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Evaluation of Health and Diabetes Knowledge of CU4Health Participants by Food Frequency Questionnaire and Michigan Diabetes Knowledge Test

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EVALUATION OF HEALTH AND DIABETES KNOWLEDGE OF CU4HEALTH PARTICIPANTS BY FOOD FREQUENCY QUESTIONNARE AND MICHIGAN DIABETES KNOWLEDGE TEST

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ABSTRACT

Type 2 Diabetes (T2D) has been steadily rising in the United States. The condition is characterized by elevated blood glucose levels and is preceded by insulin resistance. Before the onset of T2D patients go through a state of pre-diabetes. To be tested for pre-diabetes and diabetes, either a Fasting Plasma Glucose test or an Oral Glucose Tolerance Test may be used. While an estimated 24 million Americans have T2D, another 57 million Americans are estimated to be in a state of pre-diabetes. There are many risk factors that may contribute to the development of T2D including obesity, a high calorie diet, lack of physical activity, genetic factors and aging. The complications associated with T2D may affect the kidney, nerves, eyes and feet. The prevalence of T2D continues to increase in the US and around the world including the developing world. Lifestyle interventions have been shown to be an effective way of treating and delaying T2D. There is a need for an effective intervention to reduce the rising incidence of T2D.

DEDICATION

I would like to dedicate this work in loving memory of my grandmother Denga Thilivhali. I cherish dearly everything you did to help raise me to be the person I am.

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CHAPTER ONE

LITERATURE REVIEW

Introduction

Type 2 Diabetes (T2D) is one of the major causes of death in the United States. The Centers for Disease Control and Prevention (CDC) has estimated that 8% of the US population or about 24 million Americans are living with diabetes. Another 57 million people are estimated to have pre-diabetes, and the total prevalence continues to increase (1). By 2004 there were 1.3 million new cases of diabetes occurring annually in the United States, and in 2007 the number of cases had risen to 1.6 million (2).

T2D is characterized by the body's inability to adequately manage blood glucose levels. T2D is usually preceded by insulin resistance which may indicate the initial stages of elevated blood glucose, progressing to pre-diabetes and eventually to diabetes. Along with insulin resistance, T2D may also be caused by genetic, environmental factors and cell dysfunction (3). The two environmental factors that have been identified as contributing the most to the development of T2D are a lack of physical activity and unhealthy eating habits (4, 5, 6, 7, 8). The prevalence and the increasing rise in the incidence of T2D, along with the factors potentially causing this disease, call for innovative ways to diagnose, treat, and manage T2D.

Diabetes versus Pre-diabetes

Definitions

Normal blood glucose levels are defined as fasting plasma glucose (FPG) <100 mg/dL. The hallmark of T2D is hyperglycemia which is defined as abnormally high levels of blood glucose of >125 mg/dL using the FPG test. Before the onset of T2D, the body goes through a period of elevated blood glucose termed “pre-diabetes”. Pre-diabetes is a condition defined by impaired glucose tolerance (IGT) or impaired fasting glucose (IFG) (7, 57). IGT is defined as a two-hour blood glucose levels (2h PG) of 140-199 mg/dL (7.8-11.0 mM/L) using the 75-g oral glucose tolerance test (OGTT), and IFG is defined as glucose levels (FPG) of 100-125 mg/dL (5.6- 6.9 mM/L) after an 8 hour fast (7, 9, 10).

The OGTT which measures IGT is a tool that is used to identify people who are at a greater risk of developing diabetes (10). Schwartz reported in 2007 that the development of diabetes and IGT could be predicted by impaired fasting glucose (11). The utilization of both FPG and the OGTT has been instrumental in identifying individuals who are at risk for diabetes. The FPG is quick and convenient while the OGTT takes more time and is expensive, however, there remain questions about which test is best used at various time in diagnosing T2D (10). Health professionals would like to identify more easily people who are at risk of developing T2D so that they may be provided useful education and interventions. One of the problems with diagnosis is that most people do not know when to get tested or what the risk factors are for pre-diabetes and diabetes. Individuals with IGT or IFG do not show any symptoms nor have scientists

associated pre-diabetes with any known disabilities, conditions or specific biomarkers (10). Perhaps the best early intervention would be to test people who have at least one diabetes risk factor so that they will know their glucose level.

Many researchers have proposed that health professionals explore all avenues to enable them to determine the specific blood glucose levels at which to start lifestyle intervention for pre-diabetics (11, 12, 13). It would be ideal to keep the blood levels at the normal range and avoid the development of hyperglycemia. The ability to identify and treat people who are developing these early signs of diabetes could be a good starting point in the quest to reverse the current upward trend of diabetes rates. To be successful in combating the current surge of T2D cases, it is imperative to understand the progression of pre-diabetes to diabetes (12).

Regulation of Blood Glucose Levels

Blood glucose levels are regulated by a negative feedback loop. Insulin and glucagon are hormones produced by pancreatic cells. When the body is functioning normally, insulin is released from the pancreatic β-cells into the blood in response to increased levels of blood glucose. This generally happens after consuming food. The glucose transporters help to usher glucose into the cells when blood glucose levels are elevated and to the skeletal muscle for storage and fat cells for use, lowering blood glucose levels**.** Glucose enters the liver by facilitated diffusion independent of insulin**.** Sodium/glucose co-transporter (SGLT) use an symport Na^+/glucose mechanism to move glucose against a concentration gradient into the intestinal and kidney cells**.** Glucagon, produced by the pancreatic alpha cells helps raise blood glucose levels. It stimulates

glycogen catabolism in the liver when the blood glucose levels are low. Glucagon also signals the liver to become active in gluconeogenesis and decrease its glycolytic activity. It also signals the pancreas to stop insulin production when blood glucose levels increase. This negative feedback loop helps maintain blood glucose homeostasis. Because they lack the enzyme glucose 6 phosphatase, the muscles do not directly contribute to blood glucose (although lactate produced in white muscle can be converted to glucose via the Cori Cycle in the liver).

Etiology of Type 2 Diabetes

Insulin Resistance

Insulin resistance can be defined as a condition in which the body fails to properly respond to insulin. This may be due to insulin deficiency, or the body's inability to use the available insulin. With insulin resistance, glucose concentration increases due to glucose appearance exceeding glucose disappearance in the blood. Insulin concentration will be increased simultaneously with the blood glucose concentration. When this happens the cells will fail to respond to the available insulin and the pancreas will produce more insulin because of the elevated blood glucose levels. However, sometimes the pancreas is not able to produce adequate insulin to compensate for the increasing insulin "resistance" and this may be a result of β-cells' exhaustion (progressive decline in β-cells' function) (14). Insulin resistance may be a result of the reduction in the numbers of insulin receptors, the affinity of the receptors or their diminishing function (15). This may be a result of genetic predisposition or aging. Insulin resistance can develop simultaneously with elevated blood glucose levels or it may occur independently. This

negative feedback loop will not help if insulin receptors are decreased in number or defective. Glucagon production may be inhibited by the high levels of insulin in the blood. Blood glucose will continue to increase and may be at much higher levels than normal. Over a period of time this will eventually lead to sustained elevated serum glucose levels, termed hyperglycemia. Over time, the elevated levels of glucose in the blood and the inability of the body to clear glucose fast enough from the blood, may result in pre-diabetes and eventually T2D (16).

Obesity and Fat Distribution

There is an increase in the prevalence of diabetes, pre-diabetes, and obesity in the adult population (17, 18). While previously thought to be adult onset diabetes, according to the ADA, T2D is now diagnosed in >40% of all adolescence diabetes cases in certain parts of the US (18, 19). This is of enough concern to call for a major policy change to avoid a public health catastrophe (17, 20). The National Health and Nutrition Examination Survey (NHANES) estimated the adult obesity rates at 33.8% (21). Several studies have reported that 85-90% of people who have T2D are usually overweight or obese (22, 23, 24, 25, 26). Individuals whose Body Mass Index (BMI) range from 25-29.9 are said to be overweight, while those with a BMI of over 30 are considered to be obese. BMI is an indicator of body fat based on an individual's height and weight.

Obesity will often precede insulin resistance and eventually T2D. However, overweight or obese people who do not have high amounts of intra-abdominal fat may be able to remain in the state of insulin resistance with less chance of developing diabetes (27). As a result, obesity increases the risk of developing T2D, but is not a guaranteed

risk factor for T2D. Fat distribution plays a role in determining the level of risk that may be associated with the development of diabetes. Fat may be distributed viscerally or peripherally in the body. Peripheral subcutaneous fat is the fat that is deposited under the skin and is mostly well distributed over the body**,** mostly in the hips, upper arms and thighs. Visceral fat is stored in the abdomen and it is thought to have a higher metabolic activity level. When visceral fat is accumulated in organs such as the liver and muscle, it is likely to impair the function of organs and this may contribute to insulin resistance (28, 29). This may also be caused by increased lipolysis, along with impaired glucose uptake which will lead to elevated free fatty acids. This is also likely to eventually lead to insulin resistance. Fatty acids will bind to the cell membranes of non-adipose cells and this will result in the impaired function of the tissue. An example of this would be skeletal muscle cells which will be less efficient if the free fatty acids bind to their membrane and as a result reduce their effectiveness at glucose uptake (30, 31).

Nuclear factor *κ*B (NF-*κ*B) is a nuclear transcription factor that regulates DNA transcription (32). It is found in the cytoplasm bound by inhibitor protein. NF-*κ*B activates gene expression for inflammatory compounds, regulation of cell proliferation and apoptosis in response to stimuli such as stress, free radicals, cytokines, lymphokines and growth factors (33) and may contribute to incidences of autoimmune disease**.** Studies have reported that high levels of fat and fatty acids can lead to the activation Jun N-terminal kinase (JNK), inhibitor of NF-κB kinase (IKK), and novel isoforms of protein kinase C in insulin sensitive cells (30, 34, 35) (Fig.1). This could happen in the adipocytes, liver and skeletal muscle cells. Once activated, the kinases can lead to

"inflammation and cell adhesion" (30, 36, 37). Individuals whose fat mass is mostly distributed as peripheral subcutaneous fat may have less risk for development of diabetes; while fat that is mostly distributed in the abdomen will result in an increased risk for diabetes. This is because excessive abdominal fat contributes to the development of insulin resistance by releasing high amount of free fatty acids into the blood. High levels of lipid accumulated in non adipose tissue is associated with insulin resistance (80). This conclusion is consistent with the fact that about 90-95% of all people with diabetes have T2D and about 90% of those who have T2D are either overweight or obese (24, 25).

A number of studies have shown that increased subcutaneous abdominal fat or increased visceral fat may underlie central adiposity, particularly if the two conditions are coexisting (6, 22, 23). However, using a CT scan, Bray and colleagues found that subcutaneous fat measured by CT scan did not predict diabetes, and that waist circumference was a much better predictor of diabetes risk (22). In an earlier study of participants who were in a fat and weight reduction targeted exercise regimen, Carr and colleagues found that people who decreased their weight and body fat had better insulin sensitivity. They also found that the decrease in "weight and intra-abdominal fat, but not percent body fat or abdominal subcutaneous fat, were associated with a 24-month positive improvement in β-cell function" (6). The findings from Bray's study seem to suggest that being overweight or obese does not necessarily lead to the development of diabetes. The Carr study indicates that intra-abdominal fat could be a more reliable target for fat reduction. This information should be borne in mind for understanding the

complexities of the disease and when designing interventions that could restore the quality of life for many people who have T2D.

Environmental Factors

Diet

A diet high in calories and saturated fat will likely result in the development of obesity, unless the calorie consumption is countered with adequate caloric expenditure. A balanced diet is one of the more effective approaches to diabetes prevention and treatment. The 2005 Dietary Guidelines for Americans recommends that a person on a 2000 kcal diet plan should consume a diet composed of 45-65% kcal from carbohydrates, 20-35% from fat (< 10% saturated fat), and 10-35% of protein (38). The USDA MyPyramid recommends that this person should consume at least 2 cups of fruits, 2.5 cups of vegetables, 6 oz of grains, 5.5 oz of meats and legumes, 3 cups of milk, and 6 teaspoons of oil each day (39). However, when people are given a choice they seem to select foods which are high in saturated fat and low in vegetables, fruits, and whole grains. It is possible to consume only foods that are considered to be healthy, and still become overweight or obese or even develop diabetes. As a result, while it is important to consume foods that are high in fiber and whole grain, the total amount of calories consumed also needs to be considered (40). In a Finnish study (n = 4,344) of dietary patterns, participants aged 40-69 consumed a diet high in vegetables and fruits or one high in butter, potatoes, and whole milk (79). Researchers found those participants whose

dietary patterns included high amount of fruits (185 ± 143 g/day) and vegetables (180 ± 85.4 g/day) had a lower risk of developing diabetes. In the study of Schulze et al. 35, 340 participants aged 30–55 yrs whose self- reported dietary patterns were high in refined grains, sweetened drinks and processed meat had a higher risk of developing diabetes associated inflammation (41). Dietary patterns with high vegetable and fruit consumption can be clearly associated with a reduction in risk of developing diabetes.

For people living with diabetes, keeping blood glucose levels as close to normal as possible is the major goal. This can be hard to achieve for many patients, and since diabetes could be caused by different factors in different people, one approach to lower blood glucose may not achieve desired results for all diabetes patients (42). An individualized approach is therefore vital for successful diabetes treatment. Notwithstanding effects of reducing diabetes due to dietary changes, treating diabetes with diet is difficult because changing what people eat for the rest of their lives or changing the consumption of foods that define their culture is a daunting task (43, 44). People may be able to reduce their weight through a weight loss regimen which includes lifestyle changes of caloric restriction and physical activity. However, it has been reported that most people who lose their weight regain it one year later (40). This may help explain the ever-increasing rates of obesity and excess weight which in turn have a negative impact on the diabetes rates.

Physical Activity

Along with nutrition, physical activity is a major component of maintaining a healthy lifestyle. The CDC defines physical activity as “any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level” (45). Drawing from this definition, it would be wise to state the difference between physical activity and exercise because the two terms are sometimes used interchangeably. Exercise is a kind of physical activity which is usually designed and structured to increase physical fitness (45, 46). There are three components that can be used to assess the level of physical activity or of exercise and these are frequency, intensity and duration.

The frequency of the exercise or physical activity is an important aspect of the exercise program. It is important that an exercise reach the objective for which it was initially intended, and an exercise program should be performed for the duration of the time prescribed. The CDC and the American College of Sports Medicine (ACSM) recommend that people should participate in 30 min of moderate physical activity 3-5 times weekly (45, 46). The intensity of an exercise program can be measured using the metabolic equivalent (MET), where 1 MET is the rate of energy expenditure while sitting at rest for an hour (47). With this in mind the intensity of an exercise program can be defined as being light, moderate or vigorous activity. On a scale of 0-10, low intensity requires an energy expenditure of < 3 MET, while 3-5.9 is moderate intensity and 6-8 is classified as intense (45).

A number of studies have shown that physical activity along with diet can prevent, delay and reduce the risk of developing diabetes (7, 48, 49, 50, 51, 52, 53, 54, 55). For diabetes management and risk reduction, regulation of blood glucose levels should be borne in mind in order to achieve the desired blood glucose results. When performed at the above mentioned recommended levels of 30 min of moderate physical activity for 3 to 5 x/week, physical activity may produce many benefits including improvement of carbohydrate metabolism, insulin sensitivity, reducing cardiovascular risk, weight loss and weight maintenance, among others (45).

Genetic Factors

There is some evidence that fasting plasma glucose is increased when the β-cell function is decreased and that this may explain the subsequent increase in IFG for T2D (56). In individuals who have T2D, elevated blood glucose levels will continue to increase, without proper management and treatment (55). Obesity is a major risk factor for diabetes; however, if β-cell dysfunction occurs in conjunction with insulin resistance there will be an increased risk for an early onset of diabetes (20). If the body has declining β-cell function caused by genetic predisposition or other factors such as infection that can ultimately lead to low insulin levels, a cascade of events will likely occur which will increase the risk of development of T2D (14, 20). It has been reported that even after weight loss maintenance, people who are at a high risk of developing diabetes are still likely to experience continually declining β-cell function (6). Meyer et al. found that β-cell function, as measured by basal insulin release was impaired in

individuals who had impaired fasting glucose, but not in individuals with impaired glucose tolerance (56).

If insulin resistance occurs as the result of the body's inability to use insulin and the β-cells are functioning, then the β-cells may become exhausted due to increased insulin demand. This leads to hyperglycemia. After a number of years of having insulin resistance, the body will eventually progress to pre-diabetes and eventually diabetes (58)

Stress

Glucocorticoids increase in response to either physiological or psychological stress, but elevated and chronic levels of glucocorticoids will promote the development of obesity, particularly visceral obesity, because fat cells in the abdomen are more sensitive to cortisol (57). Glucocorticoids may promote insulin resistance by reducing glucose production and also reducing glucose uptake in order to preserve the available energy (58).

Family History

Lyssenko and colleagues reported that a family history of T2D was a major risk factor for the development of diabetes. They also indicated that the risk of diabetes was not reduced for the second relative of the diabetes patient (5). This is particularly disturbing given the report by Cowie and colleagues indicating that about 35.3% of the adults in the US had diabetes or pre-diabetes (17).

Gender Differences

There may be a gender bias to the development and prevalence of diabetes; however, different studies have shown variable results (59, 60). Women who gain excess weight during pregnancy may increase their chances of developing gestational diabetes. Women who have gestational diabetes have a 40% to 60% chance of developing T2D in 5 to 10 years (61, 81). Gender differences may be influenced by culture. A study of Iranian subjects found no significant difference in the prevalence of diabetes on the basis of gender (62). However, that country's national survey found a significant difference in the age-related prevalence ($P = 0.003$) of diabetes for women and men (8.3% vs. 7.1%) (17). The 2007 US Diabetes National Fact Sheet indicated 11.2% of men ≥20 years had diabetes, while 10.2% of women in this age group had the disease (61). In the US, the increased prevalence of diabetes in men (and women) may be influenced by their higher prevalence of obesity indicated by a BMI ≥30 (63).

Age

Age is a major risk factor for diabetes. The risk of developing diabetes increases at age 45, while the majority of people who have T2D are ≥ 55 yrs. (64). This risk usually peaks at ages 70-79 in most people (65). There are different reasons why middle aged people are more susceptible to developing diabetes. The pancreatic beta cells' production is decreased with age, and middle aged people often lose lean muscle tissue and increase adipose tissue. These factors may contribute to insulin resistance and eventually the development of diabetes. Ideally, delaying the onset of T2D would reduce complications and conditions related to diabetes (5, 7, 8). Additionally, conditions such as retinopathy,

high blood pressure and high cholesterol can be delayed or prevented by diabetes prevention interventions (44, 54, 66).

Educational Attainment

The prevalence of diabetes is highest in those who have <12 years of formal education (67). The benefits of modern research, intervention and treatment have substantially favored those with <12 years of education (68). This may be due to the fact that those with higher educational achievement are more likely to have access to and to embrace new technologies. The Danish national dietary survey found that men who had <12 years of education consumed less fruit (108±7.8 g/10MJ); and vegetables (84±8.4g/10MJ) in comparison with those who had more than 12 years of education, (fruits, (154±11.5g/10MJ); vegetables 126±9.5g/10MJ, P<0.001). (83). A Scottish survey found a higher education was associated with a higher health eating score for both men (22.6 vs 20.0) and women (25.3 vs 22.2) (84). It was suggested that lack of understanding and financial resources may also contribute to these differences. In a review of diabetes trends from 1989 – 2005, the prevalence of diabetes among middle-aged participants was higher (15.94%) in those with less than a high school education and lower (12.81%) in those with more high school (68). This pattern clearly suggests that education was a significant factor in diabetes prevalence and possibly for general health. In the same study, mortality rates were compared over 16 years. For middle-aged individuals, the mortality rate increased (75%) for those with lower levels of education while the rate decreased (7%) to (10.37) for those who had at least a college education or more than 12 years of schooling (68). Educational attainment was clearly an important factor in

diabetes care and prevention, and those who had more education were more likely to reap the benefits of any available care, intervention and treatment.

Increasing Prevalence

Type 2 diabetes is growing at a very fast rate in the U.S. and it continues to have a negative economic and public health impact on society (69). The disease has been shown also to be an emerging condition of major concern for American children (19). The current increasing rate for both adults and adolescents indicates that diabetes will continue to be a major cause of concern for the American public in the future (20).

Banjamin et al. (70) reported that in 2000, about 25% of the overweight adults who were between the ages of 44 and 75 had pre-diabetes, i.e., about 12 million adult Americans. By 2006, about 35.3% of the adults in the US had diabetes or pre-diabetes, a percentage that was equivalent to about 73.3 million Americans (17, 70). The CDC National Diabetes Fact Sheet report of 2007 stated that about 23% of the adult population over the age of 60 in the U.S. had diabetes (6). The CDC reported the number to be 24 million by the year 2008. What was also disturbing about this report was that about than 25% of those who had the disease did not even know about it (1).

The Southern States

While the adult incidence rates of diabetes have increased throughout the U.S., the rate of increase has been much higher in the Southern states. In South Carolina the rate of increase for adults was 113% in 2008 when comparing the diabetes rates from 2005-2007 with those from 1995-1997 (CDC, 2008). In 2010 the prevalence of diabetes in South Carolina was 10% compared to 4.9% in 1997 (82). The CDC report showed that

of all the states surveyed, South Carolina was second only to West Virginia in the prevalence of diabetes (1).

Worldwide Prevalence

The increasing diabetes prevalence rate is not limited to the United States: Rates are increasing in all populations around the world (54). Diabetes affects the developed and developing nations (71, 72, 54). Despite years of concern about the problem, not enough has been done to avert the continuing trend. In 1997, Pan and colleagues warned about the risk of diabetes and that diabetes will be a public burden. They also expressed concern that diabetes would lead to vascular complications which may lead to morbidity and premature death (72). It is thought that "population growth, aging, urbanization, and increasing prevalence of obesity and physical inactivity" are the main contributing factors to the increasing diabetes rates (73). Motala and colleagues reported that the peak age for diabetes prevalence in South Africa was 55-64 years (71). This age-related prevalence was also the case in China where diabetes increased with age and personal annual income and was about three times higher than 10 years ago (72, 73). In many countries urbanization, obesity and aging may be the major factors behind the increasing diabetes prevalence.

Diabetes Complications

Many studies have documented a strong correlation between diabetes, pre-diabetes and heart disease and low life expectancy (6, 70, 74, 75). Effective interventions could help lessen the risk for all of these conditions (54). Benjamin and colleagues found that among individuals who had pre-diabetes, the incidence of CVD risk factors was

high: dyslipidemia (94.9%), hypertension (56.5%), smoking (16.6%), and microalbuminuria (13.9%) (70). Diabetes takes a toll on the body because it usually occurs with many other risk factors such as hypertension, hypertriglyceridemia, low HDL-cholesterol, and high concentration of small dense LDL (75).

The National Institute of Diabetes and Digestive and Kidney Diseases reported that diabetes complications affect many organs but most of the damage typically occurs in the kidney, nerves, eyes and feet (76). Diabetic nephropathy occurs when high blood glucose causes kidney damage. When the kidneys are damaged their ability to filter impurities from the body could be compromised and this may lead to kidney failure (76). In diabetes, when high blood glucose causes damage to the nerves it is termed diabetic neuropathy. This occurs when the linings of the nerves and blood vessels are damaged and may cause diabetic patients to lose feeling in their feet. The glucose transporter (glucose permease) of the red blood cells is not sensitive to insulin and operates merely based on blood glucose levels. As a result, when the blood glucose is elevated glucose movement into the red blood cells will increase. So the result is increased A1c and all the attendant problems which are associated with the statements below. Very high A1c reduces efficiency of the Bohr Effect and reduces oxygenation of the tissues. The blood oxygen is reduced due to the defective hemoglobin and its inability to transport oxygen effectively. Elevated A1c also reduces nitric oxide transport which leads to failure of vasodilation and subsequent increased blood pressure. Damage to the blood vessels (and defective hemoglobin) may reduce oxygen to the feet and reduce transport of nitric oxide which will adversely affect vasodilation and lead to foot damage and even amputation.

Diabetic retinopathy occurs when the blood vessels of the retina in the eyes are damaged. This may lead to blurry vision or blindness. Diabetes also increases the risk of having a heart attack and stroke and most people with diabetes die from heart attack (69, 70).

Diabetes and Pre-diabetes Intervention and Prevention

There is great interest in the medical community regarding how to detect diabetes and pre-diabetes in the early stages (77). This is particularly important as the development and progression of pre-diabetes to diabetes occurs over many years (58). Because pre-diabetes is asymptomatic, patients are not alerted to the problem and as a result, pre-diabetes may go undetected until diabetes actually develops (10, 54). Another problem is that the limited available methods of treatment, such as drug treatment, remain inadequate and do not provide a cure, which makes prevention highly desirable (49). Preventative intervention seems to be the most viable and reasonable option, and with more than 73.3 million Americans who have diabetes or pre-diabetes the need for intervention is quite strong (17). A successful intensive intervention for both diabetes and pre-diabetes will be challenging and will not produce the desired results overnight, because obesity (as one of the main contributing factors) and diabetes develop over many years (58). It is likely that successful interventions require lifelong lifestyle change with the additional involvement of local communities and organizations (7). It is inevitable that the cost of this kind of intervention will be large and it would be wise to have reliable risk and cost assessments prior to embarking on such a large endeavor (75). The cost of large intervention studies may be substantially high in monetary and emotional terms; however, the expected reduced morbidity and mortality rates linked to the remediation of

T2D justify this kind of investment (20). Investing in the community's health in the form of accessible intervention and wellness programs will be helpful and rewarding for the public and may reduce the public health burden of diabetes (53).

Many studies have shown that diabetes can be prevented or delayed by lifestyle intervention in people who are in a pre-diabetic state, and that reduction in weight and an increase in physical activity can decrease the risk of developing diabetes for people who have pre-diabetes (8, 53, 54, 56). Some of the more notable diabetes intervention studies are the Chinese Da Qing IGT and Diabetes Study, Diabetes Prevention Program, as well as the Finnish Diabetes Prevention Study. In the above mentioned studies, researchers found that over a period of 3 years or more, there was a reduction in the development of diabetes by 42–58% as a result of their lifestyle intervention programs (4, 51, 55, 75). In the Finnish study, researchers found that weight loss and increased physical fitness were equally correlated to improved glucose tolerance which decreased by –2±12 mg/dL when compared to an increase of +0.2±0.8 mg/dL in the control group ($P<0.001$) (53). Individuals who reduced their weight and increased their oxygen uptake attained the best improvement. This indicated that weight reduction along with physical activity were the best interventions when applied together. Additionally Lindstrom and colleagues reported that participants had an A1c metabolic improvement of -0.2 ± 0.6 in the treatment group compared to an increased A1c in the control group (0.06+/ $P= 0.002$), and that if the dietary counseling and resistance training and increased physical activity lifestyle changes used in the intervention were continued diabetes could be delayed by several years (54). In 2005, Carr and colleagues reported that lifestyle modifications consisting of

the American Heart Association (AHA) Step 2 diet and endurance exercise for 24 months in Japanese Americans with IGT improved insulin sensitivity, decreased percentage body fat, reduced visceral and subcutaneous abdominal fat and increased weight loss (6).

Interventions may need to be designed differently for different populations and locations, taking into consideration cultural and social aspects of each community (53). When designing an intervention it would be more cost effective to focus on the communities that are more severely affected by obesity and diabetes, thus providing a greater initial impact on reducing the prevalence of diabetes in the future (76). It appears reasonable to introduce lifestyle interventions to people who are at a higher risk of developing diabetes before a diagnosis of pre-diabetes, especially in individuals who are obese. As individuals age, β-cell function decreases and they are more inclined to gain weight. This makes long-term lifestyle intervention more difficult (6). It would be a challenge for public health professionals to single out obese people to participate in interventions because not all obese people develop diabetes (24, 25).

Those who have pre-diabetes should be given priority for lifestyle interventions as they are at a much higher risk of developing diabetes (57). Individuals with IGT may reduce T2D risk by implementing lifestyle modifications resulting in improved insulin sensitivity, improved β-cell function or both (6). It has been reported that increasing regular physical activity and preventing weight gain are essential in order to slow down the transition toward the high visceral adipose fat content and high insulin resistance state shown to promote the highest metabolic risk for diabetes (78).

Conclusions

Diabetes prevalence has continued to increase along with the obesity prevalence. There is a need for an effective and feasible solution to curb this prevalence. Public health professionals have implemented many strategies to address the obesity epidemic including diabetes education and promotion of physical activity and a healthy diet. Diabetes interventions involving exercise and diet are more likely the better approach to treating and preventing diabetes. However, while most studies including the large-scale Da Qing IGT and Diabetes Study, the Diabetes Prevention Program, and the Finnish Diabetes Prevention and the work of Carr et.al showed insulin sensitivity improved with diet and exercise; there have been some conflicting data, with a lesser number of studies showing minimal improvement in glucose tolerance and β-cell function (3, 6, 57). Given the evidence, it is reasonable to conclude that since current medications have shown little or no success in combating the onset and prevalence of diabetes, it would be better to use preventative measures. Individuals who have a diagnosis of pre-diabetes and those who have diabetes risk factors should be informed of the lifestyle changes that can reduce the risk of developing diabetes.

References

1. Centers for Disease Control and Prevention. Number of People with Diabetes Increases to 24 Million. *Estimates of Diagnosed Diabetes Now Available for all U.S. Counties.* Available at: http://www.cdc.gov/media/pressrel/2008/r080624.htm Accessed March 20, 2009.

2. American Diabetes Association. Diabetes statistics. 2007. Available at: http://www.diabetes.org/diabetes-basics/diabetes statistics/ Accessed March 25, 2009.

3. Gungor N, Bacha F, Saad R, Janosky J, Arslanian S. Youth Type 2 Diabetes Insulin resistance,ß-cell failure, or both? *Diabetes Care.* 2005;28:638-644.

4. Jonker JT, De Laet C, Franco OH, Peeters A, Mackenbach J, Nusselder WJ. Physical activity and life expectancy with and without diabetes: life table analysis of the Framingham Heart Study. *Diabetes Care.* 2006;29:38-43.

5. Lyssenko V, Almgren P, Anevski D, Perfekt R, Lahti K, Nissen M, Isomaa B, Forsen B, Homstrom N, Saloranta C, Taskinen M, Leif G, Tuomi T. For the Botnia Study Group. *Diabetes.* 2005;54:166–174.

6. Carr DB, Utzschneider KM, Boyko EJ, Asberry PJ, Hull RL, Kodama K, Callahan HS, Matthys CC, Leonetti DL, Schwartz RS, Kahn SE, Fujimoto WY: A reduced-fat diet and aerobic exercise in Japanese Americans with impaired glucose tolerance decreases intra-abdominal fat and improves insulin sensitivity but not β-cell function. *Diabetes.* 2005;54:340–347.

7. Ackermann RT, Finch EA, Brazening E, Zhou H, Marrero DG. Translating the Diabetes Prevention Program into the Community: The DEPLOY Pilot Study. *American Journal of Preventaive Medicine.* 2008;35(4):357–363.

8. Brown JS, Wing R, Barrett-Connor E, Nyberg LM, Kusek JW, Orchard TJ, Ma Y, Vittinghoff E, Kanaya AM. Lifestyle intervention is associated with lower prevalence of urinary incontinence: the Diabetes Prevention Program. *Diabetes Care.* 2006;29:385–90.

9. Rao SS, Disraeli P, McGregor T. Impaired glucose tolerance and impaired fasting glucose. *American Family Physician.* 2004;69:1961-8.

10. Stern PM, Williams K, Haffner SM. Identification of Persons at High Risk for Type 2 Diabetes Mellitus: Do We Need the Oral Glucose Tolerance Test? *Annals of Internal Medicine.* 2002;136:575-581.

11. Schwarz PE, Bornstein SR. Pre-diabetes and metabolic syndrome in Germans. *Hormone and Metabolism Research*. 2006;38:359.

12. Perreault L, Bergman BC, Playdon MC, Man CD, Cobelli C, Eckel RH. Impaired fasting glucose with or without impaired glucose tolerance: progressive or parallel states of pre-diabetes? *American Journal of Physiology, Endocrinology and Metabolism.* 2008;95:428-435.

13. Schwarz PEH, Bornstein SR, Hanefeld M. Elevated fasting glucose levels predicts IGT and diabetes also in middle-age subjects. *Diabetes Research and Clinical Practice.* 2007;77:48–150.

14. Rhee SY, Chon S, Oh S, Kim SW, Kim J, Kim YS, Woo J. Insulin secretion and insulin resistance in newly diagnosed, drug naive pre-diabetes and type 2 diabetes patients with/without metabolic syndrome. *Diabetes Research and Clinical Practice.* 2007;76:397–403.

15. Stefan N, Thamer C, Staiger H, Machicao F, Machann J, Schick F, Venter C, Niess A, Laakso M, Fritsche A, Haring HU. Genetic variations in PPARD and PPARGC1A determine mitochondrial function and change in aerobic physical fitness and insulin sensitivity during lifestyle intervention. *Journal of Clinical Endocrinology Metabolism*. 2007;92:1827–1833.

16. Meigs JB, Muller DC, Nathan DM, Blake DR, Andres R. The natural history of progression from normal glucose tolerance to type 2 diabetes in the Baltimore Longitudinal Study of Aging. *Diabetes.* 2003;52:1475–1484.

17. Cowie CC, Rust KF, Byrd-Holt DD, Eberhardt MS, Flegal KM, Engelgau MM, Saydah SH,Williams DE, Geiss LS, Gregg EW. Prevalence of diabetes and impaired fasting glucose in adults in the U.S. population: National Health and Nutrition Examination Survey 1999–2002. *Diabetes Care.* 2006;29:1263–1268.

18. Grinstein G, Muzumdar R, Aponte L, Vuguin P, Saenger P, DiMartino-Nardi J. Presentation and 5 year follow-up of type 2 diabetes mellitus in African-American and Caribbean- Hispanic adolescents. *Hormone Research in Pediatrics.* 2003;60(3):121–126.

19. American Diabetes Association. Type 2 Diabetes in Children and Adolescents. *Diabetes Care.* 2000;23(3):381–390.

20. Elder DA, Prigeon RL, Wadwa RP, Dolan LM, D'Alessio DA ß-Cell Function, Insulin Sensitivity, and Glucose Tolerance in Obese Diabetic and Nondiabetic Adolescents and Young Adults. *Journal of Clinical. Endocrinology Metabolism.* 2006;91:185–191.

21. Flegal KM, Carroll DM, Ogden CL, Curtin LR. Prevalence and Trends in Obesity Among US Adults, 1999-2008. *Journal of American Medical Association*. 2010;303:235–241.

22. Bray GA, Jablonski KA, Fujimoto WY, Barrett-Connor E, Haffner S, Hanson RL, Hill JO, Hubbard V, Kriska A, Stamm E, Pi-Sunyer FX. For the Diabetes Prevention Program Research Group Relation of central adiposity and body mass index to the development of diabetes in the Diabetes Prevention Program. *American. Journal of. Clinical Nutrition.* 2008;87:1212–1218.

23. Fujimoto WY, Jablonski KA, Bray GA, Kriska A, Barrett-Connor E, Haffner S, Hanson R, Hill JO, Hubbard V, Stamm E, Pi-Sunyer FX. For the Diabetes Prevention Program Research Group Body Size and Shape Changes and the Risk of Diabetes in the Diabetes Prevention Program. *Diabetes.* 2007;56:1680–1685.

24. 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. *Diabetes.* 1987;*36:*523–534.

25. Zimmet P, Alberti KG, Shaw J. Global and societal implications of the diabetes epidemic. *Nature*. 2001;414(6865):782–7.

26. Centers for Disease Control and Prevention. Prevalence of Overweight and Obesity Among Adults with Diagnosed Diabetes --- United States, 1988--1994 and 1999—2002. Available at: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5345a2.htm Accessed April 20, 2010.

27. Mokdad AH, Ford ES, Bowman BA, Dietz WH, Vinicor F, Bales VS, Marks JS. Prevalence of obesity, diabetes, and obesity-related health risk factors. *Journal of American Medical Association.* 2001;289:76–79.

28. Unger RH, Zhou Y-T, Orci L. *Proceedings National Academy of Sciences*. U.S.A 1999; 96:2327-2337.

29. Houmard JA. Intramuscular lipid oxidation and obesity. *The American Journal of Physiology -Regulatory, Integrative and Comparative Physiology.* 2008;294:R1111–R1116.

30. Maher JJ, Leon P, Ryan JC. Beyond insulin resistance: Innate immunity in nonalcoholic hepatitis. *Hepatology.* 2008;48(2):670-678.

31. Kotronen A, Juurinen L, Tiikkainen M, Vehkavaara S, Yki–Jarvinen H. Increased Liver Fat, Impaired Insulin Clearance, and Hepatic and Adipose Tissue Insulin Resistance in Type 2 Diabetes. *Gastroenterology.* 2008; 135(1) 122-130.

32. Ignatowicz E, Baer-Dubowska W. Resveratrol, a natural chemopreven-tive agent against degenerative diseases. *Polish journal of pharmacology.* 2001;53(6):557-69.

33. D'Acquisto F, May MJ, Ghosh S. Inhibition of nuclear factor kappa B (NF-κB): an emerging theme in anti-inflammatory therapies. *Molecular Interventions.* 2002;2:22-35.

34. Shoelson SE, Lee J, Goldfine AB. Inflammation and insulin resistance. *Journal of Clinical Investigation.* 2006;116:1793-1801.

35. Hotamisligil GS. Role of endoplasmic reticulum stress and c-Jun NH2-terminal kinase pathways in inflammation and origin of obesity and diabetes. *Diabetes.* 2005;54(Suppl 2):S73-S78.

36. Heilbronn L, Smith SR, Ravussin E. Failure of fat cell proliferation, mitochondrial function and fat oxidation results in ectopic fat storage, insulin resistance and type II diabetes mellitus. *International Journal of Obesity.* 2004;28:S12–S21.

37. Kotronen A, Juurinen L, Tiikkainen M, Vehkavaara S, Yki–Järvinen H. Increased Liver Fat, Impaired Insulin Clearance, and Hepatic and Adipose Tissue Insulin Resistance in Type 2 Diabetes. *Gastroenterology.* 2008; 135(1)122-130.

38. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Dietary Guidelines for Americans*. 2005.

39. United States Department of Agriculture. My Pyramid Available at: http://www.mypyramid.gov/. Accessed January 22, 2010.

40. Foreyt JP. Evidence for success of behavior modification in weight loss control. *Annals of Internal Medicine*. 1993;119:698-701.

41. Schulze M, Hoffmann K, Manson JE, Willett WC, Meigs JB, Weikert C, Heidemann C, Colditz GA, Hu FB. Dietary pattern, Inflammation, and incidence of type 2 diabetes in women. *American Journal of Clinical Nutrition.* 2005;82:675–684.

42. American Diabetes Association: Standards of medical care for patients with diabetes mellitus. *Diabetes Care*. 1998;(Suppl.1):S23-S31.

43. Bantle JP: Thoughts on the dietary treatment of diabetes mellitus. *Diabetes Care.* 1992;15:1821-1823.

44. American Diabetes association: American Diabetes Association Guide to Medical Nutrition Therapy. Alexandria, VA. American Diabetes Association, 1999.

45. Centers for Disease Control and Prevention (CDC). Division of Nutrition, Physical Activity and Obesity, National Center for Chronic Disease Prevention and Health Promotion, 2008.

46. American College of Sports Medicine. Guidelines for Exercise Testing and Prescription. 6th ed. Baltimore, Md: Lippincott Williams & Wilkins, 2000.

47. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Division of Nutrition and Physical Activity. *Promoting physical activity: a guide for community action*. Champaign, IL: Human Kinetics, 1999.

48. Eriksson AK, Ekbom A, Granath F, Hilding A, Efendic S, Östenson CG. Psychological distress and risk of pre-diabetes and Type 2 diabetes in a prospective study of Swedish middle-aged men and women. *Diabetic Medicine*. 2008;25:834–842.

49. Eriksson J, Lindström J, Valle T, Aunola S, Hämäläinen H, Ilanne-Parikka P, Keinänen- Kiukaanniemi S, Laakso M, Lauhkonen M, Lehto P, Lehtonen P, Louheranta A, Mannelin M, Martikkala V, Rastas M, Sundvall J, Turpeinen A, Viljanen T, Uusitupa M, Eriksson KF, Lindgiirde E. Prevention of Type 2 (non-insulin-dependent) diabetes mellitus by diet and physical exercise: The 6-year Malmo feasibility study. *Diabetologia.* 1991;34:891-898.

50. Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, Nathan DM. The Diabetes Prevention Program Research Group: Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *New England Journal of Medicine.* 2002;346:393–403.

51. Pan X, Yang W, Li G, Liu J. The National Diabetes Prevention and Control Cooperative Group: Prevalence of diabetes and its risk factors in China, 1994. *Diabetes Care.* 1997;20:1664-9.

52. Tuomilehto J, Lindstrom J, Eriksson JG, Valle TT, Hamaainen H, Ilanne-Parikka P, Keina¨nen-Kiukaanniemi S, Laakso M, Louheranta A, Rastas M, Salminen V, Uusitupa M. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *New England Journal of Medicine.* 2001;344:1343–1350.

53. Tuomilehto J. On behalf of the Finnish Diabetes Prevention. Study Group Prevention of Type II diabetes in subjects with impaired glucose tolerance: the Diabetes Prevention Study (DPS) in Finland. *Diabetologia* 1999; 42:793-801.

54. Lindstrom J, Louheranta A, Mannelin M, Rastas M, Salminen V, Eriksson J, Uusitupa M, Tuomilehto J. The Finnish Diabetes Prevention Study (DPS): lifestyle intervention and 3- year results on diet and physical activity. *Diabetes Care*. 2003; 26(12):3230-6.

55. Mason CC, Hanson RL, Knowler, WC. Progression to Type 2 Diabetes Characterized by Moderate Then Rapid Glucose Increases. *Diabetes.* 2007;568:2054-2061.

56. Weyer C, Bogardus C, Mott DM, Pratley RE. The natural history of insulin secretory dysfunction and insulin resistance in the pathogenesis of type 2 diabetes mellitus. *Journal of Clinical Investigation.* 1999;104:787–794.

57. Rizza RA, Mandarino LJ, Gerich JE. Cortisol-induced insulin resistance in man: impared suppression of glucose production and stimulation of glucose utilization due to a postreceptor detect of insulin action. *Journal of Clinical Endocrinology and Metabolism.* 1982;54:131-138.

58. Macfarlane DP, Forbes S, Walker BR. Glucocorticoids and fatty acid metabolism in humans: fuelling fat redistribution in the metabolic syndrome. *Journal of Endocrinology.* 2008;197:189–204.

59. Cowie CC, Eberhardt MS. Sociodemographic characteristics of persons with diabetes. In National Diabetes Data Group. Diabetes in America, 2nd ed. Washington, DC: National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, 1995;85-116.

60. Kenny SJ, Aubert RE, Geiss MA. Prevalence and incidence of non-insulin-dependent diabetes. In: National Diabetes Data Group. Diabetes in America, 2nd ed. Washington, DC: National Institutes of Health, National Institute of Diabetes and Digestive and Kidney. *Diseases*, 1995;47-67.

61. Centers for Disease Control and Prevention, *National Diabetes Fact Sheet: General Information and National Estimates on Diabetes in the United States, 2007*. Available at: http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2007.pdf Accessed February 10, 2010.

62. Hadaegh F, Bozorgmanesh RM, Ghasemi A, Harati H, Saadat N, Azizi F. High prevalence of undiagnosed diabetes and abnormal glucose tolerance in an Iranian urban population: Tehran Lipid and Glucose Study. *BMC Public Health*. 2008;8:176.

63. West KM. Epidemiology of Diabetes and its vascular lesions. New York Elsevier, 1978.

64. U.S. Department of Health and Human Services. *Healthy People 2010*. 2nd ed. With Understanding and Improving Health and Objectives for Improving Health. vols. Washington, DC: U.S. Government Printing Office, 2000.

65. The DECODE Study Group. Age-and Sex- Specific Prevalence of Diabetes and Impaired Glucose Regulation in 11 Asian Cohorts. *Diabetes Care* 2003; 26:1770-1780.

66. Jenkins DJA, Kendall CWC, McKeown-Eyssen G, Josse RG, Silverberg J, Booth GL, Vidgen E, Josse AR, Nguyen TH, Corrigan S, Banach MS, Ares S, Mitchell S, Emam A, Augustin LSA, Parker TL, Leiter LA. Effect of a Low–Glycemic Index or a High–Cereal Fiber Diet on Type 2 Diabetes: A Randomized Trial**.** *Journal of the American Medical Association.* 2008;300(23):2742-2753.

67. Schillinger D, Sarkar U. Numbers Don't Lie, but Do They Tell the Whole Story? *Diabetes Care.* 2009;32:1746-1747.

68. Miech R, Kim J, McConnell C, Hamman RA. Growing Disparity in Diabetes-Related Mortality U.S. Trends, 1989–2005. *American Journal of Preventive Medicine.* 2009;36(2):126-132.

69. Eriksson J, Lindström J, Valle T, Aunola S, Hämäläinen H, Ilanne-Parikka, Keinaonen-Kiukaanniemi S, Laakso M, Lauhkonen M, Lehto P, Lehtonen A, Louheranta A, Mannelin M, Martikkala V, Rastas M, Sundvall J, Turpeinen A, Viljanen T, Uusitupa M, Tuomilehto J. Prevention of Type II diabetes in subjects with impaired glucose tolerance: the Diabetes Prevention Study (DPS) in Finland. Study design and 1-year interim report on the feasibility of the lifestyle intervention program. *Diabetologia.*1999;42(7):793-801.

70. Benjamin SM, Valdez R, Geiss LS, Rolka DB, Narayan KM. Estimated number of adults with pre-diabetes in the US in 2000: opportunities for prevention. *Diabetes Care.* 2003;26(3):645-9.

71. Motala AA, Esterhuzen T, Gouws E, Pirie FJ, Omar MA. Diabetes and other disorders of glycemia in a rural South African community: prevalence and associated risk factors. *Diabetes Care.* 2008;31:1783-8.

72. Pan X, Yang W, Li G, Liu J. The National Diabetes Prevention and Control Cooperative Group: Prevalence of diabetes and its risk factors in China, 1994. *Diabetes Care.* 1997;20:1664-9.

73. Wild S, Green A, Sicree R, King H. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care.* 2004; 27:1047–53.

74. Franco OH, Steyerberg EW, Hu FB, Mackenbach J, Nusselder W. Associations of diabetes mellitus with total life expectancy and life expectancy with and without cardiovascular disease. *Archives of Internal Medicine.* 2007; 167:1145–1151.

75. Hanefeld M, Schmechel H, Schwanebeck U, Lindner J. The DIS Group Predictors of coronary heart disease and death in NIDDM: The Diabetes Intervention Study experience. *Diabetologia.* 1997;40:S123–S124.

76. The National Institute of Diabetes and Digestive and Kidney. Available at: http:/www.nlm.nih.gov/medlineplus/diabetescomplications.html Accesses February 18, 2010.

77. El Bassuoni EA, Ziemer DC, KolmbP, Rhee MK, Vaccarino V, Tsui CW, Kaufman JM, Osinski GE, Koch DD, Narayan KMV, Weintraub WS.

Phillips LS. The “metabolic syndrome” is less useful than random plasma glucose to screen for glucose intolerance. *Primary Care Diabetes.* 2008; 2:147–153.

78. Piche ME, Weisnagel SJ, Corneau L, Nadeau A, Bergeron J, Lemieux S: Contribution of abdominal visceral obesity and insulin resistance to the cardiovascular risk profile of postmenopausal women. *Diabetes.* 2005;54: 770–777.

79. Montonen J, Knekt P, Härkänen T, Järvinen R, Heliövaara M, Aromaa A, Reunanen A. Dietary patterns and the incidence of type 2 diabetes. *American Journal of Epidemiology.* 2005;161(3):219–227.

80. van Herpen NA, Schrauwen-Hinderling VB. Lipid accumulation in non-adipose tissue and lipotoxicity. *Physiology and Behavior*. 2008;94: 231–241.

81. Lauenborg J, Hansen T, Jensen DM, Vestergaard H, Mølsted-Pedersen L, Hornnes P, Locht H, Pedersen O, Damm P. Increasing incidence of diabetes after gestational diabetes: a long-term follow-up in a Danish population. *Diabetes Care.* 2004;27:1194-1199.

82. The South Carolina Department of Health and Environmental Control. SC BRFSS – About BRFSS. Available at: www.scdhec.gov/ad/administration/library/CR009477.pdf Acessed July 6, 2010.

83. Groth, MV, Fagt, S, Brøndsted L. (2001). Social determinants of dietary habits in Denmark. *European Journal of Clinical Nutrition*. 2001; 55:959–966.

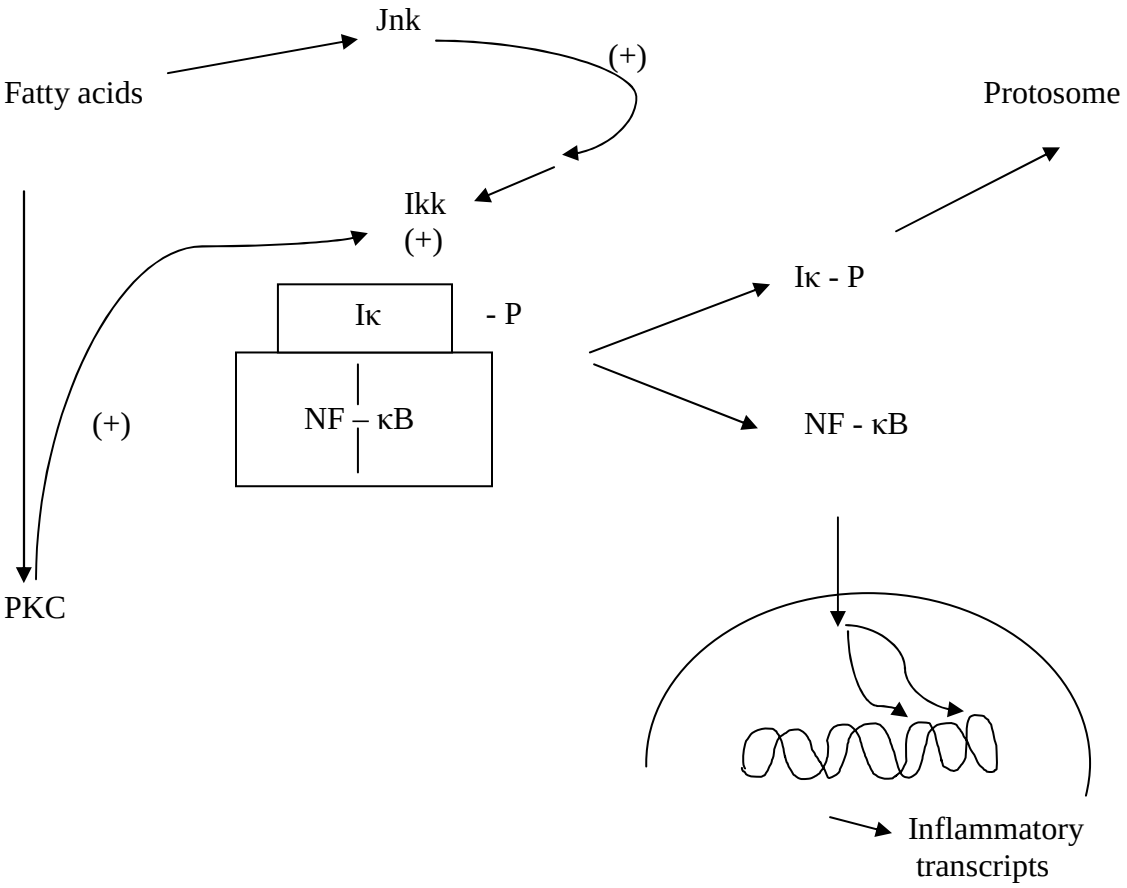

Fig. 1 How NF – κB Elicit the Events that Lead to Inflammation Initiated by Fatty Acids

High levels of circulating free fatty acids may activate inflammatory signals. Fatty acids and fat activate factors that lead to inflammation through IKK and JNK. Once activated IKK and JNK promote the transcription factor NF - κB, which activate inflammatory transcripts in the DNA. Iκ - P may be removed by proteasome.

CHAPTER TWO

DIABETES AND PRE-DIABETES INTERVENTION STUDIES: A REVIEW

Type 2 Diabetes (T2D) is one of the major diseases in the world today and the prevalence of the disease seems to be increasing at an alarming pace. To combat this disease there is a need for lifestyle interventions that could be implemented efficiently and affordably. Following is a review of lifestyle intervention studies conducted in the US and around the world. The review was used to establish the most effective way of implementing a diabetes or pre-diabetes intervention. The majority of the interventions focused on T2D interventions and the rest were targeted to those who had pre-diabetes. Overall, the risk of developing diabetes was reduced 20% to 58% as a consequence of the different lifestyle intervention protocols.

Introduction

In this literature review, diabetes and pre-diabetes interventions were assessed to determine the most effective treatments. The review was limited to articles published from 2000 to 2009. The review search was performed on General OneFile, Expanded Academic, Academic OneFile, Academic Search Premier, Medline, and Cinahl Plus. The included articles were those which had interventions for diabetes or pre-diabetes as the main focal point. The search terms used were “type 2 diabetes interventions”, “impaired glucose tolerance”, “impaired fasting glucose tolerance”, and “pre-diabetes interventions”. Articles which focused more on obesity and cardiovascular interventions were included in the review only if the primary focus was on diabetes patients or individuals classified as having pre-diabetes.

Participants' Classifications

Participants' blood glucose status was classified as being "normal" for participants who had fasting blood glucose levels of <100 mg/dl. Participants were classified as having pre-diabetes if their blood values were found to have been at the impaired fasting glucose (IFG) or impaired glucose tolerance (IGT) value. The classifications were made using one or both of the two blood glucose measuring tests. The fasting plasma glucose test (FPG) (6.1-7.0 mM/L or 100 and 125 mg/dl) is administered after an overnight or eight hour fast, and the oral glucose tolerance test (OGTT) (7.8-11.1 mM/L or 140–199 mg/dl) is used to assess blood glucose levels after an overnight fast and also two hours after 75g glucose challenge (1, 2). In US studies, researchers either used the ADA levels (Table 2.1) or followed the World Health Organizations' (WHO) (Table 2.2) (3) levels. Studies involving Asians, Asian Americans and Native Americans used WHO standards. One study used measurements which followed the Japanese Diabetes Society (JDS) recommendations (Table 2.3) (4).

Analyzed Studies

There were 28 articles included in the final analysis (Table 2.4). The articles were from studies in the US, Mexico, India, Germany, Finland, Canada, Norway, Austria, Denmark, Sweden, Israel, Spain, Japan, UK, Australia and China. Some studies (5, 6) were conducted in more than one country. The international scope of this research indicates that many countries have realized the importance of finding an effective way of responding to increasing global diabetes rates fueled by the obesity epidemic (6, 7). Diabetes continues to increase in all countries and among all groups of people, and it is

expected to continue to increase worldwide (7). It is now well known that individuals who have T2D are usually overweight or obese (7). Currently, the diabetes and obesity rates continue to increase in all nations and all ethnic groups. It is logical to deduce that we have not been able to produce drugs or a message powerful enough to change the course of the epidemic or to at least halt its current rate (5, 6, 7). For the current diabetes trends to change there is a need for serious fundamental lifestyle changes in America and around the world.

Table 2.4 summarizes the main characteristics from the research articles reviewed. The table includes: purpose of the relevant intervention, location or country where the intervention took place, sample size, subject blood glucose status at the beginning of the intervention (diagnosis), type of intervention used, length of study, and some of the key findings. More details about each reviewed study are discussed at the end of the table.

Table 2.4: Characteristics of Reviewed Diabetes and Pre-diabetes Interventions

Citation/ Location	Initial Subject Diagnosis	Type of Intervention	Length of intervention	Sample Size	Purpose of Intervention	Key Findings/ Treatment effects
Watanabe M, 2003 (4) Tokyo, Japan	#Pre-diabetes	Educational counseling	1 year	173 Males	Implement new dietary education program to reduce plasma glucose levels	Lowered energy intake (P=0.002) and blood glucose levels (P < 0.001). in the treatment group
Tuomilehto J, 2001 (8) Helsinki, Finland	Pre-diabetes	Diet[1,2] and physical activity[1]	3 years	522 Male =172 Female = 350	Implement the Finnish Diabetes Prevention Study intervention	Average weight reduction of 3.5 kg (treatment group) avg 0.9 kg in control group. Treatment group -58% reduction in diabetes risk.
Kosaka K, 2005 (10) Japan	Pre-diabetes	Diet[1] and exercise[2]	4 years	458 Males	Asses a diabetes prevention program aimed at maintaining ideal body weight.	After 4 years diabetes incidence in control group was 9.4% and 3% in intervention group (P< 0.001).

Characteristics of Reviewed Diabetes and Pre-diabetes Interventions

Laatikainen T, 2007 (11) Southwest Victoria and Southeast South Australia	Pre-diabetes	Diet[1] and exercise[2]	1 year	237 Male = 88 Female = 223	To test whether randomized controlled trials can achieve the 60% success rate in a primary care facility setting	Successful mean weight reduction of -2.52kg (95% CI -2.79,-1.98) and -4.17cm 3.16 (95% CI -3.72,-2.60) in waist circumference
Absetz P, 2007 (12) Paijat-Hame Province, Finland	Pre-diabetes	Energy reduction, increased fiber intake and moderate physical activity[1,2] through counseling	1 year	352 Male =103 Female = 286	Determine if the findings of diabetes intervention studies can be achieved in a real world scenario.	Only 20% of participants reached 4 of 5 goals; and weight loss physical activity achieved by fewer participants
Ackermann RT, 2008 (13) Indiana, US	Pre-diabetes	Diet[1] and physical activity[1,2]	6 and 12 months	92 Male = 41 Female = 51	Determine if YMCA workers can be trained to conduct group interventions	YMCA weight reduction of 6% in the intervention group and 2% in the control group after 6 mos. (*P*<0.001)

Characteristics of Reviewed Diabetes and Pre-diabetes Interventions

Li G, 2008 (14) Da Qing, China	Pre-diabetes	Diet[1] and physical activity[1]	6 years	577 Male = 312 Female = 265	Assess long term intervention improvements on diabetes and microvascular risk.	Diabetes risk reduced 51% However no significant difference in CVD rate 0.96 (95% CI 0.65−1.41)
Chiasson J, 2002 (5) Canada, Germany, Austria, Norway, Denmark, Sweden, Finland, Israel and Spain.	Pre-diabetes	The α-glucosidase inhibitor acarbose	3 years	1302 Male = 695 Female = 697	Assess acarbose and placebo as diabetes preventatives	Acarbose reversed impaired glucose tolerance to normal glucose in treatment group (P<0.0001). placebo group developed diabetes w/in 3 mos
Knowler WC, 2002 (16) National, US	Pre-diabetes	Metformin and lifestyle modification	2.8 years	3234 Male = 1043 Female = 2191	Determine if lifestyle and metformin interventions may delay or prevent diabetes development.	58 % (95% CI 48%- 66%) reduction in diabetes in lifestyle group 31% (95% CI 17%-43%) reduction in metformin group.

Characteristics of Reviewed Diabetes and Pre-diabetes Interventions

Kitabchi AE, 2005 (17) National, US	Pre-diabetes	Metformin and lifestyle modification	3 years	3234 Male = 1043 Female = 2191	Determine if deterioration in insulin sensitivity and insulin secretion lead to type 2 diabetes	Intensive lifestyle intervention, reduced diabetes incidence, improved insulin sensitivity and preserved β-cell function
Orchard TJ, 2005 (18) National, US	Pre-diabetes	Multitherapy	3.2 years*	3234 Male = 1043 Female = 2191	Determine prevalence of metabolic syndrome in people with impaired glucose tolerance in an intervention	Metabolic syndrome hazard was reduced by 41% in the treatment group ($P<$ 0.001) and 17% in metformin group ($P = 0.03$) in comparison with the control
Ramachandran A, 2006 (19) India	Pre-diabetes	Indian Diabetes Prevention Program (IDPP), lifestyle modification and metformin in people with pre-diabetes	3 years	531 Male = 421 Female =110	Lifestyle modification and metformin to prevent the development of diabetes in people with pre-diabetes (IGT)	Risk reductions in impaired glucose tolerance (IGT) to diabetes with relative risk reductions of 28.5 (LS) and 26.4% (metformin), ($P = 0.029$)

Characteristics of Reviewed Diabetes and Pre-diabetes Interventions

Torgerson JS, 2004 (20) National, Sweden	Pre-diabetes	Multitherapy	4 years	3,277 Male = 1810 Female = 1467	Determine if orlistat supplementation to normal and pre-diabetes individuals would be more effective than intervention alone	Greater weight loss in both the orlistat and normal glucose tolerance groups compared to the placebo group (5.8 vs. 3.0 kg with placebo)($P < 0.001$).
Thamer C, 2008 (21) Tuebingen, Germany	Pre-diabetes	Physical activity[1]	9 months	156 Male = 61 Female = 95	Determine *PPARD gene* SNPs influence on lifestyle intervention changes	Significant decrease in body weight, BMI, visceral adipose tissue, non-visceral adipose tissue ($P<0.0001$ all)
Stefan N, 2007 (22) Tuebingen, Germany	Pre-diabetes	Exercise and dietary[1,2]	9 months	136 Male = 63 Female = 73	Determine if SNPs in *PPARD* and *PPARGC1A* influences the outcome of physical activity program	Physical activity had a significant independent association in an allele of SNP in *PPARD* ($P= 0.002$) and the allele of SNP in *PPARGC1A* ($P = 0.005$)

Characteristics of Reviewed Diabetes and Pre-diabetes Interventions

Seidel MC, 2008 (23) Pennsylvania, US	Pre-diabetes and diabetes	Counseling, diet[1] and exercise[1]	12 weeks	88 Male =14 Female =74	Assess Group Lifestyle Balance (GLB) intervention included counseling, diet and exercise	Sustained weight reduction BP(P=0.04) and waist circumference(P<0.009) improvements
Bacardí-Gascón, M 2004 (24) Tijuana, Mexico	Diabetes	Physical activity[2]	Not stated	100 Females	Examine participation of Mexican migrant women in physical activity	No significant difference between activity levels of insured and uninsured group
Kirk A, 2003 (25) Scotland, UK	Diabetes	Physical activity[2]	6 months	70 Male = 35 Female = 35	Assess the effectiveness of a consultant based exercise program to encourage physical activity	Participants increased their physical activity levels (P < 0.001) and their biochemical variables.
Mayer-Davis EJ, 2004 (26) South Carolina, US	Diabetes	Intense lifestyle, reimbursed-lifestyle and the usual diabetes care	1 year	152 Male = 30 Female =122	Implement a lifestyle intervention designed for patients in rural communities	Reduction in weight (P<0.01) and glycemia (P<0.05) in the lifestyle intervention groups.

Characteristics of Reviewed Diabetes and Pre-diabetes Interventions

Jenkins JDA, 2008 (27) Ontario, Canada	Diabetes	Low glycemic index diet[2] and high fiber cereals	6 months	210 Male = 128 Female = 82	Test effects of low–glycemic index diets on glycemic control and cardiovascular risk factors in patients with type 2 diabetes.	Low glycemic diet lowered A1c of patients compared to the high fiber cereal (*P*<001)
Wolever MST, 2008 (28) Toronto, Canada	Diabetes	Dietary[1,2]	1 year	162 Females	Assess efficacy of glycemic-index carbohydrate diets on diabetes management	Not many differences in diet intervention results, postprandial glucose and CRP were reported to be lower with low-glycemic index diet.
Wolf AM, 2004 (29) Virginia, US	Diabetes	Dietitian-led case management lifestyle	1 year	147 Male = 60 Female = 87	Assess a diabetes intervention program that can be used for obese patients	Greater weight reduction in treatment group (*P*<0.001), reduced waist circumference (*P*<0.001), reduced medication use (*P* = 0.03).

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Ménard J, 2005 (30) Quebec, Canada	Diabetes	Multi-therapy	1 year	69 Male = 49 Female = 23	Evaluate multi-therapy vs. regular care in people with poorly controlled T2D	Intensive intervention therapy patients met the goals set by the Canadian national diabetes association
Corse W, 2007 (31) Michigan, US	Diabetes	Educational empowerment	1.2 years	58 Male = 33 Female = 25	Evaluate effectiveness of shared decision-making (SDM) goal-setting intervention	Improvement in A1c, weight, and diabetes empowerment score ($P<.001$) and patient's diabetes knowledge ($P<.001$)
West DS, 2007 (32) Alabama, US	Diabetes	Behavioral and motivational	1.5 years	217 Females	Determine if adding a motivational portion to a weight control program would be more beneficial in women	Weight reduction ($P=0.04$), and glycemic control ($P=0.02$), were attained

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Kahn SE, 2006 (6) US, Canada and Europe	Diabetes	Single drug pharmacotherapy	4 years*	4351 Male = 2511 Female =1840	Assess effectiveness of rosiglitazone, metformin, and glyburide for T2D patients.	Rosiglitazone risk reduction was 32% more than metformin, and 63%, more than glyburide (P<0.001).
Gaede P, 2003 (34) Copenhagen, Denmark	Diabetes	Intensive drug, diet[1] and exercise[1]	7.8*	160 Male = 119 Female = 41	Modify CVD risk factors in T2D patients	CVD risk was reduced 50% (hazard ratio, 0.47; 95 CI, 0.24- 0.73)
Gaede P, 2008 (35) Copenhagen, Denmark	Diabetes	Intensive[1] drug, diet and exercise[1]	13.3*	160 Male = 119 Female = 41	Assess mortality and benefit maintenance post intervention	Risk of death reduced 20% in T2D participants and microalbuminuria (P = 0.02)

Type of Diet Program: 1-Caloric restriction diet, 2-Increase fruits and vegetables,
Type of Physical Activity: 1-Weight loss physical activity, 2- Regular physical activity.
Type of Exercise: 1-Regular exercise program 2-Moderate intense program.
* The average length of participation for all the participants in the study.
# Definitions used: The Japanese Diabetes Society (JDS) measurements,
LS-Lifestyle Intervention.

Intervention Studies

Pre-diabetes Studies

In Tokyo, Japan, Watanabe and colleagues (4) studied working men (n = 173) who had pre-diabetes, or were at high risk of developing diabetes. Pre-diabetes was diagnosed according to the Japanese Diabetes Society (JDS) standard which defines 1-h PG values of ≥10 mM/L as "borderline diabetic" (Table 2.3) (4). The researchers developed a new dietary education (NDE) program which included individualized dietary counseling. Participants aged 35-70 were randomly divided into two groups: NDE (n = 86), and controls (n = 87) who received standard care. Patient responses to a 65-item semi-quantitative food frequency questionnaire were the basis for prescribing individualized diets. Participants in the treatment group received individualized feedback from their questionnaire responses and were counseled on ways they could best improve their health by following the recommended guidelines. The counseling session was conducted a month after the health checkup; six months later the second session was conducted following another health checkup. The results from the study indicated that an individualized approach was significantly better than standard care. The intervention group had lower energy consumption in comparison with the controls, and had a 15.3%, (P = 0.002) success rate for following the recommended dietary guidelines compared to 6.0% (P = 0.002) in controls. The intervention group had a decreased 2-h PG after 1 year, while the control group increased, the percentage difference between the two groups was 15.2% (P <0.001) (4).

In the Finnish Diabetes Prevention Study (DPS) (8, 9), a diet and exercise intervention was shown to reduce the risk of developing diabetes by 58 % (P<0.001) in subjects (n = 522) who had pre-diabetes. This ground-breaking, randomized, controlled study was one of the first to show that diabetes can be prevented through diet and exercise in people who have pre-diabetes (8). In the DPS, subjects were randomly assigned to two groups 1) a regular care group (control) or 2) an intensive intervention group (treatment). Inclusion criteria were based on the following: (1) age 40-64 yrs at screening, (2) BMI >25 kg/m^2 at screening and (3) a mean value of two 75-g OGTTs in the IGT range based on WHO criteria (8, 9). The treatment group was given the following goals: reduce weight by ≥5%; moderate-intensity physical activity for ≥30 min every day; reduce dietary fat energy intake to <30% of total energy (E%); reduce saturated fat consumption to <10 E%; and increase fiber consumption by ≥15 g/1,000 kcal (9). At year one, average weight was reduced 4.5±5.0kg (5.1%) in the intervention group (n = 256), compared to an average reduction of 1±3.7kg (1.1%) in the control group (n = 250) (P<0.0001). At 3 years, results were 3.5±5.1kg (4.0%) for the intervention group (n = 231) and 0.9±5.4kg (1.1%) for the control group (n = 203), respectively (P<0.0001). BMI for the 1 year period was reduced on average by 1.6 kg/m^2 in the intervention group and by 0.4 kg/m^2 in the control group (P<0.0001). These results were similar at year 3 with BMI reduced 1.3 kg/m^2 in the intervention group and 0.3 kg/m^2 in the control group (P<0.0001). There were significant improvements in the fasting plasma glucose -0.2±0.7 mg/dL (P <0.0001), 2-h plasma glucose -0.9±1.9 mg/dL mg/dL (P<0.001) and the A1c -0.1± 0.7 (P<0.003) in the treatment group (9). It was

concluded that the diabetes risk reduction and the improvements in the glucose tolerance and body weight were a direct result of the lifestyle intervention (8). It is worth noting that the DPS study was suspended because the diabetes incidence was significantly (P<0.001) lower in the treatment group than in the control group (8, 9). The DPS and Diabetes Prevention Program (DPP) studies showed that people with pre-diabetes and those at risk of developing diabetes can reduce their risk by 58% through lifestyle interventions.

In a long-term study in Japan, male participants (n = 458) with pre-diabetes were assigned to a standard intervention group (control group) or an intensive intervention group (10). The intensive diet and exercise intervention was designed to promote attainment of an ideal weight indicated by a BMI $\leq$ 22 kg/m^2 (10). Participants in the intensive treatment group were asked about their diet, advised on ways to reduce caloric intake and maintain their weight, and asked to participate in physical activity or exercise, such as walking for 30–40 min per day (10). Control group participants were encouraged to exercise and diet to avoid weight gain and to attain a BMI $\leq$24 kg/m^2. At year 4 diabetes incidence was 9.4% and 3%, standard vs. intensive intervention, respectively, (P<0.001) (10). There was a significant difference in weight loss between groups with the standard intervention group losing -0.39±1.42 kg and -2.1±1.63 kg in the intensive intervention group (P<0.001) (10). The study was effective in reducing the risk of developing diabetes. The percentage improvement in impaired glucose tolerance was 53.8% to normal BG values in the improvement intensive intervention group and 33.9% improvement in the control group (P<0.001) (10).

In Australia, Laatikainen and colleagues' Greater Green Triangle (GGT) Diabetes Prevention Project (11) included adults aged 40-75 diagnosed with pre-diabetes or at a high risk of developing diabetes due to other risk factors. The goal was to determine if it was possible to attain previous results of randomized controlled trials (8, 9, 10) that had achieved close to 60% success rate in a primary care facility setting. The GGT trial was based on the Finnish DPS study (8). The intervention included six motivational sessions of 90 minutes each, with the first five sessions given within the first 3 months and the final session given during the eighth month. During these sessions patients were encouraged to take charge of their diabetes-related conditions and choose the best ways to reduce the risk of developing diabetes through diet and exercise management. There was an average improvement of 4.0% in waist circumference, a weight reduction of 2.7% and BMI reduction of 2.8%. This study achieved less robust results than those seen in clinical trial interventions; however, it demonstrated that it is possible to achieve a successful intervention in a primary care facility (11).

Absetz and colleagues (12), conducted a study in subjects (n = 352) aged 50–65, who had a higher risk of developing T2D (indicated by elevated blood glucose, or lipids, obesity and hypertension). Subjects were divided into groups and offered either a counseling intervention or diet and exercise intervention to reduce their risk of developing diabetes. After 3 years of counseling there were improvements, but the counseling group results were less than those seen in the diet and exercise intervention group. The intervention was designed to emulate a real life scenario to provide evidence that people can do things that may improve their lifestyle and health (12). The study had

5 criteria set for the participants to reach by the end of the study: (1) <30% of total energy intake from fat; (2) <10% of total energy intake from saturated fat; (3) ≥15 g of fiber/1,000 kcal; 4. 4 h/week moderate level physical activity; and (5) >5% weight reduction (12). The authors reported that 20% of the participants were able to reach 4 of these goals and in addition some of the risk factors, such as diastolic blood pressure, weight and waist circumference were reported to have decreased. However, BMI was decreased in male participants only. While 71 of the participants were able to improve and reach some of the 5 goals set (average = 3) for the study, there were 281 participants who did not reach the goals set (12).

The Diabetes Education & Prevention with a Lifestyle Intervention Offered at the YMCA (DEPLOY) study conducted by Ackermann and colleagues (13), evaluated how an adapted DPP program would work in a community, or a "real-world" setting (13). The researchers wanted to assess how the DPP achievements (8) can be attained in a study conducted by YMCA staff members. To achieve this goal, YMCA staff members were trained to conduct the study utilizing some of the strategies used by professionals in the DPP and other similar programs (13). The study paired 92 participants from two YMCA facilities; 46 received standard advice on diet and physical activity and the other 46 were enrolled in the DPP (17). After 4-6 months there was a reduction in weight of 2.0 % (95% CI = 3.3 - 0.6) for the standard advice and 6.0% (95% CI = 7.3 - 4.7) for the DPP group (P<0.001) (13). There was also a significant reduction in BMI of 2.3 kg/m^2 (95% CI = 3.7 - 0.8) and 5.8 kg/m^2 (95% CI = 7.3 - 4.4) in control and intervention groups (P = 0.001). No significant difference in A1c, 0.1 (95% CI = 0.2 - 0.01) occurred at 4-6

months for either standard advice or DPP groups ($P = 0.96$). At 6-12 there were BMI changes of 1.4 kg/m^2 (95% CI = 3.6 - 0.8) and 6.7 kg/m^2 (95% CI = 9.1 - 4.4) ($P = 0.002$) in the standard advice and DPP, respectively. There was no significant change in A1c for both groups ($P = 0.28$) (13). There were fewer significant improvements in DEPLOY participants compared to the DPP and similar programs. It may still be more advantageous to be enrolled in an intervention run by professionals within a medical or academic setting as the improvements are significant. However, this study demonstrated that by training employees to conduct interventions and providing more financial resources; organizations such as the YMCA can provide additional opportunities for community-based lifestyle interventions aimed at decreasing the prevalence of chronic metabolic disorders.

In a 20 year follow up of the participants in the Chinese Da Qing Diabetes Prevention study (n = 110,660), Li and colleagues (14) measured the impact of participation in a long term intervention to determine if such intervention had longer term effects which extended beyond diabetes prevention (14, 15). The participants in the original study, aged 25-74, were at risk of developing diabetes, and resided in the Hei Long Jiang Province of China (14). The intervention, which lasted for 6 years, recruited subjects (n = 577) with pre-diabetes from 33 clinics (14, 15). This diet and exercise trial was one of the first studies to show that diet and exercise can prevent or delay the onset of diabetes in people who have pre-diabetes or who are at risk of developing diabetes. The risk of developing diabetes was reduced by 31% in the diet only intervention group, 46% in the exercise only group, and by 42% in the diet and exercise group (14). After 20

years, participants in the diet and exercise intervention group had a risk reduction of 51% compared to 43% risk reduction after the 6 year intervention. At 20 years, diabetes rates were 11% in the control group and 7% in the intervention group. Participants in the intervention group also spent an average of 3.6 fewer years with diabetes when compared to controls (14). This study showed that participating in a lifestyle intervention program was far more beneficial and suggested that beneficial effects could last throughout the participant's life.

Chiasson and colleagues' Study To Prevent Non-insulin-dependent Diabetes Mellitus (STOP-NIDDM) (5) was a double-blind, placebo-controlled randomized study conducted in Canada, Germany, Austria, Norway, Denmark, Sweden, Finland, Israel and Spain. Subjects with pre-diabetes were recruited from high risk populations defined by having a BMI of 25 to 40 kg/m^2 and being 40 - 70 years old, and patients with an immediate relative with diabetes. Eligible patients were randomly assigned to either the placebo or the acarbose treatment. Acarbose is a α-glucosidase inhibitor used to treat diabetes patients in the US and is used to treat both diabetes and pre-diabetes in some European countries. Participants met with a dietician and were encouraged to lose weight, maintain a healthy body weight and participate in regular physical activity. Weight reduction was modest compared with other pre-diabetes interventions. Average weight for subjects in the acarbose group slightly decreased from 87.6±15.2 kg to 87.1±15.3 kg, while average weight increased slightly in the control group from 87.0±14.1 kg at baseline to 87.3±15.2 kg at 3 years. Diabetes risk reduction was 25% in the acarbose study. About a quarter of the patients in this study dropped out due to drug side effects.

Half of those dropped out during the first year, and about 31% were from the acarbose group compared to 19% from the placebo group. Acarbose increased the reversal of pre-diabetes to normal glucose state, but the relative risk of developing diabetes was 0.75 (95% CI = 0.63 - 0.9) (P = 0.0015). This meant 32% of the acarbose group and 42% from the placebo group developed diabetes (5).

Knowler and colleagues' Diabetes Prevention Program Research Group (16, 17) included pre-diabetic and non-diabetic subjects (n = 3,234) assigned to 3 different intervention groups; 1) received placebo (n = 1082); 2) received 850mg metformin twice daily (n = 1073); 3) lifestyle intervention program with goals of ≥7% weight loss and ≥150 minutes of physical activity/week (n = 1079). Lifestyle group subjects were given a training session to help with adherence to diet, exercise and a healthy lifestyle; while groups receiving metformin or a placebo had individual 20-30 minute sessions in which subjects were asked to eat a healthy diet and increase their physical activity (16). Subjects were ≥25 years. Participants reduced energy by 249±27 kcal, 296±23 kcal and 450±26 kcal in placebo, metformin, and lifestyle groups respectively (P<0.001, all).

There was a difference in the amount of weight lost by the participants in each group; average weight loss/group was 0.1kg with placebo, 2.1 kg with metformin, and 5.6 kg with lifestyle-intervention (P<0.001, all). Calculated diabetes incidence per group was 11.1% with placebo, 7.8% with metformin, and 4.8% with lifestyle intervention (16). The diabetes incidence was reduced 58% (95% CI = 48% - 66%) for the lifestyle group and 31% (95% CI = 17% - 43%) in the placebo group. Metformin, with a 31% diabetes risk reduction (16, 17), was a very good intervention medication and was more effective

than acabose which had a risk reduction of 25% as noted below (21). The study findings also indicated that metformin and lifestyle intervention were similar in restoring normal fasting glucose, however, lifestyle was more effective in restoring post load glucose (16). Pharmacological intervention may be ideal for some patients, but to gain greater risk reduction it would be advisable for people at risk of developing diabetes to use lifestyle interventions as the preferred first line of prevention. It must be stated; however, that pharmacological intervention may be preferable for patients who are not able to participate in moderate and vigorous physical activity. Metformin was shown to have the capacity to reduce the fasting plasma glucose by levels close to those of physical activity during the entire 3 year period of the intervention: This may be promising for impaired fasting glucose reduction in patients who have difficulty walking (17).

Orchard and colleagues set out to determine the prevalence of metabolic syndrome in subjects (n = 3234) with pre-diabetes using participants from the DPP study (18). Participants' risk of metabolic syndrome was reduced by 41% in the lifestyle group ($P < 0.001$) and by 17% in the metformin group ($P < 0.03$) compared with placebo (18).

Results from the Indian Diabetes Prevention Program (IDPP) (19) compared the effects of diet + exercise to the use of metformin on BMI and A1c. There was a risk reduction, measured by blood glucose levels and lifestyle changes, of 26.4% in the drug therapy group compared to a 28.5% risk reduction in lifestyle modification intervention (19). The A1c for the control group was 6.2±05, 6.2±06 for the metformin group and 6.1±05 lifestyle group with 6.2±0.6 for the lifestyle and metformin combined ($P>0.05$).

BMI was 26.3±3.7 for the control group, 25.7±3.3 lifestyle group, 25.6±3.7 for the metformin group and 25.6±3.3 for lifestyle and metformin combined (P>0.05) (19).

Torgerson and colleagues' The Swedish XENical in the prevention of Diabetes in Obese Subjects (XENDOS) study was conducted using the diabetes drug orlistat and lifestyle intervention to prevent the onset of diabetes (20). Subjects were pre-diabetes patients and those with a high risk of developing T2D. The study was conducted over a 4 year period, was aimed at determining both how effective orlistat was in treating metabolic disorders and the safety of the drug (20). Study participants (n = 3305) were randomly assigned to either treatment with orlistat, and the lifestyle changes group (n = 1,650) or the placebo and lifestyle changes group (n = 1,655). At 4 years, both the Orlistat (n = 1640) and the placebo (n = 1637) groups had lost very few subjects. Patients in the orlistat intervention had a higher diabetes prevention rate as compared to the placebo group. The diabetes rate was 9.0% in the placebo group and 6.2% in the orlistat group and this was translated into a 37.3% decrease in the risk of developing diabetes with orlistat (P = 0.0032) (20). At one year there was a weight reduction of 10.6 kg in the oristat group compared to a mean weight loss of 6.2 kg for the placebo group (P<0.001); and 5.8 kg compared to 3.0 kg weight reduction at the end of the study for the orlistat and the placebo groups, respectively (P<0.001).

In a study of 156 pre-diabetic and non-diabetic participants, Thamer and colleagues reported that the hormone receptor, peroxisome proliferator-activated receptor (PPAR)-δ was a significant factor in how much benefit an individual would gain from a lifestyle intervention program (21). Thamer and colleagues had previously demonstrated

that a single nucleotide polymorphism in the PPRD gene was corrected to predict how a subject would respond to diet and physical activity lifestyle intervention (22). This polymorphism to insulin sensitivity and the rate at which skeletal muscle would burn fatty acids during an aerobic activity (21, 22). The study included parts of the DPP program, including a weight reduction of 7% and an increase of at least 150 min/week in physical activity (21). They also recommended that participants reduce their saturated fat intake, and increase daily fiber intake and physical activity (21, 22). In the current study (n = 156), 27% of subjects had impaired glucose tolerance, and none had diabetes. By the end of the study, one subject had developed diabetes, and 123 (79%) had normal glucose tolerance. Only 32 (21%) still had impaired glucose tolerance. After nine months of physical activity and dietary and lifestyle intervention there were significant improvements in insulin sensitivity from 11.8 U/kg at baseline to 13.4 U/kg at follow-up (P <0.01). The fasting glucose levels remained the same at 5.2 mM/L (P<0.07) before and after the intervention while the 2-h glucose (OGTT) improved from 6.7 to 6.3 mM/L (P<0.01). The subjects also had significant improvements in body weight, averaged 86.3 kg (95% CI = 52.5 - 124.7) at baseline, and had an overall weight reduction to 84.0 kg (95% CI = 53.3 - 121.8) (P<0.0001). Another significant improvement was noticed in the BMI, which initially was 29.0 kg/m^2 (95% CI = 19.4 - 43.5), and by the end of the study was reduced to 28.0 kg/m^2 (95% CI= 18.6 = 39.4) (P<0.0001). Thamer stated that increasing muscle volume and reducing body fat were important for maintaining a successful and effective lifestyle intervention (21).

In the Seidel study, subjects (n = 88) from an underprivileged urban setting with diabetes or pre-diabetes were enrolled into a Diabetes Prevention Program. The authors tested the hypothesis that a successful group lifestyle balanced intervention for individuals with metabolic syndrome could reduce the prevalence of diabetes (23). The intervention included attending group classes, choosing healthy foods, reducing fat and calorie intake and using a pedometer. The 12-14 week study was comprised of 12 weekly sessions. Subjects were given local gym memberships, and provided a pedometer and a fat calorie counter. Subjects monitored their food intake and physical activity, and were given real time feedback on results of the program. At 3 months (12 weeks), 46.4% reported a weight loss of ≥5%, and at 6 months, 66.7% retained the body weight loss. Assessment of metabolic syndrome status resulted in ≥1 metabolic syndrome component improved in the 30 subjects (43.5 %) who submitted their data for review (23).

Diabetes Studies

In Mexico, Bacardı´-Gasco´n et al. conducted a physical activity study of women (n = 100) in the migrant working communities (24). Subjects were assigned to the uninsured (n = 37) and the insured (n = 63) groups. Participants attended 1 hr exercise counseling and were given physical activity leaflets. They also attended a 30 min group exercise which included strength training, flexibility and aerobic exercises. Participants were then encouraged to exercise 20 min during the week. There were no differences between insured (1.53±0.03) and uninsured (1.56±0.04) groups in their levels of participation in both outdoor and indoor physical activity (P = 0.5) (24).

A study conducted by Kirk and colleagues attempted to devise ways to encourage physical activity in T2D patients (n = 70) over a 6 month period. Participants were assigned to two groups of 35 each with the treatment group given a physical activity consultant while the control group had no consultant. The exercise consultant met with each participant individually and helped him/her make proper adjustments aimed at changing to a more physically active lifestyle (this included 30 min physical activity for most days of the week). The adjustment was done in 5 stages of behavior change (pre-contemplation, contemplation, preparation, action and maintenance). Some of the strategies included encouraging participants to increase physical activity and reduce relapse. After 6 months the activity per week was different between the groups (95% CI = 594,501 - 1,723,539) and (95% CI = -1,786,768 - -491,490) for counted activities per week as measured by CSA uniaxial accelerometer (25). Patients in the treatment group had a 7.2x increase or 128 min of moderate activity per week (95% CI = 85.0 - 182.5) and a 7.6x increase or a 153 min of moderate activity per week (95% CI = 112.5 - 207.5) (25).

Mayer-Davis and colleagues developed the POWER (Pounds off with Empowerment) diabetes intervention study, conducted for 12 months in rural South Carolina for low income T2D patients at rural health care centers (26). Subjects had diabetes, were aged ≥45 years, and had a BMI of ≥25 Kg/m^2. Participants were randomly divided into 3 groups: intensive lifestyle intervention, reimbursable-lifestyle intervention, or usual care (26). The structure and design of the intervention were influenced by the DPP (14) with the aim of attaining ≥10% weight loss by reducing dietary fat intake to

<25% of caloric intake and maintaining 150 minutes of moderate physical activity/week. The POWER study produced modest results for both men and women at 3 and 6 months (P>0.05). There was a gender difference at 12 months; women had a mean weight loss of 1.5 kg while men had a mean weight loss of 4.7 kg (P = 0.02). The study had a high number of African American women and the weight loss in this group was lower than that attained in other groups and other intervention studies (7, 14). The researches in the POWER study cited reasons participants had given as obstacles to behavioral change, which included caring for family members, feeling exhausted and being anxious about diabetes (26).

A study in Canada by Jenkins and colleagues (n = 210) (27) was designed to test the effectiveness of a low-glycemic index diet compared to a high-cereal fiber diet in controlling blood glucose and cardiovascular disease risk factors. A1c was used as an indicator of chronic blood glucose elevation in participants with T2D. Subjects were randomly assigned to either the low-glycemic index or high-cereal fiber group. Fiber intake was different between the treatment group (low-glycemic index) and the control group (high-cereal fiber) group. Fiber increased in the low-glycemic index diet group (18.7 g/1000 kcal at week 24) in comparison with the high-cereal fiber diet (15.7 g/1000 kcal at week 24; P<0.001). A1c decreased 0.50% (95% CI = –0.61% - –0.39%) with the low-glycemic index diet and 0.18% (95% CI = –0.29% - –0.07%) with the high-cereal fiber diet. This indicated that those in the low-glycemic index diet had a more positive outcome in comparison with those who consumed a high–cereal fiber diet. The reduction

of the glycemic index indicated that there was a positive correlation with reducing the A1c ($r = 0.35$, $P<0.001$) (27).

The Canadian Trial of Carbohydrates in Diabetes (28) was a 1 year diet-only T2D management study conducted by Wolever and colleagues. The study was aimed at assessing the effects of carbohydrates on A1c, blood glucose and C-reactive protein (CRP) based on the source and amount of carbohydrates consumed (28). Participants (n = 162), who managed diabetes with diet only, were randomly assigned to a high-carbohydrate, high-glycemic index (high-GI) diet (n = 52), high-carbohydrate and low-glycemic-index (low-GI) diet (n = 56), or low-carbohydrate, high-monounsaturated-fat (low-CHO) diet (n = 54) (28). Participants were assigned key foods to help adherence to the prescribed diet, had help from a dietician, and were allowed to continue taking their diabetes medications. At one year, carbohydrate energy contributed 47% for the high-GI, 52% for the low-GI, and 39% for the low-CHO group (28). The energy from fat was 31% for the high-GI, 27% for the low-GI, and 40% for the low-CHO diet group. The GIs for the three diet groups were 63, 55, and 59 for the high-GI, low-GI and low-CHO respectively (28). The A1c declined at the beginning for the low-GI diet ($P=0.084$), and in the same way fasting plasma glucose declined at the beginning for the low-GI and low-CHO diet groups. These benefits, however, were erased by the end of the study period at which time the high-GI diet group had the lowest fasting plasma glucose. With no differences between the groups, however, the A1c for both groups combined increased from approximately 6.1 at the beginning of the study to approximately 6.3 by the end of the study ($P<0.0001$) (28). There was some weight loss at the beginning in the low-GI

diet group and some weight gain towards the end of the study period for the low-CHO diet group and both were insignificant (28). There were differences in the effects of diet on CRP between the low-GI group ($P = 0.0078$) and the high-GI diet group ($P<0.05$) with the CRP of the low-GI group being less than that of the high-GI group. CRP had a reduction of >20% which was sustained throughout the study (28).

In the Improving Control with Activity and Nutrition (ICAN) study (29), Wolf and colleagues utilized a case management-based intervention for diabetes patients. The randomized controlled study had a registered dietician as case manager for diabetes patients. The participants were assigned into two groups, the regular care or the dietician case management group. All patients continued to receive their regular care during the 12 months intervention period. A $350 per person fee was required for diabetes patients assigned to receive professional help from a registered dietician. Patients in the regular care group were free to join any diabetes or weight management programs. The researchers assessed how effectively the dietitian-led intervention would work, and how economical it would be in a primary care environment compared to the usual care. At 12 months the intervention group had lost an average of 2.4 kg, while those in the usual care group had gained on average 0.6 kg. The intervention group lost 5.5 cm in waist circumference while those in the usual care group had only lost 1.4 cm. There was a difference, in blood glucose levels, between groups as measured by A1c ($P = 0.02$). Patients who received counseling and education from the dietician had a significantly improved health outcome compared to those who received the regular protocol ($P < 0.05$) (29).

A Canadian study by Ménard et al. assessed whether a multi-therapy intervention had an improved effect on fasting plasma glucose levels and A1c concentrations. The multidisciplinary team set out to determine whether such benefits would be maintained for up to 6 months after the 1 year intervention had been completed (30). T2D patients (n =72) with ≥8% A1c concentration were put into either usual care (control group) or into the multi-therapy intervention group. Baseline A1c for the intervention group was 9.1±1.0 and 9.3±1.0 for control group and 7.5±1.0 for the treatment group at 12 months compared to 8.61±0.3 for the control group. At the 18 month follow-up, it seemed that the benefits of the intervention were diminishing as A1c for the intervention group was 8.1±1.2 compared to 8.6±1.3 for the controls. At 18 months there were no significant difference between groups and most of the benefits attained at 12 months had vanished for the intervention group (30). Similar to A1c, the fasting plasma glucose at beginning of the study was 10.8±3.5 mM/L for the intervention group and 10.7±3.0 mM/L for the control group. At 12 months the intervention group had fasting plasma glucose of 8.2±2.8 mM/L compared to 9.8±2.7 mM/L for the control group. At 18 months the benefits of the intervention were again eroding as the intervention group had 8.7±2.5 mM/L compared to 9.6 ±3.5 mM/L in the control group (30).

Corse and associates (31) enrolled 58 diabetes patients in a shared decision-making model. In this model, patients and their primary care provider together decide the best way to improve the patients' diabetes knowledge and care. Patients attended a 2-hr educational session in which patients were helped by their primary care provider in setting individual goals and also provided some supportive reading materials. In the 10

workshops and sessions, patients were asked to determine what was important to them about their conditions, and what would be a priority in easing their conditions. Study results were disappointing, perhaps due to small sample size. A1c values (n = 33), decreased slightly from 7.94±1.49 to 7.62± 1.92 (P = 0.222). The average body weight (n = 38) was 228.21±55.11 lbs. and 225.48±55.09 lbs (P = 0.222), initial and final, respectively. Significant improvement in diabetes understanding was observed using a Diabetes Attitude Scale of 1-7 (1 = poor; 7 = excellent understanding), pre-intervention and post-intervention averages were 4.35±1.46 and 5.42±1.27 (P<.001) (31). However, this intervention may not be feasible for some patients as it depends heavily on the cooperation of the physician and the ability of the patient to pay for extra services needed. For a successful intervention a low income patient may need the financial resources to pay for required extra services. As a result, this type of intervention may not be readily available to the greatest percentage of at-risk subjects.

West and colleagues (32) used motivational interviewing to encourage female subjects (n = 217) with T2D to lose weight and improve their blood glucose levels. Participants were assigned to a motivational interviewing or a control group. At 6 months the intervention group had a significantly greater mean weight loss (4.7±0.45 kg) when compared to control (3.1±0.47 kg) (P=0.01) (32). Participants in the intervention group began to regain weigh after 12 months, while the control group began to regain weight after 6 months. These results suggest that there may be a need to change the intervention every 6 to 12 months to avoid weigh regains. A1c was 8 ±0.1 in the treatment group and 7.1 ±0.1 for the control group (P = 0.02) at six months, at 18 months A1c was equal

between the groups (7.4 ± 0.11). This could imply that the benefits of the intervention were too small for the A1c levels to be significantly different between the groups

A Diabetes Outcome Progression Trial (ADOPT) (n = 4127), developed by Khan and colleagues (6), was a large study with participating scientists in 15 countries in Europe, the US, and Canada. The collaborative intervention evaluated the efficacy and effectiveness of several diabetes drugs. The diabetes dugs rosiglitazone, metformin, and glyburide were given to diabetes patients who had not been treated with other diabetes drugs. The drugs were thought to have failed if the blood glucose levels were >180 mg/dL (>10.0 mM/L) after an overnight fast. A positive outcome was a fasting plasma glucose level <140 mg/dL (7.8 mM/L) after drug therapy. Diabetes patients were randomly assigned to three groups; rosiglitazone (n = 1393), metformin (n = 1397), and glyburide (n = 1337). Participants received the drugs in identical capsules, with dosages increasing over time. Using the >180 mg/dL fasting blood glucose standard set as a drug theraputic failure, 143 patients in the rosiglitazone group "(2.9 per 100 patient-years)" fell in this category and 207 in the metformin group "(4.3 per 100 patient-years)", while 311 patients in the glyburide group "(7.5 per 100 patient-years)" were in this category. The incidence occurrence measured using the Kaplan–Meier distribution was 15%, 21% and 34% for rosiglitazone, metformin, and the glyburide groups, respectively. The secondary drug outcome measured a <140 mg/dL fasting plasma glucose progression rate. For patients assigned to the rosiglitazone group the rate was 79 of 511 participants. Metformin group rate was 127 of 520 with risk reduction of 36% (95% CI = 15 - 52) (P = 0.002) and the glyburide group was 160 of 480 participants with risk reduction of 62%

(95% CI = 51 - 72) (P<0.001). After 4 years of treatment 1456 (40%) patients in the rosiglitazone drug group had A1c level of less than 7%, in comparison to 1454 (36%) for the metformin group (P = 0.03) and 1441 for the glyburide group (26%) (P<0.001). A1c was significantly different between groups (95% CI = 0.49 to 1.9) (6).

In the Danish Steno-2 Study (n=160), Gaede and co-workers (33) recruited T2D patients with microalbuminuria who were treated for an average of 7.8 years. Participants were randomly assigned to either the conventional therapy or the intensive therapy. Study goal for the intervention group was to achieve: A1c <6.5%, <75 mg/dL (4.5 mM/L) total cholesterol, <150 mg/dL (1.7 mM/L) triglycerides, <130 mm Hg and <80 mm Hg for the systolic and diastolic blood pressure respectively (33). Patients in the intervention group were given blood pressure treatment drugs and a low dose of aspirin (33, 34). At the conclusion of the study changes in BMI were not significant. BMI change of males was 0.4±0.4 kg/m^2 for conventional therapy and 0.7±0.4 kg/m^2 for intensive therapy (P=0.61), while females' change in BMI was 1.3±1.3 kg/m^2 for conventional therapy and 2.3±1.2 kg/m^2 for intensive therapy (P = 0.29) (34). Fasting plasma glucose with conventional therapy decreased by 18±11 mg/dL; with intensive therapy it decreased by 52±8 mg/dL (P <0.001). A1C with conventional therapy increased by 0.2±0.3 and decreased 0.5±0.2 in intensive therapy (P <0.001). By the end of the 13.3-year follow up the two groups (total n = 93) seemed to be similar with regard to both clinical and biochemical variables. Of the 160 diabetes patients who started the intervention, nine patients in the intervention group died from cardiovascular complications compared to 19 patients in the control group (P = 0.03) (34). Unlike the 20

year follow up of the Chinese Da Qing Diabetes Prevention study (15), the benefits attained through this intervention seem to have been reversed at the 13.3 years follow up. There were no significant differences between the groups in regard to physical activity, body weight and waist circumferences, but there were some significant differences in fat and carbohydrate intake (34).

Conclusion

Of the 28 studies reviewed the average length of study was approximately 2 years, however the median length of the studies was 1.4 years. In 15 of the studies reviewed, the subjects had pre-diabetes, while 12 studies were primarily for diabetes patients and one study had participants who had diabetes or pre-diabetes. This review included studies utilizing different types of interventions, including 13 using diet, 13 using physical activity, 8 using drug interventions and 5 studies using education/counseling. Studies conducted for an average length of 1 year showed a large improvement in the health status of participants. The greatest improvements were found in studies which combined physical activity and diet interventions (8, 20). Participants in studies lasting more than one year showed similar benefits during the first year; however, most of the benefits seemed to be reversed after the first year (8, 10, 14). This was the case particularly for weight regain. There may be a need to change the intervention structure every 6 to 12 months to avoid weigh regains. This could also be achieved by the implementation and emphasis of a weight loss maintenance program after the desirable weight loss is achieved.

The Danish Steno-2 Study (33) indicated that it is best to prevent diabetes from occurring rather than to wait and treat the disease and as can be seen in the follow up at 13.3 years the benefits of the intervention seem to have disappeared. Even prescription drugs taken resulted in no significant difference in the outcome, with an average of 5.5 medications in the intervention group and 5.7 in the control group ($P = 0.64$). The study strengthens the case that lifestyle intervention through diet and exercise is the best way to delay or prevent the onset of T2D in adults. In the DPP study (16), the metformin group had a risk reduction of 31 % compared to 58% in the lifestyle group. This was an indication that even though metformin is a powerful diabetes medication, it is better to implement lifestyle changes and prevent the onset of the disease. Preventative intervention offers the best solution not only for diabetes but also for other related metabolic and chronic diseases such as cancer, cardiovascular disease, stroke, etc (14, 18, 29, 33).

Lifestyle interventions were shown to improve health and to reduce the diabetes risk in all the reviewed studies. Studies were conducted in different countries around the world, indicating the global nature of the disease. The Da Qing follow up (14) study demonstrated the potential benefits for people who are at risk of developing diabetes to participate in interventions as the long term gains of doing so could extend far beyond the intervention period. The best improvements and diabetes risk reductions (measured by fasting plasma glucose, A1c and BMI) were found in participants who had diabetes risk factors and those with pre-diabetes. Those who already had diabetes seemed to have minor death risk reduction of 20% in one study (35) vs a 28.5% (19) and 58% (8)

diabetes risk reduction for those who did not have diabetes at the beginning of the intervention. One study (26) demonstrated that in a multiethnic country such as the United States healthcare providers need to be sensitive to the needs of people of different cultural backgrounds. For studies like this to attain a high success rate, clients' different socioeconomic and cultural needs must be taken into consideration. An individualized diet recommendation can be an effective means to encourage people at risk of developing diabetes to reduce their levels of blood glucose and delay the onset of diabetes. The success of the individualized dietary recommendation used in Japan (4) further supports this approach. In the future it may also be advisable to find ways of addressing some of the factors that were reported (26) as being barriers to participating in intervention activities. Thus, a community collaborative effort can reduce the burden on mothers who have to be caregivers to multiple family members. Another outcome of this study was that increased participation was achieved by providing transportation for some patients, while others were given intervention material though teleconference. If many participants are faced with the same problems/barriers, it may be beneficial to organize them into groups that share similar experiences and in that way they may find a common solution to problems.

To improve the general health of the population it is imperative that blood glucose levels are tested regularly and that the appropriate therapies are offered to those who need them. It would be beneficial for people who are at high risk of developing diabetes to be physically active and eat a proper diet.

References

1. American Diabetes Association and National Institutes of Diabetes, Digestive and Kidney Diseases. The prevention or delay of type 2 diabetes. *Diabetes Care.* 2003;26 Supplement 1:S62–8.

2. American Diabetes Association (ADA) Executive Summary: Standards of Medical Care in Diabetes—2010. *Diabetes Care*. 2010;33 Supplement 1: S4-S10.

3. World Health Organization/International Diabetes Foundation. Definition and Diagnosis of Diabetes Mellitus and Intermediate Hyperglycemia: report of a World Health Organization/International Diabetes Foundation Consultation. Geneva, Switzerland: WHO Document Production Services 2006;1-46. (*LOE 4*).

4. Watanabe M, Yamaoka K, Yokotsuka M, Tango T. Randomized controlled trial of a new dietary education program to prevent type 2 diabetes in a high-risk group of Japanese male workers. *Diabetes Care*. 2003;26:3209-14.

5. Chiasson JL, Josse RG, Gomis R, Hanefeld M, Karasik A, Laakso M. Acarbose for prevention of type 2 diabetes mellitus: the STOP-NIDDM randomized trial. *Lancet* 2002;359:2072-7.

6. Kahn SE, Haffner SM, Heise M A, Herman W, Holman RR. Jones NP, Kravitz BG, Lachin JM, O'Neill MC, Zinman B, Viberti G. Glycemic Durability of Rosiglitazone, Metformin, or Glyburide Monotherapy. *New England Journal of Medicine*. 2006;355(23):2427-43.

7. Zimmet P, Alberti KG, Shaw J Global and societal implications of the diabetes epidemic. *Nature*. 2001;414(6865):782–7.

8. Tuomilehto J, Lindstrom J, Eriksson JG, Valle TT, Hamalainen H, Ilanne-Parikka P, Keinanen-Kiukaanniemi S, Laakso M, Louheranta A, Rastas M, Salminen V, Uusitupa M. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *New England Journal of Medicine.* 2001;344:1343–1350.

9. Lindstrom J, Louheranta A, Mannelin M, Rastas M, Salminen V, Eriksson J, Uusitupa M, Tuomilehto J. The Finnish Diabetes Prevention Study (DPS): lifestyle intervention and 3-year results on diet and physical activity. *Diabetes Care.* 2003;26(12):3230-6.

10. Kosaka K, Noda M, Kuzuya T. Prevention of type 2 diabetes by lifestyle intervention: a Japanese trial in IGT males. *Diabetes Research and Clinical Practice.* 2005;67:152-162.

11. Laatikainen T, Dunbar J, Chapman A, Vartiainen E, Heistaro S, Philpot B, Absetz P, Bunker S, O'Neil A, Reddy P, Best J, Janus E. Prevention of Type 2 Diabetes by Lifestyle Intervention in an Australian Primary Health Care Setting: Greater Green Triangle (GGT) Diabetes Prevention Project. *BMC Public Health*. 2007;7(249) 1-20.

12. Absetz P, Valve R, Oldenburg B, Heinonen H, Nissinen A, Fogelholm M, Ilvesmaki V, Talja M, Uutela A. Type 2 diabetes prevention in the "Real World". *Diabetes Care*. 2007;30:2465-2470.

13. Ackermann RT, Finch EA, Brazening E, Zhou H, Marrero DG. Translating the Diabetes Prevention Program into the Community: The DEPLOY Pilot Study. *American Journal of Prevention Medicine.* 2008;5(4):357–363.

14. Li G, Zhang P, Wang J, Gregg EW, Yang W, Gong Q, Li H, Li H, Jiang Y, An Y, Shuai Y, Zhang B, Zhang J, Thompson TJ, Gerzoff RB, Roglic G, Hu Y, Bennett PH. The long- term effect of lifestyle interventions to prevent diabetes in the China Da Qing Diabetes Prevention Study: a 20-year follow-up study. *Lancet.* 2008;371(9626):1783-9.

15. Pan XR, Li GW, Hu YH, Wang JX, Yang WY, An ZX, Hu ZX, Lin J, Xiao JZ, Cao HB, Liu PA, Jiang XG, Jiang YY, Wang JP, Zheng H, Zhang H, Bennett PH, Howard BV. Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance: The Da Qing IGT and Diabetes Study. *Diabetes Care.* 1997;20:537–544.

16. Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, Nathan DM. The Diabetes Prevention Program Research Group: Reduction in the Incidence of type 2 diabetes with lifestyle intervention or metformin. *New England Journal of Medicine.* 2002;346:393–403.

17. Kitabchi AE, Temprosa M, Knowler WC, Kahn SE, Fowler SE, Hafner SM, Andres R, Saudek C, Edelstein SL, Arakaki R, Murphy MB, Shamoon H. Role of insulin secretion and sensitivity in the evolution of type 2, diabetes in the diabetes prevention program: effects of lifestyle intervention and metformin. *Diabetes.* 2005;54:2404–14.

18. Orchard TJ, Temprosa M, Goldberg R, Haffner S, Ratner R, Marcovina S, Fowler S, The Diabetes Prevention Research Group. The effect of metformin and intensive lifestyle intervention on the metabolic syndrome: the Diabetes

Prevention Program randomized trial. *Annals of Internal Medicine.* 2005;142:611-9.

19. Ramachandran A, Snehalatha C, Mary S, Mukesh B, Bhaskar AD, Vijay V. The Indian Diabetes Prevention Program shows that lifestyle modification and metformin prevent type 2 diabetes in Asian Indian subjects with impaired glucose tolerance (IDPP-1). *Diabetologia.* 2006;49:289–297.

20. Torgerson JS, Hauptman J, Boldrin MN, Sjostrom L. Xenical The prevention of diabetes in obese subjects (XENDOS) study: a randomized study of orlistat as an adjunct to lifestyle changes for the prevention of type 2 diabetes in obese patients. *Diabetes Care.* 2004;27:155-61.

21. Thamer C, Machann J, Stefan N, Schafer SA, Machicao F, Staiger H, Laakso M, Bottcher M, Claussen C, Schick F, Fritsche A & Haring HU. Variations in PPARD determine the change in body composition during lifestyle intervention: a whole-body magnetic resonance study. *Journal of Clinical Endocrinology Metabolism* 2008;93:1497–1500.

22. Stefan N, Thamer C, Staiger H, Machicao F, Machann J, Schick F, Venter C, Niess A, Laakso M, Fritsche A, HaringHU. Genetic variations in PPARD and PPARGC1A determine mitochondrial function and change in aerobic physical fitness and insulin sensitivity during lifestyle intervention. *Journal of Clinical Endocrinology Metabolism*. 2007;92:1827–1833.

23. Seidel MC, Powell RO, Zgibor JC, Siminerio LM, Piatt GA. Translating the Diabetes Prevention Program into an urban medically underserved community: a nonrandomized prospective intervention study. *Diabetes Care*. 2008;31(4):684-689.

24. Bacardi-Gascon M, Garay PR, Jiménez-Cruz A. A diabetes intervention program of physical activity carried out at primary care settings in Mexico. *Diabetes Research and Clinical Practice*. 2004;68*:*135–140.

25. Kirk A, Mutrie N, MacIntyre P, Fisher M. Increasing physical activity in people with type 2 diabetes. *Diabetes Care.* 2003;26:1186–92.

26. Mayer-Davis EJ, D'Antonio AM, Smith SM, Kirkner G, Martin SL, Parra-Medina D, Schultz R**.** Pounds off with empowerment (POWER): a clinical trial of weight management strategies for black and white adults with diabetes who live in medically under-served rural communities. *American Journal of Public Health.* 2004;94:1736–1742.

27. Jenkins DJA, Kendall CWC, McKeown-Eyssen G, Josse RG, Silverberg J, Booth GL, Vidgen E, Josse AR, Nguyen TH, Corrigan S, Banach MS, Ares S, Mitchell S, Emam A, Augustin LSA, Parker TL, Leiter LA. Effect of a Low–Glycemic Index or a High–Cereal Fiber Diet on Type 2 Diabetes: A Randomized Trial**.** *Journal of the American Medical Association.* 2008;300(23):2742-2753.

28. Wolever TMS, Gibbs AL, Mehling C, Chiasson J, Connelly PW, Josse Rg, Leiter LA, Maheux P, Rabasa-Lhoret R, Rodger NW, Ryan EA. The Canadian Trial of Carbohydrates in Diabetes (CCD), a 1-y controlled trial of low-glycemic-index dietary carbohydrate in type 2 diabetes: no effect on glycated hemoglobin but reduction in C-reactive protein. *American Journal of Clinical Nutrition.* 2008;87(1):114-125.

29. Wolf AM, Conaway MR, Crowther JQ, Hazen KY, L Nadler J, Oneida B Bovbjerg VE. Improving Control with Activity and Nutrition (ICAN) Study, Translating lifestyle intervention to practice in obese patients with type 2 diabetes: Improving Control with Activity and Nutrition (ICAN) Study. *Diabetes Care*. 2004;27:1570–1576.

30. Ménard J, Payette H, Baillargeon J, Maheux P, Lepage S, Tessier D, Ardilouze J. Efficacy of intensive multitherapy for patients with type 2 diabetes mellitus: a randomized controlled trial. *Canadian Medical Association journal.* 2005;173(12):1457-66.

31. Corser W, Holmes-Rovner M, Lein C, Gossain V. A shared decision-making primary care intervention for type 2 diabetes. *The Diabetes Educator*. 2007;33(4):700-8.

32. West DS, DiLillo V, Bursac Z, Gore SA, Greene PG. Motivational interviewing improves weight loss in women with type 2 diabetes. *Diabetes Care.* 2007;30:1081–1087.

33. Gaede P, Vedel P, Larsen N, Jensen GVH, Parving H-H, Pedersen O. Multifactorial intervention and cardiovascular disease in patients with type 2 diabetes. *New England Journal of Medicine.* 2003;348:383-93.

34. Gaede P, Lund-Andersen H, Parving HH, Pedersen O. Effect of a multifactorial intervention on mortality in type 2 diabetes. *New England Journal of Medicine*. 2008;358:580-91.

35. Kuzuya T, Nakagawa S, Satoh J, Kanazawa Y, Iwamoto Y, Kobayashi M, Nanjo K, Sasaki A, Seino Y, Ito C, Shima K, Nonaka K, Kadowaki T. Report of

the Committee on the classification and diagnostic criteria of diabetes mellitus. *Diabetes Researcher and Clinical Practice.* 2002;55(1):65-85.

36. American Diabetes Association (ADA). Clinical Practice Recommendations. *Diabetes Care.* 2008;31 Supplement 1:S1-108.

Table 2.1 American Diabetes Association criteria for the Diagnosis of Normal Blood Glucose Values, Pre-Diabetes and Diabetes

Blood Glucose	Fasting Plasma Glucose (mg/dl)[1]	2-hr Plasma Glucose (mg/dl)[2]	A1C (%)[3]	Random[4] (mg/dL)
Normal	<100	<140	<6	≤125
Pre-diabetes	100 – 125	140 – 199	5.7 – 6.4	-
Diabetes	≥126	≥200	≥6.5	≥200

1. Fasting values are defined as 8 hours with no caloric intake.
2. The test should use the World Health Organization criteria using a glucose load equivalency of 75 g anhydrous glucose dissolved in water.
3. Test should use a certified National Glycohemoglobin Standardization Program (NGSP) protocol that is standardized to the Diabetes Control and Complications Trial (DCCT) assay.
4. Random or casual blood glucose values are collected regardless of fasting/fed state or time of day.

Table 2.2 World Health Organization Definitions and Diagnosis of Diabetes

Blood Glucose	Fasting Plasma Glucose (mg/dl)[1]	2-hr Plasma Glucose (mg/dl)[2]	A1C (%)[3]
Normal	<100	<140	<6
Pre-diabetes	110 – 125	140 – 199	-
Diabetes	≥126	≥200	≥6.5

1. Fasting values are defined as 8 hours with no caloric intake.
2. The test should use the World Health Organization criteria using a glucose load equivalency of 75 g anhydrous glucose dissolved in water.
3. Test should use a certified National Glycohemoglobin Standardization Program (NGSP) protocol that is standardized to the Diabetes Control and Complications Trial (DCCT) assay.

Table 2.3 Japanese Diabetes Society Definitions and Diagnosis of Diabetes

	Fasting Plasma Glucose (mg/dl)[1]	1-h Plasma Glucose (mg/dl)[2]	2-hr Plasma Glucose (mg/dl)[3]	A1C (%)[4]
Normal	<100	-	<140	<6
Borderline	-	≥180	-	-
Pre-diabetes	110 – 125	-	140 – 199	-
Diabetes	≥126	-	≥200	≥6.5

1. Fasting values are defined as 8 hours with no caloric intake.
2. 1-h Plasma Glucose according to the Japanese Diabetes Society (JDS) standard definitions.
3. The test should use the World Health Organization criteria using a glucose load equivalency of 75 g anhydrous glucose dissolved in water.
4. Test should use a certified National Glycohemoglobin Standardization Program (NGSP) protocol that is standardized to the Diabetes Control and Complications Trial (DCCT) assay.

CHAPTER THREE

CU4HEALTH STUDY

Abstract

The purpose of this study was to assess the nutrition-related health behaviors and diabetes knowledge of employees at Clemson University who had already shown interest in their health status by their participation in the CU4Health program. CU4Health is the Clemson University Worksite Wellness Screening Program which is provided to Clemson University employees, in partnership with the South Carolina Employee Insurance Program. Invitations were sent to the CU4Health participants to take part in three online questionnaires: 1) demographic; 2) diabetes knowledge; and 3) food intake patterns. The surveys included the Michigan Diabetes Knowledge Test, the Block Food Frequency Questionnaire and a demographic questionnaire. The objective was to compare the results from the college degree-holding participants and those with less than a college degree. There were different response rates for the three questionnaires, with the Diabetes Knowledge Test receiving the highest number of participants. A total number of 50, 46 and 40 participants completed the Diabetes Knowledge Test, the Demographic Questionnaire and the Block Food Frequency Questionnaire, respectively. There were no differences between the mean responses of those with a college degree and those without college degree ($P = 0.4921$).

Introduction

Diabetes

According to the American Diabetes Association, 8% of the population of the US has diabetes and the total prevalence of diabetes increased 13.5% from 2005 to 2007 (1). In 2007, the CDC reported that about 23 percent, or 12.2 million, of those aged 60 and over in the U.S. had diabetes. They also estimated that, in this time frame, about 536,000 new cases appeared among that age group (2). In 2008, the CDC reported that Type 2 diabetes (T2D) had increased 90% since 1997 and that about a third of those with diabetes don't yet know they have this dangerous disease (3). In this report, it was stated that South Carolina diabetes rates increased by 113%, from 1995-1997 to 2005-2007. Of the 33 states surveyed by the CDC for T2D, South Carolina had the second highest prevalence (3). T2D affects certain groups more than others. Individuals with close relative who have diabetes, those who are older than 45 and obese individuals are at a greater risk of developing diabetes (2). Minority groups such as Native Americans, African Americans,and HispanicAmericans are disproportionately affected by diabetes (3)

Pre-diabetes

People who have pre-diabetes are particularly at risk of developing diabetes. More than 60 million Americans are estimated to have pre-diabetes, defined by impaired glucose tolerance (IGT) or impaired fasting glucose (IFG) (4). According to the ADA, a person who has fasting plasma glucose of at least 100 mg/dl (5.6 mM/L) but less than 126 mg/dl (7.0 mM/L) is classified as pre-diabetic (1). It would be desirable for people at high risk of developing diabetes to take early preventative measures so that they may

delay the progression of pre-diabetes into T2D (5, 6). However, many people do not get treatment until they already have developed the disease and, by that time, the treatment options for T2D are limited or less effective (7). As there is no cure for diabetes, it is important that people are made aware of the complications associated with diabetes especially as prevention of the disease is the best option (7, 8). In the process of identifying those with pre-diabetes, Benjamin and colleagues predicted that additional millions of people with undiagnosed diabetes would be identified as well (9).

In response to increasing healthcare costs, along with the increasing prevalence of diabetes, Cousineau et al. initiated a 2008 Online Worksite Nutrition Program from which they concluded that both the private and public sectors are aware of the need for worksite interventions to prevent chronic metabolic conditions (10). Diabetes is known to develop along with other chronic conditions such as cardiovascular disease. It, along with another causative factor, obesity, may also contribute to the development of hypertension, dyslipidemia and increased need for medical amputation (11, 12, 13, 14). Therefore, there are many reasons to work toward prevention for those who are at risk.

CU4Health

Clemson University is a public university in Upstate South Carolina that employs 4,909 people, 50.8% male, 49.2% female (15). Of these, the majority are Caucasian (84.21%), followed by African American (10.21%), Asian (04.01%), Hispanic (1.22%), Native American (0.122%) and individuals who listed their race as unknown (0.22%).

The Clemson University Worksite Screening Program (CU4Health) is an employee wellness screening program initiated in 1998 for Clemson University

employees at the Joseph F. Sullivan Center, in partnership with the South Carolina Employee Insurance Program (16). The CU4Health program is provided at a low cost and is available to all the Clemson University employees. The Sullivan Centre health professionals, who administer the program, assess health risks in individuals by measuring height, weight and other parameters which include blood pressure, blood lipid profile, and a blood chemistry profile hemogram (16).

The CU4Health program uses the Personal Wellness Profile (PWP) provided by Wellsource, Inc. (Clackamas, OR) to determine an overall wellness score for each participant based on the person's data, which indicates the general condition of the patient's health. Information from the PWP and a follow-up counseling session are made available to each participant (16). The areas that are discussed during the counseling session include the patients' overall fitness which is based on their "cardiovascular endurance, or aerobic fitness, flexibility, strength and BMI" (16). The patients are encouraged to exercise regularly and exercise tips are provided for patients who have not been exercising regularly (16). Another area that is discussed is the patient's risk for developing heart disease. The score given could be influenced by "smoking, cholesterol, blood pressure, exercise, diabetes risk, and the patient's BMI as well as other blood tests" (16). Each health-related topic is discussed with the patient and appropriate recommendations made.

The nutrition score on the PWP reflects how well the patient follows the food guide pyramid, low-fat meals, high-fiber foods, fast food/snacks, and breakfast daily (16). Other areas included in the counseling session are substance use, coping with stress,

cancer risk, and osteoporosis. The counseling session helps to determine if there are areas that need follow-up and what the patient should do to make improvements (16).

By April 2009, the CU4Health program had 1321 names on file of individuals who had enrolled between October 1998 and April 2009. In 2008, an assessment of the CU4Health data collected by the Sullivan Centre at Clemson University was undertaken. The data of the 1321 patients in the CU4Health program indicated that 322 individuals (25.7%) had a BMI ≥30, classified as being obese, while 800 CU4Health patients were overweight or obese with a BMI of≥25.

Subjects and Methods

Subject Selection

A review of the CU4Health records revealed that 826 (63%) of CU4Health participants were at risk of developing diabetes. After this review, it was decided that it would be better to develop a survey assessment and make it available to the CU4Health participants. This would provide an idea as to how many of the 1321 participants who had participated in the program at any time from 1998 to 2009, and were still on campus, would be willing to participate in a diabetes and wellness-related study.

Subject Recruitment and Participation

Of the identified potential participants, 861 had a valid Clemson University email as of May, 2009; a Sullivan Center employee contacted these CU4Health participants and invited them to participate in the study. Invitations were extended by email. The CU4Health participants who responded were asked to participate by filling in 3 survey questionnaires. Those who chose to participate were provided a link to the website which

provided more information on accessing the questionnaires. Participants were given two options for participation: 1) complete the questionnaires and grant access to their CU4Health clinical data [clinical data included health and diet history plus height, weight, BMI, blood pressure, Blood Lipid Profile (cholesterol values and triglycerides); and Blood Chemistry Profile including blood glucose (blood sugar) and electrolytes as well as demographic information] or 2) complete the 3 questionnaires without giving access to the clinical data.

Questionnaire Selection and Administration

Questionnaire Determinants

The questionnaires used were chosen to assess the eating patterns and behaviors of CU4health participants, with particular interest in what participants consumed during the past year. The food frequency questionnaire method has been shown to be the most effective research method for determining the types of food the participants consumed during the past 12 months (17). To achieve this, a validated full length 2005 Block Food Frequency Questionnaire (FFQ) (18, 19) was used. A demographic questionnaire, the Michigan Diabetes Knowledge Test (MDKT) and the Block FFQ provided by NutritionQuest (Berkley, CA) (an organization that provides nutrition and physical activity assessment and behavioral support to many universities and research organizations, including NASA) (20) were used.

Questionnaires

Michigan Diabetes Knowledge Test

The MDKT is validated to reliably assess diabetes knowledge, and is used primarily for those who have diabetes (21). The test, developed by the Michigan Diabetes Research Training Center (Ann Arbor, MI), can be administered in a 14 question short version which is specific for diabetes patients who do not use insulin or those who have T2D, and takes about 15 minutes to complete (21, 22).

Block Food Frequency Questionnaire

The Block FFQ, a 110 food-related item questionnaire that was originally developed from NHANES 1999-2002 (23) was used. This questionnaire provides nutrient and food group data about the foods habitually consumed by the participants (24). The electronic version of the 2005 Block FFQ was used, which is estimated to take 30-40 minutes to complete. It can be self-administered and can minimize variability by assessing foods consumed over a year. The electronic version of the Block FFQ was ideal for this website-based study.

Demographic Questionnaire

The demographic questionnaire was designed by a co-investigator. The questions included categories such as gender, age, race, marital status, occupation, and household income. The questionnaire had a total of 17 questions.

Questionnaire Administration

Website Design and Content

A website was designed for the purpose of administering the on-line surveys (Appendix A). The website contained a welcome message and participant instructions. An informed consent document and the three online surveys were posted on the website which was accessible to CU4Health employees only. The MDKT and demographic questionnaires were accessible from the first website and were hosted by Zoomerang (available at www.Zoomerang.com). A link, provided at the bottom of the first website, opened a second website, which contained instructions for participation in the FFQ. The second website provided the username and password required for the FFQ and had a link to the NutriQuest 2005 Block FFQ.

Questionnaire Completion Procedures

The participants were given a choice to either fill in the questionnaires only, or to fill in the questionnaires and also allow access to their CU4Health medical history data by the principle investigator and collaborators. Those who chose the second option were provided with a consent form to download, print and complete permitting access to their clinical data. Signed consent forms were delivered via Clemson mail or in person to the principle investigators. Only individuals with signed consent forms were included in the CU4Health medical history data protocol. The protocol for the study and consent form were approved by Clemson University Institutional Review Board.

Statistical Analysis

Data were compiled and entered in an Excel 2007 spreadsheet. The analysis was performed using SAS 9.13 (SAS Institute, 2001). Level of education was used as an independent variable and dependent variables of interest were compared between educational levels. Pearson product-moment correlations were performed for a subset of variables at the significance of $\alpha=0.05$.

A multiple linear regression analysis was also performed on the demographic data, as well as clinical and nutritional variables. The stepwise multiple linear regression was used to develop a model for the diabetes knowledge score based on demographic variables. A second model which included the clinical variables also was developed. Variables of interest were chosen based on their relationship with the MDKT score. A comparison was made for the 25 participants who allowed access to their clinical CU4Health values and some of the values they reported in the study.

Results

Questionnaire Completion Results

Of the 861 emails sent to CU4Health participants to invite them to participate in the study, approximately 100 emails were sent back as “Invalid users”, which left about 760 emails that were assumed to have been received. Of these, three potential participants called to inquire about the study and 15 replied by email to get more information on how to participate in the study. One participant indicated that she did not want to participate in the study. Twenty five participants agreed to have their medical records evaluated; consent forms were obtained from all of these participants.

The MDKT had the highest number of participants completing the questionnaire. There were a total of 85 visits to the MDKT website. Fifty one (60%) participants completed the MDKT; the results from one were not included in the final data set because less than half of the questions were answered. From a total of 61 visits to the demographic questionnaire, 47 (77.04 %) participants completed the questionnaire. For the Block FFQ, there were 46 visits, 40 (86.95%) were completed. Thirty six participants completed the Block questionnaire on the first visit. Six participants who had not fully completed their questionnaires were contacted and reminded to complete the questionnaire; 4 complied, for a total of 40 completed questionnaires.

Forty-seven participants completed the Demographic Questionnaire (Appendix B); however, 1 subject had <50% completion and was excluded from analysis resulting in 46 satisfactorily completed questionnaires.

Demographic Questionnaire Results

The results from the demographic questionnaire are in Table 3.1. Demographic information for CU4Health participants (1998 to 2009) is in Table 3.2. Most of the participants in this study were female (80%) compared to 59.4% female in the CU4Health program (785/1321). Both of these percentages were higher than the percentage of female employees at CU (49.20%) in early 2008 (Table 3.3) (16).

The age group most highly represented was 50-59 years (46%) in this study and in the CU4Health data (33.8%) (Table 3.4). Most study participants reported they were Caucasian; (84%); the same percentage applied to the CU4Health and CU employee population. Only 4% of participants reported that they smoked. Forty five percent of the

participants reported they had BMI normal in the study, compared to 39.5% from CU4Health data. Fifty-five percent of participants reported being either overweight (33%) or obese (22%) (Table 3.1). BMI information in Table 3.1 was calculated from the self reported height and weight values from the participants' in this study. For participants who allowed access to their CU4 Health clinical data, 52% had normal BMI, 26% were overweight and 22% were obese.

Sixty seven percent of study subjects were married and 22% divorced. CU4Health participants who allowed access to their clinical data marital status were; 63.3% married, 23.3% divorced, 10% widowed and 3.3% single. The highest percentage of the participants in the on-line study, 35%, had a graduate degree, and 33% had some college education, while 43.3% of the CU4Health participants and 45.7% of all the university employees had earned graduate degrees, and 25% of CU4Health participants and 20.4% of university employees were college graduates. Of the study participants, 28% indicated that they had a household income of ≥$80,000 and above while 36.2%, of the CU4Health group were at this income level. For university employees, the most common income level (41%) was $20,000 - $39, 999 while only 14.9% of employee households belonged to the ≥$80, 000 income bracket. For the study group, 46% of the participants lived in a 2-person household, and there were no persons <18 yrs in 79% of the households, and no persons > 65 in 94% of the households. An equal percentage of participants, 39%, lived in Pickens and Oconee counties with 59% of the participants reporting that they lived in a town or city of 10,000 to 15,000 residents.

Questionnaire Results

The mean (±SD) MDKT score, from the 50 participants, was 76.85±15.17 (P<0.001) with a mode of 85.71. Only 5 participants scored 100, with the five lowest scores ≤57.14. Of the 16 questions asked, the HbA1c knowledge item had to lowest percentage of correct answers (25%). Question 4, which assessed fat content in food, was answered correctly by only 55 % of participants. Sixty percent of participants correctly answered question 9 (treatment of low blood sugar), and 61% knew the effects of infection on blood glucose (question 11). Sixty two percent of participants answered question 5 correctly, which pertained to identifying calorie levels presented in food labeling. Ninety two per cent of the participants answered a carbohydrate-related question (question 12) correctly and 94% correctly answered the question on foot care. Ninety eight percent of the participants were able to identify the correct answer in a cardiovascular disease related question (question 13) (Appendix C).

The Block Food Frequency Questionnaire

Participants who completed the Block FFQ were Caucasian (87.5%) > African American and Hispanic (7.5%, each) > Native Americans (2.5%), with 5% "other". Females (77.5%) of average age 53.54± 8.50 and men (22.5%) of average age 48.44±10.46 participated. The mean for BMI was 27.09±5.85. In a scale of 2-7 (2-completed HS; 7-Graduate degree), the mean educational attainment was a college education. Only two participants reported smoking 6 and 15 cigarettes a day, respectively. Approximately 37% reported drinking less alcohol than they used to, and 65% reported currently trying to lose weight.

Health status was reported as excellent (20%), very good (47.5%), good (30%), and fair (2.7%). Mean calories consumed were 1780±512.38 kcal. Average caloric consumption was: protein 71.71g (36.58%); fat 72.85g (16.01%), and carbohydrates, 210.89g (47.69 %); sweets (12.60%) and alcohol (3.23%). Average fat sources were; saturated fat 22.12±9.1g, monounsaturated fat 28.93±10.52g, and polyunsaturated fat 16.34±5.80g with 1.73±0.68mg Omega-3 fatty acids and 2.28±1.38mg trans fats. Daily cholesterol intake was 70±97.95mg. The amount of dietary fiber consumed was 20.623±9.22g. The total amount of sugar consumed was 96.76±42.16g.

Participants reported that they consumed a relatively healthy diet with low total calories for both the college educated and those without a college education. The data in Table 3.5 indicates that there was no significant difference in caloric intake based on level of education. Table 3.6 is composed of data of a comparison of My Pyramid recommended diet and the results from this study. Participants in this study consumed, on average, more vegetables (3.8± 2 cups) compared to the recommendations (2.5 cups). They also consumed 1.5± 1 cups of fruits and juices compared to a recommended 2 cups. Saturated fat intake was measured at a mean of 22± 9.10 g.

A Stepwise multiple linear regression was used to develop a model for the diabetes knowledge score based on demographic and clinical variables was used. The model formula is below:

MDKT score =72.3747*intercept-0.1214*total calories-0.0506*income +30.8564*diabetes+ 17.1742*gender-0.2447*age-1.0365*bmi+3.69707*fat calories+0.72651*carbohydrates colories-0.33111*saturated fat.

The results from the stepwise multiple linear regression model which did not include the CU4Health clinical variables are shown in Table 3.9. There were 46 participants who were included in the full model. In a multivariate statistical (Table 10.9) analysis it was shown that total calories ($P = 0.0066$), having diabetes ($P = 0.0013$), gender ($P = 0.0457$), BMI ($P = 0.0394$), calories from fat ($P = 0.0341$), calories from carbohydrates ($P = 0.0018$), were factors affecting diabetes knowledge score. Insignificant factors in the model were income ($P = 0.9801$), age ($P = 0.2863$) and education ($P = 0.0793$). Having diabetes was a significant factor ($P = 0.0013$), while educational attainment was not ($P = 0.0793$). This meant that, for this group, people with diabetes had better diabetes knowledge regardless of their educational attainment.

In a second model (Table 3.10) which included the clinical variables, hemoglobin ($P = 0.0004$) and triglycerides ($P = 0.0004$) were important predictors of diabetes knowledge. Other significant variable in the model were income ($P = 0.0354$), having diabetes ($P = 0.0021$), education ($P = 0.0250$) and calories from carbohydrates ($P = 0.0007$). The formula for the second model is shown below:

MDKT score = -16.064*intercept+1.6281*income+14.4343*diabetes
+0.35468*bmi-2.1924*education+0.05366*carbohydrates calories
+7.04135*hemoglobin+0.03519*triglycerides-12.40535*diabetes2.

A comparison was made for the 25 participants who allowed access to their clinical CU4Health values and some of the values they reported in this study (Table 3.7). The longest time that any one participant had stayed in the program was 10 years and the mean was 6.88± 3.04 ($P <0.0001$). The mean change in BMI was -0.58 ($P<0.41$) while

the mean change in weight was -0.59 (P = 0.8680). The mean change in fasting glucose was -4.01 (P = 0.3083).

Discussion

The CU4Health program provided an ideal group of candidates for this study. The program participants are a self-selected group of individuals who have shown an interest in seeking health information and education. The information given to them from the blood profile tests and various scores on health and wellness provided yet another reason for the individuals to improve their health. The nutritional score and counseling given to the program participants provided some knowledge of healthy eating habits and encouraged the individuals to seek more information in any areas that were problematic for them.

In their health literacy study for diabetes patients, Powel and colleagues found that there was a significant association between the level of literacy and the high score in their program (P = 0.02) (25). In the present study there was no significant difference detected among the education groups (P = 0.4921). Contrary to this study, Powell found that there was a significant difference between high literacy patients and those with low literacy and those with low literacy missed 13% to 18% of the questions. In this study however, all the participants were of arguably high literacy level, making this difference hard to measure. It could be said that the CU4Health program has produced positive results because of the lack of significant difference between diabetes knowledge observed among educational levels. CU4Health participants who did not have a college degree did not score significantly different compared to those who had college degrees. This could

mean that the information received through the CU4Health program may have reduced the potential difference in diabetes knowledge score for CU4health participants. In a large sample size study, Fitzegerald and colleges found that the Diabetes Knowledge Test score increased with the level of education (21). This was also the case in this study; however, the difference was not significant. The DKT means ±SD for different education levels in this study were 74.1±15.8, 75.81±14.1 and 79.46±15.8 for those who do not have a college degree, those with a college degree, and those with a graduate degree respectively.

In 2001, Groth and colleagues reported that educational attainment was an important factor in explaining the difference in healthy dietary habits between low and higher education groups in Denmark (26). There was also a similar finding in a Canadian study where high education participants were more likely to follow a meal plan (27) This was not the case in our MDKQ results, as only 55% of the participants correctly answered a question on types of food that were high on fat (question 4). It is rather troubling that such a high percentage of people, who were mostly well educated, did not understand variations in fat content among various food products. It is well known that consuming a diet that is high in saturated fat and low in vegetables, fruits and whole grains increases the chance of weight gain and the development of metabolic chronic disorders. The reported food intake results from this study were encouraging, for example participants reported a high intake of vegetables. However, the clinical data suggests that this group needed to improve its diet. The average cholesterol levels were: total cholesterol, 201±42.5 mg/dl; LDL cholesterol, 121.5±37.34 mg/dl; and HDL cholesterol,

57±15.24 mg/dl; with mean triglycerides 138±162.98mg/dl. Desirable cholesterol numbers are ≤200 mg/dl for total cholesterol, ≤100 mg/dl for LDL and ≥60 mg/dl for HDL. Desirable triglycerides levels are ≤150 mg/dl. Subject lipid levels were less than optimal and indicate that the CU4Health participants need to reduce their saturated fat intake. This can be achieved by choosing their fats wisely and increasing their consumption of whole grains and high fiber foods.

Some of the CU4Health program participants had already developed diabetes or other chronic metabolic disorder as indicated in Table 3.1. With this in mind, this study tested the diabetes and nutritional knowledge of the CU4Health program participants. Participants with diabetes had better diabetes knowledge, regardless of educational attainment.

The CU4Health program can best address health concerns of its participants if the participants are familiar with diabetes education information. It has been shown that a lifestyle that reduces the risk of developing diabetes is likely to reduce the risk of developing other metabolic disorders, particularly stroke and CVD (most people with diabetes die from stroke and CVD). Therefore, it was encouraging to find that there was no significant difference between the college-educated group and those without a college education in this study.

It was anticipated that an online study would increase participation of university employees; however, this was not the case (participation rate was 7% of 760 emails sent). It may be advisable to re-evaluate the recruitment method to increase participation. The majority of the participants (~80%) were female; as a result there may be a need to

conduct focus groups to gain more information on increasing male participation. Conducting the study online did have the benefit of cost reduction and increased ease of obtaining data.

Conclusions

In the CU4Health participants, no significant difference in diabetes knowledge was observed between those with less than a college degree and those with a college degree. No difference in reported amount of calories consumed/group was seen. The factors, total calories ($P = 0.0066$), having diabetes ($P = 0.0013$), BMI ($P = 0.0394$), that were found to be useful in predicting diabetes knowledge could be used when constructing lifestyle interventions. The study findings indicated that the participants consumed less than recommended servings of whole grain and dairy products. An intervention that encourages the consumption of aforementioned products would be ideal for the study participants. Participants had high diabetes knowledge but most did not know much about the A1c test. An intervention that has an educational component providing the latest information about diabetes and other chronic metabolic disorders would increase their knowledge. The findings of this study enhance the understanding of the eating habits and health conditions and diabetes knowledge of the CU4Health participants. Information obtained from the current study can be used to design future worksite interventions for diabetes, and other related chronic diseases, for CU4Health participants or other interested Clemson University employees.

References

1. American Diabetes Association. Diabetes Statistics. 2007. Available at: http://www.diabetes.org/diabetes-statistics.jsp Accessed August 28, 2009.

2. Centers for Disease Control and Prevention. Available at: http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2007.pdf Accessed March 12, 2009.

3. Centers for Disease Control and Prevention. Available at: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5743a2.htm Accessed February 11, 2010.

4. Ackermann RT, Finch EA, Brizendine E, Zhou H, Marrero DG. Translating the Diabetes Prevention Program into the Community: The DEPLOY Pilot Study. *American Journal of Preventative Medicine.* 2008;35(4):357–363.

5. Weyer C, Bogardus C, Mott DM, Pratley RE. The natural history of insulin secretory dysfunction and insulin resistance in the pathogenesis of type 2 diabetes mellitus. *Journal of Clinical Investigation*. 1999;104:787–794.

6. El Bassuoni EA, Ziemer DC, Kolmb P, Rhee MK, Vaccarino V, Tsui CW, Kaufman JM, Osinski GE, Koch DD, Narayan KMV, Weintraub WS, Phillips LS. The "metabolic syndrome" is less useful than random plasma glucose to screen for glucose intolerance. *Primary Care Diabetes.* 2008;2:147–153.

7. Pan X, Yang W, Li G, Liu J. The National Diabetes Prevention and Control Cooperative Group: Prevalence of diabetes and its risk factors in China, 1994. *Diabetes Care.* 1997;20:1664-9.

8. Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA,Nathan DM. The Diabetes Prevention Program Research Group: Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *New England Journal of Medicine.* 2002;346:393–403.

9. Benjamin SM, Valdez R, Geiss LS, Rolka DB, Narayan KM. Estimated number of adults with prediabetes in the US in 2000: opportunities for prevention. *Diabetes Care*. 2003;26(3):645-9.

10. Cousineau T, Houle B, Bromberg J, Fernandez KC, Kling WC. A Pilot Study of an Online Workplace Nutrition Program: The Value of Participant Input in

Program Development. *Journal of Nutrition Education and Behavior*. 2008;40:160-167.

11. AACE Medical Guidelines for Clinical Practice for the Management of Diabetes Mellitus. *Endocrine Practice*. 2007;13(Suppl 1):3-66.

12. Shelton NJ. What not to eat: Inequalities in healthy eating behavior, evidence from the 1998 Scottish Health Survey. *Journal of Public Health*. 2005;27, 36–44.

13. Benjamin SM, Valdez R, Geiss LS, Rolka DB, Narayan KM. Estimated number of adults with pre-diabetes in the US in 2000: opportunities for prevention. *Diabetes Care*. 2003;26(3):645-9.

14. Ménard J, Payette H, Baillargeon J, Maheux P, Lepage S, Tessier D, Ardilouze J. Efficacy of intensive multitherapy for patients with type 2 diabetes mellitus: a randomized controlled trial. *Canadian Medical Association journal*. 2005;173(12):1457-66.

15. Clemson University. Joseph F. Sullivan Center. CU4Health Wellness Program. Available at: http://virtual.clemson.edu/groups/wellness/Wellness_Programs.htm Accessed August 13, 2009.

16. Clemson University. Office of Institutional Research. Fact Sheet 2008. Available at: http://www.clemson.edu/oirweb1/fb/factbook/factbook.cgi conf_file_name=CHTE_EmployeeCountA Accessed July 16, 2009.

17. NutriQuest. 2005 Block Food Frequency Questionnaire. About Dietary Analysis. Available at: http://www.nutritionquest.com/research/about_dietary_analysis.htm Accessed June 14, 2009.

18. Block G. Block Adult Questionnaire. NutritionQuest Questionnaires and Screener. Available at: http://www.nutritionquest.com/products/ questionnaires_screeners.htm> Accessed May 10, 2009.

19. Block G, Thompson FE, Hartman AM, Larkin FA, Guire KE. Comparison of two dietary questionnaires validated against multiple dietary records collected during a 1- year period. *Journal of American Dietetic Association* 1992: 92: 686-693.

20. NutritionQuest. Block Dietary Data services. Available at: http://www.nutritionquest.com/ Assessed May 14, 2009.

21. Fitzgerald JT, Funnell MM, Hess GE, Barr PA, Anderson RM, Hiss RG, Davis WK. The reliability and validity of a brief diabetes knowledge test. *Diabetes Care* 1998;21:706–710.

22. Dickerson FB, Goldberg RW, Brown CH, Kreyenbuhl JA, Wohlheiter K, Fang L, Medoff D, Dixon LB. Diabetes knowledge among persons with serious mental illness and type 2 diabetes. *Psychosomatics.* 2005; 46(5):418-24.

23. Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Data. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2007-2008. Available at: http://www.cdc.gov/nchs/data/nhanes/nhanesgeneralguidelinesjune04.pdf Accessed June 13, 2009.

24. NutriQuest. 2005 Block Food Frequency Questionnaire. Dietary Screeners. Available at: http://www.nutritionquest.com/products/questionnaires_screeners.htm Accessed June 13, 2009.

25. Powell CK, Hill EG, Clancy CDE. The Relationship between Health Literacy and Diabetes Knowledge and Readiness to Take Actions. *The Diabetes Educator.* 2007;33(1):144-151.

26. Groth MV, Fagt S, Brondsted L. Social determinants of dietary habits in Denmark. *European Journal of Clinical Nutrition.* 2001;55:959–966.

27. Alguwaihes A, Shah BR. Educational Attainment is Associated with Health Care Utilization and Self-Care Behavior by Individuals with Diabetes. *The Open Diabetes Journal*. 2009;2:24-28.

Table 3.1: Study Population Demographic Characteristics

Variable	Values	Number	Percentage
Sex	Female	36	80%
	Male	9	20%
Age Group, yrs	30-39	3	6%
	40-49	13	28%
	50-59	21	46%
	60-69	8	18%
	70-79	1	2%
Race	Black/African-American	3	6%
	Caucasian	40	84%
	Hispanic/Latino	3	6%
	Native American	2	4%
Smoke	Yes	2	4%
	No	44	96%
BMI[1], kg/m^2	Normal (18.5-24.9)	20	45%
	Overweight (25-29.9)	15	33%
	Obese (30 or greater)	10	22%
Marital Status	Married	31	67%
	Never married	1	2%
	Separated/Divorced	10	22%
	Widowed	4	9%
Education	Completed High School	1	2%
	Some College	15	33%
	Bachelor degree	13	28%
	In Graduate School	1	2%
	Graduate degree	16	35%
Employment	Full Time	43	94%
	Part Time	2	4%
	Unemployed	1	2%
Household Income	$20,000-29,000	2	5%
	$30,000-39,000	5	12%
	$40,000-49,000	5	12%
	$50,000-59,000	9	20%
	$60,000-69,000	4	9%
	$70,000-79,000	6	14%
	$80,000 – 89,000	2	5%
	$90,000 – 99,000	6	14%
	≥$100 000	4	9%
Individuals in household n (%)[2]	1	9	20%
	2	21	46%
	3	9	20%

	4	6	14%
< 18 yrs	0	36	79%
	1	4	9%
	2	5	12%
> 65 yr	0	42	94%
	1	3	6%
County Residence	Anderson	7	16%
	Greenville	2	4%
	Oconee	18	39%
	Pickens	18	39%
	Other	1	2%
Residence	Farm	1	2%
Population	> 150,000	2	4%
	> 50,000 <150,000	3	7%
	10,000 - 50,000	27	59%
	< 10,000	13	28%
Reported Health	cardiovascular disease	1	2%
condition	diabetes	11	24%
	high blood glucose levels	4	9%
	high blood pressure	15	33%
	high cholesterol values	14	30%
	overweight or obese	12	26%

[1]BMI values derived from self reported height and weight values.
[2] Percentages based on the total number of participants who answered each question.

Table 3.2 CU4Health Participant Demographic Characteristics, Fall 1998-Spring 2009

Variable	Values	Number	Percentage
Sex	Male	536	40.6%
	Female	785	59.4%
Age Group	< 20	2	0.2%
	20-29	90	6.8%
	30-39	249	18.8%
	40-49	376	28.5%
	50-59	446	33.8%
	60 and above	158	12.0%
Family Income	< 20,000	29	3.6%
	20,000-39,999	155	19.5%
	40,000-59,999	169	21.2%
	60,000-79,999	155	19.5%
	≥80,000	288	36.2%
Level of Education	Some High School	22	2.2%
	High School Graduate	98	10.0%
	Some College	192	19.5%
	College Graduate	246	25.0%
	Graduate Degree	426	43.3%
Race	African American	98	8%
	Asian	44	3.6%
	Hispanic	22	1.8%
	Native American	24	2%
	Caucasian	1031	84%
	Other	8	0.7%
Family History of	Colorectal Cancer	94	7.1%
Disease	Breast Cancer	142	10.7%
	Diabetes	438	33.2%
	Cardiovascular Disease	364	27.6%
Diabetes Risk Score	High	87	6.6%
	Moderate	252	19.1%
	Low	487	36.9%
	Ideal	495	37.5%
Male BMI, kg/m^2	<25	178	33.3%
	25-29.9	220	41%
	≥30	138	25.7%
Female BMI, kg/m^2	<25	343	43.7%
	25-29.9	240	30.6%
	≥30	202	25.7%
Group BMI, kg/m^2	<25	521	39.5%
	25-29.9	460	34.8%

	≥30	340	25.7%

Table 3.3 2008 Clemson University Employee Demographic Data

Variable	Values	Number	Percentage
Sex	Male	2494	50.80%
	Female	2415	49.20%
Race	African American	501	10.21%
	Asian	197	04.01%
	Hispanic	60	01.22%
	Native American	6	00.12%
	Caucasian	4134	84.21%
	Other	11	00.22%
Income (n = 3978)	< 20,000	264	6.6%
	20,000-39,999	1631	41.0%
	40,000-59,999	888	22.3%
	60,000-79,999	605	15.2%
	≥80,000	590	14.9%
Education (n = 3978)	Not Indicated	55	1.4%
	Some High School	34	1.0%
	High School Graduate	531	13.4%
	Some College	735	18.1%
	College Graduate	806	20.4%
	Graduate Degree	1817	45.7%

*The percentages were rounded to the nearest 10^{th} and total of 99.99
#Additional data provided by Dr. Ronald Chrestman, Office of Institutional Research, Clemson University, Clemson, SC 29634
http://www.clemson.edu/oirweb1/fb/factbook/factbook.cgi?conf_file_name=zcFBE_EmployeeFacBGR

Table 3.4. Subject Demographic Information from the Current Study, Clemson University and CU4health

Variable	Values	Current Study	CU4Health	University
Gender	Male	9 (20%)	536 (40.6%)	2494 (50.80%)
	Female	36 (80%)	785 (59.4%)	2415 (49.20%)
Race	African American	3 (6%)	98 (8%)	501 (10.21%)
	Asian	-	44 (3.6%)	197 (04.01%)
	Hispanic	3 (6%)	22 (1.8%)	60 (01.22%)
	Native American	2 (4%)	24 (2%)	6 (00.12%)
	Caucasian	40 (84%)	1031 (84%)	4134 (84.21%)
	Other	-	8 (0.7%)	11 (00.22%)
Income	Under 20,000	-	29 (3.6%)	264 (6.6%)
	20,000-39,999	7 (16.2%)	155 (19.5%)	1631 (41.0%)
	40,000-59,999	14 (32.5%)	169 (21.2%)	888 (22.3%)
	60,000-79,999	10 (23.2%)	155 (19.5%)	605 (15.2%)
	80,000 and above	12 (28.1%)	288 (36.2%)	590 (14.9%)
Education	Not Indicated	-	-	55 (1.4%)
	Some HS	-	22 (2.2%)	34 (1.0%)
	HS Graduate	1 (2.2%)	98 (10.0%)	531 (13.4%)
	Some College	15 (32.6%)	192 (19.5%)	735 (18.1%)
	College Graduate	14 (30.4%)	246 (25.0%)	806 (20.4%)
	Graduate Degree	16 (34.8%)	426 (43.3%)	1817 (45.7%)

Table 3.5: Characteristics of CU4Health Participants by Educational Categories

		No College		With College	
Item	N	Means±SD	N	Means±SD	*p-value*
MDKT Score	17	74.78±15.79	27	78.56±15.24	<0.611
Total Calories (kcal)	14	1882.8±595.10	23	1724.8±465	<0.378
Income[1]	16	2.06±0.92	25	3.11±1.21	<0.003
Age (yrs)	14	53.57±.17	25	51.76±10.06	<0.650
Gender* (M/F)	14	1.94±0.24	25	1.72±0.45	<0.045
BMI (kg/m^2)	14	29.80±6.46	25	25.5±4.17	<0.431
Fat Calories (kcal)	14	712.17±25	23	625.32±224	<0.324
Carbohydrate Calories (kcal)	14	881.52±32	23	807.56±242	<0.440
Saturated Fat Calories (kcal)	14	224.64±83.60	23	185.22±79.1	<0.205

1. Income categories: 1 = $20,000 – 29,000, 2 = 30,000 – 39,000, 3 = 40,000 – 49,000, 4 = 50,000– 59,000

*Gender: 1 = Male, 2 = Female

Table 3.6 Comparison of Foods Consumed by Subjects with the Recommended MyPyramid Food Groups

Item	Means Intake Per Day[1,2]	Recommended[3]
Vegetables	3.8± 2cups	2.5 cups
Fruits & fruit juices	1.5±1 cups	2 cups
Breads, cereals, rice, pasta	4.6±2.2 oz	10 oz
Meat, fish, poultry, beans, eggs	2.2±1.1 oz	5.5 oz
Milk, yogurt, cheese	1.3±0.8 cups	3 cups
Fats & oils, sweets, sodas	3.0±1.1 tsp	6 tsp
Whole grains	0.6± 0.8oz	6 oz

1. n=25
2. Means ±SD
3. Servings Recommended by MyPyramid, 2005

Table 3.7 Clinical Characteristics from the CU4Health Participants (n = 25) Grouped by College Education*[1]

No degree	Hgb[2] g/dL	Cholesterol[3] mg/dL	LDL mg/dL	HDL mg/dL	TAG[4] mg/dL	Glucose mg/dL	BMI[5] kg/m^2
Mean	12.8±1.0	218±36.6	131.7± 32	59.7±16.2	131.3± 87.3	92.4± 19.6	27.2± 7.7
With degree	Hgb	Cholesterol	LDL	HDL	TAG	Glucose	BMI
Means	14.1± 0.8	191± 43.7	115.0± 39	56.1±14.9	142.7± 197	99.5± 27.3	26.0± 5.5

*The characteristics above were not significant at the 0.05 levels of significance.

[1]. Values are expressed as means ± standard deviation

[2]. Hgb – Hemoglobin

[3]. Cholesterol – Total Cholesterol

[4]. TAG – Triglycerides

[5]. BMI – Body Mass Index from CU4Health data

Table 3.8. Correlated Valuables from the Full Research Data

Variables	*P-Value*	R
Score and Age	<0.0092	-0.32
Score and Being married	<0.0094	-0.31
Score and Income	<0.0225	0.37
Education and Gender	<0.0203	-0.34
Education and BMI	<0.0372	-0.30
Education and Income	<0.0278	0.33
Total calories and BMI	<0.0106	0.40
Total calories and age	<0.0092	-0.40

P-Value: 0.05 levels of significance

r- Is the correlation coefficient

Table 3.9 MDKT Score Model for Data Set 1

Variable	Coefficient	*P-value*
Constant	72.3747	<0.0082
Total calories	-0.1214	<0.0066
Income	-0.0506	<0.9801
Diabetes	30.8564	<0.0013
Gender	17.1742	<0.0457
Age	-0.2447	<0.2863
BMI	-1.0365	<0.0394
Education	3.6970	<0.0793
Fat calories	1.0760	<0.0341
Carbohydrates Calories	0.7265	<0.0018
Saturated fat	-0.3311	<0.7124

Overall P-value 0.0102
Overall R^2 0.8531

Table 3.10 MDKT Score Model for Data Set 2

Variable	Coefficient	*P-value*
Constant	-16.0640	<0.3361
Income	1.6281	<0.0354
Diabetes	14.4343	<0.0021
BMI	0.35468	<0.0819
Education	-2.1924	<0.0250
Carbohydrates Calories	0.05366	<0.0007
Hemoglobin	7.04135	<0.0004
Triglycerides	0.03519	<0.0004
Diabetes 2	-12.40535	<0.0135

Overall P-value 0.001
Overall R^2 0.9492

APPENDICES

Appendix A

Study Website Page

Welcome to the

"Evaluation of Health, Diabetes Knowledge & Behaviors of CU4Health Participants at Clemson University"

You are invited to participate in a research study conducted by Vivian Haley-Zitlin, Ph.D., R.D., L.D., and Peter Mukwevho from the Department of Food Science and Human Nutrition.

The purpose of this research is to assess health and diabetes knowledge and behavior of employees at Clemson University who have shown interest in their health status by their participation in the CU4Health program. The results from this study will be used to design a comprehensive nutrition and health intervention for Clemson University employees participating in CU4Health

In this website you will find the following:

- You will be able to download and print a consent form
- The Michigan Diabetes Knowledge Test
- A Demographic Questionnaire
- The Block Food Frequency Questionnaire

Please note that each link will open in a new window

Please review the IRB approved consent form (pdf format)

Note: consent form must be read before opening the questionnaires

- Click here for the Diabetes Knowledge Test
- Click here for the Demographic Questionnaire
- Click here for the Food Frequency Questionnaire

Upon completion of consent forms participants will receive a packet of educational materials which will include fact sheets and health related websites. Additional items may include measuring cups, etc. Participants' names will be included in random drawings for giveaways.

If you have any questions regarding this research, please contact me at the following location:

Peter Mukwevho
Department of Food Science and Human Nutrition
A203C Poole Agricultural Center
Clemson University
(864) 656-5693

Appendix B

Demographic Questionnaire

Demographic Questionnaire

Created: June 30 2009, 8:11 AM
Last Modified: June 30 2009, 8:11 AM
Design Theme: Basic Blue
Language: English
Button Options: Labels
Disable Browser “Back” Button: False

Page 1 - Question 1 - Open Ended - One Line
Name: please enter your name

Page 1 - Question 2 - Choice - Multiple Answers (Bullets)
What is your age group?

- ❑ 18-19 years old
- ❑ 20-29 years old
- ❑ 30-39 years old
- ❑ 40-49 years old
- ❑ 50-59 years old
- ❑ 60-69 years old
- ❑ 70-79 years old
- ❑ 80 years old and over

Page 1 - Question 3 - Choice - Multiple Answers (Bullets)
I would best describe myself as

- ❑ Female
- ❑ Male

Page 1 - Question 4 - Choice - Multiple Answers (Bullets)
I would best describe myself as

- ❑ Asian
- ❑ Black/African-American
- ❑ Caucasian
- ❑ Hispanic/Latino
- ❑ Native American
- ❑ Other, please specify

Page 1 - Question 5 - Open Ended - One Line
What is your height?

Page 1 - Question 6 - Open Ended - One Line
What is your height

Page 1 - Question 7 - Choice - Multiple Answers (Bullets)

Do you smoke cigarettes?

- ❑ No
- ❑ Yes
- ❑ How many cigarettes do you smoke each day?

Page 1 - Question 8 - Choice - Multiple Answers (Bullets)

What is your marital status? (please check one)

- ❑ Married
- ❑ Never married
- ❑ Separated/Divorced
- ❑ Widowed

Page 1 - Question 9 - Choice - Multiple Answers (Bullets)

What is your highest education level completed? (please check one

- ❑ Completed college (4 year Bachelor degree)
- ❑ Completed Graduate or Professional School
- ❑ Completed High School/GED
- ❑ Currently attending college (4 year Bachelor degree)
- ❑ Currently attending Graduate School (Masters, Ph.D., M.D., etc.)
- ❑ Less than 12th grade
- ❑ Some College or Vocational School Training

Page 1 - Question 10 - Choice - Multiple Answers (Bullets)

Please check the one(s) which apply to you

- ❑ Employed full-time
- ❑ Employed part-time
- ❑ Not employed

Page 1 - Question 11 - Choice - Multiple Answers (Bullets)

What is the approximate level of your household income before taxes? (please check one)

- ❑ $10,000 – 19,000
- ❑ $100,000 and above
- ❑ $20,000 – 29,000
- ❑ $30,000 – 39,000
- ❑ $40,000 – 49,000
- ❑ $50,000 – 59,000
- ❑ $60,000 – 69,000
- ❑ $70,000 – 79,000
- ❑ $80,000 – 89,000
- ❑ $90,000 – 99,000
- ❑ Under $10 000

Page 1 - Question 12 - Open Ended - One Line

Number of people in household

Page 1 - Question 13 - Open Ended - One Line

Number of people in household under 18 years of

Page 1 - Question 14 - Open Ended - One Line

Number of people in household over 65 years of age

Page 1 - Question 15 - Choice - Multiple Answers (Bullets)

Place of residence

- ❑ City of 2000,000 – 400,000 people
- ❑ City over 400,000 (example: Greenville, SC)
- ❑ City with over 100,000 people
- ❑ City with over 150,000 people (example: Anderson, SC)
- ❑ Farm
- ❑ Suburb of city with over 50,000 people
- ❑ Town of less than 10,000 people or rural non-farm (example: Pendleton, SC; Easley, SC)
- ❑ Town or city with 10,000 to 50,000 people or their suburb (example: Clemson, SC; Seneca, SC)

Page 1 - Question 16 - Choice - Multiple Answers (Bullets)

County residence

- ❑ Anderson county
- ❑ Greenville county
- ❑ Oconee county
- ❑ Pickens county
- ❑ Spartanburg county
- ❑ Other, please specify

Page 1 - Question 17 - Choice - Multiple Answers (Bullets)

Have you been diagnosed with any of the following by your health care provider? Please check all that apply

- ❑ cardiovascular disease
- ❑ diabetes
- ❑ high blood glucose levels
- ❑ high blood pressure
- ❑ high cholesterol values
- ❑ overweight or obese

Appendix C

Diabetes Knowledge Test

Michigan Diabetes Knowledge Test

Created: June 30 2009, 1:53 PM
Last Modified: June 30 2009, 1:53 PM
Design Theme: Basic Blue
Language: English
Button Options: Labels
Disable Browser “Back” Button: False

Diabetes Knowledge Test

Page 1 - Question 1 - Open Ended - One Line
What is your name? (Please write your first and last name

Page 1 - Question 2 - Choice - Multiple Answers (Bullets)
The diabetes diet is:

- ❑ a healthy diet for most people
- ❑ the way most American people eat
- ❑ too high in carbohydrate for most people
- ❑ too high in protein for most people

Page 1 - Question 3 - Choice - Multiple Answers (Bullets)
Which of the following is highest in carbohydrate?

- ❑ Baked chicken
- ❑ Baked potato
- ❑ Peanut butter
- ❑ Swiss cheese

Page 1 - Question 4 - Choice - Multiple Answers (Bullets)
Which of the following is highest in fat?

- ❑ Corn
- ❑ Honey
- ❑ Low fat milk
- ❑ Orange juice

Page 1 - Question 5 - Choice - Multiple Answers (Bullets)
Which of the following is a “free food”?

- ❑ Any dietetic food
- ❑ Any food that has less than 20 calories per serving
- ❑ Any food that says “sugar free” on the label
- ❑ Any unsweetened food

Page 1 - Question 6 - Choice - Multiple Answers (Bullets)
Glycosylated hemoglobin (hemoglobin A1) is a test that is a measure of your average blood

glucose level for the past

- ❑ 6 months
- ❑ 6-10 weeks
- ❑ day
- ❑ week

Page 1 - Question 7 - Choice - Multiple Answers (Bullets)
Which is the best method for testing blood glucose?

- ❑ Blood testing
- ❑ Both are equally good
- ❑ Urine testing

Page 1 - Question 8 - Choice - Multiple Answers (Bullets)
What effect does unsweetened fruit juice have on blood glucose

- ❑ Has no effect
- ❑ Lowers it
- ❑ Raises it

Page 1 - Question 9 - Choice - Multiple Answers (Bullets)
Which should not be used to treat low blood glucose?

- ❑ 1 cup diet soft drink
- ❑ 1 cup skim milk
- ❑ 1/2 cup orange juice
- ❑ 3 hard candies

Page 1 - Question 10 - Choice - Multiple Answers (Bullets)
For a person in good control, what effect does exercise have on blood glucose?

- ❑ Has no effect
- ❑ Lowers it
- ❑ Raises it

Page 1 - Question 11 - Choice - Multiple Answers (Bullets)
Infection is likely to cause

- ❑ a decrease in blood glucose
- ❑ an increase in blood glucose
- ❑ no change in blood glucose

Page 1 - Question 12 - Choice - Multiple Answers (Bullets)
The best way to take care of your feet is to

- ❑ buy shoes a size larger than usual
- ❑ look at and wash them each day
- ❑ massage them with alcohol each day
- ❑ soak them for one hour each day

Page 1 - Question 13 - Choice - Multiple Answers (Bullets)
Eating foods lower in fat decreases your risk for

- ❑ eye disease
- ❑ heart disease
- ❑ kidney disease
- ❑ nerve disease

Page 1 - Question 14 - Choice - Multiple Answers (Bullets)

Numbness and tingling may be symptoms of

- ❑ eye disease
- ❑ kidney disease
- ❑ liver disease
- ❑ nerve disease

Page 1 - Question 15 - Choice - Multiple Answers (Bullets)

Which of the following is usually not associated with diabetes

- ❑ kidney problems
- ❑ lung problems
- ❑ nerve problems
- ❑ vision problems

Appendix D

Consent Form for Research Study

Consent Form for Participation in a Research Study
Clemson University

Evaluation of Health, Diabetes Knowledge and Behaviors of CU4Health Participants at Clemson University.

Description of the research and your participation

A. You are invited to participate in a research study conducted by Dr. Vivian Haley-Zitlin and Peter Mukwevho. The purpose of this research is to assess health and diabetes knowledge and behavior of employees at Clemson University, who have shown interest in their health status by their participation in the CU4Health program. The results from this study will be used to design a comprehensive nutrition and health intervention for Clemson University employees participating in CU4Health.

B. There are 2 options for participation:

1. **You may choose to participate by completing the questionnaires and granting us access to your CU4Health data.**

Or

2. **You may choose to participate by completing the questionnaires only.**

Participation details are:

a) Assessment of your health and diabetes knowledge by completing a food intake and diabetes knowledge questionnaire and demographic information.
b) Granting access to your CU4Health program data which will include your health and diet history along with your height, weight, BMI, blood pressure, Blood Lipid Profile (cholesterol values and triglycerides), and Blood Chemistry Profile including blood glucose (blood sugar) and electrolytes as well as your demographic information.

The amount of time required to complete the online questionnaires will be approximately 35-60 minutes. Assessing your CU4Health program data will require no additional time from you.

Risks and discomforts

No identifiable risk is expected to occur to participants from participating in this study; however, there is always a risk of electronically transferred data being illegally intercepted. The benefits to the participants will outweigh the risks, as the information obtained will be used to

help develop a program for CU4Health participants to delay or prevent the development of chronic disease.

Potential benefits

The information obtained from the questionnaires will be used to assess the health habits of Clemson University employees who have participated in the CU4Health Wellness Program. The information acquired may be used to recommend specific changes that will be beneficial to the CU4Health participants. Information gained will used to design a nutrition and health intervention for Clemson University employees. The information that is obtained from this study may be used scientifically and may be helpful to others.

Protection of confidentiality

The records of your participation will be kept confidential. The investigator will maintain your information, from your participation in this study and the information to be obtained from the CU4Health data, in a locked cabinet and on a password-protected computer. Your name will be used to link your questionnaire responses with your CU4Health information. Your name and the data acquired from the questionnaires will be shared with the Sullivan Center. Individuals will not be identified in publications arising from this study.

In rare cases, a research study will be evaluated by an oversight agency, such as the Clemson University Institutional Review Board or the federal Office for Human Research Protections that would require that we share the information we collect from you. If this happens, the information would only be used to determine if we conducted this study properly and adequately protected your rights as a participant.

Voluntary participation

Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. You will not be penalized in any way should you decide not to participate or to withdraw from this study. It is preferable to the research team if you participate fully in the study.

Contact information

If you have any questions or concerns about this study or if any problems arise, please contact Vivian Haley-Zitlin, Ph.D., R.D., L.D. at Clemson University phone number, 864-656-7716. You are encouraged to ask questions you may have during the course of this study. If you have any questions or concerns about your rights as a research participant, please contact the Clemson University Office of Research Compliance at 864.656.6460.

C. Please check the box below to indicate your preferred level of participation.
If you would like to grant us access to your CU4Health data please sign and send in / drop off the signed consent forms back to us.

☐ I wish to participate fully (questionnaires + CU4Health)
☐ I wish to complete the questionnaires only

If you have any questions or concerns please contact Peter or Vivian prior to submitting your consent form or check the boxes below

☐ Please contact me for informed consent questions
☐ Please do not contact me

Consent
I have read this consent form and have been given the opportunity to ask questions. I give my consent to participate in this study.

Name (please print): _____

Participant's signature: _____ Date: _____

Please submit your consent form by interoffice mail by (date) to:

Dr. Vivian Haley-Zitlin
Food Science and Human Nutrition Department
211 Poole Agricultural Center
Clemson University
Clemson, SC 29634-0316

Or

Contact Peter Mukwevho at (864) 656-5693 for a consent form delivery or pick-up.