of obesity and diabetes in Saudi population 30 years of age and older.

ORGANIZATION OF THE DISSERTATION

This dissertation consists of studies. in addition to the introduction. the literature review and the conclusions. The research on which these studies are based was conducted using data from a national survey of chronic diseases in Saudi Arabia that included diabetes and obesity.

The first study estimates the prevalence of diabetes among Saudi Arabians and evaluates the impact of undiagnosed diabetes. The second study focuses on prevalence of obesity and overweight and their associated risk factors. The third study examines the relationship between obesity and type 2 diabetics.

THE OBJECTIVE OF THE STUDY

The overall objective of this research was to investigate the relationship between type 2 diabetes and obesity then investigate their risk factors in the adult Saudi population, through statistical modeling, using a cross-sectional national survey data.

Aim of study one

The aim of the study is to describe the problem of type 2 diabetes among adult Saudis and evaluate the impact of undiagnosed diabetes in the overall problem of diabetes.

Specific Objectives

1) To determine the prevalence of diagnosed and undiagnosed diabetes in a Saudi Arabia population and describe how the frequency of these conditions were modified by sociodemographic characteristics, general lifestyle behaviors family history of diabetes and medical history.

2) To explore the relationship between various obesity measurements, body mass index, waist hip ratio and waist circumference, and the prevalence of diagnosed and undiagnosed diabetes and on the control of fasting blood glucose in diabetics.

3) To examine the relation between level of fasting blood lipids, i.e. total cholesterol, triglycerides and HDL-cholesterol, on diagnosed and undiagnosed diabetes and on the control of fasting blood glucose in diabetics.

Aim of study two

The aim of study two was to determine the frequency of overweight and obesity in Saudi Arabia and investigate factors associated with these conditions.

Specific Objectives

1) To determine the frequency of the population that were overweight or obese and how the prevalence was modified by sociodemographic and lifestyle factors.

2) To investigate rates of high risk waist hip ratio and high risk waist circumference among the population.

Aim of study three

The aim of study three was to describe the relationship between obesity and type 2 diabetes.

Specific Objectives

1) To determine the prevalence of obesity in type 2 Saudi diabetics and explore how the frequency of obesity in the type 2 diabetics were modified by sociodemographic characteristics, general lifestyle behaviors family history of diabetes and medical history.

2) To examine the relation between obesity in diabetics and blood lipids including: total cholesterol, triglycerides, HDL-cholesterol, LDL-cholesterol, and LDL/HDL index.

CHAPTER 2

LITERATURE REVIEW

TYPE 2 DIABETES

The symptoms of diabetes mellitus were first described by an ancient Hindu physician 3000 years B.C., and 1500 years later, Egyptian physicians noted an illness associated with passage of much urine. Greeks described diabetes mellitus as a disease that melts down the tissues into urine. Because of the frequent drinking and urination as well as the sugar content of the urine, the disease was named diabetes mellitus (18).

More currently, there are two main types of diabetes mellitus, type 1 (insulin dependent diabetes mellitus) and type 2 (non-insulin dependent diabetes mellitus). Type 1 diabetes usually affects about 15% of the diabetic population, and occurs primarily in young people and it is usually characterized by an abrupt onset of symptoms (19). Type 2 diabetes occurs in about 85% of the diabetic population and usually diagnosed in adulthood, it is recognized as having a genetic basis, as evidenced by studies of identical twins and by familial transmission of diabetes (20). Type 2 diabetes is a complex metabolic disorder characterized by alterations in carbohydrate, lipid and protein metabolism, resulting from an imbalance between insulin sensitivity and insulin secretion (21).

Globally, type 2 diabetes outnumbers all other types of diabetes. In all populations, type 2 diabetes is far more prevalent than type 1 diabetes. It constitutes about 90% of all cases of diabetes in Western countries. In certain groups, such as some Native American tribes and populations in the South Pacific, type 2 diabetes is the only form of diabetes (22).

The prevalence of type 2 diabetes, however, varies greatly between population. In the US, it is estimated as 6.6% in persons aged 18 years and over. The highest prevalence of type 2 diabetes in the world was established in Pima Native Americans of Arizona, where the age-adjusted prevalence rate was at least 10 times higher than that of the general US population. In contrast, other Native Americans, such as Eskimos were reported to have the lowest prevalence rates in the world (22). King and Rewers compiled an international prevalence data on type 2 diabetes and Impaired Glucose Tolerance (IGT). Within the age range of 30-64 years, diabetes was absent or rare (1%) in the least developed countries, like Tanzania (1%), Melanesian in Papua New Guinea. In Europeans, US non-Hispanic whites, American blacks, the prevalence varied from 3 to 10%. A high prevalence (11-20%) was observed in Arabs, Asian Indians, Creoles, and US Hispanic groups. Extremely high prevalence were observed in the Pima and Papago Native Americans of Arizona (50%) and the Micronesian Naruans (40%) (23).

Few studies have been performed on the incidence of type 2 diabetes in the Pima Native Americans of Arizona and among Micronesians in the central Pacific Island of Nauru. The incidence of type 2 diabetes in the Pima Native Americans was 19 times that of the predominantly Caucasian population in Rochester, Minnesota. A high incidence of type 2 diabetes has also been found in the population of Nauru. The incidence of diabetes has risen considerably in the US, and there are also indications that the prevalence of type 2 diabetes has increased in England during the last 20 years (22).

In Saudi Arabia, a drastic change in life-style caused by the rapid economic growth has affected people's health, nutritional status and the expression of disease patterns. In the past 25 years, there have been many studies, which assumed the task of determining the prevalence of diabetes mellitus in Saudi Arabia. In 1976, Cook was the first to report about diabetes mellitus in Saudi Arabia, when he observed that maturity onset of diabetes and impaired glucose tolerance were common in Riyadh. He noted that these conditions were not usually associated with obesity (24). Five years later, Bacchus et al. surveyed 1,385 male government workers who were living outside Riyadh City. They found the prevalence of diabetes mellitus to be low (<2.6%) in the age groups under 44 years, but a higher prevalence for the older age groups (>9.9%) (9). Rural areas in the western region of Saudi Arabia were studied with testing 5,222 people and noting a prevalence of 4.3%. This prevalence was found to increase with age, obesity, and income, and also in females (25). The southwest region of Saudi Arabia was explored for the prevalence of diabetes in a study on 290 families (2,150 participants). The overall prevalence was 4.6%, which increased with age, and was higher in males (26). In Riyadh City, a study found a prevalence of 13.7% in people over 30 years of age and it was higher in males (8). The southwest of Saudi Arabia was investigated again in a semi-urban area. A 6.5% prevalence of diabetes was found in a sample of 2,060 males and females, with a higher prevalence in the age group over 30 years old and in females (27).

DETERMINANTS OF TYPE 2 DIABETES

AGE

The prevalence of type 2 diabetes increases with age in most populations, however some studies have shown a fall in the oldest age groups (28). In large compilation data of international prevalence on type 2 diabetes, Pima Native Americans had an age related increase of prevalence of diabetes, with three fold increases between the groups of 40-50 and 60-70 years of age (23).

In Saudi Arabia, type 2 diabetes is associated with aging as in other countries. In their study Bacchus et al., found no diabetic subjects under the age of 25 years, 1% under the age of 34 years, and an overall prevalence of 6.5%. A prevalence of 11% was found in the age group 55-64 years and 23% in those above 65 years (9). In a study that surveyed no females older than 65 years, there was no type 2 diabetes in females less than 35 year of age and with the peak (29%) at age group 45-54 years (29). Rural population had a prevalence of (13.4%) in the age group 55 years, compared to 11.9% in the age group 35-54 years (25).

GENDER

The relative frequency of type 2 diabetes in relation to gender varies. In many populations, as in the US as a whole, there is a higher prevalence of type 2 diabetes in females than in males. On the other hand, in some countries such as India, a greater prevalence among men has been demonstrated (22). The differences in the gender ratio of diabetes in different societies can probably be explained by differences in the relative frequency of obesity and physical activity among the sexes in different cultures and ethnic background (28). In Saudi Arabia, studies on type 2 diabetes revealed conflicting results with regard to its association with gender. The diabetes rate in males was found to be 5.6% and in females, 4.2% in an urban survey (30). In a semi-urban community survey, the males population had a higher rate of diabetes compared to females [4.6% vs. 3.6%] (26). A study performed in Riyadh City in 1995, found the rate to be 8.2% in males and 6.5% in females (8). However another group of studies showed opposite findings (29,6). One study showed a lower prevalence of diabetes 2.5% in males compared to 4.7% in females (29). The rate of males and females with type 2 diabetes in a national study with 23,493 participants was 5.5% and 4.5% respectively (6).

FAMILY HISTORY

Type 2 diabetes has long been recognized as showing familial aggregation. The incidence and prevalence of type 2 diabetes in first-degree relatives of subjects with type 2 diabetes are appreciably greater than in the general population (31). In the Pima Native Americans, stratification analyses taking into account the high frequency of the disease in the background population and the variable prevalence with age, suggests that the distribution in families is best ascribed to inheritance of a single major codominant gene (32). A study reported a strong familial aggregation of type 2 diabetes, with almost 60% of diabetics having at least one first-degree diabetic relative (33).

In Saudi Arabia new and untreated referred adult diabetics, first-degree family history of diabetes was found more commonly than overall positive family history (34). Saudi women were investigated with regard to their diabetes, and 70% of 300 diabetic participants was found to have a family history of diabetes (35).

PHYSICAL ACTIVITY

Physical activity influences glucose metabolism; well-trained athletes have less glycemia after a glucose load, and insulin responses are diminished compared to untrained persons of similar weight. Conversely, profound physical inactivity, for example bed rest, is associated with the development of abnormal glucose tolerance and higher insulin levels (36). Moderate physical activity was concluded to be strongly associated with reduced risk for type 2 diabetes in African-Americans. Type 2 diabetes risk for moderately active subjects was one-third that for the physically inactive subjects (37).

In Riyadh City, a study found that the tendency toward taking extensive exercise is very low due to the hot and dry climate of the city (24). A national diabetes study found that the climate condition and the population lifestyle encourages them to be sedentary and prevent them from exercising (6). A study in Al-Baha region in southwest of Saudi Arabia partially accounted for a lower prevalence of diabetes in males, by the fact that males tends to work in the farms, which give them a chance to be physically active (27).

ETHNICITY

The prevalence and incidence of type 2 diabetes varies widely among different ethnic groups. For example Native American are at particularly high risk. Mexican Americans have rates of type 2 diabetes that are two to three times greater than those of the general US population. Furthermore, Australian Aborigines living in urban environments likewise also have much higher rates of type 2 diabetes than the remainder of the Australian population (22). Elderly

Hispanics had twice the prevalence of type 2 diabetes compared to non-Hispanic whites (38). In Saudi Arabia, the vast majority of the population has an ethnic background of Arab descent. However, there is different social classes, and higher proportion of diabetics was found among high social class (30). In rural dwellers, a similar trend of diabetes prevalence was reported (25).

DIET

Diet has long been suspected to have a role in the development of diabetes (28). The diabetes mortality rates were found to be decreased in countries that experienced food shortages during World War I and World War II (39). Studies of migrant populations suggest that diet may play a role in the development of type 2 diabetes. They were found to be consuming diets that were at least as high in caloric content and contain much higher quantities of refined carbohydrates than in the traditional environment (40). Another study showed that high energy intake can result in an increased frequency of diabetes, in Japanese sumo wrestlers who consume 4,500-6,500 kilocalories a day for several years, after retiring they develop diabetes (28). The effect of diet on the risk of developing type 2 diabetes was investigated, in two groups of Hispanic Americans. The first group consumed a plant-based diet and second group did not. The researchers found that the first group exhibited a lower risk for type 2 diabetes (41).

Saudi dietary habits and diabetes were investigated in several studies. Cook noted, in the first published paper about diabetes in Saudi Arabia, that the diabetic subjects in his study consumed a lot of refined sugar throughout the day in the form of sweetened tea (24). Traditional foods were one of the factors indicated to be causing the high prevalence of type 2 diabetes in Saudi Arabia as being rich in calories and carbohydrates. In addition, the emerging food habit of consuming fast food would exaggerate an already high prevalence of type 2 diabetes (8).

OBESITY

The association between obesity and type 2 diabetes has long been recognized. Obesity is a frequent precipitant of type 2 diabetes among those who are otherwise susceptible to its development (28). In a 12-year follow-up study of 11,654 Norwegian participants age 35-53 years to investigate diabetes, BMI was found to be the dominant risk factor in men and predicted diabetes in a dose-response relation in both sexes (42). In studying the association between duration of obesity and the risk of diabetes mellitus, male subjects aged 30 years or older were observed for 10 years or more. It was found that, having a BMI of 25 for ten years or BMI of 27.8 for one year is an important predictor for diabetes (43).

In Saudi Arabia, although in the first published diabetes study the conclusion was that diabetes is not usually associated with obesity (24), subsequent to that study overweight began to be seen as associated factor with diabetes. In a later study, overweight was found more frequently in diabetics (65%) than in non-diabetics (26%) (9). Another study found Saudi female diabetics to be more obese than the female non-diabetic population (73% vs. 38%). A similar trend was observed, in the male population (49% vs. 34%) (27).

INSULIN RESISTANCE

Insulin resistance is a major determinant for the development of type 2 diabetes. Subjects with high fasting insulin levels have a much higher risk of developing IGT and type 2 diabetes than persons with lower fasting insulin levels (44). In Australian Aborigines, who have high rate of diabetes, the average fasting and stimulated insulin levels, even in subjects with normal glucose tolerance, are greater than in non-diabetic Caucasians controls with identical degrees of glucose tolerance (45). Fasting insulin concentrations are increased two-to-threefold in type 2 diabetic patients as compared to controls, which indicates the inability of insulin to suppress hepatic glucose production, and results in the condition of insulin-resistance in the liver (46).

Glucose uptake by peripheral tissues in diabetics was found to be reduced compared to controls (47). As the diabetic condition worsens, glucose clearance diminishes progressively until the restraining effect of hyperinsulinemia on the liver is lost, and hepatic glucose production increases, leading to fasting hyperglycemia (48). In a recent study, hyperinsulinemia in a normal population over a period of 15 years was used as a predictor of type 2 diabetes. Results indicated that the 25% of the population with the highest insulin response in the beginning of the study had significant increases at the incidence type 2 diabetes at the end of the study (49).

INSULIN INSUFFICIENCY

With the increase in the plasma glucose levels there is a corresponding increase in insulin secretion to offset that. However, at glucose levels exceeding 7 mmol/l, insulin levels sensibly decrease, indicating the inability of β-cells to maintain a higher rate of insulin secretion (50). Studies in first degree relatives of type 2 diabetics have shown that a reduced first phase of insulin release was already present in those who had impaired glucose tolerance, but not in the normal glucose tolerant (51). In a longitudinal study a greater first phase insulin release was shown to be predictive of diabetes, suggesting that in the early stages of the disease the β-cells were compensating for the insulin resistance already present (52).

Changes in serum insulin concentrations were observed in normal glucose tolerant subjects whom later developed type 2 diabetes. They had higher fasting and post-load insulin concentrations than in normal subjects. The progression from normal to impaired glucose tolerance was associated with an increase in fasting and glucose-stimulated insulin secretion. Progressing from impaired glucose tolerance to type 2 diabetes there was a further increase in fasting, but not glucose-stimulated, insulin release. After the onset of type 2 diabetes, further increments in glucose concentration were associated with a progressive decline of fasting and post-prandial insulin concentration. These results indicate that hyperinsulinaemia precedes the development of type 2 diabetes, suggesting that insulin-resistance may be the primary cause of diabetes (53).

GENETICS

The importance of the genetic contribution to type 2 diabetes has been established by the study of certain inbred populations, which demonstrated an almost 100% concordance of disease in monozygotic twins and by familial clustering (53). In 1962, Neel proposed the "thrifty" genotype hypothesis. According to this hypothesis, populations that were exposed to alternate periods of adequate food supplies and famine have selected a genotype that would allow storage of energy in times of plentiful supply, and that could have allowed survival in famine (54).

This theory has been examined by using the Paleo Native Americans, from whom the Pima Native American evolved, who are known to have an extremely high prevalence of type 2 diabetes. The researchers concluded that the "thrifty" genotype hypothesis was feasible, and would explain such a high prevalence of diabetes in Pima Native American, whose is now enjoying a sedentary lifestyle and constant food supply. They proposed that the "thrifty" genotype was associated with insulin-resistance seen in muscle, which would preserve energy in time of fasting and fat deposition when food was available (55).

O'Dea, has reached similar conclusions in her studies of Australian Aborigines. She concluded that the behavioral traits which were so central in survival as hunter-gatherers, such as the strong preference for energy-rich foods, in combination with the altered metabolism described above, produced a vicious cycle of weight gain and worsening insulin-resistance, culminating in obesity and type 2 diabetes (39).

COMPLICATIONS OF TYPE 2 DIABETES

Type 2 diabetes is associated with morbidity and mortality from microvascular and macrovascular disease. The complications associated with diabetes makes it a major public health problem (56). A prospective study of newly diagnosed diabetics found that 29% of patients had diabetes complications by the end of the nine years (57). Retinopathy is the most frequent ophthalmic complication and its development and severity is closely linked with length of time since the onset of diabetes (58). The incidence of diabetes nephropathy among type 2 diabetics appears to be rising (59). Diabetics have an increased risk for cardiovascular disease when compared to the general population (11).

Nephropathy, defined as macroproteinuria (> 550 mg/24 h with a positive reagent strip-test) was found in 13% of type 2 diabetes within 5 years of onset, and 18% after 5 years of diabetes (58). Neuropathy was observed in 17% of newly diagnosed diabetic adults (34). The correlation between duration of diabetes mellitus and neuropathy was found to be significant in type 2 diabetes (58). A retrospective study on 1,000 diabetic patients in a University hospital in Riyadh City compared type 2 diabetes non-obese and obese patients with regard to, among other things, complications of diabetes. The researchers differences in the prevalence of the following complications: neuropathy (32 vs. 47%), retinopathy (29% vs. 44%), nehpropathy (17% vs. 19%), and amputation (3.6% vs. 7.7%) (5).

A significant positive correlation has been established between the duration of diabetes mellitus and macrovascular complications in type 2 diabetes (4.5 ± 0.3 years) (58). Normal blood pressure, low cholesterol and low insulin levels may individually, or in combination, account for the low frequency of atherosclerotic complications in diabetics (60). The majority of type 2 diabetes (71%) had one or more complications. In type 2 diabetes patients with a mean age of 46.5 years, a significant positive correlation was found between duration of diabetes (4 years) and nephropathy, retinopathy, and macrovascular complications, but there was no correlation between duration and neuropathy (58). More recently, the prevalence of macrovascular complications was found to be higher than what was previously reported in Saudi Arabia. In 1992, Famuyiwa et al.

examined the complications of diabetes and established the prevalence of ischemic heart disease and stroke, in type 2 diabetes patients, to be 13.3% and 11.3%, respectively (5).

OBESITY

Obesity can be defined as the status in which the accumulation of fat has occurred to such an extent that the health of the individual is impaired (61). Obesity is usually defined as a body mass index (BMI) of 30 kg/m^2 or higher. Overweight is defined as a BMI between 25 and 29.9 kg/m^2 (62). Accumulation of body fat has many causative factors, including genetic, metabolic, hormonal and behavioral (63).

Obesity is a risk factor for many chronic diseases, including type 2 diabetes mellitus, hypertension, coronary heart disease, and stroke (64). Obesity has been noted as a major public health problem in many developed and developing countries. In Europe obesity is common among men and women, however more obese women were reported in Southern and Eastern European countries, while among men the distribution of obesity is similar in most countries of Europe (65). The prevalence of obesity in adults is 10% to 25% in most countries of Western Europe and 20% to 25 % in some countries in the Americas (66). A total of 7419 Swedish were surveyed in study during the 1980's. A significant increase in the prevalence of overweight and obesity, and a stronger effect of the socio-cultural environment on the body weight were found in women compared to men (67).

In the WHO MONICA study, the average prevalence of obesity among Europeans between 1983 and 1986, was 15% in men and 22% in women. There were great differences within and between countries (68). In the United States, 33 percent of adults are considered obese (69). Approximately 25% of women and 20% of men in America have a BMI of 30 or higher (70). In 34 years, from 1960 until 1994, the U.S. overweight population increased from 37.8% to

39.4% in men and from 23.6% to 24.7% in women (70). Thus obesity and overweight are common public health problem in America.

In developing countries, as the economy expand and grow, the adoption of western lifestyle increases the prevalence of non-communicable disease and obesity among these countries. In very poor communities in developing countries, obesity is usually absent, however, it is found in affluent communities (71). In 1990, about 44% of African women in the Cape Peninsula area of South Africa were considered to be obese (72). However in Sub-Saharan Africa, obesity is found among urban and higher educated women (73). In Jordan, a study on 2836 adults found the prevalence of obesity to be 32.7% in men, 59.8% in females, and 49.7% overall (74). A high prevalence of obesity has been observed among adult females (52.5% overweight, 42% obese) from Kuwait (75). The overall mean BMI was 28.3 in a sample of 3435 adult Kuwaiti and it was higher in women (29.0) than in men (27.5) (76).

In Saudi Arabia, a national study surveyed more than 14,000 adults and reported the highest prevalence of obesity in males living in the Western Province (16.65%) and in the females living in the Central Province (24.40%) (13). A study on college student found that 31.2% were overweight or obese (BMI > 25) (77). A cross-sectional national epidemiological household survey screened more than 13,000 Saudis over the age of 15 years old. The mean BMI for females was found to be higher than for males. The prevalence of overweight among males (29%) was higher than females (27%). However the prevalence of obesity among females (24%) was higher than males (16%) (78). In a cross-sectional study of 1385 Saudi adult females attending 15 health centers in urban and rural areas in the Riyadh region. The mean BMI was 29.2, the prevalence of overweight and obesity was 26.8% and 47%, respectively (15).

DETERMINANTS OF OBESITY

AGE

The Obesity prevalence has been documented to increase with age in many studies. In a longitudinal study in the UK, young schoolchildren were surveyed for 23 years until 1994. The researchers found a significant increase in the triceps skinfold measurement in both males and females (79). In a study in Saudi Arabia on 16 years old and above, the investigators reported a significant increase in BMI with age (80). The obesity rates among adult Saudis were investigated and the highest prevalence of overweight and obesity was found to be among subjects between the age of 40-49 years old (81). Moreover, higher BMI was reported in Kuwaiti middle age subjects (40-49 years) as compared to the younger age groups (30-39 years) (82). In addition, Bahraini men older than 50 years were found to have higher rates of obesity when compared to younger men (83). Obesity was more prevalent in the older age groups in Jordan (74). Furthermore, an Indian study, on 18 to 75 years old subjects, showed an increase of BMI with age reaching a peak at 50 years old (84). In contrast, data from Sweden showed no association between age and obesity. However, the highest rate of obesity, in their ten years study, was found in the 25-34 years old (67,85).

GENDER

Females are more affected by obesity than males (86). The obesity rates for women from Middle East and North Africa (mostly Arab countries) are among the highest in world (87). A study in Riyadh, Saudi Arabia, on age 15 years old and above found that 19.8% of males were either overweight or obese compared with 43.2% of females (88). In a national survey that included more than 13,000 Saudi males and females, they found that the mean BMI for female subjects was significantly higher than for male subjects (78). About 60% of Jordanian females were reported to be obese compared to 33% in males (74). Moreover, European studies show that more women then men were obese (89). Furthermore, a study in Scotland found females to have higher prevalence of obesity (79).

FAMILY HISTORY

A correlation between the risk of obesity and the parent's BMI was reported in an Italian study that included more than 1300 subjects, in addition, the mother's BMI was found to have an effect on the rate of childhood obesity in girls (90). Researchers in Britain suggested that having obese and overweight parents may increase the risk of childhood obesity. In their study on more than 12,000 subjects, the children's BMI was found to be increased as the parent's BMI increased. Most importantly, adult obesity was found to be correlated with parents' obesity (91).

The risk for becoming an obese adult was 2 to 6.5 folds higher for obese children than for non-obese children. Up to 41% of obese preschool children were found to be obese as adult, and up to 63% of obese school-age children were found to be obese as adults (92). In a cohort study of 300,000 Dutchmen exposed to the Dutch famine during the World War II, a higher prevalence of obesity in adults was associated with under nutrition in the first and the second trimester of pregnancy (79).

PHYSICAL ACTIVITY

The increasing prevalence of obesity may be explained by behavioral changes related to a decreasing physical activity (76). Regular exercise has predicted weight reduction and maintenance (93), while eating more and exercising less lead to weight gain (94). Not exercising regularly by the majority of the Saudi population was reported in a Saudi community survey (6). In a study of Saudi women, the results showed that they did not exercise daily and the obese had a poor attitude and little knowledge of the benefits of exercise. The majority of females (83%) either did not exercise at all or exercised irregularly (77). Obesity in Bahraini men, was found to be inversely associated with physical activity at work (95). In Iranian study, the mean BMI was reported to be increased with decreased physical activity level (96).

ETHNICITY

Researchers found the rate of obesity to be much higher among the Pima Native Americans versus the Caucasian Americans (97). In Britain, a study compared the inner city whites to English whites, found the inner city whites to have fatness comparable to the others (98). When African Americans were compared to Nigerians in a study, more African Americans were found to be obese and overweight when compared to the Nigerians. However, body fat distribution patterns based on waist to hip ratio showed no significant differences between the two groups (99).

Although they are economically less developed, obesity rate in females from Eastern Europe and the Middle East was higher than in Western Europe. In addition, higher obesity rate was found among American Indians, Hispanic Americans, and Pacific Islands. The highest rates were found among Melanesians, Microesians, and Polynesians (66).

DIET

Epidemiological studies suggest that high fat diet promoted the development of obesity (100). In protecting against obesity, breast feeding was proven effective, and the protective effect of breast feeding against obesity later in life appeared to rise slightly with the increased duration of breast feeding (92). Dietary changes are occurring rapidly in Saudi Arabia. Western fast food and food item with empty calories are now being consumed in large amounts, and are replacing the fruit and vegetable components of the traditional Arabian diet (77). Higher Socioeconomic status (SES) in Saudi Arabia was associated with several behaviors that contributed importantly to change in dietary intake. A lower fat diet and a higher prevalence of dieting to control weight were observed in the high SES population compared to low SES population (4).

GENETICS

Obesity tends to aggregate in families, and the strength of this aggregation is higher in those with morbid obesity (101). Studies looking at adoptees have demonstrated a correlation between the BMI of the adult adoptees and that of their biological parents, while there was no correlation to that of their adoptive parents (102). Between 25-40% of the obese phenotype has been estimated to be accounted for by genetic heritability (103). Gene linkage studies have identified several loci that may be linked to obesity, but these seem to differ from population to population (104). Other studies on parents and their biologic children, parents and their adopted children, blood-related brothers and sisters, siblings by adoption, and dizygotic and monozygotic twins did not distinguish between the effects of genes shared by descendents and the effects of household and environmental conditions shared by relatives living together (105). The genetic and non-genetic components effect in the BMI phenotype was studied and the researchers suggested that BMI is susceptible to lifestyle and environmental conditions. (106).

Skinfold measurements at various sites of the body can be used to estimate the amount of subcutaneous fat. Studies of skinfold measurements correlations have established that, in each individual skinfold measurement, the correlation to be ranging from 0.15 to 0.25 for parent-child and from 0.20 to 0.40 for siblings. The correlations was the highest for monozygotic twins (0.8 to 0.9) (107,108).

The two general indicators of regional fat distribution was investigated and the distribution of subcutaneous fat in the trunk relative to the limbs exhibited a genetic effect of 25%, while the ratio of subcutaneous fat to fat mass was characterized by a heritability coefficient of about 30% (105). It has been suggested that for a given level of fatness, the size of the abdominal fat varies among individuals, and these variations are significantly influenced by the genotype of the individual (96=105).

COMPLICATIONS OF OBESITY

Obesity can be a precursor for type 2 diabetes, hypertension, and dyslipidemia, coronary heart disease. Obesity is associated with respiratory, musculoskeletal, and gallbladder problems, as well as with certain types of cancer (66). A six year cohort study which included about 50,000 Dutch men and women found that mortality from all causes was significantly related to obesity among men (109). In Hagerstown, Maryland, the height and weight of 13,146 participants were measured between 1933 and 1945. Overweight in school children was established to be associated with adult mortality (110).

As degree of overweight increases, the risk of developing diabetes increases dramatically, even with modest amounts of weight gain after 18 years of age (111). Visceral adiposity increases the risk for hyperinsulinemia and glucose intolerance (112). Obesity has an association with coronary heart disease, through aggravating the risk factors of the coronary heart disease, including hypertension, dyslipidemia, impaired glucose tolerance, and type 2 diabetes mellitus. Obesity also contributes to the development of congestive heart failure through its relationship to systemic hypertension, and in normotensive and hypertensive obese patients, through increases in stroke volume and cardiac output along with diastolic dysfunction (16).

Obesity is a major correlate of sleep apnea in men and women, with those having BMI of at least 30 at the greatest risk. Obesity is believed to change upper-airway geometry through loading of the wall of the pharynx or through increased deposition of periluminal fat (113). Nonalcoholic steatohepatitis (NASH) is more common in persons with obesity and with type 2 diabetes mellitus. Increases in visceral adiposity, free fatty acids, and hyperinsulinemia that occur with obesity are postulated to play a role in pathogenesis of NASH (114). In women, increased body weight is associated with menstrual irregularities. Overweight has been found to be a risk factor for primary ovulatory infertility (115).

An increase in mortality rate is associated with BMI of at least 30. An intentional weight loss in obese individuals reduces risk factors for and improves symptoms of obesity-related conditions, including heart disease, type 2 diabetes mellitus, osteoarthritis, and others (17).

OBESITY AND DIABETES

The association between obesity and type 2 diabetes is not new and has been known for several hundred years. This association has constantly been demonstrated in both cross-sectional (116) and prospective (117) studies. Obesity plays a major role in the etiology of type 2 diabetes, and the Worldwide prevalence of type 2 diabetes continues to rise and is set to reach 180 million in the year 2010 (118). Diabetes occurs in obese persons three times the rate in non-obese (119). Central obesity is associated with the development of type 2 diabetes and cardiovascular disease. Individuals with upper body obesity have been found to be more insulin resistant than other obese individuals and type 2 diabetics often have central or upper body fat distribution (120).

Epidemiologic studies have found associations between obesity and many risk factors for diabetes. These risk factors include total cholesterol, LDL- cholesterol, VLDL-cholesterol, HDL-cholesterol, blood pressure, blood glucose (121). In Framingham the study, changes in weight were compared with changes in cholesterol, blood pressure, and blood glucose. Weight gain was significantly correlated with harmful changes in each of the variables studied in both men and women (122). In the Framingham offspring Study, weight gain was associated with elevated total, LDL and VLDL cholesterol as well as with depressed HDL cholesterol. All of these results were established in both men and women (123).

The main actions of insulin are involved in the regulation of carbohydrate, protein and lipid metabolism. In the liver, insulin inhibits gluconeogenesis and glycogen breakdown, as well as increasing glycogen storage. In the peripheral tissues, insulin acts on both skeletal muscle and fat (124). Obesity and type 2 diabetes frequently share the syndrome of insulin resistance. Obese individuals and majority of type 2 diabetics have insulin resistance. Obesity and diabetes share the characteristic of insulin resistance, but the presence hyperglycemia is also seen in diabetes. Furthermore, the concepts of insulin secretion and insulin resistance are of importance in the pathogenesis of type 2 diabetes (125).

In Pima Indians, Nauruans, and Mexican Americans, hyperinsulinemia an accepted marker for insulin resistance, is a strong predictor of the development of diabetes (126). Caucasian subjects with a positive family history of type 2 diabetes have been reported to be insulin resistant (127). Similar evidence has been found in Mexican Americans (128).

In obese subjects, the non-esterified fatty acids (NEFA) level is elevated, and in type 2 diabetic patients there is both hyperglycaemia and elevated NEFA levels. Raised NEFA levels impair glucose metabolism by reducing insulin-stimulated glucose uptake, particularly in skeletal muscle (129). In normal individuals, NEFAs stimulate insulin production. However, obese individuals may be predisposed to type 2 diabetes and the stimulation of insulin by NEFAs would eventually fail (130).

Circulating NEFA can potentially increase liver glucose output and impair glucose removal by a substrate competition mechanism in peripheral tissues which might be causing and sustaining peripheral (skeletal muscle) insulin resistance in obesity. This mechanism has a minor role, if any, in mediating the metabolic imbalance that characterizes overt diabetes (125). Substrate competition has been postulated to play a significant part in the passage from normal glucose tolerance to type 2 diabetes. As NEFA oxidation increased, it is paralleled by impairment in insulin-mediated inhibition of hepatic glucose production. As glucose tolerance worsens, a parallel deterioration of hepatic insulin sensitivity and increase in fatty acid oxidation should take place (125).

Type 2 diabetics have a specific defect in the ability of the B-cells to respond to glucose. Obese type 2 diabetics, when compared with obese individuals, are characterizes by a decrease in glucose-stimulated insulin secretion, an increase in hepatic glucose production, and a decrease in insulin-mediated glucose uptake (125). The pathogenic pathway leading to hyperglycemia in obese diabetic individuals can be described as the induction of hyperglycemia by impaired insulin secretion and insulin sensitivity. Decreased insulin secretion causes increased fatty acids output, which is normally regulated by insulin. Increased fatty acid levels decrease glucose utilization and stimulate glucose production. Both effects would result in greater hyperglycemia (125).

CHAPTER 3

UNDIAGNOSED DIABETICS: ARE THEY DIFFERENT FROM DIAGNOSED DIABETICS IN THE ADULT SAUDI POPULATION?

INTRODUCTION

Type 2 diabetes is a complex metabolic disorder characterized by alterations in carbohydrate, lipid and protein metabolism, resulting from an imbalance between insulin sensitivity and insulin secretion (21). Globally, type 2 diabetes outnumbers all other types of diabetes and it is far more prevalent than type 1 diabetes. Type 2 diabetes constitutes about 85% of all cases of diabetes in developed countries (131). In certain groups, such as some Native American tribes and populations in the South Pacific, type 2 diabetes is the only form of diabetes (132). The prevalence of type 2 diabetes varies greatly among populations. The highest reported prevalence is among Pima Native Americans of Arizona (132). However, other Native American groups, such as Eskimos, have a lower prevalence of type 2 diabetes (132). The prevalence among Europeans and US non-Hispanic white adults range from 3 to 10%, while a higher prevalence (11-20%) is reported among Arabs, Asian Indians, and US Hispanics (23).

Type 2 diabetes is emerging as a leading chronic non-communicable disease among adult Saudis. In Saudi Arabia, the overall prevalence of diabetes in the early 1990's was reported to be between 4.6% and 6.5% (26,27), with 88% of those cases being type 2 diabetes (6). Among the previously recognized correlates of type 2 diabetes in Saudi Arabia are age (26), family history (35), and obesity (25,27). Major sociodemographic changes have occurred in Saudi Arabia. The transition to greater economic affluence has been associated with changes in physical activity and dietary patterns. These trends have promoted the development of diabetes and other non-communicable diseases (4).

Undiagnosed diabetes as a public health problem is increasingly recognized both in the developed and developing world (133,134,135). In the United States among adults 20 years and above, the prevalence of undiagnosed diabetes was 2.7% compared to 5.1% for the diagnosed diabetics (133). A study in Manitoba Canada established the prevalence of undiagnosed diabetes to be 2.2% in adult population 18-74 years old (134). In a cross sectional study in Egypt, 4% of the population 20 years and older was determined to be undiagnosed diabetics (135). However, in Saudi Arabia there has been no emphasis on establishing the prevalence of undiagnosed diabetes, which will be undertaken in this study.

This study will report the prevalence of diabetes and undiagnosed diabetes (individuals with high fasting blood glucose level but no prior diagnosis of diabetes) and how these groups differ in the contributing risk factors. The purpose of this study is to highlight the problem of diabetes among adult Saudis and describe the potential of undiagnosed diabetes.

MATERIALS AND METHODS

OVERVIEW

The data used in this study were collected as a part of a national survey to determine the prevalence of chronic diseases and its related risk factors in the Saudi population. The survey targeted Saudis age 15 years and older living in Saudi Arabia. The survey defined a Saudi as a person either holding a Saudi Nationality Identification Card or a dependent of a holder. Age was calculated from the official date of birth on the Identification Card.

The survey population was drawn from the thirteen administrative regions of Saudi Arabia with the sample size selected to be proportional to the size of the population in each administrative region, taking into consideration the urban to rural ratio. The final survey sample would then reflect a random sample from age and gender groups of the total population and the population of each region.

Multistage stratified cluster sampling was used by the survey team to select the survey sample. Urban and rural localities were selected randomly in each administrative region and the primary health care centers (PHCCs) were randomly selected within each locality. In each of the selected centers, the family health registry was used to select and recruit a random sample of Saudi females and males ages 15 years and older.

This current study uses data collected from three administrative regions during the early 1990s. These regions represent the most heavily populated regions in Saudi Arabia that include about 60% of the total population according to the national population census of 1992.

DATA COLLECTION

In each participating PHCC, a physician was appointed as the supervisor of the field research team. The supervisor or an assistant contacted the randomly identified eligible subjects. All personnel received training in the conduct of interviews, completion of questionnaires, specimen collection, and handling and transport of blood samples.

Eligible subjects were contacted directly while at the PHCC or by telephone for recruitment into the study and to schedule an appointment for an interview, clinical examination and laboratory tests. Every effort was made to encourage participation. In case of non-availability or lack of response, another person from the same PHCC age and sex cluster was randomly selected. Medical records at the PHCC were used to verify self reported diagnosis, complete missing demographic or past clinical data and supplied the research team with the address and telephone number of the household.

Interviews were all completed either at the participant's home or at the PHCC by trained clinic staff. However, clinical examination and blood samples collection were conducted at the

PHCC. The standardized survey questionnaire sought information on demographic data, medical history, level of usual physical activity, and dietary and social habits. Fasting blood samples were obtained for glucose (FBG), total cholesterol (TC), high-density lipoproteins cholesterol (HDL) and, triglycerides (TG) analyses. The questionnaire was pre-tested in a pilot study for clarity and wording and the necessary changes were made. The study protocol was approved by the general directorate of primary health care centers. All study population gave their approval and consent to be included in the study.

LABORATORY METHODS AND QUALITY CONTROL

Overnight fasting blood samples were collected at the PHCC and refrigerated for at least 30 minutes, but no more than 4 hours, before being centrifuged at 4°C for 30 minutes at 2000-3000 rpm. Immediately after separation, samples were frozen at -20°C, until analysis. At the end of sample collection, samples were transported in batches representing each PHCC to the survey clinical laboratory at Riyadh City, where the analyses were performed immediately.

Samples were analyzed for glucose, TC, HDL, and TG using automated analyzer (KONE Instruments, Helsinki, Finland). The analyzer was calibrated by two separate calibrators (low and high values) supplied by the manufacture of the instruments. Normal and abnormal control sera, supplied by the manufacturer, were included in each analytical run for each parameter. Random serum samples were also sent for analysis to two well-recognized laboratories in Riyadh City, Saudi Arabia. Results between laboratories were close (95-98%) to the survey laboratory results for all analyses.

Glucose level was determined by a glucose oxidase method, which uses glucose oxidase and a modified color reaction, catalyzed by the enzyme peroxidase (136). The formed hydrogen peroxide was determined colorimetrically. The intra-and inter assay coefficients of variation were 1.1% and 0.8% at the level of 5.6 ± 0.55 mmol glucose/L. Total cholesterol was measured after the hydrolysis of cholesteryl esters by an esterase to cholesterol and fatty acids (137). Cholesterol was then oxidized by cholesterol oxidase and the formed hydrogen peroxide was determined colorimetrically. The intra-and inter assay coefficients of variation were 1.9% and 1.1% at the level of 5.6±1.3 mmol cholesterol/L. HDL-cholesterol levels were measured after precipitation of low-density lipoproteins (VLDL and LDL) (138) and after centrifugation: the HDL-cholesterol fraction was determined in the clear supernatant. The intra-and inter assay coefficients of variation were 0.35% and 0.21% at the level of 1.3±0.21 mmol HDL cholesterol/L. Triglycerides level was determined after enzymatic hydrolysis with lipases to give glycerol and fatty acids (138 ,139). The intra-and inter assay coefficients of variation were 0.45% and 0.32% at a level of 1.9±0.62 mmol triglycerides/L.

CLASSIFICATION OF DIABETES

Diabetes was classified by both medical history and the current FBG test. Self-reported diagnosis was verified by review of the PHCC medical records. The American Dietetic Association (ADA) and World Health Organization (WHO) adopted the level of fasting blood glucose (FBG) ≥ 7 mmol/L to diagnose new diabetics (140,141). However, both ADA and WHO required a confirmatory test, which was not possible for this cross-sectional study. In this present study, FBG ≥ 7 mmol/L from a single fasting blood glucose test was used to define undiagnosed "new" diabetics, as it was done in a previous study (142). Diabetes status of this study population was categorized into four groups: non-diabetics (no prior history of diabetes and FBG < 7 mmol/L), controlled diabetics (prior history of diabetes and FBG < 7 mmol/L), uncontrolled diabetics (prior history of diabetes and FBG ≥ 7 mmol/L), and undiagnosed diabetics (no prior history of diabetes and FBG ≥ 7 mmol/L).

PHYSICAL MEASUREMENTS

All physical measurements were taken with the participant wearing light clothing, standing relaxed but still, looking straight ahead, with arms at the sides, feet together, and with weight equally distributed over both legs. Weight measurements were made to the nearest 0.1kg (143). The weighing scale was zeroed before and after every measurement and standardized with a certified weight every day before data collection. Weight measurements were taken using the Clinical Detecto Balance-Beam scale (Detecto scale Inc., Brooklyn, NY). Height was measured by a stadiometer attached to the weighing scale and participant was barefooted. The horizontal rod was lowered slowly until it touched the participant hair without pressing the crown of the head too hard. Measurements were made to the nearest 0.1cm (143).

Body mass index (BMI) was used as an index of adiposity and was calculated by dividing weight (in kg) by height (in meters squared). Subjects were categorized as normal weight (BMI < 25), overweight (BMI ≥25, BMI < 30), or obese (BMI ≥ 30) (17). Circumferences were measured, in similar conditions as weight and height, to the nearest 0.1cm (143), and a standard measuring tape was used. Waist circumference was measured by first locating and marking of the lowest rib margin, then palpating and marking the iliac crests in the midaxillary line. A plastic tape was applied horizontally midway between the two marked points, and held firmly about the level of the umbilicus and the reading was taken (143). Blood pressure was measured using an automatic sphygmomanometer while the participant was sitting and the mean of three measurements was calculated and recorded.

OTHER RISK FACTORS

Most sociodemographic variables were categorized. For analysis, age was categorized into four groups (30-39, 40-49, 50-59, and 60-70). Martial status was grouped into currently married and not married which included single, divorced, and widowed. Education levels were defined as illiterate (a person who did not complete any form of education and did not read or write), primary education only (persons with less than high school education or person who could read and write but without a formal education), high school education only, and college educated and above (persons with at least some college or university education). Income was categorized as low ($\leq$ 16,000 $US/yr), middle (>16,000 $US/yr and < 32,000 $US/yr), or high ($\geq$ 32,000 $US/yr). The survey participants' residence was categorized as urban or rural according to the official regional categorization.

Usual physical activity levels were categorized into inactive or active based on response to the question of how frequent do you exercise. An inactive individual either did not report any exercising or exercising $\leq$3 times a month. Smoking status was categorized as never smoked, former smoker, and current smoker. A positive family history of diabetes was defined if the individual stated that they had at least one parent or a sibling with diabetes. A person was classified as hypertensive if there was a pervious diagnosis of hypertension (verified by medical record) or the measurement of systolic/diastolic blood pressure was $\geq$ 160/95 (144).

STATISTICAL ANALYSIS

Data were analyzed using Stata 5.0 package (Stata, College Station, TX). Edit checks were used to identify presence of outlying and potentially erroneous observations. Descriptive analyses were performed including calculation of the frequency, mean, median, variance, skewness and ranges for all variables. Variables were checked for normality and there was no need to transform any variable. Pearson Correlation was performed to compare association between two variables. Chi-square was used to test for differences between categorical variables.

One-way analysis of variance (ANOVA) was used to test the significance between the means for more than two groups. Multiple linear regression was used to evaluate the association between fasting blood glucose (FBG) and the potential risk factors. Multiple logistic regression was used to evaluate the independent effect of the optional risk factors for the presence of an elevated FBG ($\geq$ 7 mmol/L).

RESULTS

The study population consisted of 3271 persons, 50.5% females and 49.5% males. A total of 24 females and 24 males did not provide blood samples for analysis. Table 1 shows the general characteristics of the population by gender. More females (75%) than males (60%) were between 30 and 49 years of age, while more men (40%) were between ages 50-70 years old than women (25%). The majority of the population was married and more males (97.71%) than females (84.84%) were currently married. Illiteracy was significantly more common in females (63.06%) than males (25.62%).

The prevalence of diagnosed type 2 diabetes as determined by survey was 16.48% overall, with the frequency slightly higher in males (18.56%) as compared to females (14.43%). However, within the population there were an additional 369 individuals (11.45%) of the total population, who had no previous diagnosis of diabetes but who had FBG $\geq$ 7 mmol/l (undiagnosed diabetics). Using a combined definition for type 2 diabetes of prior diagnosis or a single test of FBG $\geq$ 7 mmol/l, the prevalence of diabetes could be 25.31% of females, 30.60% of males, and 27.93% overall.

Table 2 shows characteristics of the population by various categories of diabetes. Diagnosed diabetics are subcategorized by level of FBG. In this population, only 21.65% of the diagnosed diabetics had controlled serum glucose levels of FBG < 7 mmol/l. Furthermore, 14% of people with no history of diabetes were undiagnosed as diabetics. Men were 56% of the diagnosed diabetics, 56% of the diabetics with uncontrolled FBG and 52% of the undiagnosed diabetics. Age was related to diabetic status, with non-diabetics as the youngest group, and the

Table 1. General characteristics of the population by gender.

	Number of subjects	Females (%) n = 1652	Males (%) n = 1619
Age			
30-39	1257	45.70	31.01
40-49	947	29.36	28.54
50-59	655	16.46	23.66
60-70	412	8.47	16.80
Martial Status			
Married	2981	84.84	97.71
Others	287	15.16	2.29
Education			
Illiterate	1451	63.06	25.62
Primary	1090	26.18	40.88
High School	418	6.44	19.35
College and above	299	4.31	14.14
Income			
Low	1797	57.97	52.32
Middle	1163	33.82	37.63
High	297	8.21	10.04
Residence			
Urban	2706	83.60	81.84
Rural	565	16.40	18.16
Prior diagnosis of DM			
FBG < 7 mmol/l	115	3.13	4.01
FBG $\geq$ 7 mmol/l	416	11.30	14.55
No Prior diagnosis of DM			
FBG < 7 mmol/l	2323	74.69	69.40
FBG $\geq$ 7 mmol/l	369	10.87	12.04

Table 2. Characteristics of the study population by diabetes status.

	Non-Diabetic[1]	Diagnosed Diabetic		Undiagnosed diabetics[2,**]	P
		Controlled FBG[1,*]	Uncontrolled FBG[2]		
	n = 2323	n = 115	n = 416	n = 369	
Age, mean ±SD	42.70±10.14	50.80±10.54	51.60±9.29	46.85±10.54	0.001
Gender F, (n, %)	1216 (52.35)	51 (44.35)	184 (44.23)	177 (47.97)	0.010
Education (n, %)					
Illiterate	983 (42.44)	52 (45.22)	216 (52.30)	176 (48.09)	
Primary	790 (34.11)	45 (39.13)	125 (30.27)	117 (31.97)	
High school	317 (13.69)	12 (10.43)	41 (09.93)	38 (10.38)	
College and above	226 (09.76)	6 (05.22)	31 (07.51)	35 (09.56)	0.010
Income (n, %)					
Low	1255 (54.28)	63 (54.78)	241 (58.07)	213 (58.04)	
Middle	840 (36.33)	43 (37.39)	134 (32.29)	126 (34.33)	
High	217 (09.39)	9 (07.83)	40 (09.64)	28 (07.63)	0.600
Physical Activity (n, %)					
Inactive	1377 (59.28)	67 (58.26)	246 (59.13)	222 (60.16)	
Once or more/week	946 (40.72)	48 (41.74)	170 (40.87)	147 (39.84)	0.990
Smoking status					
Never	1722 (81.42)	82 (83.67)	296 (76.88)	261 (77.45)	
Former	168 (07.94)	10 (10.20)	54 (14.03)	31 (09.20)	
Current	225 (10.64)	6 (06.12)	35 (09.09)	45 (13.35)	0.010
Parent/Sibling DM history (n, %)	836 (35.99)	60 (52.17)	247 (59.38)	137 (37.13)	0.001
Hypertension (n, %)	281 (12.10)	32 (27.83)	107 (25.72)	65 (17.62)	0.001
Body Mass Index[***]					
Normal weight (≤25)	575 (24.83)	26 (22.81)	88 (21.15)	72 (19.62)	
Over weight (>25 and <30)	854 (36.87)	47 (41.23)	154 (37.02)	123 (33.51)	
Obese (≥ 30)	887 (38.30)	41 (35.96)	174 (41.83)	172 (46.87)	0.040

1 = (FBG < 7 mmol/l). 2 = (FBG ≥ 7 mmol/l).

[*] FBG (Fasting Blood Glucose level). [**] Do not have a diagnosis of diabetes but have FBG ≥ 7 mmol/l.

[***] Body Mass Index (weight in Kg/Height in meter^2).

"uncontrolled" diabetics being an older group ($P < 0.001$). Diagnosed diabetes and undiagnosed diabetes were more common among men, the less educated people (< high school), and lower income groups.

Regular exercise (defined as participating in an activity at least once per week) was not common in this population. Overall, about 60% reported themselves as inactive and there were no differences between the diabetic categories. Smoking was most common among undiagnosed diabetes, which was followed by diabetics with uncontrolled FBG. Furthermore, a higher proportion of people who never smoked were diabetics with controlled FBG, and was followed by non diabetics.

Family history of diabetes was common with 52-59% of the diagnosed diabetics reported a sibling or a parent with diabetes. Prevalence of hypertension was much higher among diabetics both with controlled and uncontrolled FBG. Furthermore, the prevalence of hypertension in undiagnosed diabetics was higher than among non-diabetics (17.6% verses 12%). Among the total population, 40% were obese and 37% were overweight. In addition, the prevalence of obesity was the highest among undiagnosed diabetics.

Table 3 describes biochemical and anthropometric characteristics. The two groups, undiagnosed diabetics and diabetics with uncontrolled FBG had significantly higher mean serum FBG, total cholesterol and triglycerides levels and BMI as compared to the other two groups (non-diabetic and controlled diabetes). The non-diabetic group had the best anthropomentric measurements and blood biochemistry parameters in the study. Mean HDL-cholesterol levels, although not significant, were the lowest in undiagnosed diabetics then diabetics with uncontrolled FBG. Undiagnosed diabetics had the highest BMI mean. Mean waist circumference for men was the largest in undiagnosed diabetics, while for female it was the diabetgics with uncontrolled FBG level.

Table 3. Biochemical and anthropometric profile (mean ±SD) of the population by diabetic status.

	Non-Diabetic	Diagnosed Diabetic		Undiagnosed diabetics	P[1]
		Controlled FBG	Uncontrolled FBG		
Glucose[2] mmol/L	5.23 (± 00.90)	5.61 (± 00.98)	12.67 (± 04.37)[A]	9.44 (± 03.15)[A]	0.001
Total Cholesterol[2] mmol/L	5.22 (± 01.38)	5.33 (± 01.55)	6.03 (± 01.66)[A]	6.38 (± 01.92)[A]	0.001
Triglycerides[2] mmol/L	1.65 (± 01.05)	1.88 (± 01.09)	2.39 (± 01.37)[B]	2.38 (± 01.43)[B]	0.001
HDL-Cholesterol[2] mmol/L	1.13 (± 00.39)	1.13 (± 00.38)	1.12 (± 00.41)	1.10 (± 00.37)	0.480
BMI[3]	28.88 (± 05.72)	29.24 (± 05.25)	29.64 (± 05.67)	30.18 (± 06.30)	0.001
Waist circumference (cm)					
Females	89.07 (± 12.12)[A]	94.56 (± 11.74)	94.90 (± 10.68)	93.02 (± 12.66)	0.001
Males	94.97 (± 13.19)	96.20 (± 13.01)	98.07 (± 12.35)	98.22 (± 12.87)	0.001

[1] p value of F statistics from ANOVA.
[2] Fasting serum.
[3] Body Mass Index (weight in kg/height in meter^2)
[A] *Significantly different from all of the other three groups.*
[B] Significantly different from non-diabetics and diabetics with controlled FBG level.

Table 4 shows the multivariate relationship associated with fasting blood glucose (FBG) level among individuals with no prior diagnosis or history of diabetes. Multiple linear regression was used with FBG as continuous dependent variable. The independent variables included in the models were significantly related to FBG in separate univariate analysis. This model shows a significant positive association between FBG levels and increasing age, fasting serum total cholesterol and triglycerides.

Table 5 shows the results of a multiple logistic regression analysis to determine factors associated with having an elevated fasting blood glucose level (FBG $\geq$ 7 mmol/l). The first model is for individuals with no prior history or diagnosis of diabetes (predicting undiagnosed diabetes) and the second model is for individuals with previous diagnosis of diabetes (predicting uncontrolled diabetes).

In the population without a prior history of diabetes, age, gender, and fasting cholesterol and triglycerides were all independently related to the elevated FBG. People with elevated FBG (undiagnosed diabetics) were 3% more likely to be older, 31% less likely to be female (OR = 0.69), 40% more likely to have higher fasting serum cholesterol (OR = 1.4), and 29% more likely to have higher fasting serum triglycerides (OR = 1.29). In the population with prior history of diabetes, although higher fasting serum cholesterol and smoking were the closest to be significant, none of the variables showed a significant independent relation with elevated FBG.

Table 6 displays factors associated with being undiagnosed diabetic (no prior history of diabetes and FBG $\geq$ 7 mmol/l) using multiple logistic regression analysis. Undiagnosed diabetics were 6% less likely to be older and almost 72% less likely to have a sibling or a parent with a history of diabetes (OR = 0.28). However, they were 21% more likely to have higher fasting serum cholesterol compared to diagnosed diabetics (OR = 1.21).

Table 4. Factors associated with FBG level among persons without a self-reported history of diabetes.

Variable	No history of diabetes Coefficient	P
Age (years)	0.02	0.001
Gender	- 0.13	0.120
Cholesterol*	0.30	0.001
Triglycerides*	0.27	0.001
Family history of DM	0.04	0.540
Waist circumference	0.005	0.060
Hypertension	0.07	0.530
Smoking	0.008	0.900
Cons	2.34	0.000

* Fasting serum.

Table 5. Factors associated with having an elevated fasting blood glucose stratified by self-reported history of diabetes.

	No history of diabetes FBG ≥ 7 mmol/l		Self-reported history of diabetics FBG ≥ 7 mmol/l	
Variable	OR(1)	95% C.I.	OR(2)	95% C.I.
Age	1.03	1.02, 1.04	1.01	0.98, 1.03
Gender	0.69	0.52, 0.93	0.71	0.42, 1.22
Cholesterol*	1.40	1.29, 1.52	1.20	1.00, 1.44
Triglycerides*	1.29	1.16, 1.44	1.26	0.98, 1.62
Family history of DM	1.00	0.77, 1.30	1.44	0.86, 2.39
Waist circumference	1.01	1.00, 1.02	1.00	0.98, 1.02
Hypertension	1.15	0.82, 1.63	0.79	0.46, 1.40
Smoking	1.17	0.96, 1.43	1.66	1.00, 2.76

OR(1) 0 = FBG < 7 mmol/l, 1 = FBG ≥ 7 mmol/l. OR(2) 0 = FBG < 7 mmol/l, 1 = FBG ≥ 7 mmol/l.
* Fasting serum.

Table 6. Factors associated with being undiagnosed diabetic compared to self-reported history of diabetes.

Variable	Odds Ratio*	95% C.I.
Age	0.94	0.92, 0.95
Gender	1.01	0.71, 1.43
Cholesterol**	1.21	1.10, 1.34
Triglycerides**	0.90	0.79, 1.03
Family history of DM	0.28	0.20, 0.39
Waist circumference	0.99	0.98, 1.01
Hypertension	0.90	0.61, 1.34
Smoking	1.24	0.96, 1.60

* 1 = Undiagnosed diabetic, 0 = diagnosed diabetic

** Fasting serum.

DISCUSSION

In this study we present data about the prevalence of type 2 diabetes and its associated factors in Saudi Arabia. The prevalence of type 2 diabetes varies greatly between populations. In Europeans and US non-Hispanic whites, the prevalence varies from 3 to 10%. However, higher prevalence estimates (11-20%) are seen in Arabian, Asian Indian, and US Hispanic groups. Furthermore, extremely high prevalence estimates have been observed in special cases like Micronesian Naruans and Pima Native American (-40%) (23).

In Saudi Arabia, the prevalence and risk factors for type 2 diabetes are major health concerns. Twenty years ago, the prevalence of diabetes mellitus among adult Saudis (above the age of 30 years old) was estimated at 5.4% (9). Our data suggest that the prevalence of type 2 diabetes has potentially increased to 27.9% (16.5% diagnosed diabetics and 11.5% undiagnosed diabetics). This increase in the prevalence of diabetes has been attributed partly to changes in lifestyle, food habits, and standard of living (4). Similar increases in diabetes prevalence are found in neighboring Gulf countries. A study in Kuwait reported a prevalence of 18.3% diagnosed type 2 diabetes in the population between the age of 40-60 years old (145). In addition, a higher prevalence estimate of 30% was reported in adult Bahraini between the age of 40-70 years old (95).

Undiagnosed diabetes comprises a substantial portion of the prevalence of diabetes both in the first and third world countries (133, 134,135). In adults Americans, 20 years and above, 34.6% of the total diabetic population were undiagnosed diabetics (133). In Canada, undiagnosed diabetics accounted for one third of the adult diabetics population (aged 18-74 years) (133,134). However, in Egypt they were 42% of the total diabetic population that were 20 years and older (135). In our study population (30-70 years old), we found that 41% of the diabetics population was identified as undiagnosed diabetics, which is similar to the findings in Egypt.

Age has been associated with type 2 diabetes in many studies (23,145,95,146,147). Likewise, the oldest age group (60-70 years) in our population, had higher prevalence compared to the youngest age group (30-40 years) and age was significantly related to FBG level among those without a diagnosis of diabetes. Similarly, age was significantly associated with higher prevalence type 2 diabetes in Gulf countries (145,95,146,147).

The relative frequency of type 2 diabetes by gender varied between populations. In the USA, there was a higher prevalence of type 2 diabetes in females than in males (132), while India reported a greater prevalence among men (132). Studies in Saudi Arabia and other Arab countries also varied. Some of the studies found that females had a higher prevalence of diabetes (29 ,25), while others found the opposite (30,8,6). In this current study, there was a higher overall prevalence of diabetes among adult males (30.60%) compared to (25.30%) females. Furthermore, in our study, the prevalence of diabetes was significantly higher in males of the under 40 years old group. However, there is a trend for the females to have a higher prevalence, although not significant, in the age group of 40 years and older. Some studies in other Arab countries reported higher prevalence in females (95,135), while others concluded the opposite (148), and the rest found no association between gender and the prevalence of diabetes (145,147).

The differences in the gender ratio of diabetes in different societies may be explained by differences in the frequency of obesity and physical activity among the sexes in the different culture (28). Physical activity is known to influence glucose metabolism and insulin levels (36). Previous studies showed moderate physical activity was associated with reduced risk for type 2 diabetes (37). In Saudi Arabia, the general consensus is that levels of physical activity are low due to the harsh climate and sedentary life style (8,6). One study showed, however, physical activity was associated with lower prevalence of diabetes in Saudi Arabian men (27). In a neighboring country, sedentary lifestyle and physical inactivity were the predominant behavior associated with type 2 diabeteic patients (145). In this study, the majority (60%) of the participants, regardless of their FBG level did not practice any regular exercise, and of those who did, only a very small percentage (1.5%) reported regular vigorous exercise. With this low level of physical activity, it is perhaps not surprising that no relationship was seen between physical activity and diabetes or FBG level.

The relation between smoking and diabetes is a controversial one. Some earlier researchers found no association between the development of type 2 diabetes and smoking (149). Others have suggested that cigarette smoking might be an independent, modifiable risk factor for type 2 diabetes (150). Most recently, smoking was found to be independently associated with diabetes after adjustment for age, body mass index, alcohol, and family history of diabetes (151). Our data show a significant association between smoking and diabetes status. We found a greater proportion of current smokers in the undiagnosed diabetics and non-diabetic groups.

Type 2 diabetes has long been recognized to demonstrated familial aggregation. The incidence and prevalence of type 2 diabetes in first-degree relatives of subjects with type 2 diabetes are appreciably greater than in the general population (31). One study in France, reported that almost 60% of diabetics had at least one first-degree diabetic relative (33). Similarly, another study in Saudi Arabia reported about 70% of Saudi diabetics had a family history of diabetes (35). Prior studies in the Gulf region, reported a significant association between family history of diabetes and having diabetes (95,145).

In this current survey, we show a strong association between family history of diabetes and diabetes of the subjects. Fifty-five percent of the diabetics (diagnosed and undiagnosed) and 55% of those with elevated fasting blood glucose level ($\geq$ 7 mmol/l) had a relative with diabetes. Furthermore, these associations independently predicted FBG levels among those with a history of diabetes. Persons with elevated FBG were 57% more likely to report family history of diabetes.

An association between obesity and type 2 diabetes has also been observed, with type 2 diabetes reported more frequently among obese persons (28). In a 12-year follow-up study, BMI was found to be the dominant risk factor for diabetes incidence in men and predicted diabetes in a dose-response relation for both sexes (42). The role of waist size on the risk of type 2 diabetes was studied in a survey of African men and women from the US, Jamaica and Nigeria. This survey reported an elevated risk of type 2 diabetes among those in the highest quartile of waist circumference compared to those in the lowest quartile (152).

Obesity was common among Saudi diabetics (9,29,27). One study reported that 65% of the diabetics were overweight or obese (9). Moreover, obesity was more common in female diabetics (73%) compared to male diabetics (49%) (27). In our study, over 80% of the diabetic subjects (diagnosed and undiagnosed) were either overweight or obese (BMI >25). In addition, waist circumference was associated with high FBG compared to WHR. Moreover, diabetes studies from Arab countries reported that diabetics had higher body weight and BMI (145, 148, 135) as well as larger waist girth than non-diabetics (95).

A previous study demonstrated no difference in the prevalence of hypercholesterolaemia between type 2 diabetes and non-diabetic subjects, while the prevalence of hypertriglyceridaemia and of low HDL-cholesterol among diabetics was about double that of the normal group (153). In Saudi Arabia, the absence of hyperlipidemia was considered an explanatory factor for the lower incidence of macrovascular complications in diabetics (5). Moreover, total cholesterol was not found to be high in another study on diabetics (58). In our study, about 70% of the diabetics (diagnosed and undiagnosed) had high cholesterol (≥ 5.2 mmol/l) and 26% had high triglycerides (≥ 2.8 mmol/l).

Findings from the present study suggest that high blood glucose levels are associated with higher blood levels of cholesterol and triglycerides. Our data are in agreement with findings from other studies, which demonstrated that higher levels of cholesterol and triglycerides were strongly associated with type 2 diabetes (145,95,146).

Diabetes and hypertension are interrelated disorders that strongly predispose people to atherosclerotic cardiovascular disease. High blood pressure is about twice as frequent in individuals with diabetes as in those without diabetes (154). Surveyed Saudi type 2 diabetics had a normal average (128/75) blood pressure (58). Our data showed that hypertension was significantly associated with type 2 diabetes, where hypertension prevalence was found to be more than doubled in diagnosed diabetics compared to normal subjects. Similar data were reported from many Gulf countries (145,95,148).

In this current study, undiagnosed diabetics were found to have high rates of obesity, unfavorable lipid profile and hypertension. Undiagnosed diabetes in Canada was found to be associated with a higher prevalence of obesity, unfavorable lipid profile and hypertension (134). Similar findings were observed in American undiagnosed diabetics (155). Furthermore, obesity was the highest among Egyptian undiagnosed diabetics followed by diagnosed diabetics (135).

Our data suggest that there is substantial under diagnosis of diabetes and that a huge proportion of the population may have to deal with this problem. A probable diabetic may have no prior history of diabetes but would have higher levels of total cholesterol and triglycerides and would be older. When compared to non-diabetic population, there is closer resemblance between undiagnosed diabetics and diagnosed diabetics in age, gender, education, blood lipids, and obesity.

Our data imply that there is a great need to train Saudi diabetic educators and health care providers. More emphasis needs to be placed on identification and treatment of diabetes. There is an urgent need for a national diabetes control and prevention plan that would include diabetes public awareness campaigns. The campaigns must provide knowledge to diabetics for the control of their diabetes, and for non-diabetics to take preventive actions before the problem extravagate and become uncontrollable health problem with enormous human and monetary costs.

CHAPTER 4

PREVALENCE AND RISK FACTORS OF OBESITY AND OVERWEIGHT IN ADULT SAUDI POPULATION.

INTRODUCTION

The epidemic of obesity is becoming a global health problem seen in most parts of the world as populations adopt sedentary lifestyles and increase their per capita caloric intake (156.67 .85). Obesity itself is a risk factor for many chronic diseases, including hypertension, type 2 diabetes mellitus, coronary heart disease, and stroke (64). Obesity is usually defined as a Body Mass Index (BMI) of 30 kg/m^2 or higher, and overweight is defined as a BMI between 25 and 29.9 kg/m^2 (62). Accumulation of body fat leads to being overweight or obese, which has many causative factors, including genetic, metabolic, hormonal and behavioral (63).

Obesity has been noted as a major public health problem in many Arab countries (76,148, 83,72). Many non-Arab developing countries also reported increased level of obesity in their population (157). Although studies in Saudi Arabia reported high rates of overweight and obesity (15,81,78,80), more information is needed. In order to develop appropriate prevention strategies, we must understand the factors related to the increasing levels of overweight and obesity as will as their implications. This study will examine risk factors of obesity and overweight among adult Saudis using data from three of the largest regions of Saudi Arabia.

MATERIALS AND METHODS

OVERVIEW

The data used in this study were collected as a part of a national survey to determine the prevalence of chronic diseases and its related risk factors in the adult Saudi population. The survey targeted Saudis age 15 years and older residing in Saudi Arabia. The survey defined a Saudi as a person either holding a Saudi Nationality Identification Card or a dependent of a holder. Age was calculated from the official date of birth on the Identification Card.

The survey population was drawn from the thirteen administrative regions of Saudi Arabia with the sample size selected to be proportionate to the size of the population in each administrative region, and adjusted for the urban to rural ratio. The final survey sample would then reflect a random sample from age and gender groups of the total population and the population of each region.

Multistage stratified cluster sampling was used by the survey team to select the survey sample. Urban and rural localities were selected randomly in each administrative region and the primary health care centers (PHCCs) randomly selected within each locality. In each of the selected centers, the family health registry was used to select and recruit a random sample of Saudi females and males age 15 years and older.

This current study uses data collected from three administrative regions during the early 1990s. These regions represent the most heavily populated regions in Saudi Arabia that include about 60% of the total population according to the national population census of 1992.

DATA COLLECTION

In each participating PHCC, a physician was appointed as the supervisor of the field research team. The supervisor or an assistant contacted the randomly identified eligible subjects. All personnel received training in the conduct of interviews and completion of questionnaires.

Eligible subjects were contacted directly while at the PHCC or by telephone for recruitment into the study and to schedule an appointment for an interview and clinical examination. Every effort was made to encourage participation. In case of non-availability or non-response, another person from the same PHCC age and sex cluster was randomly selected.

Medical records at the PHCC were used to verify self reported diagnosis, complete missing demographic or past clinical data and supplied the research team with the address and telephone number of the household.

Interviews were all completed either at the participant's home or at the PHCC by trained clinic staff. However the clinical examination was conducted at the PHCC. The standardized survey questionnaire sought information on demographic data, medical history, level of usual physical activity, and dietary and social habits. The questionnaire was pre-tested in a pilot study for clarity and wording and the necessary changes were made. The study protocol was approved by the general directorate of primary health care centers. All study population gave their approval and consent to be included in the study.

PHYSICAL MEASUREMENTS

All physical measurements were taken with the participant wearing light clothing, standing relaxed but still, looking straight ahead, with arms at the sides, feet together, and with weight equally distributed over both legs. Weight measurements were made to the nearest 0.1kg (143). The weighing scale was zeroed before and after every measurement and standardized with a certified weight every day before data collection. Weight measurements were taken using the Clinical Detecto Balance-Beam scale (Detecto scale Inc., Brooklyn, NY).

Height was measured by a stadiometer attached to the weighing scale and participant was barefooted. The horizontal rod was lowered slowly until it touched the participant hair without pressing the crown of the head too hard. Measurements were made to the nearest 0.1cm (143).

Circumferences were measured in similar conditions as weight and height to the nearest 0.1cm (143), and a standard measuring tape was used. Waist circumference was measured by first locating and marking of the lowest rib margin, then palpating and marking the iliac crests in the midaxillary line. A plastic tape was applied horizontally midway between the two marked points, and held firmly about the level of the umbilicus and the reading was taken (143). The hip circumference measurement was taken at the point yielding to the maximum circumference over the buttocks, with the tape held in a horizontal plane touching the skin but not indenting the soft tissue (143). Blood pressure was measured using an automatic sphygmomanometer while the participant was sitting and the mean of three measurements was calculated and recorded.

CLASSIFICATIONS OF ADIPOSITY

Body mass index (BMI) was one measure of adiposity, as well as waist to hip ratio (WHR), and waist circumference. BMI was calculated using weight (in kg) divided by height (in meters squared). Subjects were then categorized as non-obese (BMI < 25), overweight (BMI ≥ 25 and BMI < 30), or obese (BMI ≥ 30) (17). WHR was calculated by dividing waist circumference by hip circumference. The variable was then dichotomized as non-obese with < 0.80 for females and with < 0.95 for males (158). A high-risk waist circumference was categorized as high risk at > 88 cm for females and > 102 cm for males (159).

OTHER RISK FACTORS

Most sociodemographic and related variables were categorized. For analysis, age was categorized into four groups (30-39, 40-49, 50-59, and 60-70). Education levels were defined as illiterate (a person who did not complete any form of education and did not read or write), primary education only (persons with less than high school education or person who could read and write but without a formal education), high school education only, and college educated and above (persons with at least some college or university education). Income was categorized as low (≤ 16,000 $US/yr), middle (>16,000 $US/yr and < 32,000 $US/yr), or high (≥ 32,000 $US/yr). The survey participants' residence was categorized as urban or rural according to the official regional categorization.

Smoking status was categorized in three groups; never smoked, former smoker, and current smoker. Usual physical activity levels were categorized into inactive or active based on response to the question of how frequent do you exercise. An inactive individual either did not report any exercising or exercising ≤3 times a month. A person was classified as hypertensive if there was a pervious diagnosis of hypertension (verified by medical record) or the measurement of systolic and diastolic blood pressure was ≥160/95 (144).

STATISTICAL ANALYSIS

Descriptive analysis was performed including calculation of the frequency, mean, median, variance, skewness and ranges for all variables were determined for men and women. Variables were checked for normality and there was no need to transform any of the variables. Correlation between continuous variables was evaluated using Pearson correlation coefficients. Chi-square was used to test the differences between categorical variables, while t-tests were used to compare means of two continuous variables.

Correlations between the different Socio-economic status (SES) variables were calculated and the most significant variable(s) of SES was used in regression models. Association between BMI and other variables was performed to obtain crude odds ratio. The adjusted association between BMI and independent variables using multiple logistic regression was performed. Data were analyzed using Stata 5.0 statistical package (Stata, College Station, TX).

RESULTS

A total of 3271 participants (50.5% females and 49.5% males) completed the survey questionnaire in the 3 regions. Of this sample, ten participants did not provide height and weight measurements and 156 participants did not provide waist and hip circumferences measurements. The available sample composed of 1613 men and 1648 women. The mean age was 44.6 years

(±10.6), with women somewhat younger (mean age = 42.5 years ±10) than men (46.7 years ±10.8). The mean weight was 71.7kg ± 15.5 in females and 77.1kg ± 15.7 in males.

The prevalence of overweight and obesity, using BMI as the index of adiposity, are shown in Table 1. For the overall population and for each age group, there were higher proportions of males in the non-obese and overweight categories, and more females in the obese category. Furthermore, Females had significantly higher mean BMI for all age categories. The data revealed that 31.55% of females were overweight and 49.15% obese when compared to 41.91% of men were classified as overweight and 29.94% as obese.

Obesity was most prevalent (44.49%) in the age group 40-49 years and less prevalent in the 60-70 years old groups (32.85%). In contrast, overweight was most prevalent among 60-70 years old group (40.63%) and less prevalent in the 30-39 years old group (34.48%). Only 17.48% of 40-49 years old group and 27.2% of 30-39 years old group were classified as normal weight.

Table 2 reports the other measures of adiposity, using gender-specific cut off points for WHR and waist circumference. Significantly more females were in the high risk categories of WHR (63%) and waist circumference (66%) as compared to the male population with 36.98% in the high risk WHR and 33.91% in the high risk waist circumference, P <0.001. Higher WHR and waist circumference were seen in females in the age groups of under 50 years old and in men over 50 years of age (data not shown). less likely to be overweight (OR = 0.73). A higher proportion, although not significant, of physically inactive people were obese.

Table 3 reports the socio-demographic characteristics of the study population by level of obesity. The strength of the associations of being overweight or obese as compared to non-obese, among adult Saudis with respect to education, income, residence, smoking, physical activity, and hypertension are presented in this table by odds ratio. Logistic regression was used to estimate the odds ratio, adjusted for gender and age groups, because both were significantly associated with

Table 1. Prevalence of overweight and obesity in the Saudi population by gender and age groups using BMI[1].

	N	Female (n = 1648) % or x̄(SD)	Male (n = 1613) % or x̄(SD)	P valve*
All ages	3261	50.54	49.46	
Non-obese[2]	772	41.19	58.81	
Overweight[3]	1196	43.48	56.52	
Obese[4]	1293	62.65	37.35	0.001
BMI x̄(SD)		30.34 (6.10)	27.89 (5.13)	0.001
30-39 years old	1253	60.02	39.98	
Non-obese	346	54.34	45.66	
Overweight	432	53.24	46.76	
Obese	475	70.32	29.68	0.001
BMI x̄(SD)		29.64 (6.18)	27.58 (5.37)	0.001
40-49 years old	944	51.27	48.73	
Non-obese	165	37.58	62.42	
Overweight	359	41.50	58.50	
Obese	420	65.00	35.00	0.001
BMI x̄(SD)		31.29 (6.00)	28.47 (5.37)	0.001
50-59 years old	653	41.65	58.35	
Non-obese	152	30.26	69.74	
Overweight	238	36.55	63.45	
Obese	263	52.85	47.15	0.001
BMI x̄(SD)		30.58 (6.06)	28.03 (4.83)	0.001
60-70 years old	411	34.06	65.94	
Non-obese	109	20.18	79.82	
Overweight	167	32.34	67.66	
Obese	135	47.41	52.59	0.001
BMI x̄(SD)		30.39 (5.71)	27.27 (4.56)	0.001

BMI[1]: Body Mass Index: (weight in kg/ height in m^2)
Non-obese[2]: BMI ≤ 25
Overweight[3]: BMI >25 & BMI <30
Obese[4]: BMI ≥ 30
* P value testing difference in values between men and women using chi squared or ttest.

Table 2. Prevalence of high risk waist hip ratio (WHR) and waist circumference categories by age and gender.

	N	Female % n = 1613	Male % n = 1502	P valve
High risk WHR[1]				
All ages	1774	63.02	36.98	0.001
30-39 years old	641	71.61	28.39	0.001
40-49 years old	507	64.10	35.90	0.001
50-59 years old	385	55.84	44.16	0.001
60-70 years old	241	49.38	50.62	0.001
High risk Waist[2]				
All ages	1442	66.09	33.91	0.001
30-39 years old	504	74.21	25.79	0.001
40-49 years old	451	67.41	32.59	0.001
50-59 years old	315	57.46	42.54	0.001
60-70 years old	172	54.65	45.35	0.001

WHR[1]: Waist Hips Ratio (cm). male > .95 & females > .80
Waist[2]: Waist (cm). male > 102 & female > 88
* P value of chi squared test comparing males and females.

level of obesity. In general, the risk of being obese or overweight compared to non-obese increased for those with a primary education, middle or high income background, and hypertension. In contrast there was less obesity or overweight in individuals residing in rural areas, and in current smokers.

Education was associated with a higher level of obesity. Overweight people were 38% and obese people were 43% more likely to have a primary education than non-obese (OR = 1.38 and OR = 1.43). Also overweight people were 50% more likely to be high school educated. Level of income was also associated with level of obesity; overweight individuals were 64% more likely and obese individuals were 57% more likely to come from a middle income group vs. low income than non-obese. Also overweight individuals were 43% more likely and obese individuals were 56% more likely to come from a high income group than non-obese. Place of residence was associated with level of obesity. Obese individuals were 48% less likely to be residing in rural areas than were non-obese (OR = 0.52) and overweight individuals were 38% less likely to be residing in rural areas (OR = 0.62).

Smoking status was associated with level of obesity. Obese individuals were 45% less likely to be smokers than were non-obese people (OR = 0.55) and smokers were 27% Hypertension was significantly associated with level of obesity. Obese individuals were more than twice as likely to also have hypertension, and overweight individuals were 76% as likely to have hypertension (OR = 1.76).

Multiple logistic regression was used to explore the relationship of being obese or overweight with various characteristics. Table 4 presents the results for women and table 5 presents the results for men. Separate models were constructed for obesity and overweight as the dependent variables. Independent variables selected to be included in the models were based on the univariate comparisons.

Table 3. Socio-demographic, lifestyle, and health characteristics of the study population by level of obesity.

Characteristics	Total Population		Non-obese (n = 772) BMI ≤ 25		Overweight (n = 1196) BMI >25 & <30			Obese (n = 1293) BMI ≥ 30		
	n	%	*n*	%	n	%	OR[1]	n	%	OR[2]
Education										
Illiterate	1449	44.61	344	44.68	490	41.21	1.00	615	47.71	1.00
Primary	1084	33.37	243	31.56	408	34.31	1.38 (1.09, 1.74)	433	33.59	1.43 (1.13, 1.79)
High School	418	12.87	102	13.25	175	14.72	1.50 (1.10, 2.04)	141	10.94	1.35 (0.97, 1.86)
College	297	9.14	81	10.52	116	9.76	1.26 (0.89, 1.77)	100	7.76	1.22 (0.86, 1.75)
Income										
Low	1794	55.25	482	62.60	621	52.14	1.00	691	53.73	1.00
Middle	1157	35.63	226	29.35	457	38.37	1.64 (1.34, 2.00)	474	36.86	1.57 (1.28, 1.93)
High	296	9.12	62	8.05	113	9.49	1.43 (1.02, 1.99)	121	9.41	1.56 (1.11, 2.18)
Residence										
Urban	2699	82.77	588	76.17	997	83.36	1.00	1114	86.16	1.00
Rural	562	17.23	184	23.83	199	16.64	0.62 (0.49, 0.78)	179	13.84	0.52 (0.41, 0.66)
Smoking										
Never	2387	79.67	523	74.71	855	77.24	1.00	1009	84.86	1.00
Former	288	9.61	64	9.14	121	10.93	1.18 (0.84, 1.65)	103	8.66	1.30 (0.91, 1.85)
Current	321	10.71	113	16.14	131	11.83	0.73 (0.55, 0.98)	77	6.48	0.55 (0.39, 0.76)
Physical Activity										
Inactive	1770	57.12	402	54.40	639	56.40	1.00	729	59.41	1.00
≥ Once a week	1329	42.88	337	45.60	494	43.60	0.92 (0.76, 1.11)	498	40.59	0.86 (0.71, 1.04)
Hypertension										
No	2770	84.94	705	91.39	1019	85.20	1.00	1046	80.90	1.00
Yes	491	15.06	67	8.68	177	14.80	1.76 (1.29, 2.39)	247	19.10	2.37 (1.76, 3.21)

OR[1] odds of overweight individual having factor compared to odds of non-obese adjusted for age and sex.
OR[2] odds of obese individual having factor compared to odds of non-obese adjusted for age and sex.

Age was categorized into four groups (30-39, 40-49, 50-59, 60-70) with dummy variables entered in the model and the age group 30-39 was the reference group. Income was categorized as 1 = income of > \$16,000/yr, and 0 = income of ≤ \$16,000/yr. Exercise was grouped as 1 = exercise < once a week, and 0 = exercise ≥ once a week. Smoking was coded as 1 = never a smoker or formerly a smoker, and 0 = currently smoking. Hypertension was categorized as 1 = a diagnosis of hypertension or blood pressure measurement ≥ 160/95, and 0 = no diagnosis of hypertension and blood pressure measurement blood pressure < 160/95.

Table 4 shows the results for the female population. Overweight and obese women were significantly more likely to be in the age groups 40-49 years, in higher income group and have hypertension, than the normal-weight women (BMI < 25). However, obese women were also significantly more likely to perform less regular exercise.

Table 5 shows the association of being overweight and obese for men, adjusted for the various personal and demographic characteristics mentioned above. Age group 40-49 years old, not currently smoking and have hypertension were all independently and statistically associated with being overweight or obese among Saudi men. Furthermore, higher income was significantly associated with overweight.

DISCUSSION

This population-based study examined the prevalence of obesity and overweight among the adult Saudi population between 30-70 years of age and evaluated risk factors for level of obesity. The population came from the three major regions in Saudi Arabia, which constituted about 60% of the total population. The sample included representative females, males, urban, and rural participants. A striking finding of the study was the very high prevalence of being overweight or

Table 4. Factors associated with being overweight (BMI >25-30 kg/m^2) and obese (BMI > 30 kg/m^2) among adult Saudi females.

Factor	Overweight OR* N = 618	95% C.I.**	Obese OR* N = 815	95% C.I.**	Coding
Age					
30-39 years old	1.00		1.00		1 = Yes; 0 = No
40-49 years old	1.85	1.25, 2.73	2.24	1.56, 3.20	1 = Yes; 0 = No
50-59 years old	1.50	0.94, 2.39	1.55	0.99, 2.41	1 = Yes; 0 = No
60-70 years old	1.46	0.81, 2.64	0.95	0.52, 1.71	1 = Yes; 0 = No
Income	1.46	1.05, 2.03	1.77	1.30, 2.41	1 = Mid & upper; 0 = Low
Exercise	1.26	0.91, 1.73	1.51	1.11, 2.04	1 = Inactive; 0 = Active
Smoking	0.57	0.19, 1.66	1.07	0.34, 3.29	1 = Never+Former; 0=Current
Hypertension	1.91	1.11, 3.29	3.01	1.79, 5.07	1 = HBP; 0 = No HBP

OR* = odds of being overweight (obese) individual having factor compared to odds of being non-obese. all variables listed are adjusted for other variables in the table. C.I.** = confidence interval.

Table 5. Factors associated with being overweight (BMI >25-30 kg/m^2) and obese (BMI > 30 kg/m^2) among adult Saudi males.

Factor	Overweight OR* N = 859	95% C.I.**	Obese OR* N = 721	95% C.I.**	Coding
Age					
30-39 years old	1.00		1.00		1 = Yes; 0 = No
40-49 years old	1.85	1.30, 2.60	1.83	1.26, 2.66	1 = Yes; 0 = No
50-59 years old	1.12	0.78, 1.59	1.14	0.78, 1.66	1 = Yes; 0 = No
60-70 years old	1.02	0.69, 1.51	0.72	0.46, 1.12	1 = Yes; 0 = No
Income	1.58	1.21, 2.06	1.31	0.98, 1.75	1 = Mid & upper; 0 = Low
Exercise	1.09	0.84, 1.42	1.03	0.77, 1.36	1 = Inactive; 0 = Active
Smoking	1.45	1.06, 1.98	1.96	1.37, 2.81	1 = Never+Former; 0=Current
Hypertension	1.78	1.15, 2.76	2.48	1.56, 3.93	1 = HBP; 0 = No HBP

OR* = odds of being overweight (obese) individual having factor compared to odds of being non-obese. all variables listed are adjusted for other variables in the table. C.I.** = confidence interval.

obese. The majority of the population was either overweight (36.68%) or obese (39.65%), with only 23.67% of normal weight or non-obese. This high prevalence has been noted in other Saudi studies (15,81,78,80), although one study of Saudi subjects > 14 years old reported a lower prevalence of obesity (17.2%) and overweight (26%)(160). This lower prevalence, however, might be attributed to the inclusion of teenagers and young adults.

In figures 1 and 2, the prevalence of overweight and obesity in Saudi Arabia were compared to prevalence data from different European countries (Malta, Czech Republic, Iceland, and Denmark) (161) and Kuwait (76). Among males, the overweight prevalence was lowest in Kuwaitis followed by the Saudis and highest in the Czech Republic, while the prevalence of being overweight in Saudi females was comparable to Kuwaiti and most European countries. However, the Kuwaitis and then the Saudi had the highest prevalence of obesity in men and women when compared to Europeans. Other Arab countries report a similar high prevalence of overweight and obesity (95,72). In Kuwait, which has a similar economic condition to Saudi Arabia, the mean BMI for men and women shows increase over the fourteen years 1980-1993 (82). Published data from Bahrain suggest that about one quarter of the Bahraini adult population between 40-60 years of age are obese (BMI > 30) (95), while data from Jordan report almost half of the adult population are obese (72).

Some developing countries, like Brazil, also reported a problem of rising obesity rates (157), while others, like Iran, did not seem to have that problem. In a cross-sectional study on 20-74 years old Iranians found the mean BMI to be 22.8 for men and 23.6 for women. The low BMI in Iran could again be attributed to the inclusion of young subjects in the study (96). The prevalence of obesity and overweight is also expanding in the developed nations as well (67,85, 156). In Sweden there has been a significant increase in the mean BMI, which resulted in higher prevalence of obesity and overweight (67,85). Similarly, the prevalence of obesity has increased

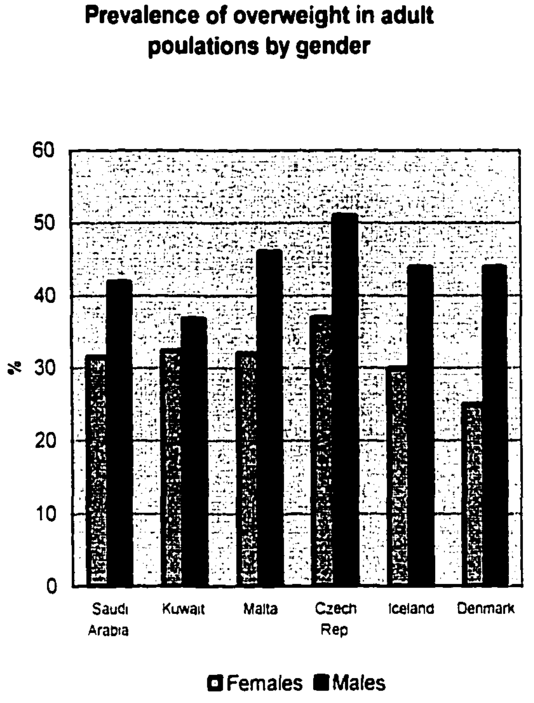

Figure 1

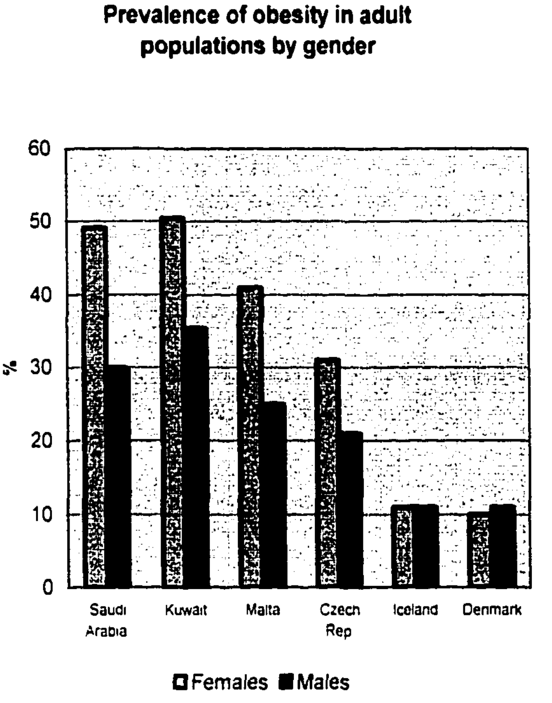

Figure 2

in England and the Netherlands. The increase is greater in England and has reached a prevalence comparable to that of the USA (156).

Middle aged people have the highest rates of obesity, in our data the highest prevalence of overweight and obesity was among subjects between the 40-49 years of age, which is in agreement with previous Saudi studies (81,78) and similar to patterns seen in other Arab countries (162,83,72). As shown in other studies, women were more affected by obesity than men (86,87). Females, in our study population, showed a significantly higher prevalence of obesity than males in all age groups. Previous studies in Saudi Arabia and other Middle Eastern countries support the gender differences (76,148,83,72,15,81,78,80,160,163). European studies show more men than women to be overweight, while more women then men are obese (89). In our study the high frequency can be due to many factors, such as increased calorie intake or keeping the weight gained after childbearing. Limited physical activity, perhaps as a result of the wide spread usage of housemaids or the limited availability of exercising facilities for women has led to the increase in overweight and obesity.

Illiteracy and low level of education seem to be associated with level of obesity in our data as well as in previously published studies (15,162,72). Our study showed a higher proportion (42.44%) of illiterates and (40%) primary educated individuals in the obese category. Perhaps the low level of education reflects a limited awareness of associated health risk of obesity and/or limited access to active lifestyle opportunities. Rising incomes in developing nations may be a potential contributor to the high rates of obesity (87). Among our participants, higher rates of overweight and obesity were seen in the middle and high-income subjects. Data from other surveys in Saudi Arabia concur with this finding (81). This might indicate that higher income could lead to having disposable income, which can be spent on buying high calorie foods leading to obesity. A study in the neighboring country of Bahrain did not find an association between income and obesity (83). However, high-income urban Brazilian men had the highest obesity rate among men, while low-income women had the highest obesity rate among women (157).

Our data showed that residing in urban areas was significantly associated with obesity. This might be due to less regular physical activity and a sedentary lifestyle associated with living in cities. Other studies in Saudi Arabia showed inconsistent results regarding the effect of place of residence on the bodyweight (15,81). Studies from some Arab countries concur with our findings (148,83). In a developing country, urban Brazilian men had higher obesity rate (157).

Smoking cessation usually leads to weight gain (164). This trend might be due to the cigarette effect on depressing the appetite. Our data revealed that Saudi smokers were thinner than nonsmokers, a finding that is similar to other studies (81,80). In contrast, smokers in India constituted greater percentage of the obese group (86). Weight reduction and maintenance has been best predicted with regular exercise (93), while eating more and exercising less lead to weight gain (94). Regular exercise, though not common practice in this study population, was much less reported by the obese group. The lack of regular exercise by the majority of the Saudi population was seen in other Saudi community surveys (6). Obesity, in Bahraini men, was also found to be inversely associated with physical activity at work (95). In addition, mean BMI has been found to be increased with decreased physical activity level in Iran (96). Obesity has been seen as a prime risk factor for the development of hypertension (165). Likewise high blood pressure was more common in the obese group of this study. Systolic and diastolic blood pressure were significantly higher in both genders in the obese group than the non-obese group (80). Another community survey found that obesity was more prevalent in hypertensive subjects (72).

It can be concluded from this survey that obesity and overweight are enormous public health problems in the adult population of Saudi Arabia. Within this population, the people at most risk of obesity and overweight are between 40-49 years of age, female, middle and high income, residing in urban areas, non-smokers, physically inactive, and hypertensive. Detailed genetic, metabolic and nutrition studies are needed to explore the factors causing the alarming high prevalence of both obesity and overweight. In addition, detailed studies are needed to extensively survey the population under 30 years old for obesity and overweight. Finally, awareness campaigns of the etiology and related morbidity effects of obesity should be directed to all segments of the society.

CHAPTER 5

IN TYPE 2 DIABETES: DOES OBESITY MAKE IT WORSE, A STUDY OF ADULT SAUDI POPULATION.

INTRODUCTION

Type 2 diabetes affects large segments of the world population from different ethnic, social, and economic backgrounds (131). Type 2 diabetes is increasing in prevalence and widely recognized as a major cause of morbidity and mortality (166). Type 2 diabetes affects over 100 million people around the world (167) and is projected to reach 180 million by the year 2010 (118).

While obesity has been a problem for the developed world, recently it has emerged as a worldwide problem (168). Obesity is closely correlated to the prevalence of type 2 diabetes (61) and plays an important role in its etiology (118). The increase in the prevalence of obese diabetics seems so be connected to the degree of social wealth and urbanization (169). In the industrialized countries, about 80% of the type 2 diabetics are obese (170,171) but only 10% of the obese are diabetics (170). The high prevalence of obesity in type 2 diabetics might be an indication of the pathophysiological role of obesity in the development of diabetes in genetically predisposed individuals (171,172).

The prevalence of type 2 diabetes varies between population. In Europeans, US non-Hispanic whites, and American blacks, the prevalence ranges between 3 and 10%. Higher prevalences (11-20%) are then seen in Arabs, Asian Indians, US Hispanic groups. The highest frequencies are in Pima and Papago Native Americans of Arizona (50%) and the Micronesian Naruans (40%) (23). In Saudi Arabia, the prevalence of diabetes has ranged between 4.3% and

4.6% (25,26). Recent data among Saudis 30 years and older, who live in Riyadh City, reports the prevalence of diabetes as 13.7% (8).

The prevalence of obesity in adults ranges between 10% and 25% in most countries of Western Europe and 20% to 25 % in some countries in the Americas (65). In the United States, obesity is a common public health problem, where about 33 of adults are considered obese (68). In Saudi Arabia, in a cross-sectional national study of males and females 15 years old and older, the prevalence of being overweight was higher for males (29%) than females (27%). However the prevalence of obesity was higher among females (24%) than males (16%) (77).

Generally the high prevalence of obesity in a community coincides with a high prevalence of type 2 diabetes. In Pima Native Americans, the prevalence of obesity can reach 80% and the prevalence of type 2 diabetes is 40-50% (169). A high prevalence of obesity, 69%, in the Polynesians Pacific Islanders also has been suggested as an explanation for the higher prevalence of type 2 diabetes (173). However, this relationship does not universally hold. In rural Mapuche population in Chile, the prevalence of type 2 diabetes is 4% although the prevalence of obesity is 56% (174). The prevalence of obesity in adult Saudis is reported in a study in 1997 as nearly 29% and the prevalence of diabetes was as 18% (175). Similar levels of obesity in diabetics were found in neighboring countries (145,95).

A recent survey was completed among adults living in the three major provinces of Saudi Arabia. The subjects had been interviewed and blood samples collected for analysis of lipids and glucose. This analysis sought to describe the relationship between obesity and type 2 diabetes in a region that has experienced substantial economic changes and to highlight the problem of obesity in type 2 diabetes among adult Saudis.

MATERIALS AND METHODS

OVERVIEW

Data were collected as a part of a national survey to determine the prevalence chronic diseases and its related risk factors in the Saudi population. The survey targeted Saudis age 15 years and older living in Saudi Arabia. The survey defined a Saudi as a person either holding a Saudi Nationality Identification Card or a dependent of a holder. Age was calculated from the official date of birth on the Identification Card. The survey population was drawn from the thirteen administrative regions of Saudi Arabia, with the sample size selected to be proportionate to the size of the population in each administrative region, taking into consideration the urban to rural ratio. The final survey sample would then reflect a random sample from age and gender groups of the total population and the population of each region.

Multistage stratified cluster sampling was used to select the survey sample. Urban and rural localities were selected randomly in each administrative region and primary health care centers (PHCCs) then randomly selected within each locality. In each of the selected centers, the family health registry was used to select and recruit a random sample of Saudi females and males age 15 years and older. This current study uses data collected from three administrative regions during the early 1990's. These regions represent the most heavily populated regions in Saudi Arabia that include about 60% of the total population (176).

DATA COLLECTION

In each participating PHCC, a physician was appointed as the supervisor of the field research team. The supervisor or an assistant contacted the randomly identified eligible subjects. All personnel received training in the conduct of interviews, completion of questionnaires, specimen collection, and handling and transport of blood samples.

Eligible subjects were contacted directly while at the PHCC or by telephone for recruitment into the study and to schedule an appointment for an interview, clinical examination and laboratory tests. Every effort was made to encourage participation. In case of non-availability or non-response, another person from the same PHCC age and sex cluster was randomly selected. Medical records at the PHCC were used to verify self-reported diagnoses, complete missing demographic or past clinical data, and supply the research team with the address and telephone number of the household.

Interviews were completed either at the participant's home or at the PHCC by trained clinic staff, however clinical examination and blood sample collection were conducted at the PHCC. A standardized survey questionnaire sought information on demographic data, medical history, level of usual physical activity, and dietary and social habits. Fasting blood samples were obtained for glucose (FBG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL), and triglycerides (TG) analyses. The questionnaire was pre-tested in a pilot study for clarity and wording and the necessary changes were made. The study protocol was approved by the general directorate of primary health care centers. All study population gave their approval and consent to be included in the study.

LABORATORY METHODS AND QUALITY CONTROL

Overnight fasting blood samples were collected at the PHCC and refrigerated for at least 30 minutes, but no more than 4 hours, before being centrifuged at 4°C for 30 minutes at 2000-3000 RPM. Immediately after separation, samples were frozen at -20°C until analysis. At the end of sample collection, samples were transported in batches representing each PHCC to the survey clinical laboratory in Riyadh City, where the analysis began immediately. Samples were analyzed for glucose, TC, HDL, and TG using automated analyzer (KONE Instruments, Helsinki, Finland). The analyzer was calibrated by two separate calibrator values (low and high) supplied by the manufacturer of the instruments. Normal and abnormal control sera, supplied by the manufacturer, were included in each analysis run. Duplicate random serum samples were also sent for analysis to two well-recognized laboratories in Riyadh City, Saudi Arabia. Results between laboratories were similar (95-98%) to the survey's laboratory results for all the analyses.

Glucose level was determined by a glucose oxidase method, which uses glucose oxidase and a modified color reaction, catalyzed by the enzyme peroxidase (136). The formed hydrogen peroxide was determined colorimetrically. The intra-and inter assay coefficients of variation were 1.1% and 0.8% at level 5.6 ± 0.55 mmol glucose/L. Total cholesterol was measured using hydrolysis of cholesterol esters by an esterase to cholesterol and fatty acids (137). Cholesterol was then hydrolyzed by cholesterol oxidase and the formed hydrogen peroxide was determined colorimetrically. The intra-and inter assay coefficients of variation were 1.9% and 1.1% at a level 5.6 ± 1.3 mmol cholesterol/L. HDL-cholesterol levels were measured after precipitation of low-density lipoproteins (VLDL and LDL) (138) and after centrifugation: the HDL-cholesterol fraction was determined in the clear supernatant. The intra-and inter assay coefficients of variation were 0.35% and 0.21% at level 1.3 ± 0.21 mmol HDL cholesterol/L. Triglycerides level was determined after enzymatic hydrolysis with lipases to give glycerol and fatty acids (138,139). The intra-and inter assay coefficients of variation were 0.45% and 0.32% at a level 1.9 ± 0.62 mmol triglycerides/L.

CLASSIFICATION OF DIABETES

Diabetes was classified by both medical history and the current FBG test results. Self-reported diagnosis was verified by review of the PHCC medical records. The American Dietetic Association (ADA) and World Health Organization (WHO) recommended a fasting blood glucose (FBG) ≥ 7 mmol/L to diagnose new diabetics (140,141). However, both organizations also required a confirmatory test, which was not possible for this cross-sectional study. In this present study, as was done in a previous study (142), a cut point of FBG ≥ 7 mmol/L was used with a single fasting blood glucose test to define new "undiagnosed" diabetics. Diabetes status was then categorized into either diabetics (prior history of diabetes or FBG ≥ 7 mmol/L) or non-diabetics (no prior history of diabetes and FBG < 7 mmol/L).

PHYSICAL MEASUREMENTS

All physical measurements were taken with the participant wearing light clothing, standing relaxed but still, looking straight ahead, with arms at the sides, feet together, and with weight equally distributed over both legs. Weight measurements were made to the nearest 0.1kg (143). The weighing scale was zeroed before and after every measurement and standardized with a certified weight every day before collecting the data. Weight measurements were taken using Clinical Detecto Balance-Beam scale (Detecto scale Inc., Brooklyn, NY). Height was measured by a stadiometer attached to the weighing scale and participant was barefooted. The horizontal rod was lowered slowly until it touched the participant hair without pressing the crown of the head too hard. Measurements were made to the nearest 0.1cm (143).

Circumferences were measured in similar conditions as weight and height to the nearest 0.1cm (143), using a standard measuring tape. Waist circumference was measured by first locating and marking of the lowest rib margin, then palpating and marking the iliac crests in the midaxillary line. A plastic tape was applied horizontally midway between the two marked points, and held firmly about the level of the umbilicus and the reading was recorded (143). The hip circumference measurement was taken at the point yielding to the maximum circumference over the buttocks, with the tape held in a horizontal plane touching the skin but not indenting the soft tissue (143). Blood pressure was measured using an automatic sphygmomanometer while the participant was sitting and the mean of three measurements was calculated and recorded as systolic and diastolic pressure (177).

CLASSIFICATIONS OF ADIPOSITY

Body mass index (BMI) was one measure of adiposity, as well as waist to hip ratio (WHR), and waist circumference. BMI was calculated using weight (in kg) divided by height (in meters squared). Subjects were considered obese if they had a BMI $\geq$ 30 (17). WHR was calculated by dividing waist circumference by hip circumference. The variable was then dichotomized with high risk defined as $\geq$ 0.80 for females and $\geq$ 0.95 for males (158). Waist circumference was categorized as high risk at $\geq$ 88 cm for females and $\geq$ 102 cm for males (159).

STUDY VARIABLES

During analysis, the study population was classified into four groups based on obesity and diabetic status: normal non-obese non-diabetic (BMI < 30, FBG < 7 mmol/L and no prior history of diabetes), Obese only (BMI $\geq$ 30, FBG < 7 mmol/L and no prior history of diabetes), Diabetic only (BMI < 30 and prior history of diabetes or FBG $\geq$ 7 mmol/L) or Obese diabetic (BMI $\geq$ 30 and prior history of diabetes or FBG $\geq$ 7 mmol/L).

Most sociodemographic and related variables were categorized for analysis: age (30-39, 40-49, 50-59, and 60-70), martial status (currently married and not married), education level (illiterate, primary education or able to read and write without a formal education, high school education only, or college education), income (low $\leq$ 16,000 $US/yr, medium > 16,000 $US/yr and < 32,000 $US/yr), or high ($\geq$ 32,000 $US/yr), and residence (urban or rural according to the official regional categorization).

Usual physical activity level was categorized into inactive or active based on response to the question of "how frequently do you exercise?" An inactive individual either did not report any exercise or exercised $\leq$ 3 times a month. A physical activity score was also calculated by multiplying the reported exercise frequency by duration by intensity. Smoking status was categorized as never smoked, former smoker, or current smoker. Hypertension was defined as individuals with a pervious diagnosis of hypertension (verified by medical record) or the measurement of systolic and diastolic blood pressure at ≥160/95 (144). A positive family history of diabetes was defined as individuals reporting at least one parent or sibling with diabetes.

In some analyses, blood biochemistry variables were dichotomized as high and low risk. High risk cholesterol level was classified as ≥ 6.21 mmol/L, high risk triglycerides level as ≥ 1.69 mmol/L, high risk HDL-cholesterol as ≤ 0.9 mmol/L, high risk LDL-cholesterol as ≥ 4 mmol/L, and high risk LDL/HDL cholesterol index as ≥ 5.

STATISTICAL ANALYSIS

All analyses were performed using Stata 5.0 package (Stata, College Station, TX). To identify presence of outlying and potentially erroneous observations, edit checks were used and then all variables were checked for normality. There was no need for transformation for any of the continuous biochemical measures. Descriptive analysis was done including calculation of the frequency, mean, median, variance, skewness and ranges for all variables. Pearson Correlation was performed to compare association between two variables. Chi-square was used to test differences between categorical variables. Student's t test was used in testing the difference between the means of two groups. All tests were two-tailed with a 5% significant level.

One-way analysis of variance (ANOVA) was used to test the significance between means of more than two continuous variables. Multiple logistic regression was used for multivariate models to investigate associations between blood lipid profile and obesity and diabetes with crude and adjusted odds ratio calculated. Adjustment variables included age, gender, hypertension, smoking, fitness score, and residence.

RESULTS

This study population consisted of 3213 adult Saudi men and women: (50.50% were females and 49.50% males). Obese diabetics constituted 12% of the population. The prevalence of diabetes was 15.87%, while the prevalence of obesity was 27.61%. Only 44% of this study population were neither diabetics and nor obese. Among the 897 diabetics, 43% were obese, while among the obese (n = 1274) 30% were diabetics.

Table 1 reports characteristics of the population by the joint obesity-diabetes classification. Obese diabetics were slightly younger (mean age 48 years) than the diabetic only individuals. However these obese diabetics were older than obese only or normal groups. The obese diabetics were also more likely to be females, less educated, from lower income background, living in urban areas, and least physically fit. Family history of diabetes as highest in the obese diabetic group, with 57% reporting a sibling or a parent with diabetes. Hypertension was most prevalent in the obese diabetics (almost three times the prevalence in the normal population). Furthermore the obese diabetic group had the highest proportion of people with high risk WHR and waist circumference.

Table 2 displays the lipid profile of the study population. Diabetes, whether alone or combined with obesity was associated with a poorer lipid profile. There were significant differences between diabetic groups and non-diabetic groups regardless of the obesity status, except for the HDL-cholesterol, which showed no difference by group. There were no significant differences between obese diabetics and diabetics only in any of blood lipids parameters.

Table 3 shows the prevalence of higher risk blood lipid levels among the four groups. The obese diabetic group had the highest frequency of all high risk blood lipids parameters, except for LDL-cholesterol. There were no significance different between the obese diabetic and the diabetic only groups in the percentage of people with high risk blood lipids, except in

Table 1. Socio-demographic, behavioral and medical characteristics by obesity and diabetes status.

	Not obese nor diabetic[1] n (%) 1429 (44.48)	Obese only[2] 887 (27.61)	Diabetic only[3] 510 (15.87)	Obese and diabetic[4] 387 (12.04)	(P)
Age, x̄ (SD)	42.78 (10.48)	42.53 (09.58)	50.33 (10.43)	48.58 (09.84)	0.001
Female n (%)	651 (45.56)	563 (63.47)	177 (34.71)	233 (60.21)	0.001
Education, *n* (%)					
Illiterate	594 (41.65)	388 (43.94)	228 (45.24)	215 (55.56)	
Less than High School	468 (32.82)	318 (36.01)	173 (34.33)	112 (28.94)	
High School	213 (14.94)	104 (11.78)	58 (11.51)	33 (08.53)	
College and above	151 (10.59)	73 (08.27)	45 (08.93)	27 (06.98)	0.001
Income, n (%)					
Low	805 (56.49)	448 (50.91)	281 (55.42)	235 (60.72)	
Middle	494 (34.67)	342 (38.86)	179 (35.31)	122 (31.54)	
High	126 (08.84)	90 (10.23)	47 (09.27)	30 (07.75)	0.054
Residence, n (%)					
Urban	1147 (80.27)	761 (85.79)	409 (80.20)	334 (86.30)	
Rural	282 (19.73)	126 (14.21)	101 (19.80)	53 (13.70)	0.001
Fitness Score, x̄ (SD)	9.60 (14.91)	8.38 (13.45)	8.34 (11.64)	7.20 (10.49)	0.010
Sibling or parent with DM, n (%)	541 (38.18)	439 (50.00)	268 (53.07)	219 (56.74)	0.001
Smoking, n (%)					
Never smoked	1015 (78.26)	706 (86.95)	347 (74.30)	291 (82.91)	
Former smoker	108 (08.33)	58 (07.14)	59 (12.63)	36 (10.26)	
Current smoker	174 (13.42)	48 (05.91)	61 (13.06)	24 (06.84)	0.001
Hypertension, n (%)	143 (10.01)	138 (15.56)	96 (18.82)	108 (27.91)	0.001
WHR**, n (%)	663 (49.00)	537 (62.08)	279 (58.99)	274 (73.85)	0.001
Waist***, n (%)	302 (22.32)	659 (76.18)	142 (30.02)	321 (86.52)	0.001

[1]Body Mass Index < 30 & No prior history of diabetes & FBG < 7 mmol/l.
[2]Body Mass Index ≥ 30.
[3]Prior history of diabetes or FBG ≥ 7 mmol/l.
[4]*Body Mass Index ≥ 30 & prior history of diabetes or FBG ≥ 7 mmol/l.*
* P value for F statistic or Chi^2 statistic.
** WHR females with waist hip ratio ≥ 0.80 or males with waist hip ratio ≥ 0.95.
*** Waist females with waist ≥ 102cm or males with waist ≥ 88cm.

Table 2. Fasting blood biochemistry (mean ±SD) profile of the population.

Population n (%)	Not obese nor diabetic[A] 1429 (44.48%)	Obese[B] 887 (27.61%)	Diabetic[C] 510 (15.87%)	Obese and diabetic[D] 387 (12.04%)	P**
Cholesterol $\bar{x}$ (SD)	5.17 (1.40)	5.30 (1.36)	6.08 (1.77)†	6.09 (1.81)‡	0.001
Triglycerides $\bar{x}$ (SD)	1.64 (1.09)	1.66 (0.97)	2.27 (1.24)†	2.38 (1.52)‡	0.001
HDL-Cholesterol $\bar{x}$ (SD)	1.13 (0.40)	1.14 (0.37)	1.12 (0.40)	1.10 (0.38)	0.410
LDL-Cholesterol $\bar{x}$ (SD)	4.36 (1.55)	4.50 (1.46)	5.42 (1.88)†	5.47 (1.96)‡	0.001
LDL/HDL index $\bar{x}$ (SD)	4.44 (2.43)	4.42 (2.20)	5.54 (3.36)†	5.52 (2.78)‡	0.001

† Significantly different from group A and B ($P < 0.001$).
‡ *Significantly different from group A and B ($P < 0.001$).*
**P value for F statistics.

Table 3. Percentage of people with high risk blood lipids profile.

Population n (%)	Not obese nor diabetic 1429 (44.48%)	Obese 887 (27.61%)	Diabetic 510 (15.87%)	Obese and diabetic 387 (12.04%)	P*
Cholesterol (> 6.21 mmol/l)	265 (18.54)	200 (22.55)	201 (39.41)	158 (40.83)	0.001
Triglycerides (> 1.69 mmol/l)	469 (32.82)	309 (34.84)	306 (60.00)	242 (62.53)	0.001
HDL-Cholesterol (< 0.9 mmol/l)	434 (30.37)	241 (27.17)	158 (30.98)	130 (33.59)	0.107
LDL-Cholesterol (> 4 mmol/l)	787 (55.07)	535 (60.32)	411(80.59)	308 (79.59)	0.001
LDL/HDL index (> 5 mmol/l)	471 (32.96)	285 (32.13)	258 (50.59)	197 (50.90)	0.001

*P value for chi^2 statistics.

the LDL/HDL index where obese diabetics had higher percentage ($P < 0.05$). Also there was a significant difference between the obese only and the normal groups in the percentage of people with high risk cholesterol ($P < 0.05$) and high risk LDL-cholesterol ($P < 0.05$).

The combined adjusted effect of obesity and diabetes on having high-risk levels of blood lipids is shown in table 4. Adjustment was included for age, gender, residence, education, family history of diabetes, smoking, fitness score, and hypertension. Not shown in the table, 12% of the total survey population were labeled as obese and diabetic. However, obese diabetics constituted 19% of those with high-risk cholesterol, 18% of those with high-risk triglycerides, and 16% of those with high-risk LDL/HDL index.

Compared to the non-obese and non-diabetic group, the diabetic non-obese individuals were 2.5 times more likely (95% C.I. = 1.95 – 3.21) and the obese diabetics individuals were 2.6 times more likely (95% C.I. = 1.97 – 3.42) to have high-risk fasting cholesterol level. Compared to normal population, the diabetic non-obese subjects were 2.8 times more likely (95% C.I. = 2.20 – 3.56) and the obese diabetics were 4.02 times more likely (95% C.I. = 3.05 – 5.30) to have high-risk fasting triglycerides level. Compared to the normal population, the diabetic non-obese were 1.73 times more likely (95% C.I. = 1.36 – 2.20) and the obese diabetics were 2.37 times more likely (95% C.I. = 1.81 – 3.10) to have high-risk fasting LDL/HDL index level.

Table 5. Shows the result of logistic regression examining the association of obesity, diabetes and obesity in diabetes with different variables that were significant in univariate analysis. The normal population (neither obese nor diabetic) were the reference group. The obese compared to normal population were more likely to be females (95% C.I. = 0.44 - 0.71), from higher income background (95% C.I. = 1.03 - 1.21), urban dwellers (95% C.I. = 0.52 - 0.87), nonsmoking (95% C.I. = 0.69 - 0.97), hypertensive (95% C.I. = 1.19 - 2.12). The diabetic population were more likely to be older (95% C.I. = 1.05 - 1.07), and have hypertension (95%

Table 4. Independent and interactive effects of obesity and diabetes on the risk of high blood lipids level.

Obesity[1]	Diabetes[2]	N	N	Odds Ratio (95% Confidence Interval) Adjusted*
		(FTC** < 6.21)	(FTC** ≥ 6.21)	High Cholesterol
0	0	1164	265	1
1	0	687	200	1.26 (1.01 - 1.58)
0	1	309	201	2.50 (1.95 - 3.21)
1	1	229	158	2.60 (1.97 - 3.42)
P for trend		2389	824	0.001
		(FTG** < 1.69)	(FTG** ≥ 1.69)	High Triglycerides
0	0	960	469	1
1	0	578	309	1.24 (1.01 - 1.51)
0	1	204	306	2.80 (2.20 - 3.56)
1	1	145	242	4.02 (3.05 - 5.30)
P for trend		1887	1326	0.001
		(LDL/HDL < 5)	(LDL/HDL ≥ 5)	High LDL/HDL Index
0	0	958	471	1
1	0	602	285	1.09 (0.89 - 1.33)
0	1	252	258	1.73 (1.36 - 2.20)
1	1	190	197	2.37 (1.81 - 3.10)
P for trend		2002	1211	0.001

* Adjusted for age, gender, residence, education, family history of diabetes, smoking, fitness score, and hypertension.
** mmol/L
[1]Obesity status defined as: not obese (0 = BMI < 30) and obese (1 = BMI ≥ 30).
[2]Diabetic status defined as: not diabetic (0 = no prior diagnosis of diabetes and FBG < 7 mmol/l) and diabetic (1 = diagnosed diabetics or FBG ≥ 7 mmol/l).

Table 5. Factors associated with being obese, diabetic and obese-diabetic compared to normal population.

	Normal OR	Obese OR	Diabetic OR	Obese Diabetics OR
Age	1	0.99	1.06*	1.04*
Gender	1	0.56*	1.28	0.52*
Education	1	0.92	0.96	0.95
Income	1	1.12*	1.09	1.03
Residence	1	0.68*	0.91	0.56*
Fitness score	1	0.99	0.99	0.99
Smoking	1	0.81*	1.04	0.96
Hypertension	1	1.59*	1.41*	2.20*

* Significantly different from the normal group

C.I. = 1.01 - 1.96). However, the obese diabetics were more likely to be older (95% C.I. = 1.03 - 1.06), females (95% C.I. = 0.38 - 0.71), urban residences (95% C.I. = 0.39 - 0.81), and have hypertension (95% C.I. = 1.58 - 3.08).

DISCUSSION

This study describes the association between obesity and type 2 diabetes in an adult Saudi population between the age 30-70 years old. The study population comes from the three major regions in Saudi Arabia. In our study the prevalence of obesity without diabetes was 27.6%, while 15.8% have type 2 diabetes without obesity, and 12% have combined obesity and type 2 diabetes. The overall prevalence of type 2 diabetes in this population was high at 27.8%. An earlier study in Saudi Arabia published in 1995 reported the prevalence of diagnosed diabetes at 13.7% in people over 30 years old (8). Other neighboring Gulf countries also have reported a high prevalence of diabetes (95,145).

Furthermore, the prevalence of obesity (obese plus obese diabetics) was also very high, at 39.6%. Other studies also reported a high prevalence of obesity in Saudi Arabia and other Gulf countries (81,76,80,74). An earlier Jordanian study reported that almost half of the adult population could be categorized as obese (74). Type 2 diabetes and obesity have been closely correlated and reported as increasing in prevalence worldwide (166,168,61). BMI was found to be a dominant risk factor for diabetes incidence and predicted diabetes in a dose-response relationship (42). The prevalence of type 2 diabetes has been reported more frequently among obese individuals (28) and increased waist size was reported to elevate the risk of type 2 diabetes (152). In our study, 43% of the diabetic population were obese, and had the highest proportion of subjects with high risk WHR and waist circumference. A similar rate of obesity in our diabetic population was reported in prior Saudi studies (25,9).

Studies in Arab countries compared normal glycemic with diabetics and found a similar correlation between BMI and diabetes (95,76). Arab diabetics were reported to have higher BMI (145,135) and larger waist circumference than non-diabetics (95). Also, a significant association between obesity and diabetes has been found in other parts of the world (178,179). In the U.S., larger waist circumference and higher waist hips ratio were found in diabetics (180).

In our study, the obese diabetics were slightly younger than the diabetic only group, however, both diabetic groups were older than obese and normal groups. The majority of the obese diabetics were between 40-49 years old. In contrast, other studies reported diabetes prevalence to be higher in a 50-59 years old population (95,78). Moreover, the prevalence of obesity was reported in Saudi Arabia and neighboring countries to be the highest between 40-49 years of age (81,83,76).

Females were the majority of the obese diabetics which could be due to many factors, such as higher food consumption, not losing weight after childbearing, and the limited physical activity, perhaps as a result of the wide spread usage of housemaids or the limited availability of exercising facilities for women. Our findings are in agreement with previous data that showed that obesity was more common among Saudi female diabetics (73%) compared to male diabetics (49%) (27). There was no consensus on the prevalence of diabetes in studies performed in Saudi Arabia and other Arab countries, some found it to be higher in females (25,95) others found the opposite (8,135). Furthermore, studies in the Gulf region found obesity more prevalent in females (81,76,80,83). Obese diabetics in our study were the least educated which limit their awareness of the health risks associated with obesity and diabetes. Also they were mostly urban dwellers, which limit the physical activity. In Saudi Arabia, urban residences had higher glucose blood levels (181), and illiteracy was higher among Kuwaiti type 2 diabetics (145). Saudi studies did not find a consistence effect of urban or rural residence on bodyweight (81,15), however, low level of education was found to be associated with high level of obesity (15,76). In our study, low level of education in obese diabetics might be a reflection of a limited awareness of associated health risk of diabetes and obesity and urban dwelling is associated with less regular physical activity which is a risk factor for both diabetes and obesity.

Moderate physical activity was found to be associated with reduced risk for type 2 diabetes (37) and the frequency of physical activity and obesity affects the prevalence of diabetes (28). Weight reduction has been best predicted with regular exercise (37). Obese diabetic group in this study had the highest percentage of physically inactive people among the four groups, and those who are active among them had lowest fitness score. The harsh climate and sedentary life style were postulated to be behind the low levels of physical activity in Saudi Arabia (8,93). In the Gulf countries, sedentary lifestyle and physical inactivity were the significant behavior associated with type 2 diabetes (145) and Obesity (95). In our study, the low level of physical activity might be due to the extremely hot weather most of the years and the limited access to gymnasiums.

Familial aggregation of type 2 diabetes has long been recognized (6). In Europe, a study found that about 60% of diabetics had at least one first-degree diabetic relative (31). The same association was found in Saudi Arabia and the Gulf countries (33,145,95). In Saudi Arabia, 70% of diabetics had a family history of diabetes (33). In this current study, the highest prevalence of first degree relative with diabetes was seen in the obese diabetic group followed by the diabetic group, which might reflect a genetic component of the condition.

Smokers were thought to have lower incident of diabetics compared to non-smokers (180). However, smoking was recently found to be associated with diabetes (35). Smoking has been noticed to have an inverse relationship with obesity and smoking cessation usually leads to weight gain (151). Moreover, other Saudi Arabia studies found smokers to be thinner than nonsmokers (81,76). In our study, the obese had the highest proportion of never smokers, and the non-obese had the highest proportion of current and former smokers. The appetite depressing effect of cigarettes smoking may have partially contributed to the observed reduction of body weight among smokers.

Hypertension and diabetes are interrelated disorders, and in diabetics the prevalence of hypertension is about twice that of non-diabetics (164). Blood pressure is significantly higher in obese individuals as compared to non-obese (76). The prevalence of hypertension was more than doubled in diagnosed diabetics in Gulf countries (145,95). Our data showed that hypertension is most prevalent among the obese diabetics (almost three times the prevalence in the normal population), which might be due to having two risk factors of hypertension (obesity and diabetes).

In type 2 diabetes, dyslipidaemia consists of hypertriglyceridemia, low HDL-cholesterol (154) and enhanced formation of LDL (183). Dyslipidemia in obese individuals is frequently characterized with increase levels of LDL/HDL index (183), triglycerides and LDL, as well as low level of HDL (183,184). In our study population, although there were no significant differences between obese diabetics and diabetics in any of the values of blood lipids, obese diabetics had the poorest blood lipid profile which was followed by the diabetics only, except for the LDL/HDL index. Among our data for the high-risk blood lipids, obese diabetics were not significantly different from the diabetics, except for the LDL/HDL index. In addition, the obese diabetics had the highest proportion of subjects with high-risk blood lipids levels followed by the diabetics, except for the LDL. A study in Saudi Arabia found higher cholesterol, LDL, and triglycerides and low HDL levels among diabetics compared to non-diabetics (185). Data from the Gulf Arab states found that diabetics had significantly higher levels of cholesterol and triglycerides (145,95). A study in Kuwait found that diabetics had the poorest blood lipids means values including cholesterol, LDL, HDL, LDL/HDL index, and triglycerides (186).

In a study on the effect of bodyweight on Saudis, it was reported that there was no significant difference found between obese and non-obese in blood lipids (cholesterol, HDL, and LDL) (187). In a study on syndrome X, researchers did not find obesity and dyslipidemia to be significantly related (179). However, a significantly higher prevalence of hyperlipidemia (cholesterol, triglycerides, LDL, and low HDL) was found among obese Jordanians compared to the non-obese (76). The prevalence of high cholesterol levels and low HDL-cholesterol levels increased with the increase of BMI (188). In our study population, the combinatory effect of obesity and diabetes in our obese diabetic subjects demonstrated the worst effect on blood lipids.

In summary, our findings indicate that obese type 2 diabetes is highly prevalent in our population. Moreover, the risk factors associated with being obese type 2 diabetic were females, illiterate, urban dwellers, physically inactive, familial history of diabetes, hypertensive, high waist/hips ratio and large waist circumference. Based on our findings, an intervention program should directed to females living in the urban areas in order to increase their awareness of health related issues. Also to increase their physical activity level in order to minimize complications of these disorders that have an immense human and monetary cost.

CHAPTER 6

CONCLUSIONS

In the developing countries, diabetes and obesity are two conditions that are highly synergistic with food abundance and sedentary lifestyle. Saudi Arabia appears to be no different form other developing countries. Since the late 1970's, Saudi Arabia has experienced an unprecedented influx of income from the oil revenues. The effects of this increase in income were experienced in all aspects of life. The population had for the first time abundance and cheap foods, after centuries of subsistence living depending on limited seasonal rainfall and ground water to farm, small boats to fish and commerce with pilgrims who visit the country every year. The population experienced in the last two decades new lifestyle with more cars on the roads, and more white color jobs that limited the physical activities in the way to work or in work. To the contrary of the time, the subsistence living the population used to live in produced limited amounts food and demanded very high level of physical activity. The consequence of this transformation of the society was a huge increase in the prevalence of chronic diseases and among them are diabetes and obesity.

In this series of studies, three primary issues were addressed. First, the prevalence of and risk factors associated with diagnosed type 2 diabetes in comparison to undiagnosed type 2 diabetes. Second, the factors associated with being obese or overweight among Saudi men and women. Third, the relationship between diabetes and obesity and risk factors associated with obesity in diabetics. There was a number of compelling findings in this research. First, there is a substantial amount of under diagnosis of diabetes. When compared to non-diabetic population, there is closer resemblance between undiagnosed diabetics and diagnosed diabetics in age, gender, education, blood lipids, and obesity. A diabetic can be characterized as being an older male, less educated, having more family history of diabetes, hypertensive, and obese. Some risk factors are modifiable to reduce prevalence and complication of type 2 diabetes. Second, there is a huge prevalence of obesity and overweight in the population. Obesity is highly prevalent in women and overweight is highly prevalent in men. The population at the highest risk of obesity and overweight are between 40-49 years of age, middle and high income, residing in urban areas, non-smokers, physically inactive, and hypertensive. Third, there is a high prevalence of obesity in type 2 diabetics compared to the non-diabetics. Obese diabetics can be characterized as being mostly females, illiterate, low income, urban, less physically active, hypertensive, familial history of diabetes, high waist hips ratio and waist circumference. In addition, poor blood lipid profile is more prevalent in the obese diabetics.

In conclusion, based on these findings, this population appears to have an alarming high prevalence of diabetes, obesity and obesity in diabetics that need immediate multidimensional interventions. First, public awareness should be enhanced to provide knowledge on how to prevent and control diabetes and obesity and their interrelationship with each other and other degenerative diseases. Second, training should be provided for all different levels of Saudi health care professionals to enable them to educate their patients in the prevention of these disorders and control their complications. Third, additional national surveys are needed to monitor these two conditions and their complications, especially in the younger population because the majority of Saudis are under 30 years of age. Finally, detailed genetic, metabolic and nutrition studies are needed to determine the factors predisposing this population to such high prevalence of type 2 diabetes and obesity.

REFERENCES

1) Royal Embassy of Saudi Arabia at Washington D.C. USA. Profile of Saudi Arabia: Facts and figures., 1999. http://www.saudiembassy.net/profile/ff/ff_geo.html. 2001 May 10.

2) United Nation Children's Fund, The State of the World's Children 1985 report, United Nations Publications. New York, USA. 1985.

3) United Nation Children's Fund. The State of the World's Children 2001 report, United Nations Publications. Ne·v York. USA. 2001.

4) Al-Nozha M. Health Care System in Saudi Arabia: Which Why to Go?. Journal of Saudi Heart Association. 6(1): 1-3, 1994.

5) Ahmed M. An overview of diabetes mellitus in the Kingdom of Saudi Arabia. Annals Saudi Medicine. 9: 425 S, 1989.

6) El-Hazmi M. Warsy A. Al-Swailem AR, Al-Swailem AM. Al-Sulaimani R. Al-Meshari A. Diabetes Mellitus and Impaired Glucose Tolerance in Saudi Arabia. Annals Saudi Medicine. 16(4): 381-385. 1996.

7) Al-Nuaim. A.. Al-Rubeaan. k.. Al-Mazrou. Y.. Khoja. Al-Attas. O. and Al-Daghari. N. National chronic metabolic disease survey, Part I. Ministry of Health and King Saud University. Riyadh. Saudi Arabia. 1995.

8) El-Hazmi M. Al-Swailm AR, Warsy AS, Al-Sudairy F, Sulimani R. Al- Swailem AM. Al-Meshari A. The prevalence of diabetes mellitus and Impaired Glucose Tolerance in The Population of Riyadh. Annals of Saudi Medicine. 15(6): 598-601. 1995.

9) Bacchus R, Bell J. Madkour M, Kilshaw B. The Prevalence of Diabetes Mellitus in Male Saudi Arabs. Diabetologia. 23: 330-332, 1982.

10) Reiber G. Stern M, Rennett P (eds). Diabetes in America 2nd ed. Washington. D.C.: US Government printing Office. 1995: 349-376.

11) Hanefeld M, Fischer S. Julius U, Schulze J. Schwanc-beek U, Schcchel H. Ziegelasch HJ. Lindner J, Th DIS Group. Risk factors for myocardial infarction and death in newly detscted NIDDM: The Diabetes Intervention Study, 11- years follow-up. Diabetologia 1996: 39:1577-1583.

12) Marks L. Counting cost: the real impact of non-insulin dependent diabetes. King's fund Policy Institute. London: British Diabetes Association, 1996: 12-17.

13) El-Hazmi M. Warsy A S. Prevalence of obesity in the Saudi population. Annals of Saudi Medicine 17(3):1997. 302-306.

14) Binhemd TA., Larbi, E.B. and Absood, G. Obesity in primary health care centers: a retrospective study. Annals Saudi Medicine. 11: 163-166. 1991.

15) Al-Shammari SA. Khoja TA. al-Maatouq MA. al-Nuaim LA. High prevalence of clinical obesity among Saudi females: a prospective, cross-sectional study in the Riyadh region. Journal of Tropical Medicine & Hygiene. 97(3):183-8. 1994 Jun.

16) Eckel RH. Obesity and heart disease: a statement for healthcare professionals from the Nutrition Committee, American Heart Association. Circulation. 96(9):3248-50. 1997 Nov 4.

17) Anonymous. Clinical Guidelines on the Identification. Evaluation, and Treatment of Overweight and Obesity in Adults--The Evidence Report. National Institutes of Health. Obesity Research. 6 Suppl 2:51S-209S. 1998 Sep.

18) Kudva BT. On diabetes mellitus. Journal of the Association of Physicians of India. 32(4):320. 375. 1984 Apr.

19) Leslie RD. Lazarus NR. Vergani D. Aetiology of insulin-dependent diabetes. British Medical Bulletin. 45(1):58-72. 1989 Jan.

20) Taylor R. Aetiology of non-insulin dependent diabetes. British Medical Bulletin. 45(1):73-91. 1989 Jan.

21) World Health Organization Study Group. Diabetes Mellitus. WHO Technical Report Series No 727. Geneva 1985.

22) Ellenberg and Rifkin's diabetes mellitus. theory and practice. 4thed. pp. 357-377. Elsvier. 1990.

23) King H. Rewers M. Global estimates for prevalence of diabetes mellitus and impaired glucose tolerance in adults. WHO Ad Hoc Diabetes Reporting Group. Diabetes Care. 16(1):157-77. 1993 Jan.

24) Cook GC. Rapid glucose absorption in Arabs in Saudi Arabia compared with that in Africans in Zambia. British Medical Journal. 1(6011):688-9. 1976 Mar 20.

25) Fatani HH. Mira SA. El-Zubier AG. Prevalence of diabetes mellitus in rural Saudi Arabia. Diabetes Care. 10(2):180-3. 1987 Mar-Apr.

26) Abu-Zeid HA. al-Kassab AS. Prevalence and health-care features of hyperglycemia in semiurban-rural communities in southern Saudi Arabia. Diabetes Care. 15(4):484-9. 1992 Apr.

27) El-Hazmi M. Warsy A. Barimah N. Al-Swailem AR. Al-Swailem AM. Sulaiman R. Al-Meshari AA. The prevalence of diabetes mellitus and impaired glucose tolerance in the population of Al-Baha. Saudi Arabia. Saudi Medical Journal. 17(5): 591-97. 1996.

28) Bennett P. Bogardus C. Tuomilehto J. Zimmet P. Epidemiology and Natural History of NIDDM: Non-obese and Obese. In: Alberti. K.G.M.M: DeFronzo. R.A: Keen. H. and Zimmet, P. (eds). International Textbook of Diabetes Mellitus. Volume 1. pp.147- 176. Chichester: John Wiley and Sons. 1992.

29) Bell J, Bacchus R. Glucose tolerance in Saudi Arabs in relation to the criteria of the world Health Organization. Saudi Medical Journal. 5 (1): 61-64, 1984.

30) Fatani H, Mira S, El-Zubier A. Prevalence of diabetes mellitus in the urban Saudi Arabia. In : Diabetes Mellitus. Nihyanant W, Vichayanrat A, Vannasaeng S, Eds. Bangkok, Crystal House, 1985.

31) Everhart J, Knowler W, Bennett P. Incidence and risk factors for non-insulin-dependent diabetes. USDHHS, NIH Publication No. (NIH) 85- 1468. pp. 35. Washington D.C. 1985.

32) Yamashita T, Mackay W, Rushforth N, Bennett P, Houser H. Pedigree analyses of non-insulin-dependent diabetes in the Pima Indians suggest dominant mode of inheritance. American Journal of Human Genetics, 36: 18-35, 1984.

33) Thomas F. Balkau B. Vauzelle-Kervroedan F. Papoz L. Maternal effect and familial aggregation in NIDDM. The CODIAB Study. CODIAB-INSERM-ZENECA Study Group. Diabetes. 43(1):63-7, 1994 Jan.

34) Laajam M, Al-Altas O, Khan M. Clinical characteristics and C-peptide status in 200 newly diagnosed Saudi Adult diabetics. Annals Saudi Medicine. 7: 5-6, 1987.

35) Binhemd TA. Diabetes Mellitus: knowledge, attitude, practice and their relation to diabetes control in female diabetics. Annals Saudi Medicine. 12(3): 247-51, 1992.

36) Horton ES. Role and management of exercise in diabetes mellitus. Diabetes Care. 11(2):201-11, 1988 Feb.

37) James SA. Jamjoum L. Raghunathan TE. Strogatz DS. Furth ED. Khazanie PG. Physical activity and NIDDM in African-Americans. The Pitt County Study. Diabetes Care. 21(4):555-62, 1998 Apr.

38) Lindeman RD. Romero LJ. Hundley R. Allen AS. Liang HC. Baumgartner RN. Koehler KM. Schade DS. Garry PJ. Prevalences of type 2 diabetes, the insulin resistance syndrome, and coronary heart disease in an elderly, biethnic population. Diabetes Care. 21(6):959-66, 1998 Jun.

39) Ekoe' J. M. Epidemiology of diabetes mellitus in Saudi Arabia. In: Diabetes Mellitus: Aspects of the Worldwide Epidemiology of Diabetes Mellitus and its Long-term Complications. p 144, Elsevier Science Puplishers, 1988.

40) Taylor R, Zimmet P. Migrant studies in diabetes epidemiology. In: Diabetes in epidemiological perspective. Mann J, Teucher A (eds). p 58-77. Churchill/Livingstone, Edinburgh, 1983.

41) Alexander H, Lockwood LP, Harris MA, Melby CL, Risk factors for cardiovascular disease and diabetes in two groups of Hispanic Americans with differing dietary habits. Journal of the American College of Nutrition. 18(2):127-36, 1999 Apr.

42) Njolstad I. Arnesen E. Lund-Larsen PG. Sex differences in risk factors for clinical diabetes mellitus in a general population: a 12-year follow-up of the Finnmark Study. American Journal of Epidemiology. 147(1):49-58. 1998 Jan 1.

43) Sakurai Y. Teruya K. Shimada N. Umeda T. Tanaka H. Muto T. Kondo T. Nakamura K. Yoshizawa N. Association between duration of obesity and risk of non-insulin-dependent diabetes mellitus. The Sotetsu Study. American Journal of Epidemiology. 149(3):256-60. 1999 Feb 1.

44) Knowler WC. Pettitt DJ. Nelson RG. Mott DM. Bennett PH. Sequential changes in serum insulin concentration during development of non-insulin-dependent diabetes. Lancet. 1(8651):1356-9. 1989 Jun 17.

45) O'Dea K. Traianedes K. Hopper JL. Larkins RG. Impaired glucose tolerance. hyperinsulinemia. and hypertriglyceridemia in Australian aborigines from the desert. Diabetes Care. 11(1):23-9. 1988 Jan.

46) DeFronzo RA. Lilly lecture 1987. The triumvirate: beta-cell. muscle. liver. A collusion responsible for NIDDM. Diabetes. 37(6):667-87. 1988 Jun.

47) McMahon M. Marsh HM. Rizza RA. Effects of basal insulin supplementation on disposition of mixed meal in obese patients with NIDDM. Diabetes. 38(3):291-303. 1989 Mar.

48) DeFronzo RA. Ferrannini E. Simonson DC. Fasting hyperglycemia in non-insulin-dependent diabetes mellitus: contributions of excessive hepatic glucose production and impaired tissue glucose uptake. Metabolism: Clinical & Experimental. 38(4):387-95. 1989 Apr.

49) Zavaroni I. Bonini L. Gasparini P. Barilli AL. Zuccarelli A. Dall'Aglio E. Delsignore R. Reaven GM. Hyperinsulinemia in a normal population as a predictor of non-insulin-dependent diabetes mellitus. hypertension. and coronary heart disease: the Barilla factory revisited. Metabolism: Clinical & Experimental. 48(8):989-94. 1999 Aug.

50) DeFronzo RA. Ferrannini E. Koivisto V. New concepts in the pathogenesis and treatment of non-insulin-dependent diabetes mellitus. American journal of medicine. 75: 52-81. 1983.

51) Mitrakou A. Kelley D. Mokan M. Veneman T. Pangburn T. Reilly J. Gerich J. Role of reduced suppression of glucose production and diminished early insulin release in impaired glucose tolerance. New England Journal of Medicine. 326(1):22-9. 1992 Jan 2.

52) Warram JH. Martin BC. Krolewski AS. Soeldner JS. Kahn CR. Slow glucose removal rate and hyperinsulinemia precede the development of type II diabetes in the offspring of diabetic parents. Annals of Internal Medicine. 113(12):909-15. 1990 Dec 15.

53) Hitman G. McCarthy M. Genetics of non-insulin dependent diabetes mellitus in 1990. In: Harrison L. thit B (eds). Genetics of diabetes. part II. Baillier s Clinical Endocrinology and Metabolism5 (3) September. p 455. Bailliere Tindall. London. 1991.

54) Neel JV. Diabetes mellitus: a "thrifty" genotype rendered detrimental by "progress". American Journal of Human Genetics 14: 353-362. 1962.

55) Wendorf M. Goldfine ID. Archaeology of NIDDM. Excavation of the "thrifty" genotype. Diabetes. 40(2):161-5. 1991 Feb.

56) Ruigomez A. Garcia Rodriguez LA. Presence of diabetes related complication at the time of NIDDM diagnosis: an important prognostic factor. European Journal of Epidemiology. 14(5):439-45. 1998 Jul.

57) Turner R. Cull C. Holman R. United Kingdom Prospective Diabetes Study 17: a 9-year update of a randomized. controlled trial on the effect of improved metabolic control on complications in non-insulin-dependent diabetes mellitus. Annals of Internal Medicine. 124(1 Pt 2):136-45. 1996 Jan 1.

58) Fatani H. Mira S. El-Zubier A. The Pattern of complications in Saudi Arabian diabetics. Annals Saudi Medicine. 9: 44. 1989.

59) Nelson RG. Knowler WC. Petter DJ. Bennett PH. Kidney diseases in diabetes. In Harris MI. Cowie CC. Reiber G. Stern M. Rennett P (eds). Diabetes in America 2nd ed. Washington. DC: US Government Printing Office. 1995: 349-376.

60) Famuyiwa OO. Sulimani RA. Laajam MA. Al-Jasser SJ. Mekki MO. Diabetes mellitus in Saudi Arabia: the clinical pattern and complications in 1000 patients. Annals of Saudi Medicine. 12(2): 140-50. 1992.

61) Leong KS. Wilding Jp. Obesity and diabetes. Best Practice & Research Clinical Endocrinology & Metabolism. 13 (2): 221-37. 1999 Jul.

62) Seidell JC. Flegal KM. Assessing obesity: classification and epidemiology. British Medical Bulletin. 53(2):238-52. 1997.

63) Campfield LA. Smith FJ. The pathogenesis of obesity. Best Practice & Research Clinical Endocrinology & Metabolism. 13(1):13-30. 1999 Apr.

64) Thompson D. Edelsberg J. Colditz GA. Bird AP. Oster G. Lifetime health and economic consequences of obesity. Archives of Internal Medicine. 159(18):2177-83. 1999 Oct 11.

65) Seidell JC. Obesity in Europe: scaling an epidemic. International Journal of Obesity & Related Metabolic Disorders. 19 Suppl 3:S1-4. 1995 Sep.

66) WWW.Who.int/archives/inf-pr-1997/en/pr97-46.html. Obesity Epipdemic puts millions at risk from related disease. WHO/46 12 June 1997.

67) Kuskowska-Wolk A. Bergstrom R. Trends in body mass index and prevalence of obesity in Swedish women 1980-89. Journal of Epidemiology & Community Health. 47(3):195-9. 1993 Jun.

68) WHO. Obesity Preventing and managing the global epidemic. Report of WHO Consultation on Obesity. Geneva, 3-5 June 1997.

69) Rosenbaum M. Leibel RL. Hirsch J. Obesity. New England Journal of Medicine. 337(6):396-407, 1997 Aug 7.

70) Flegal KM. Carroll MD. Kuczmarski RJ. Johnson CL. Overweight and obesity in the United States: prevalence and trends, 1960-1994. International Journal of Obesity & Related Metabolic Disorders. 22(1):39-47, 1998 Jan.

71) Meade TW. Imeson J. Stirling Y. Effects of changes in smoking and other characteristics on clotting factors and the risk of ischaemic heart disease. Lancet. 2(8566):986-8, 1987 Oct 31.

72) Reisin E. Abel R. Modan M. Silverberg DS. Eliahou HE. Modan B. Effect of weight loss without salt restriction on the reduction of blood pressure in overweight hypertensive patients. New England Journal of Medicine. 298(1):1-6, 1978 Jan 5.

73) Martorell R. Khan LK. Hughes ML. Grummer-Strawn LM. Obesity in Latin American women and children. Journal of Nutrition. 128(9):1464-73, 1998 Sep.

74) Ajlouni K. Jaddou H. Batieha A. Obesity in Jordan. International Journal of Obesity & Related Metabolic Disorders. 22(7):624-8, 1998 Jul.

75) Al-Awadi F. Amine EK. Overweight and obesity in Kuwait. Journal of the Royal Society of Health. 109(5):175-7, 1989 Oct.

76) Al-Isa AN. Prevalence of obesity among adult Kuwaitis: a cross-sectional study. International Journal of Obesity & Related Metabolic Disorders. 19(6):431-3, 1995 Jun.

77) Resheed P. Overweight status: body image and weight control belefs and practices among female college students. Annals of Saudi Medicine. 19(4): 365-369,1999 July.

78) Al-Nuaim AR. al-Rubeaan K. al-Mazrou Y. alAttas O. al-Dsghsri N. Khoja T. High prevalence of overweight and obesity in Saudi Arabia. International Journal of Obesity & Related Metabolic Disorders. 20(6): P 457-52, 1996 June.

79) Hughes JM. Li L. Chinn S. Rona RJ. Trends in growth in England and Scotland, 1972 to 1994. Archives of Disease in Childhood. 76(3):182-9, 1997 Mar.

80) Kordy MN. el-gamal FM. A study of pattern of body mass index (BMI) and prevalence of obesity in a Saudi population. Asia-Pacific Journal of Public Health. 8(2):59-65, 1995.

81) Al-Nuaim AA. Bamgboye EA. al-Rubeaan KA. al-Mazrou Y. Overweight and obesity in Saudi Arabian adult population, role of socio-demographic variables. Journal of Community Health. 22(3):211-23, 1997 Jun.

82) Al-Isa AN. Temporal changes in body mass index and prevalence of obesity among Kuwaiti men. Annals of Nutrition & Metabolism. 41(5):307-14, 1997.

83) Al-Mannai A. Dickerson JW. Morgan JB. Khalfan H. Obesity in Bahraini adults. Journal of the Royal Society of Health. 116(1):30-2, 37-40, 1996 Feb.

84) Reddy BN. Body mass index and its association with socioeconomic and behavioral variables among socioeconomically heterogeneous populations of Andhra Pradesh, India. Human Biology. 70(5):901-17, 1998 Oct.

85) Kuskowska-Wolk A. Bergstrom R. Trends in body mass index and prevalence of obesity in Swedish men 1980-89. Journal of Epidemiology & Community Health. 47(2):103-8. 1993 Apr.

86) Legato MJ. Gender-specific aspects of obesity. International Journal of Fertility & Womens Medicine. 42(3):184-97, 1997 May-Jun.

87) Martorell R. Khan LK. Hughes ML. Grummer-Strawn LM. Obesity in women from developing countries. European Journal of Clinical Nutrition. 54(3):247-52. 2000 Mar.

88) Al-shoshan AA. Some sociodemographic factors influencing the nutritional awareness of the Saudi teens and adults: preliminary observations. Journal of the Royal Society of Health. 110(6):213-6, 1990 Dec

89) Beer-Borst S. Morabia A. Hercberg S. Vitek O. Bernstein MS. Galan P. Galasso R. Giampaoli S. Houterman S. McCrum E. Panico S. Pannozzo F. Preziosi P. Ribas L. Serra-Majem L. Verschuren WM. Yarnell J. Northridge ME. Obesity and other health determinants across Europe: the EURALIM project. Journal of Epidemiology & Community Health. 54(6):424-30, 2000 Jun.

90) Maffeis C. Micciolo R. Must A. Zaffanello M. Pinelli L. Parental and perinatal factors associated with childhood obesity in north-east Italy. International Journal of Obesity & Related Metabolic Disorders. 18(5):301-5. 1994 May

91) Lake JK. Power C. Cole TJ. Child to adult body mass index in the 1958 British birth cohort: associations with parental obesity. Archives of Disease in Childhood. 77(5):376-81. 1997 Nov.

92) Serdula MK. Ivery D. Coates RJ. Freedman DS. Williamson DF. Byers T. Do obese children become obese adults? A review of the literature. Preventive Medicine. 22(2):167-77. 1993 Mar.

93) McInnis KJ. Exercise and obesity. Coronary Artery Disease. 11(2):111-6. 2000 Mar.

94) Sherwood NE. Jeffery RW. French SA. Hannan PJ. Murray DM. Predictors of weight gain in the Pound of Prevention study. International Journal of Obesity & Related Metabolic Disorders. 24(4):395-403. 2000 Apr.

95) Al-Mahroos F. McKeigue PM. High prevalence of diabetes in Bahrainis. Associations with ethnicity and raised plasma cholesterol. Diabetes Care. 21(6):936-42. 1998 Jun.

96) Pishdad GR. Overweight and obesity in adults aged 20-74 in southern Iran. International Journal of Obesity & Related Metabolic Disorders. 20(10):963-5. 1996 Oct.

97) Fontvieille AM. Kriska A. Ravussin E. Decreased physical activity in Pima Indian compared with Caucasian children. International Journal of Obesity & Related Metabolic Disorders. 17(8):445-52. 1993 Aug.

98) Chinn S. Hughes JM. Rona RJ. Trends in growth and obesity in ethnic groups in Britain. Archives of Disease in Childhood. 78(6):513-7. 1998 Jun.

99) Adams-Campbell LL. Wing R. Ukoli FA. Janney CA. Nwankwo MU. Obesity, body fat distribution, and blood pressure in Nigerian and African-American men and women. Journal of the National Medical Association. 86(1):60-4, 1994 Jan.

100) Lissner L. Heitmann BL. Dietary fat and obesity: evidence from epidemiology. European Journal of Clinical Nutrition. 49(2):79-90. 1995 Feb.

101) Lee JH. Reed DR. Price RA. Familial risk ratios for extreme obesity: implications for mapping human obesity genes. International Journal of Obesity & Related Metabolic Disorders. 21(10):935-40. 1997 Oct.

102) Sorensen TI. The genetics of obesity. Metabolism: Clinical & Experimental. 44(9 Suppl 3):4-6. 1995 Sep.

103) Bouchard C. Genetics of human obesity: recent results from linkage studies. Journal of Nutrition. 127(9):1887S-1890S. 1997 Sep.

104) Perusse L. Chagnon YC. Summary of human linkage and association studies. Behavior Genetics. 27(4):359-72. 1997 Jul.

105) Bouchard, C. Genetic Aspects of Human Obesity. In: Bjorntorp. P. and Brodoff. B.N. (eds). Obesity. pp. 343-351.Philadelphia:J.B. LippiflCOtt Company (1992).

106) Bouchard C. Perusse L. Leblanc C. Tremblay A. Theriault G. Inheritance of the amount and distribution of human body fat. International Journal of Obesity. 12(3):205-15. 1988

107) Mueller, WH. The genetics of human fatness. Yearbook of physical anthropology. 26: 215-230. 1983.

108) Bouchard C. Perusse L. Heredity and body fat. Annual Review of Nutrition. 8:259-77. 1988.

109) Seidell JC. Verschuren WM. van Leer EM. Kromhout D. Overweight, underweight, and mortality. A prospective study of 48,287 men and women. Archives of Internal Medicine. 156(9):958-63. 1996 May 13.

110) Nieto FJ. Szklo M. Comstock GW. Childhood weight and growth rate as predictors of adult mortality. American Journal of Epidemiology. 136(2):201-13, 1992 Jul 15.

111) Sowers JR. Modest weight gain and the development of diabetes: another perspective. Annals of Internal Medicine. 122(7):548-9, 1995 Apr 1.

112) Despres JP. The insulin resistance-dyslipidemic syndrome of visceral obesity: effect on patients' risk. Obesity Research. 6 Suppl 1:8S-17S. 1998 Apr.

113) Strohl KP. Strobel RJ, Parisi RA. Obesity and pulmonary function. In: Bray GA. Bouchard C. James WPT, eds. Handbook of Obesity. New York, NY: Marcel Dekker Inc:725-739. 1998.

114) Sheth SG. Gordon FD. Chopra S. Nonalcoholic steatohepatitis. Annals of Internal Medicine. 126(2):137-45. 1997 Jan 15.

115) Grodstein F. Goldman MB. Cramer DW. Body mass index and ovulatory infertility. Epidemiology. 5(2):247-50. 1994 Mar.

116) Skarfors ET. Selinus KI. Lithell HO. Risk factors for developing non-insulin dependent diabetes: a 10 year follow up of men in Uppsala. British Medical Journal. 303(6805):755-60. 1991 Sep 28.

117) Charles MA. Fontbonne A. Thibult N. Warnet JM. Rosselin GE. Eschwege E. Risk factors for NIDDM in white population. Paris prospective study. Diabetes. 40(7):796-9. 1991 Jul.

118) World Health Organization. Prevention of diabetes mellitus. 844. Geneva: WHO. 1997.

119) Van Itallie TB. Health implications of overweight and obesity in the United States. Annals of Internal Medicine. 103(6 (Pt 2)):983-8. 1985 Dec.

120) Kissebah AH. Vydelingum N. Murray R. Evans DJ. Hartz AJ. Kalkhoff RK. Adams PW. Relation of body fat distribution to metabolic complications of obesity. Journal of Clinical Endocrinology & Metabolism. 54(2):254-60. 1982 Feb.

121) Anderson. K.M. and Kannel. W.B. (1992). Obesity and Disease. In Bjorntorp. P. and Brodoff. B. N. (eds). Obesity. pp. 465-473. Philadelphia: J.B. Lippincott company. Ashley and Kannel 1974.

122) Ashley FW Jr. Kannel WB. Relation of weight change to changes in atherogenic traits: the Framingham Study. Journal of Chronic Diseases. 27(3):103-14. 1974 Mar.

123) Anderson KM. Wilson PW. Garrison RJ. Castelli WP. Longitudinal and secular trends in lipoprotein cholesterol measurements in a general population sample. The Framingham Offspring Study. Atherosclerosis. 68(1-2):59-66. 1987 Nov.

124) Kruszynska YT. Normal metabolism: the physiology of fuel homeostasis. In Pickup J & Williams G (eds) Textbook of Diabetes. 2nd Ed. Ch. 11. Oxford: Blackwell Science. 18. 1997.

125) DeFronzo. R. A: Bonadonna. R. C. and Ferrannin. E. Pathogenesis of NIDDM: A precarious balance between insulin action and insulin secretion. In: Alberti. K. G. M.M: Defronzo. R.A: Keen. H. and Zimmet, P. (eds). International textbook of diabetes mellitus. Volume 1. pp. 569-633. Chichester: John Wiley and Sons. 1992.

126) Mitchell BD. Hazuda HP. Patterson JK. Incidence of type II diabetes in Mexican Americans predicted by fasting insulin and glucose levels, obesity, and body-fat distribution. Diabetes. 39(3):283-8, 1990 Mar.

127) Eriksson J. Franssila-Kallunki A. Ekstrand A. Saloranta C. Widen E. Schalin C. Groop L. Early metabolic defects in persons at increased risk for non-insulin-dependent diabetes mellitus. New England Journal of Medicine. 321(6):337-43, 1989 Aug 10.

128) Gulli, G: Haffner, S; Ferrannini, and Defronzo, R.A. What inherited in NIDDM? Diabetes (Suppl.1), 39:116A. 1990.

129) Bonadonna RC, Croop LC. Zych K et al. Dose-dependent effect of insulin of plasma free fatty acid turnover oxidation in humans. American Journal of Physiology; 259: E736 -E750. 1990.

130) Boden G. Role of fatty acids in the pathogenesis of insulin resistance and NIDDM. Diabetes. 46(91): 3 -10. 1997.

131) Zimmet PZ. McCarty DJ. de Courten MP. The global epidemiology of non-insulin-dependent diabetes mellitus and the metabolic syndrome. Journal of Diabetes & its Complications. 11(2):60-8, 1997 Mar-Apr.

132) Ellenberg and Rifkin's. Diabetes mellitus, theory and practice (Epidemiology of diabetes mellitus), 4thed. Elsvier. 1990. PP. 357-77.

133) Harris MI. Flegal KM. Cowie CC. Eberhardt MS. Goldstein DE. Little RR. Wiedmeyer HM. Byrd-Holt DD. Prevalence of diabetes, impaired fasting glucose, and impaired glucose tolerance in U.S. adults. The Third National Health and Nutrition Examination Survey, 1988-1994. Diabetes Care. 21(4): 518-24, 1998 Apr.

134) Young TK. Mustard CA. Undiagnosed diabetes: does it matter? Canadian Medical Association Journal. 164(1):24-8. 2001 Jan 9.

135) Herman WH. Ali MA. Aubert RE. Engelgau MM. Kenny SJ. Gunter EW. Malarcher AM. Brechner RJ. Wetterhall SF. DeStefano F. Diabetes mellitus in Egypt: risk factors and prevalence. Diabetic Medicine. 12(12):1126-31, 1995 Dec.

136) Trinder P. Determination of blood glucose using an oxidase-peroxidase system with a non carcinogenic chromogen. Journal of Clinical Pathology. 22(2):158-61, 1969 Mar.

137) Allain CC. Poon LS. Chan CS. Richmond W. Fu PC. Enzymatic determination of total serum cholesterol. Clinical Chemistry. 20(4):470-5, 1974 Apr.

138) Cutrtius E and Roth M: Clinical Biochemistry. Berlin–New York: Gruyter, 1974. p. 1029.

139) Fredrickson DS. Levy RI. Lees RS. Fat transport in lipoproteins--an integrated approach to mechanisms and disorders. New England Journal of Medicine. 276(3): 148-56, 1967 Jan 19.

140) Expert Committee on the Diagnosis and Classification of Diabetes Mellitus: Report of the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus. Diabetes Care. 20(7): 1183-97, 1997 Jul.

141) World Health Organization: Definition, diagnosis and classification of diabetes mellitus and its complications: Report of a WHO consultation. Part I. Diagnosis and classification of diabetes mellitus. WHO, Geneva, 1999.

142) Gabir MM. Hanson RL. Dabelea D. Imperatore G. Roumain J. Bennett PH. Knowler WC. The 1997 American Diabetes Association and 1999 World Health Organization criteria for hyperglycemia in the diagnosis and prediction of diabetes. Diabetes Care. 23(8):1108-12, 2000 Aug.

143) Gibson RS. Principles of Nutritional Assessment. Oxford University Press 1990, p. 163-208.

144) Wilson PW. An epidemiologic perspective of systemic hypertension, ischemic heart disease, and heart failure. American Journal of Cardiology. 80(9B):3J-8J, 1997 Nov 13.

145) Abdella N. Al Arouj M. Al Nakhi A. Al Assoussi A. Moussa M. Non-insulin-dependent diabetes in Kuwait: prevalence rates and associated risk factors. Diabetes Research & Clinical Practice. 42(3):187-96, 1998 Dec.

146) Armstrong D. Abdella N. Salman A. Miller N. Rahman EA. Bojancyzk M. Relationship of lipid peroxides to diabetic complications. Comparison with conventional laboratory tests. Journal of Diabetes & its Complications. 6(2):116-22, 1992 Apr-Jun.

147) Asfour MG. Lambourne A. Soliman A. Al-Behlani S. Al-Asfoor D. Bold A. Mahtab H. King H. High prevalence of diabetes mellitus and impaired glucose tolerance in the Sultanate of Oman: results of the 1991 national survey. Diabetic Medicine. 12(12):1122-5, 1995 Dec.

148) El Mugamer IT. Ali Zayat AS. Hossain MM. Pugh RN. Diabetes, obesity and hypertension in urban and rural people of bedouin origin in the United Arab Emirates. Journal of Tropical Medicine & Hygiene. 98(6):407-15, 1995 Dec.

149) Wilson PW. Anderson KM. Kannel WB. Epidemiology of diabetes mellitus in the elderly. The Framingham Study. American Journal of Medicine. 80(5A):3-9, 1986 May 16.

150) Rimm EB. Chan J. Stampfer MJ. Colditz GA. Willett WC. Prospective study of cigarette smoking, alcohol use, and the risk of diabetes in men. British Medical Journal. 310(6979):555-9, 1995 Mar 4.

151) Ko GT. Chan JC. Tsang LW. Critchley JA. Cockram CS. Smoking and diabetes in Chinese men. postgraduate medical journal. 77:240-243, 2001 April

152) Okosun IS. Cooper RS. Rotimi CN. Osotimehin B. Forrester T. Association of waist circumference with risk of hypertension and type 2 diabetes in Nigerians, Jamaicans, and African-Americans. Diabetes Care. 21(11):1836-42, 1998 Nov.

153) Manzato E. Crepaldi G. Dyslipoproteinaemia in manifest diabetes. Journal of Internal Medicine. Supplement. 736:27-31, 1994.

154) Epstein M. Diabetes and hypertension: the bad companions. Journal of Hypertension. 15(2):S55-62, 1997 Mar.

155) Harris MI. Undiagnosed NIDDM: clinical and public health issues. Diabetes Care. 16(4):642-52, 1993 Apr.

156) Seidell JC. Obesity, insulin resistance and diabetes--a worldwide epidemic. British Journal of Nutrition. 83 Suppl 1:S5-8. 2000 Mar.

157) Monteiro CA. D'A Benicio MH. Conde WL. Popkin BM. Shifting obesity trends in Brazil. European Journal of Clinical Nutrition. 54(4):342-6, 2000 Apr.

158) Lean ME. Han TS. Morrison CE. Waist circumference as a measure for indicating need for weight management. British Medical Journal. 311(6998):158-61. 1995 Jul 15.

159) Molarius A. Seidell JC. Sans S. Tuomilehto J. Kuulasmaa K. Varying sensitivity of waist action levels to identify subjects with overweight or obesity in 19 populations of the WHO MONICA Project. Journal of Clinical Epidemiology. 52(12):1213-24, 1999 Dec.

160) El-Hazmi M. and Warsy A.S. Prevalence of Obesity in the Saudi Population. Annals of Saudi Medicine. 17(3):302.06, 1997.

161) Keil U. Kuulasmaa K. WHO MONICA Project: risk factors. International Journal of Epidemiology. 18(3) Suppl 1:S46-55, 1989.

162) Al-Isa AN. Changes in body mass index (BMI) and prevalence of obesity among Kuwaitis 1980-1994 International Journal of Obesity & Related Metabolic Disorders. 21(12):1093-9, 1997 Dec.

163) Musaiger AO. al-Roomi KA. Prevalence of risk factors for cardiovascular diseases among men and women in an Arab Gulf community. Nutrition & Health. 11(3):149-57, 1997.

164) Owen-Smith V. Hannaford PC. Stopping smoking and body weight in women living in the United Kingdom. British Journal of General Practice. 49(449):989-90, 1999 Dec.

165) Kunz I. Schorr U. Klaus S. Sharma AM. Resting metabolic rate and substrate use in obesity hypertension. Hypertension. 36(1):26-32, 2000 Jul.

166) Ismail AA. Gill GV. The epidemiology of Type 2 diabetes and its current measurement. Best Practice & Research Clinical Endocrinology & Metabolism. 13(2): 197-220, 1999.

167) King H. Aubert RE. Herman WH. Global burden of diabetes, 1995-2025: prevalence, numerical estimates, and projections. Diabetes Care. 21(9):1414-31, 1998 Sep.

168) Popkin BM. Doak CM. The obesity epidemic is a worldwide phenomenon. Nutrition Reviews. 56(4 Pt 1):106-14, 1998 Apr.

169) Zimmet PZ. Kelly West Lecture 1991. Challenges in diabetes epidemiology--from West to the rest. Diabetes Care. 15(2):232-52, 1992 Feb.

170) Harris MI. Hadden WC. Knowler WC. Bennett PH. Prevalence of diabetes and impaired glucose tolerance and plasma glucose levels in U.S. population aged 20-74 yr. Diabetes. 36(4):523-34, 1987 Apr.

171) Olivarius ND, Andreasen AH. Weight history and its impact on risk factors and diabetic complication of newly diagnosed diabetic patients 40 years and over. Proceedings of the 15th IDF congress. Kobe. Japan 1994: 122(Abst).

172) LeRith D, Tay SI, Olefsky JM. Diabetes Mellitus: a fundamental and clinical text. 2nd ed. Lippincott Williams and Wilkins. 2000. P.567-75.

173) Simmons D. Thompson CF. Volklander D. Polynesians: prone to obesity and Type 2 diabetes mellitus but not hyperinsulinaemia. Diabetic Medicine. 18(3):193-8. 2001 March.

174) Perez-Bravo F. Carrasco E. Santos JL. Calvillan M. Larenas G. Albala C. Prevalence of type 2 diabetes and obesity in rural Mapuche population from Chile. Nutrition. 17(3):236-8. 2001 March.

175) Al-Nuaim AR. High prevalence of metabolic risk factors of cardiovascular diseases among Saudi population, aged 30-60 years. International journal of cardiology: 62:227-235. 1997.

176) Vital Statistics. Saudi Central Department of Statistics. National Population Census. Ministry of Planing: Riyadh. 1992.

177) Stephens WP. Tunbridge RD. Moss DA. Evaluation of screening for hypertension in general practice with an automatic machine. British Medical Journal Clinical Research Ed. 287(6405):1600-2. 1983 Nov 26.

178) Tappy L. Bovet P. Shamlaye C. Prevalence of diabetes and obesity in the adult population of the Seychelles. Diabetic Medicine. 8(5):448-52. 1991 Jun.

179) Shmulewitz D. Auerbach SB. Lehner T. Blundell ML. Winick JD. Youngman LD. Skilling V. Heath SC. Ott J. Stoffel M. Breslow JL. Friedman JM. Epidemiology and factor analysis of obesity. type II diabetes, hypertension, and dyslipidemia (syndrome X) on the Island of Kosrae. Federated States of Micronesia. Human Heredity. 51(1-2):8-19, 2001.

180) Kaye SA. Folsom AR. Sprafka JM. Prineas RJ. Wallace RB. Increased incidence of diabetes mellitus in relation to abdominal adiposity in older women. Journal of Clinical Epidemiology. 44(3):329-34. 1991.

181) Al-Nuaim AR. Prevalence of glucose intolerance in urban and rural communities in Saudi Arabia. Diabetes Medicine;14:595-602. 1997.

182) Dean JD. Durrington PN. Treatment of dyslipoproteinaemia in diabetes mellitus. Diabetic Medicine. 13(4):297-312, 1996 Apr.

183) Durrington PN. Diabetic dyslipidaemia. Best Practice & Research Clinical Endocrinology & Metabolism. 13(2):265-78, 1999 Jul.

184) Sheehan MT. Jensen MD. Metabolic complications of obesity. Pathophysiologic considerations. Medical Clinics of North America. 84(2):363-85,2000 Mar.

185) El-Hazmi MA, Al-Swailem AR, Wasry AS, Al-Meshari AA. Sulaimani R. Al-Swailem AM. and Magbool GM. Lipids and related parameters in Saudi type 2 diabetes mellitus patients. Annals of Saudi Medicine 19(4):304-307,1999.

186) Al-Muhtaseb N, Al-Yuosuf AR, Bajaj JS. Plasma lipoprotein and apolipoprotein in insulin – dependent and young non-insulin dependent arab women. Acta diabetologa 28: 61-69, 1991.

187) Al-Nuaim AR. Effect of overweight and obesity on glucose intolerance and dyslipidemia in Saudi Arabia, epidemiology study. Diabetes research and clinical practice: 36:181-91,1997.

188) Brown CD. Higgins M. Donato KA. Rohde FC. Garrison R. Obarzanek E. Ernst ND. Horan M. Body mass index and the prevalence of hypertension and dyslipidemia. Obesity Research. 8(9):605-19, 2000 Dec.