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The Prevalence and Distribution of Diagnosed and Undiagnosed Type Two Diabetes Mellitus Among Young Adults Aged 20-40 Years, Utilizing NHANES Data from 1999-2010

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Abstract

Background

Within the last century, Type 2 diabetes mellitus has become one of the major health concerns both in the US and globally. Overall prevalence and incidence of the disease within younger populations including adolescents and young adults has sharply increased since 1990 and is estimated to increase further if no actions are taken. It is estimated that 5.7 million people have a form of diabetes. Of the total estimated prevalence of T2DM, 25% of persons with diabetes are unaware they have the disease. This study aims to identify populations most at risk as well as to label important risk factors associated with the rise of T2DM within the young adult population.

Objectives

This study aimed to measure the prevalence of diagnosed and undiagnosed T2DM among different populations based on ethnicity, socioeconomic status, and weight classification among a representative sample of young adults within the United States. This study also aims to identify and quantify associated risk factors of T2DM among young adults, and address current preventative and treatment measures.

Methods

Six two-year samples of the National Health and Nutrition Examination Survey (NHANES) containing a total of 62,160 individuals were compiled into one dataset. Of these, 11,874 young adults aged 20-40 were selected into the study.

Prevalence of diagnosed and undiagnosed T2DM was calculated for specific populations. The study also aimed to identify important risk factors through univariate and multivariate binomial logistic regression analysis.

Results

Among young adults aged 20-40, overall prevalence of T2DM was found to be 1.4% (CI: 1.2-1.6%). Of observed diabetes cases, an alarming 20.1% (N = 68) were categorized as undiagnosed. Significant increases in risk were observed within older age groups, overweight and obese weight categories, individuals living below poverty and within minority racial/ethnic groups.

Weight, measured by both BMI (OR: 10.7; CI:5.88-19.44) and waist circumference (OR: 5.29; CI: 3.18-8.79), was identified as the most influential risk factor, and should be a main area of focus in development of interventions.

Increases in activity levels, both at work and during leisure-time, were found to decrease one's risk of having T2DM.

Discussion

Type 2 diabetes has become a major health concern within the past decades, and will continue to be an area of focus in the future. If current trends of diabetes among the young continue, significant burden will be placed on both health facilities as well as on the economy.

Based on the findings from this study, further research should be place on prevention methods aimed at altering life-style behaviors such as diet and exercise early in one's life. Based on the alarming prevalence of undiagnosed cases, continued research and support should also be place on access to care for minorities, especially persons of Latin American decent.

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List of Acronyms:

ADA: American Diabetes Association

BMI: Body Mass Index

LTSB: Leisure-time sedentary behavior

MVPA: Moderate to Vigorous Physical Activity

NHANES: National Health and Nutritional Examination Survey

OGTT: Oral Glucose Tolerance Test

T1DM: Type one Diabetes Mellitus

T2DM: Type two Diabetes Mellitus

UODA: Usual Occupational/Domestic Activity

WHO: World Health Organization

NDDG: National Diabetes Data Group

1. Introduction

1.1 Type Two Diabetes Mellitus: History, Classification and Definition

Diabetes is quickly becoming one of the most important issues facing public health today, however it is not a new disease. The earliest description of the disease dates back to 1550 BC where it was described as a condition of passing too much urine (Ahmed 2002). Documented within the 5th and 6th centuries, Indian doctors observed a sweet honey-like taste to patient's urine. They also noticed that the disease occurred in two different populations: the older more obese and within the young who did not survive past childhood. (Narayan 2011)

There were early reports within the 17th century, documenting an increasing incidence of diabetes. Thomas Willis (1621 – 1675) noticed, "Although the disease was rare in ancient times its frequency is increasing." With increases in incidence and prevalence, public health and medicine were forced to develop strategies to defend against the increasing burden of disease. Standardizations of classifications of the different forms of hyperglycemia were necessary for epidemiological studies, diagnosis, and other areas of research.

Urine testing was the standard diagnosis tool used for diabetes and other forms of hyperglycemia until the mid 20th century. Oral glucose tolerance tests (OGTTs) later replaced urine tests and became the gold standard. (ADA 1969) These tests were useful in identifying patients with abnormal glucose tolerance. However, healthy post-load categorical values changed with age, which made uniform standardizations difficult (Andres 1967). In 1965, the World Health Organization (WHO) made the first attempt to provide recommendations for international standardization. (WHO Expert Committee

1965) Unfortunately, these recommendations were not widely accepted. During this time, there were three classifications for diabetes based on the distinguishing pattern of age: adult-onset, juvenile-onset and secondary diabetes, which was a broad category which included: chronic pancreatitis, hemochromatosis and endocrinopathies.

In 1979 and 1980 the National Diabetes Data Group (NDDG) and WHO both release updated recommendations that emphasized a need for uniform standardization. Additional research had become available that helped differentiate between the two main types of diabetes: those who presented associations with specific HLA types and who had islet cell antibodies, and another group who showed no associations with HLA types or had islet cell antibodies present. Researchers also noticed that the first group was at high risk of ketoacidosis if not treated with insulin (Rushford et al. 1979). Because of these new findings, new names were given: Insulin-dependent and non-insulin dependent diabetes. Focus switched from age of an individual at disease onset to whether insulin was needed to maintain homeostasis.

The 1979 and 1980 recommendations also included new measurement assessments of glucose concentrations. Both reports recommended using venous plasma rather than whole blood tests. Both studies claimed that variation in red-cell volume led to different glucose levels. The NDDG recommendations included diagnostic criteria based on the plasma glucose exam. Those satisfying one or both of the following tests were labeled as diabetic.

- ≥140mg/dL fasting glucose level
- ≥200mg/dL 2hr post 75g oral glucose load

These recommendations were generally accepted internationally for around twenty years until 1997, when the American Diabetes Association (ADA) (Gavin et al. 1997) and the WHO (1998-1999) (WHO Consultation Group 1999) published new reports, which amended the labels of the two main types of diabetes, as well as updated new diagnostic criteria. The old names were relabeled to type 1 and type 2 based on new findings of the pathophysiologic process of type 1 diabetes. The pathophysiologic process of type 2 diabetes, however, remained unclear. These reports lowered the threshold for diagnosis from a fasting glucose level of 140mg/dL to 126mg/dL, and included a new category labeled "impaired fasting glycemia", who's fasting glucose threshold ranged from 110mg/dL to 125mg/dL. This group was later labeled as "pre-diabetes" in 2003, and the threshold was lowered to 100mg/dL so that more preventative measures could be taken to help slow the progression of diabetes (Genuth et al. 2003).

Our current standards come from the most recent WHO report published in 2006 (WHO/IDF Consultation Group 2006). Very little was amended from the 1997-1999 recommendations except the changing of the "pre-diabetic" group's label to "intermediate hyperglycemia" based on negative social stigmas. The 75g OGTT is still the current gold standard for diagnostic testing. However, there is increasing controversy regarding its use.

- Diabetic: ≥126mg/dL fasting glucose level
- Intermediate Hyperglycemia: 110-125mg/dL fasting glucose levels

Arguments for diagnosis based on A1C use led to its consideration within the 2006 report, however lack of availability of HbA1C tests in developing regions led to its omission (Narayan 2011). Current research in improving diagnostic tools such as HbA1C tests may lead to future recommendations.

1.2 Complications associated with T2DM

Diabetes increases one's risk of many serious and debilitating life-long complications including: acute metabolic complications, vision loss, chronic kidney disease, lower-extremity diseases and cardiovascular disease (CVD). Risk of severe complications increases with time spent with the diseases as well as if diabetes is left untreated, or if compliance of corrective behavior is low. Likewise, if T2DM is detected early and if proper lifestyle behavioral changes are made, adverse complications can be delayed or even prevented. (ADA 2014)

For the purpose of this thesis, I will not review these associated complications in detail. However, they are included to underscore the potential value of early recognition and early treatment.

1.3 Purpose of Study

1.3a General Objective

The purpose of this study is to identify recent trends in prevalence and distribution of diagnosed and undiagnosed type 2 diabetes mellitus (T2DM) cases among American young adults. The study aims to identify populations most at risk and to identify populations who would benefit most from strategic intervention strategies. Additionally, this study seeks to identify major risk factors associated with T2DM, and to identify significant trends that may correspond with the increasing prevalence of T2DM.

1.3b Specific Objectives

1. Calculate the prevalence of diagnosed and undiagnosed T2DM in young adults ageing 20-40 using continuous NHANES data compiled from six datasets (1999-2010).
2. Analyze the distribution of T2DM among age groups, weight categories, different racial/ethnic groups and among individuals living above or below poverty.
3. Calculate odds ratios of risk factors associated with T2DM using univariate and multivariate binary logistic models to assess the importance of each factor.
4. Analyze trends of associated risk factors to attempt to illustrate correlations that may be present.

2. Review of Literature:

2.1 Burden of disease

Type 2 diabetes mellitus (T2DM) has quickly become one of the most common non-communicable diseases in both developed and developing countries. (Chen et al 2011) Since 1990, there has been a sharp increase in both prevalence and incidence among all age groups. T2DM is one of the leading causes of death in developed countries, and is considered an epidemic in most developing countries. Until recently, T2DM had only been diagnosed in adults. This has changed completely and is now also a major health concern for adolescences and young adults. This increase in prevalence and incidence among the young is especially important to monitor since it greatly affects the most productive years of one's life and also places a more substantial long-term strain on the health care system. Complications from T2DM including: coronary artery and peripheral vascular disease, stroke, diabetic neuropathy, and amputations. Renal failure and blindness contribute to a substantial physical and economic burden, especially when symptoms appear in the younger populations or are left untreated. (D'Adamo, Caprio 2011;Pinhas-Hamiel 2007) The CDC estimates that 25% of people with diabetes are unaware that they have the disease. (CDC 2008) Factors suspected for surplus amount of undiagnosed cases include: lack of access to care, lack of awareness, inaction of the provider in addition to T2DM being asymptomatic in its early stages. In developing countries the estimated prevalence of undiagnosed diabetes reaches 70% within rural regions. (Mohan et al. 2005)

Worldwide prevalence of T2DM has increased due to several factors including: population growth, urbanization, aging and an increasing prevalence of overweight and obesity. According to one study, the number of people living with diabetes globally is expected to double from 2000 to 2030, from 171 million cases to over 300 million in 2030 based solely on demographic changes. (Wild et al. 2004) In the development of their predictions Wild and her colleagues assumed that obesity rates and age-specific prevalence of T2DM would remain constant. Because of this, their estimates are expected to be conservative and likely an underestimate of the true projected figure. (Wild et al. 2004) Similar results were found in a Canadian study. (Ohinmaa et al. 2000) In the United States, similar increasing trends in prevalence and incidence can be observed. Since the mid 1950's, the number of individuals diagnosed with T2DM has increased from 1.6 million Americans in 1958 to 23.6 million in 2007. The number of diagnoses is predicted to increase to 48.3 million Americans by 2050. The total prevalence of T2DM of all ages has increased from 0.9% in 1958 to 5.9% in 2005, and is expected to continue to increase to 12.0% in 2050. (Narayan 2011)

The physical and economic burden of T2DM and associated complications are not evenly distributed among populations. All individuals do not share an equal risk of acquiring the disease. It has been established that different ethnicities, age groups, gender, weight class and socioeconomic strata are all factors that contribute to one's risk. (DPH)

2.2 Burden among adolescents and young adults:

Diabetes Mellitus is one of the most common chronic diseases in children and adolescents. (National Diabetes Data Group 1995) Most of these cases are type 1 diabetes mellitus (T1DM), however incidence and prevalence of type 2 diabetes mellitus

(T2DM) within the adolescent population is on the rise. (SEARCH for Diabetes in the Youth Study Group 2006) There is substantial evidence that correlates the rise in T2DM incidence among adolescents with the recent epidemic of increased childhood overweight and obesity. Similar trends as seen in adult population affected by T2DM, there have been a disproportionate increase among minority populations including: African American, Hispanic, Asian and Native American youths. (SEARCH for Diabetes in Youth Study Group 2006) (Alberti et al. 2004; Fagot-Campagna et al. 2000)

2.3 Risk factors

The causes of Type 2 diabetes mellitus are complex and interwoven. It is important to approach identifying risk factors at an ecological level; identifying risk factors within social policies, communities, personal behaviors, pathophysiological pathways and most specifically one's genetic construct.

Because diabetes is greatly influenced by behavioral factors that if changed could prevent or lessen the severity of the disease, focus has been placed on modifiable "life-style" factors as well as certain non-modifiable risk factors such as SES, race/ethnicity and gender. Further research of these risk factors is important because modification one's behaviors and/or environment within early years may have a significant impact on one's risk of developing the disease.

2.3a Modifiable risk factors

The major factors influencing the increase in incidence of T2DM have been strongly associated with several significant modifiable "life style" risk factors such as weight management, dietary intake, physical inactivity and smoking. Weight gain and obesity drastically increase the risk, and physical inactivity further compounds the risk., while smoking has been associated with a lesser increase in risk. (Hu et al 2007) T2DM and associated complications can be prevented, slowed or even reversed if caught early enough by altering these modifiable "life-style" factors.

2.3b Overweight/Obesity

Over the past 50 years, incidence of overweight and obesity has increased. (Parikh et al. 2007) For the period 2003-2004 the overall prevalence of overweight or obesity among men was 70.8% and in women 61.8%. (Ogden et al. 2006) These staggering figures suggest that the majority of people are at an increased risk of developing T2DM. Overweight can be defined as having a body mass index (BMI) (calculated by kg/m^2) of 25-29. Similarly, obesity is categorized as a BMI of 30 or higher. Current research suggests that excess body fat is the single most important determinant of type 2 diabetes. (Hu et al. 2007)

However, based on a study that used national survey data, the age and race adjusted prevalence of obesity over a 12-year period between 1999-2010, showed no significant increase among women overall (OR: 1.01; 95%CI: 1.00-1.03). This indicates that the obesity epidemic may be slowing down. However, within the same study, increases in prevalence of obesity were statistically significant for non-Hispanic black women and Mexican American women. For men, there was a significant linear trend (OR: 1.04; 95% CI: 1.02-1.06) over the 12-year period. (Flegal et al. 2012).

Recently, there has been a copious amount of research demonstrating the link between overweight and obesity with an increased risk T2DM. In one prospective cohort study, researchers found that when compared with the normal weight group (BMI: 18.5-24.9), age-adjusted odds ratios for overweight and obese men developing T2DM were 2.73 (95%CI: 2.05-3.64) and 7.26 (95%CI: 5.26-10.04), respectively. (Hart et al. 2007)

In a study of women, the relative risk of T2DM was found to be 38.8 for severely obese women (BMI: ≥35) and 20.1 for obese women (BMI: 30-34.9), when compared with women who had a normal body-mass index of less than 23.0. (Hu et al. 2001) Abdominal obesity has also been identified as a significant risk factor. Freemantle and his team found a strong association between waist circumference and incidence of T2DM (OR: 2.14 95% CI: 1.70–2.71; $p < 0.001$). (Freemantel et al. 2008) Other studies suggest using waist circumference as a good indicator of future risk for T2DM in daily primary care. (Siren et al. 2012; Okosun et al. 1998)

Similarly to increasing trends in BMI, waist circumference and abdominal obesity among both American men and women have also been on the rise. (li et al. 2007) With over half of the American population above the normal threshold for BMI, weight will remain to be a pivotal factor in the fight against T2DM and an area of future research.

2.3c Dietary Intake

Consumption of "healthy" foods such as whole grains, fiber and unsaturated fats is important in the prevention and reversal of T2DM. Consumptions of "unhealthy" foods such as foods high in sugar and saturated fats may increase one's risk of acquiring the disease. (Franz et. al 2002)

Reducing intake of fats, particularly saturated fats, may decrease one's risk for diabetes independent of weight status. (Franz et. al 2002) Excess dietary fat consumption may also have secondary health effects that are important in the development of T2DM. In obese individuals, consumption of dietary fats may have a negative effect on insulin sensitivity. (Mayer-Davis et al. 1997). Saturated fats such as butter and lard may have the largest impact on insulin activity. Alternatively, both monounsaturated and polyunsaturated fat intake, in appropriate doses, may reduce the risk of t2dm. (Meyer et al. 2001)

Consumption of whole grains and fiber have been associated with a reduction in risk for t2dm. (Franz et al. 2002; Meyer et al. 2000; Schulze et al. 2004a) Consumption of foods containing whole grains and fiber have also been associated with higher insulin sensitivity. (Liese et al. 2003)

2.3d Physical Activity

Physical activity is an important protective factor associated with prevention or delay of T2DM and associated complications. (Jeon et al. 2007) In a systematic review of more than 300,000 participants, there was a protective effect (RR:0.69; 95%CI:0.58-0.83) for participants who regularly participated in moderate physical activity when compared with no regular activity. The study also found a protective effect (RR: 0.7; 95%CI:0.58-0.84) of regular walking (>2.5hrs per week) on T2DM incidence when compared to no physical activity. (Jeon et al. 2007)

In addition, increased moderate to vigorous activities have also been associated with higher insulin sensitivity. (Mayer-Davis et al. 1998) In a meta-analysis conducted in 2006, researchers found a significant protective effect (RR 0.83) of moderate-intensity activities with development of T2DM.

Other studies suggest that physical activity is a proxy for weight loss. (Hamman et al. 2006). However, with substantial strong evidence demonstrating moderate activity reducing one's risk by ~30%, it is hard to contribute to weight loss alone. Physical activity is a key modifiable behavioral factor and should remain a major area of focus in consideration of future prevention programs.

2.3e Smoking

Smoking has been well studied and is associated with an increased risk for many chronic diseases including T2DM (Narayan 2011) As part of the IRAS prospective study, associated increased risk was observed between current smokers and development of T2DM (OR: 2.66) when compared to non-smokers. The risk more than doubled if one had more than a 20 pack-year history prior to the study (OR: 5.66). (Foy et al. 2005; Hu et al. 2001)

2.4 Non-Modifiable Risk Factors

2.4a Socioeconomic Status

The mechanism by which socioeconomic status (SES) affects the development of T2DM is relatively unclear. Individuals of low SES, whether measured by education or income, have an increased risk of diabetes. (Geiss et al. 2006; Robbins et al. 2005) Possible explanations of how SES affects one's risk include less access to care, higher stress levels, negative environmental exposures and low levels of health literacy. (Berkman et al. 2004)

2.4b Race/Ethnicity

There is ample research that describes the unequal distribution of risk among different racial/ethnic groups. (Geiss et al. 2006; McBean et al. 2004; CDC 2008) Generally, racial minorities have the highest risk of T2DM, and also have higher prevalence rates. (Burrows et al. 2000; CDC 2008; Kenny et al. 1995) Not only do minority groups have a higher prevalence, but they also tend to develop the disease at an earlier age. This exacerbates the amount of burden placed on these populations. American Indian populations tend to have the highest prevalence, however there is much variability among tribes. (Burrows et al. 2000) Non-Hispanic blacks and Hispanics also have increased prevalence in the United States when compared with non-Hispanic whites. (CDC 2007)

2.5 Preventative and Treatment Measures:

Type 2 diabetes mellitus is a complex condition that results from an unknown combination of genetic and environmental factors. In spite of the fact that there is limited knowledge regarding susceptibility mechanisms for prevention, T2DM has been proposed as a preventable disease. The main reasons for such a proposal are because major risk factors, such as obesity and inactivity are potentially modifiable, people at high risk are easily identifiable and there is usually a long period of abnormal glucose regulation that can be seen prior to disease onset that may be controllable with drugs or behavioral changes. (Knowler et al. 1995)

Within the last twenty years there has been progress in the form of treatment research. New evidence from recent randomized control trials (RCT), suggest that T2DM could be delayed or even prevented in high-risk persons by several different routes including: drug treatment focused on diet, exercise, and weight loss. (Inzucchi et al. 2012) The Finish Diabetes Prevention Study tested lifestyle change interventions that included: weight reduction, dietary fat intake regulation, saturated fat intake regulation, fiber intake regulation and moderate exercise of more than 30 minutes per day. This experimental group was then compared to a control group who received little to no health advice. Results from this study demonstrated a 58% reduction in incidence over a three-year period. (Tuomilehto et al. 2001)

Treatment of T2DM with medications that impose strict glycemic control have recently become a controversial issue. The point of contention is that long-term strict glycemic control could have an adverse effect on cardiovascular disease outcomes among diabetic patients. (Nathan et al. 2005; Holman 2008)

Recent studies such as the PROactive randomized control trial, present encouraging results that find no association between long term glycemic control and CVD events, however the controversy is far from over. (Dormandy et al. 2005)

Further research is still required especially in the field of pharmacologic approaches versus behavioral interventions as well as in comparing different pharmacologic agents with each other.

3. Materials & Methods

All analysis was preformed using SPSS version 21. Data used for this study were obtained through the National Health and Nutrition Examination Survey (NHANES) conducted by the National Center for Health Statistics (NCHS), part of the Centers for Disease Control and Prevention (CDC). The NHANES is a multi-staged probability sample that selects participants who are representative of the civilian, non-institutionalized United States. This study used twelve years of data from 1999-2010. The data consists of six data sets of two-year cycles (eg. 1999-2000, 2001-2002, 2003-2004, 2005-2006, 2007-2008, 2009-2010). (NHANES 2014) Each two-year dataset consisted of ~10,000 individuals and collected data via questionnaire, physical examination and laboratory analysis. Participation rates ranged from 78% to 84% for the six datasets.

The original population of individuals included in the six data sets (N=62,160) was reduced to include only participants who answered the NHANES diabetes questionnaire (N= 19, 269). Of this sub-sample, further restrictions where enforced to include only young adults whose reported age at the time of the interview was 20 – 40 years old (N=11,874).

The NHANES protocol was approved by the National Center for Health Statistics institutional review board, and written consent was obtained from all participants. The Georgia State University institutional review board has also accepted the NHANES data, and no IRB application was required prior to use of this secondary data.

3.1 Diabetes Classification

Diagnosis of diabetes was defined on the self-report of a previous diagnosis of diabetes by a physician or other health professional, as done in previous studies of this kind (Fagot-Campagna et al. 2001; Duncan 2006; Demmer 2013) Participants who self-reported use of no medication or use of any blood glucose-lowering medications (with or without the use of insulin) were categorized as having T2DM. Participants who reported previous diabetes diagnosis and receiving insulin therapy were categorized as having T1DM. This method isn't perfect, however it is less likely to underestimate the prevalence of T2DM and has little impact on the underestimation of T1DM. Individuals included into the fasting sub-sample (N=5,126) were used to categorize undiagnosed diabetes cases. Undiagnosed cases were defined as having a fasting blood glucose concentration of 126mg/dL or higher, and who answered "No" to the questionnaire question regarding having a previous diagnosis by a physician or other health professional. All undiagnosed diabetes cases found were categorized as undiagnosed T2DM.

Prevalence estimates of diabetes were obtained from using only the interview sample, due to the small sample size of those who participated in having their fasting plasma glucose measured.

3.2 Fasting Glucose Assessments (sub-sample)

Of those who participated in the fasting blood glucose measurement, fasting status was verified via interview prior to blood collection. During the first three datasets, (1999-2004), glucose measurements were performed by the Diabetes Diagnostic Laboratory at the University of Missouri-Columbia using the Cobas Mira Chemistry System (Roche Diagnostic Systems Inc., Montclair, New Jersey). For the 05-06 dataset, measurements were completed by the Fairview Medical Center Laboratory at the University of Minnesota using a Roche/Hitachi 911 Analyzer (Roche Diagnostics, Indianapolis, Indiana). For the remaining two datasets (07-10), glucose measurements were performed at the University of Minnesota, using the Roche Modular P Chemistry Analyzer (Roche Diagnostics). In all of the datasets, fasting plasma glucose was measured using the hexokinase enzymatic method. (NANES 2014)

3.3 Physical Activity:

Three variables were created to measure the effect of both physical activity and duration of inactivity: Leisure-time sedentary behavior (LTSB), Moderate to Vigorous Physical activity (MVPA) and usual occupational/ domestic activity (UODA). Self-reported data from the physical activity questionnaire were used to create each variable. Unfortunately, the survey questions were not the same throughout the twelve year study period. Because of this, LTSB and MVPA are measured using only available data from specific years.

Similarly to previous studies, LTSB was created using two questions: 1) “Over the past 30 days, on average how many hours per day did you sit and watch TV or videos outside of work?” and, 2) “Over the past 30 days, on average about how many hours per day did you use a computer or play computer games outside of work?” Response options for both questions included: 1) “none,” 2) “less than 1 hour,” 3) “1 hour,” 4) “2 hours,” 5) “3 hours,” 6) “4 hours,” and 7) “5 hours or more.”

Self-reported responses were compiled into two categories (≥3 or <3 hrs/day). (Sisson et al. 2009) These questions were only available within the 2003-2004 and 2005-2006 datasets.

The MVPA variable was created from self-reported data only available within the 2007-2008 and 2009-2010 datasets, that aimed to categorize an individual’s amount of physical activity throughout a normal day and includes measurement of duration of active transportation (walking or biking), household/domestic tasks and leisure-time physical activity. Four questions were taken from the physical activity questionnaire: 1) “Over the past 30 days, have you walked or bicycled as part of getting to and from work, or school, or to do errands?” and, 2) “Over the past 30 days, did you do any tasks in or around your home or yard for at least 10 minutes that required moderate or greater physical effort?” Participants who answered “Yes” to either question were asked to report the frequency and duration of these activities. Moderate and vigorous leisure-time physical activity were evaluated with two additional questions: 1) “Over the past 30 days, did you do moderate activities for at least 10 minutes that cause only light sweating or a slight to moderate increase in breathing or heart rate?" and 2) "Over the past 30 days, did you do any vigorous activities for at least 10 minutes that caused heavy sweating, or large increases in breathing or heart rate?" Participants who answered "Yes" to either question were asked to specify the activities they engaged in and the usual duration and frequency of these activities." Times reported for each variable were complied and translated into min/week. Based on previous studies as well as from recommendations from the U.S. Department of Health and Human Services 2008 physical activity guidelines, two categories were created (≥150 or <150 min/week). (Schuna et al. 2013; U.S. Department of Health and Human Services: 2008)

Lastly, the UODA variable was created to measure one's daily work/domestic activity. To create this variable a single question from the physical activity questionnaire was used: "Please tell me which of these four sentences best describes your usual daily activities?". Two categories were then created which separated those who responded to this question as mostly sitting to compare with those who mostly stand or walk, climb stairs or hills often or heavy work as previously done in another study. (Sisson et al. 2009)

3.4 Socioeconomic Status:

Socioeconomic status was measured using poverty to income ratio (PIR) as has been done in previous studies. (Sabanayagam & Shankar 2012) To compare between groups PIR was categorized into quartiles. PIR quartiles were calculated individually for each two-year interval and categorized into: the lowest 25%, 25-50%, 50-75% and the top 25% before being compiled with other two-year intervals. Comparisons were also made between people in poverty (PIR ≤1) and young adults above the poverty threshold (>1).

3.5 Obesity and Waist Circumference:

Both BMI (calculated kg/m^2) and waist circumference were used to measure overweight and obesity. According to the World Health Organization, BMI should be categorized as:

BMI	**Weight Status**
Below 18.5	Underweight
18.5 – 24.9	Normal
25.0 – 29.9	Overweight
30.0 and Above	Obese

The WHO's guidelines for waist circumference are sex specific. Men who have a waist circumference of 40 inches or more and women who have a waist circumference of 35 inches or more are at and increased risk for many chronic diseases including T2DM. (WHO 2003)

3.6 Smoking

Smoking was assessed solely on the respondents answer to the question within the smoking questionnaire, which asks if the respondent is currently smoking. Other studies discriminated between current smokers and former smokers and found no significant associations however, this same study did find associations relating to histories of 20 or more pack-years, however since we are examining a young population it is unbeneficial to examine this at this time. (Foy et al. 2005)

3.7 Diet

Diet was only assessed for the last three intervals (2005-2006, 2007-2008 & 2009-2010). Prior to 2005, NHANES did not have a question regarding one's daily dietary habits. In 2005, NHANES introduced the question: "In general, how healthy is your overall diet?" With five possible answers: excellent, very good, good, fair or poor, as well as two for don't know or refuse.

3.8 Statistical Analysis

All analysis was preformed using SPSS version 21. Descriptive analysis was preformed to assess the make up of the study sample.

Prevalence of T2DM was calculated by taking cases of T2DM found and dividing them by the total study population. 95% confidence intervals were also calculated to assure statistical significance. Stratifications were preformed by gender, race, SES and BMI to analyze the distribution of T2DM among these groups.

To calculate odds ratios of associated risk factors, univariate and multivariate binomial multivariate logistic models were constructed for the compiled dataset. Variables were tested against the outcome of having T2DM or not. Categorical variables were examined and defined using one of the categories as a reference group. Within the multivariate analysis BMI was the selected variable used to adjust for weight for all variables except for waist circumference. Adjusted OR for waist circumference was adjusted for age, gender, race, SES, smoking and UODA. Adjustment for LTSB, MVPA and diet were only conducted and adjusted for from only the years that data was available.

4. Results

4.1 Study Sample:

Of the 11,874 individuals included in this study 54.4% were female. The study population had an average age of 29.84 (SE: 0.056) years. The ethnic/racial composition of the study sample included 43.1% non-Hispanic white, 31.4% Latin American, 20.3% non-Hispanic black and 5.2% other/multi-racial. The study sample had a mean body mass index (BMI) of 28.2, and a mean waist circumference of 94.4. The sample's mean plasma glucose was 95.6 mg/dL.

There were significant differences in mean age between the combined subsets. The 2005-2006 cohort had an average age of 29.46 which was significantly younger than both the 2007-2008 and 2009-2010 cohorts (30.05, 30.42; p=<.001). There were also a significant difference between gender, PIR, BMI and Waist Circumference distributions among the six subgroups (p=<.001), which made have made it difficult to measure trends within the datasets.

4.2 Prevalence and Distribution

There were a total of 339 cases of diabetes mellitus found within the study population. The total prevalence of Diabetes within the study sample of young adults aged from 20-40 years was 2.9% (CI: 2.6-3.2%) Of the total cases, 48% (N=163; PR: 1.4%; CI: 1.2-1.6%) were found to be T2DM, 31.9% (N=108; PR: 0.93%; CI: 0.75-1.1%) T1DM, and an alarming 20.1% (N=68; PR: 0.57%; CI: 0.45-0.72%) had a fasting plasma glucose >126mg/dL, but had not received a diagnosis of diabetes from a health professional and labeled as undiagnosed cases.

The distribution of T2DM among individuals of differing ages, racial/ethnic groups, and socioeconomic groups (Table1) was found to be unequal.

Among the four age categories, prevalence increased significantly with increasing age. The 20-24 age group had a prevalence of 0.2% (CI: 0.1-0.4%), the 25-29 age group had a prevalence of 0.8% (CI: 0.6-1.2%), 30-34 age group had a prevalence of 1.4% (CI: 1.1-2.0%) and the 35-40 aged group had the highest prevalence of 2.8% (CI: 2.0-3.0%). Between the oldest two quartiles, prevalence of undiagnosed diabetes was found to be significantly higher than the lower two quartiles. The oldest age quartile including individuals aged 35-40 contained 64.7% of all undiagnosed cases.

Among racial/ethnic groups, minorities had a significantly higher prevalence of T2DM when compared to non-Hispanic whites (0.9% CI: 0.6-1.2%). There was no significant difference among the prevalence rates between minority groups; Latin Americans (1.5% CI: 1.2-1.9%), non-Hispanic blacks (2.0% CI: 1.5%-2.7%) and Other/multi-racial (2.3% CI: 1.4%-3.8%). Latin Americans had a significantly higher prevalence of undiagnosed T2DM (Prevalence:0.88%; CI: 0.62-1.2%) than non-Hispanic whites (Prevalence: 0.41%; CI: 0.27-0.63).

Individuals within the top 25% of economic status as measured by income to poverty ratios (PIR) had a significantly lower prevalence (0.8% CI: 0.5-1.2%) of T2DM than the lower three quartiles; 50-75% (1.4% CI: 1-1.8%), 25-50% (1.5% CI: 1.1-2.1) and the lowest 25% (1.8% CI: 1.3-2.4%). Prevalence of undiagnosed diabetes was approximately equal for each group, even when the group was made dichotomous and categorized as being above or below poverty.

Overweight and obese populations had significantly higher prevalence of T2DM and undiagnosed diabetes than normal and underweight people. Obese individuals had a prevalence of 3.1% (CI: 2.6-3.7%) T2DM and 1.5% (CI: 1.1-1.9%) of undiagnosed diabetes. Overweight individuals had a prevalence of 0.86 (CI: 0.6-1.2) of T2DM and 0.71% (CI: 0.48-1.0%) of undiagnosed T2DM.

4.3 Trends

There were no significant trends of T2DM prevalence found over the time period from 1999-2010. T2DM prevalence ranged from its lowest in 1999-2000 1.3% (CI: 0.8%-2.0%) to the highest in 2007-2008 1.7% (CI: 1.3-2.4%). Trends in overweight/obesity measures were also found to be insignificant, except for a significant difference in waist circumference between 1999-2000 (44% CI: 42-47%) and 2005-2006 38% (CI: 36-40%).

To assess trends among different racial and ethnic groups, proportional changes were observed throughout the six two-year time increments. No clear increasing or decreasing changes occurred. There were differences among proportion of T2Dm among racial groups, however because of the small number of cases within each group, no significant differences were found. Non-Hispanic whites consistently had a lower proportion compared to the other racial groups with exception of within the 2007-2008 period when the proportion of NHW (1.63%) with T2DM was higher than both Latin Americans (LA) (1.16%) and multi-racial (1.03%).

Table 1: Prevalence of Self-Reported Type 2 and Undiagnosed Diabetes Mellitus[a] Among 11,874 US Young Adults Aged 20-40 Years, NHANES, 1999-2010

	Total number of people[b]	All Diabetes			Undiagnosed Diabetes		
		N	%	95%CI	N	%	95%CI
Total	11874	163	1.4	1.2-1.6	68	0.57	0.45-0.72
Age							
20-24	2988	6	0.2	0.09-0.44	6	0.2	0.09-0.44
25-29	2813	23	0.82	0.55-1.2	12	0.43	0.25-0.75
30-34	2769	40	1.44	1.06-1.96	6	0.22	0.1-0.48
35-40	3304	94	2.85	2.3-3.47	44	1.33	0.99-1.78
Gender							
Male	5419	68	1.3	0.9-1.6	43	0.79	0.59-1.1
Female	6455	95	1.5	1.2-1.8	25	0.39	0.26-0.57
Race/Ethnicity							
Non-Hispanic White	5118	44	0.9	0.6-1.2	21	0.41	0.27-0.63
Latin American[c]	3734	56	1.5	1.2-1.9	33	0.88	0.62-1.2
Non-Hispanic Black	2409	49	2	1.5-2.7	11	0.46	0.26-0.82
Other/Multiracial[d]	613	14	2.3	1.4-3.8	3	0.49	0.17-1.4
Socioeconomic Status[e]							
Above Poverty	8320	100	1.2	0.9-1.4	44	0.53	0.4-0.71
Below Poverty	2640	47	1.78	1.3-2.4	14	0.53	0.32-0.89
Missing Income data	*914*	*16*	*1.75*	*1.1-2.8*	*10*	*1.1*	*0.59-2.0*
Body Mass Index[f]							
Underweight/Normal[g]	4015	12	0.3	0.17-0.52	10	0.25	0.14-0.46
Overweight	3497	30	0.86	0.6-1.2	25	0.71	0.48-1.0
Obese	3541	110	3.1	2.6-3.7	52	1.5	1.1-1.9
Missing BMI data	*821*	*11*	*1.3*	*0.75-2.38*	*4*	*0.49*	*0.19-1.3*

Abbreviations: CI, confidence interval. NHANES, National Health and Nutrition Examination Survey.
[a] Included study participants were asked "Have you been told by a doctor or health professional that you have diabetes or sugar diabetes?" Young adults who responded, "Yes" and reported use of oral diabetic pills to lower blood sugar or no use of any medication were categorized as having T2DM. Individuals reporting never been told of diabetes and had a plasma glucose of >126mg/dL were categorized as Undiagnosed cases.
[b] Number of non-institutionalized US young adults aged 20-40 years.
[c] Including Mexican Americans and Other Hispanic.
[d] Including Asian/Pacific Islander, American Indian and multiracial.
[e] Measured using income to poverty ratio. Individuals who have calculated ratios equal to one or more were placed within the above poverty group. Young adults below the threshold were classified as below poverty.
[f] Body mass index is calculated: kg/m^2.
[g] Underweight is combined with normal group, so that any protective effect from being unhealthy is not mistaken to be a safe preventative measure.

4.4 Risk factors:

Using both Univariate and multivariate binomial logistic regression models, odds ratios were calculated to attribute a quantifiable increase or decrease of one's risk to risk factors found to be associated with T2DM, as well as to assess which risk-factors should receive the most attention.

Age, BMI, waist circumference, race/ethnicity, socioeconomic status (SES), leisure time sedentary behavior (LTSB) and moderate to vigorous physical activity (MVPA) were all found to be significantly associated with T2DM. Gender, smoking, usual occupational daily activity (UODA), and Diet were all found to be not significant. Table 2 shows the outcomes of both the univariate and multivariate models as well as there associated odds ratios.

Table 2: Univariate and Multivariate Binomial Logistic Regression Models of Associated Risk Factors With T2DM Among Eligible Subjects[a], NHANES 1999-2010.

	1999-2010[1]			1999-2010[2,h]		
Variable	**OR**	**95%CI**	**p**	**OR**	**95%CI**	**p**
Age						
20-24	Ref	-	-	Ref	-	-
25-29	4.097	1.66-10.08	0.002*	2.84	1.11-7.23	.029*
30-34	7.285	3.08-17.21	<.001*	4.89	2.02-11.82	<.001*
35-40	14.55	6.37-33.27	<.001*	10.32	4.42-23.65	<.001*
Gender						
Males	Ref	-	-	Ref	-	-
Females	1.18	.859-1.61	0.312	1.06	0.74-1.53	0.74
Body Mass Index						
Normal/Underweight	Ref			Ref	-	-
Overweight	2.89	1.48-5.65	.002*	2.18**	1.07-4.44	.032*
Obese	10.7	5.88-19.44	<.001*	8.14**	4.33-15.29	<.001*

Race/Ethnicity						
Non-Hispanic White	Ref			Ref		
Latin American[b]	1.76	1.18-2.61	.005*	1.5	0.96-2.34	0.073
Non-Hispanic Black	2.39	1.59-3.61	<.001*	1.7	1.07-2.70	.026*
Other/Multiracial[c]	2.7	1.47-4.95	.001*	2.48	1.18-5.22	.017*
Waist Circumference						
Normal	Ref	-	-	Ref	-	-
At Risk	5.29	3.187-8.792	<.001*	4.38	2.54-7.55	<.001*
Socioeconomic Status[d]						
Below Poverty	Ref	-	-	Ref	-	-
Above Poverty	0.67	0.47-0.95	.025*	0.66	0.45-0.98	.037*
Smoking						
Active	Ref	-	-	Ref	-	-
Abstain	0.87	0.52-1.46	0.876	0.82	0.47-1.43	0.491
UODA						
Mostly Sitting	Ref	-	-	Ref	-	-
Stand/Walk/Lift	0.763	0.56-1.05	0.763	0.84	0.536-1.32	0.841
Diet[e]						
Excellent	Ref	-	-	Ref	-	-
Very Good	0.97	0.31-3.06	0.957	0.76	0.23-2.53	0.659
Good	1.44	0.51-4.06	0.492	1.23	0.43-3.54	0.697
Fair	1.46	0.51-4.2	0.485	0.95	0.323-2.82	0.932
Poor	1.1	0.29-4.11	0.893	0.69	0.18-2.65	0.59
LTSB[f]						
>3hrs	Ref	-	-	Ref	-	-
<3hrs	1.86	1.09-3.19	.024*	2.17	1.19-3.96	.011*
MVPA[g]						
<150 min/week	Ref	-	-	Ref	-	-
>150 min/week	0.47	0.27-0.82	.008*	0.52	0.29-0.93	.028*

Abbreviations: UODA, usual occupational/domestic activity. LTSB, Leisure-time sedentary behavior. MVPA Moderate to Vigorous physical activity.

[1] Univariate binomial logistic regression model.

[2] Multivariable binomial logistic regression model.

[a] Number of non-institutionalized US young adults aged 20-40 years.

[b] Including Mexican Americans and Other Hispanic.

[c] Including Asian/Pacific Islander, American Indian and multiracial.

[d] Measured using income to poverty ratio. Individuals who have calculated ratios equal to one or more were placed within the above poverty group. Young adults below the threshold were classified as below poverty.

[e] The question "In general, how healthy is your diet?" used to determine individuals diet, was only available for intervals 2005-2006, 2007-2008 and 2009-2010. The multivariate model was only conducted for data from those six years to calculate associated Odds Ratio. Adjustment for waist circumference was not preformed.

[f] The data available for this variable was only available within the 2003-2004 and 2005-2006 intervals. The multivariate model was only conducted for this variable from data from the four-year period. Adjustment for waist circumference was not preformed.

[g] The data available for this variable was only available within the 2007-2008 and 2009-2010 interviews. The multivariate analysis was conducted using only data from this time period. Adjustment for waist circumference was not preformed.

[h] When conducting the multivariate analysis, BMI and waist circumference were not adjusted in tandem.

* Indicates statistical significance

4.4a Age

Age was found to be a major risk factor for T2DM. Reported ages were grouped into quartiles, (20-24, 25-29, 30-34 and 35-40). The number of participants was evenly distributed among groups (~25%). Univariate analysis of age using the youngest age group as the reference group discovered that the age groups of 25-29, 30-34, and 35-40 had increased odds ratios of 4.10 (CI: 1.66-10.08; p=.002), 7.29 (CI: 3.08-17.21; p=<.001) and 14.55 (CI: 6.37-33.27; p=<.001) respectively of having T2DM.

When adjusted for gender, BMI, race/ethnicity, SES, smoking, and UODA age remained a significant risk factor. Using the youngest age group as the reference group, individuals in other quartiles remained to all have significant OR's: 25-29 OR: 2.84 (CI: 1.11-7.23; p=.029), 30-34 OR: 4.89 (CI: 2.02-11.82; p=<.001), and 35-40 OR: 10.32 (CI: 4.42-23.65; p=<.001).

4.4b Weight Management:

Overweight, obesity and increased abdominal obesity were also found to be a major contributor of one's risk of having T2DM. Univariate analysis demonstrated that when compared with individuals categorized with having an underweight/normal BMI, individuals categorized as being overweight had 2.89 (CI: 1.48-5.65; p=.002) the risk of having T2DM. Individuals categorized as obese also had an increased risk of T2DM. (OR: 10.7 CI: 5.88-19.44; p=<.001)

Individuals who had a waist circumference that categorized them as at risk had an increased risk of 5.29 (CI: 3.19-8.79; p=<.001) of having T2DM when compared with individuals with a waist circumference within the normal range.

Significance remained when adjusting for other associated risk factors in a Multivariate regression analysis. When adjusting for age, gender, race/ethnicity, SES, smoking and UODA individuals who were classified as overweight had a OR of 2.18 (CI: 1.07-4.44; p=.032) when compared to individuals within the normal/underweight category. Individuals categorized as obese had an OR of 8.14 (CI: 4.33-15.29; p=<.001).

Waist circumference also remained significant when adjusted for age, gender, race/ethnicity, SES, smoking, and UODA. Individuals who had a waist circumference that placed them at risk had an OR of 4.38 (CI: 2.54-7.55; p=<.001) when compared to those who had a waist circumference within the normal range.

4.4c Race/ethnicity:

Both univariate and multivariate analysis of self-reported race/ethnicity found significant differences of risk associated with different minority racial/ethnic groups when compared to non-Hispanic whites.. When compared within non-Hispanic whites, persons of Latin American origins had an OR of 1.76 (CI: 1.18-2.61; p=.005). Non-Hispanic backs and other/multi-racial groups also had increased OR's of 2.39 (CI: 1.59-3.61; p=<.001) and 2.7 (CI: 1.47-4.95; p=.001) respectively.

When adjusted for age, gender, BMI, SES, smoking and UODA, the significance between non-Hispanic whites and individuals of Hispanic origins was lost. Non-Hispanic blacks and individuals of other/multi-racial origins had OR's of 1.7 (CI: 1.07-2.70; p=.026) and 2.48 (CI: 1.18-5.22; p=.017) respectively when compared to non-Hispanic whites.

4.4d Socioeconomic status:

Individuals were compared based on their reported income, which was used to calculate their poverty to income ratio (PIR). For univariate analysis, individuals were compared based on their poverty status. Individuals above poverty had an OR of 0.67 (CI: 0.47-0.95; p=.025) when compared to those below poverty.

4.4e Physical activity/inactivity

Three variables were created to measure one's average physical activity: moderate to vigorous physical activity (MVPA), usual occupational or domestic activity (UODA) and leisure-time sedentary behavior. Univariate models showed a significant associated between T2DM and LTSB and MVPA. UODA was found to be insignificant (p = .763). LTSB was divided into two categories: those who on average spent three hours or more either watching TV or on the computer per day, and those who reported less than three hours per day. Individuals who reported spending on average more than three hours per day had an OR of 1.86 (CI: 1.09-3.19) when compared to those who spent less than three hours sedentary. LTSB remained significant and actually contributed more to one's risk when adjusted for age, gender, BMI, race/ethnicity, SES, smoking, and UODA; OR: 2.17 (CI: 1.19-3.96 p=.011).

MVPA was divided into two groups as well, those who on average, spent 150 min/week or less participating in moderate to vigorous acuities during their leisure time, and those who reported more than 150min/week activity. Individuals who reported more than 150min/week had an OR of 0.47 (CI: 0.27-0.82 p=.008). When adjusted for age, gender, BMI, race/ethnicity, SES, smoking and UODA, MVPA remained a significant protective risk factor for those who reported on average participating 150mins/week or more of moderate and/or vigorous activity OR: 0.52; CI: 0.29-0.93 p=.028).

5. Discussion

Findings from this study support previous evidence that proclaim T2DM as a major emerging health concern for young adults and adolescents, and with overweight/obesity prevalence climbing to 70% within the US, we have yet to reach the zenith. It is clear that the disease affects a disproportionate number of minority persons and is highest among overweight and obese populations. Prevalence of undiagnosed diabetes was also found to be disproportionately distributed among racial/ethnic groups. T2DM among young adults share similar risk factors as older populations with disease. This is important in that similar prevention and treatment strategies could possibly be used among the young adult population.

This study addressed major risk factors associated with T2DM including SES, ethnicity, physical activity, diet and obesity. High OR figures suggest that weight plays a prominent role in a young adult's risk of having or acquiring the disease. Risk trends within weight and race/ethnicity variables were explored over the twelve-year time period, however, there were no significant changes found. I speculate that with a greater amount of data predating 1999, that there would be trends correlations with increased risk among overweight and obesity, due to the evolution of the role of processed foods within our culture as well as a decrease in risk among racial/ethnic groups due to a decreasing gap between those who have and those who don't.

Analysis of risk factors associated with T2DM found that the same factors driving the risk of the disease among young adults were the same for the disease among the adult population. (Hu et al. 2001) Though this is promising, speculation and research should investigate whether implementation of adult oriented interventions would be efficacious among young adults.

Future research should focus on creating processes that catch potential or early cases before the disease fully develops. Screening may be an important potential solution. Screening of high-risk population with the use of economical finger prick blood glucose tests may be an effective and efficient solution that is currently being studied. (Anand et al. 2006)

Limitations of this study include potential variability of results due to a small sample size of cases of diagnosed and undiagnosed T2DM among sub-samples (eg. Ethnicity). Over estimation from oversampling could potentially inflate outcome values among minority populations. In addition, the analytical software used lacked the ability of weighting, and therefore results cannot be extrapolated to generalize the US population.

T2DM has a potentially promising outlook if necessary steps are taken. T2DM has been defined by some as a curable disease if caught and treated early enough with a combination of drug therapy, dietary adjustments as well as physical activity. Investment in screening as well as new diagnostic tools such as ethnicity-specific diabetes risk scores would greatly reduce the number of undiagnosed cases. Control interventions should focus on decreasing overweight and obesity prevalence since weight seems to be the driving force behind. Some recent studies suggest that obesity rates have already slowed and may even have plateaued. (Flegal et al. 2012) However, with the majority of the US population categorized as overweight or obese, there is still a lot of work left to be completed.

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