ASSOCIATION BETWEEN PHYSICAL ACTIVITY BEHAVIORS AND TYPE 2 DIABETES
STATUS AMONG OLDER ADULTS

By
Christine Forest Schelble

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ABSTRACT

The risk for type 2 diabetes increases with age, particularly past age 45 years. A
diagnosis of type 2 diabetes has many health and financial implications. Research has
shown that regular, moderate physical activity can help prevent, delay or manage the
condition. Data from the 2001-2002 National Health and Examination Survey
(NHANES) were used to explore the relationship between physical activity and type 2
diabetes in an older adult population (ages 45 years and older). Physical activity was
measured primarily as 30-day cumulative metabolic equivalent (MET) values. Once
controlling for covariates through multiple regression, physical activity was still a
predictor for HbA1c levels. The results support the hypothesis that HbA1c values are
inversely proportional to higher levels of physical activity among subjects of all diabetes
statuses (type 2 diabetes, borderline diabetes, and no diabetes).
ACKNOWLEDGEMENTS

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I am also deeply grateful to my parents, David and Lorraine Forest, for raising me to have a keen interest in health and fitness and for their support of all my academic and professional pursuits. Finally, I am profoundly thankful for the years of support and encouragement from my husband, Michael, who was by my side from the graduate school application phase through the final thesis defense.
# TABLE OF CONTENTS

ABSTRACT .................................................................................................................................... ii

ACKNOWLEDGEMENTS ........................................................................................................ iii

LIST OF TABLES ...................................................................................................................... vii

LIST OF ILLUSTRATIONS .................................................................................................... viii

Chapter

1. INTRODUCTION ............................................................................................................1

   Introduction .................................................................................................................. 1

   Physical Activity ........................................................................................................ 2

   Diabetes and Aging .................................................................................................... 2

   Financial Costs ............................................................................................................ 3

   Objective ..................................................................................................................... 4

   Primary Hypothesis .................................................................................................... 5

   Definition of Terms .................................................................................................... 5

   Uses of NHANES ...................................................................................................... 7

   Limitations .................................................................................................................. 8

   Assumptions ................................................................................................................ 9

2. REVIEW OF THE LITERATURE ................................................................................... 10

   Introduction ............................................................................................................... 10

   Type 2 Diabetes ....................................................................................................... 10
Physical Activity ................................................................. 14
Relationship between Physical Activity and HbA1c Values ......... 17
Diabetes Status: Related Factors .......................................... 18
Conclusion .............................................................................. 22

3. RESEARCH METHODOLOGY ............................................. 23
   Introduction .......................................................................... 23
   National Health and Nutrition Examination Survey ............. 23
   Subjects .............................................................................. 24
   Variables ............................................................................ 25
   NHANES Procedure .......................................................... 31
   Study Procedure .................................................................. 32
   Data Analysis ..................................................................... 34

4. RESULTS ............................................................................. 36
   Introduction ......................................................................... 36
   Primary Hypothesis ............................................................ 36
   Subject Characteristics/Demographics ................................. 36
   Relationships with HbA1c Values ....................................... 40
   Regression Analysis ............................................................ 46
   Physical Activity and Diabetes Status Analyses .................. 47

5. DISCUSSION ...................................................................... 50
   Introduction ......................................................................... 50
   Primary Hypothesis ............................................................ 50
Limitations.............................................................................................................56

Future Directions and Conclusions..................................................................58

APPENDIX A ...........................................................................................................60

REFERENCES ........................................................................................................62
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Risk Factors for Type 2 Diabetes</td>
<td>12</td>
</tr>
<tr>
<td>2. Association between HbA1c Levels and Mean Plasma Glucose Levels</td>
<td>13</td>
</tr>
<tr>
<td>3. Body Mass Index (BMI) Categories</td>
<td>19</td>
</tr>
<tr>
<td>4. Life Expectancies for Men and Women with and without Diabetes (Years)</td>
<td>21</td>
</tr>
<tr>
<td>5. Descriptions of Supporting Analyses</td>
<td>35</td>
</tr>
<tr>
<td>6. Characteristics of All Subjects, by Diabetes Status</td>
<td>37</td>
</tr>
<tr>
<td>7. Characteristics of Subjects Included in Analyses, by Diabetes Status</td>
<td>38</td>
</tr>
<tr>
<td>8. Characteristics of Subjects Excluded in Analyses, by Diabetes Status</td>
<td>39</td>
</tr>
<tr>
<td>9. Summary of Multiple Regression for Variables Predicting HbA1c</td>
<td>46</td>
</tr>
</tbody>
</table>
**LIST OF ILLUSTRATIONS**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A1c as a Function of METs</td>
<td>41</td>
</tr>
<tr>
<td>2. A1c as a Function of Diabetes Status</td>
<td>42</td>
</tr>
<tr>
<td>3. A1c as a Function of BMI Status</td>
<td>43</td>
</tr>
<tr>
<td>4. A1c as a Function of Ethnic Status</td>
<td>43</td>
</tr>
<tr>
<td>5. A1c as a Function of Age Status</td>
<td>44</td>
</tr>
<tr>
<td>6. A1c as a Function of METs Status</td>
<td>45</td>
</tr>
<tr>
<td>7. A1c as a Function of Gender</td>
<td>45</td>
</tr>
<tr>
<td>8. Mean METs as a Function of Diabetes Status</td>
<td>47</td>
</tr>
<tr>
<td>9. Mean Minutes of Activity as a Function of Diabetes Status</td>
<td>48</td>
</tr>
<tr>
<td>10. Mean Number of Activities as a Function of Diabetes Status</td>
<td>49</td>
</tr>
</tbody>
</table>
CHAPTER 1
INTRODUCTION

Introduction

The prevalence of diabetes in the United States has been increasing rapidly in recent decades and in 2005 nearly 21 million individuals (7% of the population) had diabetes (Centers for Disease Control and Prevention, 2005). The World Health Organization’s (WHO) prediction of the prevalence of diabetes in the United States by the year 2030 is more than 30 million cases (WHO, n.d.). The majority of these cases (90%) will be type 2 diabetes (WHO, 2002). As Americans get older, live longer, and become more ethnically diverse, the health and financial implications of diabetes will be compounded (Institute for the Future, 2003).

Research has shown that regular, moderate physical activity can help prevent, delay, or manage type 2 diabetes (Nelson, Reiber, Boyko, 2002). Additionally, physical activity can reduce the onset of type 2 diabetes in individuals with pre-diabetes, a condition characterized by higher than normal blood sugar levels, but not high enough to be classified as type 2 diabetes (MayoClinic, 2006). Since studies have found that only about one-third of adults engage in the recommended amounts of physical activity, the challenges for health professionals will lie in encouraging and convincing adults to achieve the levels of activity necessary to assist in managing their diabetes or to prevent
the onset of diabetes (Resnick, Bardsley, Foster, & Ratner, 2006; Nelson, Reiber, Boyko, 2002).

Physical Activity

Exercise, along with diet and medication, has been considered one of the three cornerstones of diabetes therapy (Boule, et al., 2001). In addition to helping prevent or delay type 2 diabetes, these behaviors can help manage the disease by improving glycemic control and can reduce the risk for conditions associated with diabetes, such as heart disease (Fink, 2004). The benefit of exercise in improving the metabolic abnormalities of type 2 diabetes is viewed as greatest when it is used early in the type 2 diabetes progression process (ADA, 2002).

Adults with moderate to high levels of physical activity live longer and spend more years without diabetes compared to adults with lower levels of physical activity or no activity (Jonker, De Laet, Franco, Peeters, Mackenbach, & Nusselder, 2006). Unfortunately, research has shown that only about 31% to 39% of adults with diabetes engage in regular physical activity and an additional 30% engage in insufficient levels of physical activity (Morrato, Hill, Wyatt, Ghushchyan, & Sullivan, 2006; Nelson, Reiber, & Boyko, 2002). If sedentary individuals could be stimulated to become moderately active, they could extend the years of their life and increase the number of years spent without diabetes (Jonker, et al., 2006).

Diabetes and Aging

As people age, physical activity levels tend to decline and health problems such as diabetes tend to increase. Increasing age has been associated with a decrease in glucose
tolerance, even among non-diabetics (Elahi & Muller, 2000). The American Diabetes Association (ADA) recommends that screening to detect pre-diabetes and diabetes should be considered in individuals aged 45 years and older, particularly in those with a BMI of 25 kg/m² or greater (Jonker, et al., 2006).

The prevalence of pre-diabetes or undiagnosed diabetes increases greatly between ages 40 – 49 years and peaks in people ages 60 – 74 years (American Diabetes Association & National Institute of Diabetes, Digestive and Kidney Diseases, 2003). The American Diabetes Association (ADA) estimates that nearly 41 million American adults ages 40 to 70 years have pre-diabetes (ADA, 2006).

**Financial Costs**

The ADA and the National Institute of Diabetes, Digestive, and Kidney Diseases (2003) have called diabetes, “one of the most costly and burdensome chronic diseases of our time and a condition that is increasing in epidemic proportion in the U.S. and throughout the world.”

Medication and health care costs for individuals with diabetes are greater than those for individuals without diabetes. For example, medication costs can be more than 3.5 times greater than for individuals without diabetes ($1,093 vs. $309, respectively) (Reunanen, Martikainen, Kangas, & Klaukka, 2000). Furthermore, the Centers for Disease Control and Prevention calculated the average health care costs per year of nearly $14,000 for an individual with diabetes compared to slightly more than $2,500 for an individual without diabetes (CDC, 2006).
Beyond individual costs, the Medicare and Medicaid programs spend more than $84 billion annually on five major chronic conditions that could be significantly improved by increased physical activity, including diabetes. In 2000, Medicare spent $10.4 billion on diabetes treatment and services, and was estimated to spend $12.7 billion in 2004 (U.S. DHHS, 2002). These costs are expected to increase as the population continues to age during the next several decades and the proportion of adults relying on the Medicare and Medicaid programs also increases.

**Objective**

Based on the relationships between type 2 diabetes, physical activity, and age, the primary purpose of the present study was to explore the relationship between physical activity and diabetes status in a nationally representative, noninstitutionalized older adult population. Overall, the goal was to assess if more physical activity was associated with better glycemic control among adults aged 25 years and older, particularly those with type 2 diabetes. Glycemic control was determined through glycohemoglobin (HbA1c) values, which are an indicator of glycemic control during a two to three month time period. Although covariates such as age, gender, BMI, and ethnicity can influence HbA1c values, a multiple regression model was used to examine if physical activity was an independent predictor of HbA1c values after controlling for the covariates.

Additionally, differences in physical activity behaviors (30-day cumulative MET scores, 30-day cumulative physical activity duration in minutes, and the number of different activities performed during the 30-day period prior to the interview) were compared between subjects with self-reported type 2 diabetes and subjects without
diabetes. Data were obtained from the 2001-2002 National Health and Nutrition Examination Survey (NHANES).

**Primary Hypothesis**

The hypothesis was that HbA1c values would be inversely proportional to higher levels of physical activity among subjects of all diabetes statuses (type 2 diabetes vs. no diabetes). It was anticipated that higher levels of physical activity would be associated with lower HbA1c values.

**Definition of Terms**

**Body Mass Index (BMI)**— A number calculated from a person’s weight and height. BMI provides a reliable indicator of body fatness for most people and is used to screen for weight categories that may lead to health problems (CDC, NCCDPHP, 2006).

**Borderline Diabetes**— In this study, “borderline” was a response category for subjects who were asked if a doctor or health professional had ever told them they had diabetes. Borderline diabetes is assumed to have the same definition as pre-diabetes.

**Ethnic**— For ease in analysis, the race/ethnicity categories were collapsed into two groups for the present study. The “Ethnic” group was comprised of all subjects who reported a race/ethnicity other than “Non-Hispanic White.”

**HbA1c**— A test that measures the amount of glycosylated hemoglobin in the blood; provides an estimate of how well diabetes is being managed during a two to three month time period. Alternative names include glycosylated hemoglobin, A1C, and glycohemoglobin (MedlinePlus, 2005).
Lifestyle modification—Adoption of lifestyle habits to improve health status. Examples include physical activity, weight loss for overweight or obese individuals (Moeller, 2004).

**METs**—The metabolic equivalent (MET) of an activity that represents the energy expenditure needed to perform the activity. The baseline value of one MET represents the average, seated, resting energy cost of an adult and is set at 3.5 mL/kg/min of oxygen, or 1 kcal/kg/hr. Thus, multiples of the 1-MET resting baseline represent the MET level or multiples of the resting rate of oxygen consumption of any given activity. An activity performed at the level of five METs would require five times as much energy as is expended at rest (Plowman & Smith, 2003).

**NHANES**—The National Health and Nutrition Examination Survey (NHANES) is a continuous survey to collect national health statistics and is conducted by the National Center for Health Statistics (NCHS), a division of the Centers for Disease Control and Prevention (CDC), U.S. Public Health Service. The survey is nationally representative and examines 5,000 individuals annually (U.S. Department of Health and Human Services (DHHS), CDC, NCHS, 2006).

**Not Ethnic**—In this study, the “Not Ethnic” group consisted of subjects who reported their race/ethnicity as Non-Hispanic White.

**Obese**—An adult who has a BMI of 30 kg/m² or higher is considered obese (CDC, 2006).

**Older Adults**—Defined as adults aged 45 years and older.

**Overweight**—An adult who has a BMI between 25 – 29.9 kg/m² is considered overweight (CDC, 2006)
**Pre-diabetes**— A condition characterized by higher than normal blood sugar levels, but not high enough to be classified as type 2 diabetes. Pre-diabetes involves impaired fasting glucose (IFG), impaired glucose tolerance (IGT) or both. A normal range for blood sugar levels is 70 to 100 mg/dL. Levels greater than 126 mg/dL likely indicate presence of diabetes. In this study, pre-diabetes is termed “borderline” diabetes.

**Type 2 Diabetes**— A chronic medical condition that impacts how the body metabolizes sugar (glucose). Develops when the body becomes resistant to the effects of insulin or when the pancreas produces inadequate amounts of insulin to maintain normal glucose levels. A normal range for blood sugar levels is 70 to 100 mg/dL. Levels greater than 126 mg/dL likely indicate presence of diabetes. Term used interchangeably with diabetes.

**Uses of NHANES**

The 2001-2002 NHANES data were used in the current study. Over the past 40 years, NHANES data have been instrumental in identifying the prevalence of major diseases and risk factors for diseases, as well as serving as the basis for national standards and the development of certain health policies (U.S. DHHS, CDC, NCHS, 2006). For example, data on blood lead levels led to the development of a policy to eliminate lead from gasoline, resulting in substantial reductions in elevated blood lead levels. Additionally, NHANES data have been used to establish baseline estimates for cholesterol levels and blood pressure levels for U.S. individuals (U.S. DHHS, CDC, NCHS, 2006).
Limitations

The current study was limited in several respects. Most importantly, the data associated with several key variables come from self-reported measures, which are subject to recall problems or difficulty associated with misunderstanding the question, particularly with respect to the physical activity variables. Self-reported questions included the initial question asked to all subjects aged 1 year and older, "other than during pregnancy, have you ever been told by a doctor or health professional that you have diabetes or sugar diabetes?", questions related to physical activity behaviors (i.e. frequency and intensity), and questions related to age, height, and weight. Nelson et al. (2002) reported that previous studies have demonstrated that self-reported diagnosis of diabetes is valid and reliable.

In addition to self-reported measures, the research also used data collected through laboratory exams performed in the NHANES Mobile Examination Center. Many quality assurance measures are in place to ensure the integrity of the laboratory data, but data have the potential to be impacted by human or equipment error and/or possible examiner effects.

Furthermore, many of the analyses required the use of bivariate distributions. Due to the large amount of data collected, missing values were inevitable and subsequently impacted the analyses by limiting the sample size to those with appropriate data necessary for the bivariate analyses.

Finally, measures to evaluate diabetes status and physical activity are abundant. However, the current study relied on only a few select measures for each of these...
elements, thus limiting the ability to make broad generalizations about the relationship between diabetes status and physical activity in older adults.

**Assumptions**

The biggest assumption used in the current research was that self-reported data were accurate. Additionally, results are assumed to be representative of individuals with type 2 diabetes only. A procedure used by Nelson et al. (2002) was followed to eliminate subjects with type 1 diabetes, however it is possible that some subjects with type 1 diabetes were inadvertently represented within the study.
CHAPTER 2
REVIEW OF THE LITERATURE

Introduction

Diabetes is a complex chronic disease that involves intense adherence to a multitude of lifestyle factors to prevent, delay, maintain, and/or reverse the condition. Without proper disease treatment, serious complications can develop, further reducing the quality of life. Physical activity has been deemed an essential element of type 2 diabetes disease management. Several studies have examined the relationship between physical activity and HbA1c values, an indicator of glycemic control, and have found exercise interventions to play a role in lowering HbA1c values (Boule et al., 2001; Di Loreto et al., 2006, Snowling & Hopkins, 2006).

The following sections provide an overview of type 2 diabetes, address the relationship between diabetes and physical activity, with emphasis given on HbA1c values and exercise intensity as expressed in metabolic equivalents (METs), and describe the many related factors involved in diabetes status that were addressed in the study.

Type 2 Diabetes

Type 2 diabetes is a chronic medical condition that impacts how the body metabolizes sugar (glucose). This condition develops when the body becomes resistant to the effects of insulin or when the pancreas produces inadequate amounts of insulin to
maintain normal glucose levels (MayoClinic, 2006). Diabetes is a serious, chronic condition that over time can affect every major organ, including kidneys, heart, eyes, and blood vessels; diagnosis is critical for the proper management of type 2 diabetes and related conditions.

A normal range for blood sugar levels is 70 to 100 mg/dL. Levels greater than 126 mg/dL likely indicate the presence of diabetes (ADA, 2003). Levels in-between normal and 126 mg/dL are diagnosed as pre-diabetes, a condition characterized by higher than normal blood sugar levels, but not high enough to be classified as type 2 diabetes.

Recently, pre-diabetes has been recognized as a critical diagnosis since it is a risk factor for developing type 2 diabetes, as well as other associated conditions such as heart disease and stroke. The American Diabetes Association estimates that nearly 41 million American adults ages 40 to 70 years have pre-diabetes (ADA, 2006). Pre-diabetes involves impaired fasting glucose (IFG), impaired glucose tolerance (IGT) or both (CDC, 2006). If identified, healthy lifestyle changes can return blood sugar levels to within the normal range (MayoClinic, 2006).

Currently, the ADA recommends that screening to detect pre-diabetes and diabetes should begin at age 45 years, especially among individuals with a body mass index (BMI) of 25 kg/m² or greater or those with risk factors for type 2 diabetes (ADA, 2006). The American Academy of Family Physicians has also adopted these screening guidelines (Mayfield, 1998). Based on this recommendation to initiate screening at age 45 years, this age cutoff was used in the current research to assess physical activity behaviors of a middle-age and older adult population. This group will be referred to
collectively as “older adults.” Table 1 (MedlinePlus, 2006) shows several of the key risk factors for type 2 diabetes.

Table 1. Risk Factors for Type 2 Diabetes.

- Family history/genetics
- Race/Ethnicity
  - (African-Americans, Hispanic-Americans, and Native Americans have higher rates of diabetes)
- Overweight/obesity
- Age (greater than 45 years)
- Previous diagnosis of IFG or IGT
- High blood pressure
- HDL cholesterol less than 35 mg/dL
- Triglycerides greater than 250 mg/dL
- History of gestational diabetes

HbA1c

The HbA1c test shows an individual’s average blood glucose control for the past two to three months (ADA, 2006). It measures the percentage of hemoglobin molecules in the red blood cells that have glucose attached. Since red blood cells last an average of four months before the body makes new blood cells, this test can indicate the average blood glucose levels over the life span of the blood cells being tested (University of California, San Francisco (UCSF), 2006).

Normal ranges for HbA1c vary, but are generally in the 4% to 6% range for non-diabetics. According to the ADA, the target for adults is under 7% (ADA, Standards of
Medical Care in Diabetes—2006, 2006). Table 2 shows the relationship between HbA1c levels and corresponding plasma glucose levels (ADA, Standards of Medical Care in Diabetes—2006, 2006).

Table 2: Association between HbA1c Levels and Mean Plasma Glucose Levels

<table>
<thead>
<tr>
<th>HbA1c (%)</th>
<th>Mean plasma glucose (mg/dL)</th>
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<tbody>
<tr>
<td>6</td>
<td>135</td>
</tr>
<tr>
<td>7</td>
<td>170</td>
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<tr>
<td>8</td>
<td>205</td>
</tr>
<tr>
<td>9</td>
<td>240</td>
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<tr>
<td>10</td>
<td>275</td>
</tr>
<tr>
<td>11</td>
<td>310</td>
</tr>
<tr>
<td>12</td>
<td>345</td>
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</table>

The ADA recommends that health care professionals perform the HbA1c test at least two times per year in patients who are meeting treatment goals and more often for those who are not meeting glycemic goals (ADA, Standards of Medical Care in Diabetes—2006, 2006). Data from the Behavioral Risk Factor Surveillance System (1998) revealed that only 24% of adults aged 18 years and older with diabetes had a HbA1c test at least once per year (Centers for Disease Control and Prevention & National Institutes of Health, 2000). An objective of Healthy People 2010 is to increase the proportion of adults with diabetes who have a glycosylated hemoglobin measurement at least once a year to 50% (Centers for Disease Control and Prevention & National Institutes of Health, 2000).

Recent findings show that nearly 50% of adults aged 18 years and older with diabetes had an A1c of less than 7%, leaving the remaining 50% with unhealthy levels.
above 7% (Resnick, Foster, Bardsley, & Ratner, 2006). Each 1% reduction in the HbA1c test can reduce the risk of complications by up to 30%; Keeping A1c levels below 7% can reduce the risk dramatically (UCSF, 2006). Physical activity has been associated with a reduction in HbA1c values (Snowling & Hopkins, 2006).

Physical Activity

Regular exercise is a critical lifestyle behavior for long-term health. The CDC estimates that nearly 300,000 deaths each year in the U.S. are attributable to physical inactivity and poor eating habits. These deaths range across a number of diseases, including heart disease, stroke, colon cancer, and diabetes (CDC, 2006). Regular, moderate physical activity can help prevent, delay, or manage type 2 diabetes by improving glycemic control, glucose tolerance, and insulin sensitivity (Nelson, Reiber, Boyko, 2002). Furthermore, regular physical activity can aid in the management of related conditions such as high blood pressure, obesity, or high cholesterol (AHRQ & CDC, 2002).

For individuals with diabetes, physical activity helps control weight, utilizes glucose, makes cells more sensitive to insulin, increases blood flow and improves circulation in blood vessels, and builds muscle mass (Hays & Clark, 1999). Increased muscle mass is beneficial because glucose in the blood is absorbed into muscles resulting in less sugar circulating in the bloodstream (MayoClinic, 2006). Increased insulin sensitivity has been shown to occur within a few weeks after implementation of a regular physical activity program (Hays & Clark, 1999).
The most recent published findings on prevalence of physical activity among individuals with type 2 diabetes come from the 1999-2002 NHANES. These findings reveal that only 28% of adults ages 18 years and older with diabetes reported getting the recommended level of physical activity (Resnick, Bardsley, Foster, & Ratner, 2006). The recommended level of physical activity is five or more episodes of moderate physical activity per week or three or more episodes of vigorous physical activity per week. Data from an earlier NHANES survey (NHANES III) revealed that 31% of adults ages 18 years and older with diabetes achieved the recommended levels of physical activity. An additional 38% reported an insufficient amount of physical activity and 31% reported no regular physical activity in the month prior to the survey (Nelson, Reiber, Boyko, 2002). Similar levels were also found in the 1990 National Health Interview Survey (Nelson, Reiber, Boyko, 2002).

Physical activity levels are slightly higher for non-diabetic adults. About 31% to 39% of non-diabetic adults engage in recommended amounts of physical activity on a regular basis (Morrato, Hill, Wyatt, Ghushchyan, & Sullivan, 2006; Nelson, Reiber, & Boyko, 2002). Physical activity is associated with reduced mortality among both diabetic subjects and the general population (Jonker et al., 2006).

The protection against diabetes has been shown to be similar as a result of either vigorous or moderate physical activity levels (Jonker et al., 2006). One study found that exercise training was associated with a significant reduction in insulin resistance and that both moderate intensity and high intensity exercise were equally effective when at least 400 calories were expended per session (O'Donovan et al., 2006). Additionally, in a study of sedentary obese and overweight individuals, physical activity encompassing a
wide range of intensity and volume levels significantly increased insulin sensitivity in three different exercise groups. They found that exercise programs consisting of approximately 170 minutes of exercise per week improved insulin sensitivity more substantially than exercise programs consisting of approximately 115 minutes of exercise per week, regardless of exercise intensity and volume (Houmard, et al., 2004).

However, a study from the University of Alberta concluded that walking was not enough for significant exercise benefits based on the results of their research (Betkowski, 2006). In their study, the researchers compared the 10,000 step program to a more traditional exercise program encompassing cardio-based exercise on treadmills and stationary bikes. The results showed that that the traditional program reduced systolic blood pressure more than the 10,000 step program, but that other health markers, including fasting plasma glucose levels and response to a 2-hour glucose tolerance test were not affected by either exercise program (Betkowski, 2006). In this study, the 10,000 step program participants were not instructed to exercise at a particular level while the traditional exercise group was instructed to exercise as a moderate (conversational) pace.

Metabolic Equivalents (METs)

The metabolic equivalent (MET) of an activity represents the energy expenditure needed to perform the activity. The baseline value of 1 MET represents the average, seated, resting energy cost of an adult and is set at 3.5 mL/kg/min of oxygen, or 1 kcal/kg/hr. Thus, multiples of the 1-MET resting baseline represent the MET level or multiples of the resting rate of oxygen consumption of any given activity. An activity
performed at the level of 5 METs would require 5 times as much energy as is expended at rest (Plowman & Smith, 2003).

Moderate physical activity is performed at an intensity of 3 to 6 METs, which translates to brisk walking at 3 to 4 mph for most healthy adults (Pate et al., 1995). This level of activity corresponds with the national recommendation that every U.S. adult should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week (Pate et al., 1995).

Di Loreto et al. (2005) found that energy expenditures greater than 10 METs/hour/week were associated with health benefits such as decreased body weight, decreased waist circumference, improved HbA1c, and improved blood pressure, but that levels closer to 27 METs/hour/week were even more beneficial for previously sedentary subjects with type 2 diabetes. The level of 27 METs/hour/week corresponds to a 3-mile daily walk (1 hour/day at 3mph or 45 minutes/day at 4mph) (Di Loreto et al., 2005), slightly more time per day than the national recommendation of 30 minutes of exercise most days of the week.

Relationship between Physical Activity and HbA1c Values

A recent meta-analysis evaluated the effects of different modes of exercise on HbA1c values (Snowling & Hopkins, 2006). Their findings indicate a reduction in A1c of 0.8% (SD = 0.3%) as a result of exercise interventions lasting at least 12 weeks. Aerobic exercise, resistance training, or combined aerobic exercise and resistance training programs were all similarly effective in contributing to the reductions in A1c (Snowling & Hopkins, 2006). Additionally, this meta-analysis found that the impact of increased
exercise intensity on HbA1c values was unclear. This finding was considered surprising given that most physiological adaptations to exercise are sensitive to intensity (Snowling & Hopkins, 2006).

Previous research also explored the relationship between exercise intensity and HbA1c values. In a 2001 report, Boule et al. reported no relationship between exercise intensity and HbA1c. They applied the compendium of physical activities to estimate exercise intensity as metabolic equivalents (METs) and found that although A1c was significantly lower in the exercise group compared to the control group, METs was not associated with the post-intervention reduction in A1c. In a 2003 report by Boule et al., post-intervention HbA1c values were again significantly reduced in the exercise groups compared with control groups. However, this report defined exercise intensity in terms of VO$_2$ max and found this to be a better predictor of post-intervention difference in HbA1c compared to exercise volume (METs/hour/week) (Boule et al., 2003).

Most of the studies that have investigated the relationship between exercise and HbA1c have been clinical or controlled trials with interventions involving exercise alone or exercise combined with other intervention elements such as diet (i.e. dietary fish intake, Dunstan et al., 1997). The current study explored the relationship between exercise (physical activity) and HbA1c values in a cross-sectional survey.

**Diabetes Status: Related Factors**

Diabetes status is related to many factors, many of which were addressed through the current research. The primary factors addressed were, HbA1c levels, physical activity, body mass index (BMI), gender, race/ethnicity, and age.
Body Mass Index

There are multiple risk factors for type 2 diabetes, but obesity stands out as one of the greatest risk factors and one of the strongest predictors of diabetes (Mokdad, et al., 2000). Body Mass Index (BMI) is a number calculated from a person's weight and height and serves as a reliable indicator of body fatness for most people. BMI is used to screen for weight categories that may lead to health problems, including diabetes (CDC, BMI, 2006). Table 3 outlines the standard BMI categories (CDC, 2006):

<table>
<thead>
<tr>
<th>Category</th>
<th>BMI (kg/m²)</th>
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<tbody>
<tr>
<td>Normal</td>
<td>18.5 – 24.9</td>
</tr>
<tr>
<td>Overweight</td>
<td>25.0 – 29.9</td>
</tr>
<tr>
<td>Obese</td>
<td>&gt;30.0</td>
</tr>
</tbody>
</table>

Generally, the more fatty tissue a person has in the body, the more resistant their cells become to insulin. Additionally, excess weight located around the abdomen and upper body (intraabdominal fat) is more of a risk factor than extra weight around the hips. Losing even a small amount of weight (5% to 7%) can improve glucose levels (MayoClinic, 2006). HbA1c levels are positively associated with BMI (Okada et al., 2003).

The rise in obesity across the country is alarming, but as it is related to diabetes, the impact of the obesity epidemic may take several more years to come into light. As Mokdad, et al. (2000) point out, while changes in BMI foreshadow changes in diabetes, there is a substantial delay between the onset of obesity and the subsequent development of diabetes. Data from the 1999-2002 NHANES surveys show that among those aged 18
years and older with self-reported diabetes, the mean BMI is nearly 32 kg/m$^2$ (Resnick, Bardsley, Roster, & Ratner, 2006).

Race/Ethnicity

Race/ethnicity is a risk factor for diabetes. African-Americans, Hispanic-Americans, and Native-Americans have higher rates of diabetes compared to non-Hispanic-White Americans. Several studies have found higher levels of A1c among African-American subjects compared to White Americans (Agurs-Collins, Kumanyika, Ten Have, & Adams-Campbell, 1997). Furthermore, complications of diabetes occur more often among African-Americans than White-Americans with type 2 diabetes (Agurs-Collins, Kumanyika, Ten Have, & Adams-Campbell, 1997). Race/ethnicity is also associated with lower levels of physical activity (Hays & Clark, 1999).

A randomized-controlled trial of weight reduction and exercise for diabetes management in older African-American subjects found that after a 12-week intervention HbA1c values were significantly lowered at 3 and 6 months post intervention (1.6% and 2.4%, respectively) (Agurs-Collins, Kumanyika, Ten Have, & Adams-Campbell, 1997).

Age

Overall, the risk for type 2 diabetes increases with age, particularly past age 45 years (MayoClinic, 2006). The prevalence of type 2 diabetes is about 3% to 5% at age 40 years and increases to 20% to 30% at age 60 years (LeRoith, 2005). Additionally, the incidence of impaired glucose tolerance increases with age, even if an individual is not diagnosed with type 2 diabetes (Elahi & Muller, 2000). The Agency for Healthcare
Research and Quality (AHRQ) & CDC (2002) noted that, “few factors contribute as much to successful aging as having a physically-active lifestyle.”

In the early adult and middle-age years (up to age 59 years), glucose tolerance is largely associated with physical activity and BMI. However, beyond age 60 years the decline in glucose tolerance is largely influenced by age (Elahi & Muller, 2000). Older age is also associated with lower levels of physical activity (Hays & Clark, 1999).

Among the elderly (those aged 65 years and older), approximately one-third of individuals lead a sedentary lifestyle (U.S. DHHS, 2002). As individuals age, this percentage continues to rise, with 54% of men and 66% of women aged 75 years and older engaging in no leisure-time physical activity. Furthermore, individuals aged 65 years and older account for almost 40% of the population with diabetes (CDC, 2006). Although adults at retirement age (65 years) show some increase in light and moderate-intensity physical activities, overall physical activity declines with age (Pate et al., 1995).

Diabetes can also have a substantial impact on life expectancies, although moderate to high levels of activity can contribute to longer life expectancies among men and women (Jonker, et al., 2006). Estimated life expectancies for men and women with a without diabetes are shown in Table 4 (Jonker et al., 2006):

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individuals without diabetes</td>
<td>27.2</td>
<td>33.8</td>
</tr>
<tr>
<td>Years spent without diabetes</td>
<td>25.5</td>
<td>32.1</td>
</tr>
<tr>
<td>Individuals with diabetes</td>
<td>23.8</td>
<td>24.3</td>
</tr>
</tbody>
</table>
Conclusion

Although the risk for type 2 diabetes increases with age, particularly past age 45 years (MayoClinic, 2006), regular, moderate physical activity has been shown to be an effective tool for helping reduce this risk, especially when combined with other lifestyle modification behaviors. Since nearly all studies that have looked at the relationship between exercise and HbA1c levels have been controlled trials, the relationship between these two variables in a cross-sectional survey was of interest. The 2001-2002 NHANES provided several key physical activity measures, including METs and duration of activity, that were analyzed to explore their respective relationships with type 2 diabetes status and HbA1c levels.

Furthermore, based upon the previously observed differences in the proportions of adults with and without diabetes that achieve the recommended amounts of physical activity, the differences in physical activity behaviors between subjects with diabetes and subjects without diabetes were of interest. The three physical activity measures used to assess these differences were METs, duration of activity, and the total number of different activities performed during the 30-day period prior to the survey interview.
CHAPTER 3
RESEARCH METHODOLOGY

Introduction

This chapter outlines the procedures used by the NHANES team for data collection and survey operations as well as the procedures used in the current study to address the primary hypothesis. The hypothesis was that HbA1c values would be inversely proportional to higher levels of physical activity among subjects of all diabetes statuses (type 2, borderline diabetes, and no diabetes). Descriptions of subjects, variables, and statistical analyses are also included in this chapter.

National Health and Nutrition Examination Survey

Overview

The present study utilized data from the 2001-2002 NHANES survey. NHANES has been a population-based complex sample design survey that collects information on health and nutrition measures of adults and children living in U.S. households. The survey has been nationally representative of the U.S. population of all ages and examines 5,000 individuals annually. Subjects came from counties located throughout the country and fifteen of these counties are visited each year. NHANES has been a continuous survey that began in the 1960s.
There were two primary components to the 2001-2002 NHANES: the home interview and the health exam. Upon obtaining written informed consent, in-home interviews were performed to collect self-reported data regarding health status, health history, and health behaviors. Health exams were performed in a mobile exam center (MEC) consisting of four trailers containing advanced medical equipment.

Data collected during the home interview included demographic, socioeconomic, dietary, and health-related information. The medical exam component collected information through medical and dental exams, physiological measurements, and laboratory tests. All medical exam components were conducted by trained medical personnel. Several of the diseases, medical conditions, and health indicators that were studied include diabetes, infectious diseases, nutrition, obesity, physical fitness and physical functioning, and sexually transmitted diseases.

The survey obtained data on individuals regarding dietary behaviors and body measurements. Most individuals also had a blood sample taken and a dental screening. Other tests and procedures were dependent upon factors such as age of the subject. (U.S. DHHS, CDC, NCHS, 2006).

Subjects

For NHANES 2001-2002, there were 13,156 subjects selected for the sample; 11,039 of those subjects were interviewed and 10,477 were examined in the MEC (U.S. DHHS, CDC, NCHS, 2006). All subjects were asked, “other than during pregnancy, have you ever been told by a doctor or health professional that you have diabetes or sugar
This question was designed to exclude subjects who were diagnosed with diabetes only while pregnant (gestational diabetes). It is not known how many subjects had diabetes only while pregnant. Next, subjects with type 1 diabetes were excluded. Type 1 diabetes was defined as those subjects who reported a diagnosis of diabetes younger than age 30 years and who had continuous insulin usage since diagnosis (N = 3). This method to determine subjects with type 1 diabetes was previously used by Nelson, Reiber, and Boyko (2002). Finally, all subjects younger than 45 years were excluded (N = 8,036). Thus, the remaining unweighted sample had 3,000 eligible cases (unweighted), representing 95,169,057 weighted cases. However, to be included in the analyses, subjects needed to have both HbA1c data and physical activity data (MET data) present. Only 1255 cases (unweighted) had these data present (weighted N = 51,077,078).

**Variables**

There were five separate data files used in the study: 1) Demographics, 2) Diabetes, 3) Physical Activity Individual Activities File, 4) Weight History, and 5) Glycohemoglobin. The cut-off points for outliers were determined by calculating reasonable values for the variable and then using the total percentage of values (i.e. eliminating the upper 2.5%) to determine the break point.

Additional methods for how key variables were used to test the primary hypothesis are given in the Study Procedures section. Table A1 (Appendix A) summarizes the variables, questions, and response categories for each variable used from
each of the five data files. Details of the five data files, operational definitions, and outliers for each of the variables used are discussed below.

**Demographics**

Five variables were used from the Demographics data file, including gender, age, race/ethnicity, education, and the 2-year MEC exam weight.

**Gender**—Gender was defined as Male or Female.

**Age**—Subjects reported their age at the time of the interview. According to the NHANES procedures, age was top-coded at 85 years (U.S. DHHS, CDC, NCHS, 2006). For the present study, age was divided into two groups for comparison, Low Age and High Age, by splitting the cases at the median point (57 years). The Low Age group included subjects aged 45 years through 57 years and the High Age group included subjects aged 58 years through 85 years.

**Ethnicity**—There were five categories for race/ethnicity: Non-Hispanic White, Mexican American, Other Hispanic, Non-Hispanic Black, and Other Race (including multi-racial). In the present study, race/ethnicity was explored by grouping subjects into two groups for comparison. These two groups were called Ethnic and Not Ethnic. The Ethnic group was defined by combining subjects with a reported race/ethnicity of Mexican American, Other Hispanic, Non-Hispanic Black, and Other Race (including multi-racial). The Not Ethnic group was composed of subjects with a reported race/ethnicity of Non-Hispanic White.

**Education**—There were three categories for education: less than high school, high school diploma (including GED), and more than high school. This variable was
included as part of the background/demographic characteristics of the subjects (U.S.
DHHS, CDC, NCHS, 2006).

2-Year MEC Exam Weight—The two-year sample weights were based on
counts. Sampling weights
were provided in the demographic data file and were used to produce unbiased national
estimates and proper estimates and standard errors. The 2001-2002 NHANES included
over-samples of low-income persons, adolescents, persons ages 60 years and older,
African Americans, and Mexican Americans. The sampling weights helped account for
these over-samples (U.S. DHHS, CDC, NCHS, 2006).

Diabetes

The first question on the Diabetes questionnaire asked about the subject’s diabetes
status. This question was asked as “Other than during pregnancy, have you ever been told
by a doctor or other health professional that you have diabetes or sugar diabetes?”
Response categories included, “yes,” “no,” and “borderline.” The following series of
questions were used to follow the method to determine subjects who had type 1 diabetes
and would be excluded from the analyses: “how old were you when a doctor or health
professional told you that you have diabetes or sugar diabetes?”, “are you now taking
insulin?”, and “for how long have you been taking insulin?”.

Diabetes Status—In the present study, diabetes status was divided into two
groups for comparison: Type 2 Diabetes and No Diabetes. Those with Type 2 Diabetes
included subjects with self-reported type 2 diabetes and self-reported borderline diabetes.
The No Diabetes subjects included those who reported that they had never been told by a doctor or health professional that they have diabetes.

Diabetes status was used as an independent variable in four separate analyses. The type 2 diabetes group contained slightly more than 5-million subjects (weighted) while the no diabetes group contained slightly more than 45-million subjects (weighted). Exact totals for each group varied according to the dependent measure applied to the analysis.

Physical Activity Individual Activities File

During the home interview process, subjects were first asked two questions from the general Physical Activity questionnaire (not used in the present study) about their level of activity in the past 30 days. The first question asked if they did any vigorous activities over the past 30 days for at least 10 minutes and the second questions asked if they did any moderate activities over the past 30 days for at least 10 minutes. If the subject answered yes to either question, they were then asked questions from the Physical Activity Individual Activities questionnaire.

Questions used from the Physical Activity Individual Activities file included: “Over the past 30 days, what vigorous/moderate activities did you do?”, “on average, how long did you do each activity (in minutes),” and subjects were asked to report the intensity level performed for each activity.

The Physical Activity Individual Activities File allowed subjects to enter as many different activities as necessary to describe their physical activity behaviors for the 30-day period prior to the survey interview. The highest number of different activities reported was 12 activities; only one subject reported this number. The majority of
subjects reported one to three activities (nearly 86%). As a result, each subject had a
different number of rows of data associated with their physical activity behaviors,
representing the many different activities that they performed (i.e. walking, basketball,
swimming). Data collected for the other four data files resulted in only one row of data
per subject. In order to merge the Physical Activity Individual Activity file with the
remaining data files, the physical activity data were aggregated.

**Frequency**—Subjects reported the number of times they did a given activity
during the 30-day period prior to the interview.

**Intensity Level**—Subjects gave a self-reported intensity level for the activity;
responses included vigorous or moderate.

**METs**—Based on the reported intensity level for the given activity, the NHANES
staff coded the corresponding MET level for each activity. This was done by referencing
the “Compendium of physical activities: an update of activity codes and MET intensities”
by Ainsworth, et al. (2000). For example, walking at a vigorous intensity has a MET
level of 5.0 while walking at a moderate intensity has a MET level of 3.5.

For the present study, the variable METs was recoded by summing the products
of [METs * frequency] for each activity reported by the subject to achieve a cumulative
30-day MET value. Outlier values above 554.0 were removed (upper 2.5% were not
included). The 30-day cumulative MET values for each subject were divided into two
groups of METs for comparison, Low METs and High METs, by splitting the cases at the
median point (94.5). The Low METs group included values from 2 through 94.5 and the
High METs group included values from 94.6 through 554.0.
Duration—Subjects reported on average how long they did each activity (in minutes). For the present study, duration was calculated by summing the products of [duration * frequency] for each activity reported by the subject to achieve a 30-day total of minutes of physical activity. Outlier values above 6840.0 minutes were removed (the upper 2.5% was not included).

Number of Activities—The number of activities was calculated through a count of the number of different activities reported by a subject regarding their physical activity during the 30-day period prior to the interview. Outlier values above 8 were removed (upper 0.6%).

Weight History

Two variables were used from the Weight History file: current self-reported height (inches) and current self-reported weight (pounds). Height and weight were then converted to meters and kilograms to calculate BMI. BMI was calculated by dividing the weight in kilograms by the height in meters and then multiplying the result by the height in meters.

BMI—In the present study, body mass index was divided into two groups for comparison, Low BMI and High BMI, by splitting the cases at the median point (27.18kg/m²). The Low BMI group included BMI values up to 27.18kg/m² and the High group included BMI values above 27.18kg/m². In the multivariable regression, BMI was used as a continuous variable.
**Glycohemoglobin**

The laboratory exam results used in the present study were the glycohemoglobin measurements. Glycohemoglobin measurements were performed by the Diabetes Diagnostic Laboratory at the University of Missouri—Columbia using Primus CLC330 and Primus CLC 385 (U.S. DHHS, CDC, NCHS, 2006). Further details regarding the glycohemoglobin measurements can be found in the Documentation for Laboratory Results (U.S. DHHS, CDC, NCHS, 2006).

The Glycohemoglobin file contained only data for the glycohemoglobin measurements. HbA1c values were applied as collected; the values ranged from 3.3 to 18.8 prior to the elimination of outliers. HbA1c values above 11.50 were removed (upper 1% was not included).

**NHANES Procedure**

The NHANES survey procedures are extensive and complete documentation, codebooks, analytic guidelines, and other related NHANES reference materials can be found on the NHANES website (http://www.cdc.gov/nchs/nhanes.htm). A summary of procedures is described here.

To foster participation, the NHANES provided transportation to and from the MEC and subjects were compensated for their participation. Subjects also received a complete report of medical findings (U.S. DHHS, CDC, NCHS, 2006). Notification was given to the appropriate health and government officials in each survey location through
a letter from the NCHS Director. This letter was sent to all households within the survey location to introduce the survey.

The staff team included a physician, medical and health technicians, and dietary and health interviewers. Laboratory staff received extensive training in standardized laboratory procedures prior to working in the MEC and the NHANES quality control and quality assurance protocols met the 1988 Clinical Laboratory Improvement Act mandates (U.S. DHHS, CDC, NCHS, 2006). Bilingual staff conducted the household interviews (U.S. DHHS, CDC, NCHS, 2006).

NHANES staff conducted the health interviews in respondents’ homes, but the medical examinations were conducted in the MEC. Specimens used to produce laboratory data files were collected at the MEC. Certain populations were targeted for specific laboratory tests. Before collecting any specimens, a screening questionnaire was administered to look for certain conditions that may exclude the subject. For example, hemophiliacs were excluded from any test that requires blood specimens (U.S. DHHS, CDC, NCHS, 2006).

Subjects were able to enter responses to sensitive questions in privacy through the use of touch-pad computer screens (U.S. DHHS, CDC, NCHS, 2006). All data, with the exception of the glycohemoglobin values, were collected through interviews. The glycohemoglobin values were collected through the MEC.

Study Procedure

The 2001-2002 NHANES data files used in the current study were all publicly available and were downloaded from the NHANES website.
(http://www.cdc.gov/nchs/nhanes.htm). All associated documentation and guidelines for using the data are also available on the NHANES website (U.S. DHHS, CDC, NCHS, 2006). Since the data for each topic (i.e. diabetes, weight history, etc.) were provided in individual data files, it was necessary to merge the five separate data files together into one master dataset in order to perform the desired analyses. The Demographics file was considered the master file and the other four data files were merged to this file. Subjects were matched by the respondent’s sequence number.

Missing Data

Of the 3,000 unweighted cases, 285 had a zero (0.0) value for the weight variable, thus excluding them from further analyses. The statistical software used, SPSS version 11.0, automatically excludes cases where the weight is zero when the cases have been weighted by a particular variable. Additionally, subjects who were missing data for physical activity (METs) and HbA1c were excluded from the analyses (unweighted N = 1745; weighted N = 44,091,979).

Weighting of Data

The 2001-2002 data files used for data analysis were smaller than previous NHANES data files since they contain two years of data rather than six. As a result of the smaller sample size, the weights were larger than in past NHANES (U.S. DHHS, CDC, NCHS, 2006). To produce national estimates and proper standard errors of estimates, the appropriate sampling weights were used (U.S. DHHS, CDC, NCHS, 2006).
necessary 2-year MEC exam weight was provided in the Demographics data file. Weight values ranged from 0.0 to 211,850.66 (U.S. DHHS, CDC, NCHS, 2006).

Data Analysis

Data analysis was performed with SPSS 11.0 for Windows. The following analyses were performed to explore the relationship between HbA1c values, physical activity, and diabetes status: (1) A1c as a Function of METs (METs and A1c used as continuous variables), (2) A1c as a Function of Diabetes Status (2 groups: Type 2 Diabetes vs. No Diabetes), (3) A1c as a Function of BMI status (2 groups: Low BMI vs. High BMI), (4) A1c as a Function of Ethnic status (2 groups: Ethnic vs. Not Ethnic) (5) A1c as a function of age (2 groups: Low Age vs. High Age), (6) A1c as a function of METs (2 groups: Low METs vs. High METs), (7) A1c as a function of gender (Male vs. Female), (8) METs as a function of diabetes status (2 groups: Type 2 Diabetes vs. No Diabetes), (9) Duration as a function of diabetes status (2 groups: Type 2 Diabetes vs. No Diabetes), and (10) number of activities as a function of diabetes status (2 groups: Type 2 Diabetes vs. No Diabetes).

Several statistical tests were used to evaluate the hypotheses, including bivariate correlations and comparison of means (one-way ANOVA). Cross tabulations were used to generate percentages for the tables of background/demographic characteristics. To explore the role of the covariates and other population characteristics in influencing HbA1c values, a multiple regression model was applied. Table 5 summarizes each research question, its corresponding independent and dependent measures, and the statistical test used for each question.
Table 5. Descriptions of Supporting Analyses

<table>
<thead>
<tr>
<th>Question</th>
<th>IV*</th>
<th>DV**</th>
<th>Statistical Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. As METs increase, do A1c levels decrease?</td>
<td>METs</td>
<td>A1c</td>
<td>Bivariate Correlation/Regression</td>
</tr>
<tr>
<td>2. Is there a difference in mean A1c levels between 2 groups of diabetes statuses?</td>
<td>Diabetes Status (2 groups)</td>
<td>A1c</td>
<td>ANOVA</td>
</tr>
<tr>
<td>3. Is there a difference in mean A1c levels between 2 groups of BMI statuses?</td>
<td>BMI (2 groups, low vs. high BMI)</td>
<td>A1c</td>
<td>ANOVA</td>
</tr>
<tr>
<td>4. Is there a difference in mean A1c levels between 2 groups of Ethnic statuses?</td>
<td>Ethnicity (2 groups, ethnic vs. not ethnic)</td>
<td>A1c</td>
<td>ANOVA</td>
</tr>
<tr>
<td>5. Is there a difference in mean A1c levels between 2 groups of age statuses?</td>
<td>Age (2 groups, low vs. high age)</td>
<td>A1c</td>
<td>ANOVA</td>
</tr>
<tr>
<td>6. Is there a difference in mean A1c levels between 2 groups of METs statuses?</td>
<td>METs (2 groups, low vs. high METs)</td>
<td>A1c</td>
<td>ANOVA</td>
</tr>
<tr>
<td>7. Is there a difference in mean A1c levels between males and females?</td>
<td>Gender (male vs. female)</td>
<td>A1c</td>
<td>ANOVA</td>
</tr>
<tr>
<td>8. Is there a difference in mean METs between 2 groups of diabetes statuses?</td>
<td>Diabetes Status (2 groups)</td>
<td>METs</td>
<td>ANOVA</td>
</tr>
<tr>
<td>9. Is there a difference in mean number of minutes of physical activity between 2 groups of diabetes statuses?</td>
<td>Diabetes Status (2 groups)</td>
<td>Duration (minutes)</td>
<td>ANOVA</td>
</tr>
<tr>
<td>10. Is there a difference in the mean number of activities reported between 2 groups of diabetes statuses?</td>
<td>Diabetes Status (2 groups)</td>
<td>Number of activities</td>
<td>ANOVA</td>
</tr>
</tbody>
</table>

*IV = Independent Variable  **DV = Dependent Variable
CHAPTER 4

RESULTS

Introduction

This chapter presents the main results of the study, beginning with pertinent background and demographic characteristics. Figures displaying the results in support of the hypothesis will follow the three tables of background and demographic characteristics. The results in this section are based on analyses that employed the Full Sample 2-Year MEC Exam Weight. Use of this weight allows the results to be representative of population estimates from the year 2000 Census counts (U.S. DHHS, CDC, NCHS, 2006).

Primary Hypothesis

The hypothesis was that HbA1c values would be inversely proportional to higher levels of physical activity among subjects of all diabetes statuses.

Subject Characteristics/Demographics

Subjects needed to have physical activity (MET) and HbA1c data available in order to be included in the analyses since the analyses focused on these two elements. It was found that 46.3% of the overall sample could not be included due to the absence of physical activity and HbA1c data. Therefore, analyses were restricted to slightly more than half of the total group (53.7%). The characteristics of all subjects (N = 95,169,057),
the included subjects (N = 51,077,078), and the excluded subjects (N = 44,091,979) were evaluated to see if any major differences were apparent between the three groups. Table 6 shows the characteristics of all subjects and Tables 7 and 8 illustrate the subjects that were included in the analyses (Table 7) and those that were excluded from the analyses (Table 8) due to the absence of key data on physical activity and HbA1c. In general, the subjects included in the analyses (Table 7) appeared to be somewhat younger, have lower BMIs, have less ethnicity, and have slightly higher levels of education compared to the group that was excluded from the analyses (Table 8).

Table 6 presents the characteristics of the whole sample. More than 95 million subjects are represented by 3,000 unweighted cases. The No Diabetes group is somewhat younger and has a lower BMI compared to the Borderline and Type 2 Diabetes groups. The No Diabetes group also has a larger proportion of Non-Hispanic White subjects (80.0%) compared to the borderline (71.6%) and type 2 diabetes (65.3%) groups.

Table 6. Characteristics of All Subjects, by Diabetes Status (N = 95,169,057)

<table>
<thead>
<tr>
<th></th>
<th>Type 2</th>
<th>Borderline</th>
<th>No Diabetes</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 10,408,867</td>
<td>n = 1,647,832</td>
<td>n = 83,112,359</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>63.4 ± 11.0</td>
<td>62.5 ± 10.5</td>
<td>59.1 ± 11.5</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>BMI</td>
<td>30.8 ± 6.5</td>
<td>30.4 ± 5.9</td>
<td>27.6 ± 5.9</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Gender (%)</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>49.1</td>
<td>52.4</td>
<td>46.6</td>
<td></td>
</tr>
<tr>
<td>Race/Ethnicity (%)</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>Mexican American</td>
<td>6.6</td>
<td>4.2</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Other Hispanic</td>
<td>8.2</td>
<td>0.0</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>65.4</td>
<td>71.6</td>
<td>80.0</td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>13.8</td>
<td>14.6</td>
<td>8.6</td>
<td></td>
</tr>
</tbody>
</table>

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Table 6—Continued

<table>
<thead>
<tr>
<th>Other Race (including multi-racial)</th>
<th>6.2</th>
<th>9.6</th>
<th>3.0</th>
</tr>
</thead>
</table>

Education (%)

<table>
<thead>
<tr>
<th>Less than high school</th>
<th>31.7</th>
<th>25.8</th>
<th>19.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>High school diploma (including GED)</td>
<td>26.9</td>
<td>24.6</td>
<td>23.7</td>
</tr>
<tr>
<td>More than high school</td>
<td>41.4</td>
<td>49.6</td>
<td>56.4</td>
</tr>
</tbody>
</table>

Table 7 presents the characteristics of the subjects that were included in the analyses (53.7% over the overall sample). The age and BMI characteristics of this group are similar to those of found in the group of all subjects.

Table 7. Characteristics of Subjects Included in Analyses, by Diabetes Status (N = 51,077,078)

<table>
<thead>
<tr>
<th></th>
<th>Type 2 n = 4,537,335</th>
<th>Borderline n = 850,494</th>
<th>No Diabetes n = 45,689,249</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>61.1 ± 9.7</td>
<td>63.5 ± 8.1</td>
<td>57.7 ± 10.6</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>BMI</td>
<td>30.4 ± 6.3</td>
<td>29.4 ± 3.8</td>
<td>27.2 ± 5.2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Gender (%)</td>
<td></td>
<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
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<td>61.0</td>
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<td>2.9</td>
<td>2.4</td>
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<td>54.4</td>
<td>46.6</td>
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Table 8 presents the characteristics of the subjects that were excluded from the analyses due to the absence of the necessary physical activity and A1c data. From the overall group of subjects, 46.3% of the subjects did not have the necessary data present to be included in the analyses. Compared to the group of subjects that was included, this group appeared somewhat older, appeared to have slightly higher BMIs, had a smaller proportion of males, appeared to be somewhat more ethnic, and appeared to have somewhat lower levels of education. Similar to the other two groups, the group of type 2 diabetes subjects appeared older than the other groups of subjects (borderline and no diabetes).

Table 8. Characteristics of Subjects Excluded from Analyses, by Diabetes Status (N = 44,091,979)

<table>
<thead>
<tr>
<th></th>
<th>Type 2 n = 5,871,532</th>
<th>Borderline n = 797,338</th>
<th>No Diabetes n = 37,423,109</th>
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<tr>
<td>Age (years)</td>
<td>65.1 ± 11.6</td>
<td>61.4 ± 12.4</td>
<td>60.7 ± 12.4</td>
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<tr>
<td>BMI</td>
<td>31.0 ± 6.6</td>
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<td>Gender (%)</td>
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<td></td>
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<td>&lt;.001</td>
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<tr>
<td>Male</td>
<td>39.9</td>
<td>46.7</td>
<td>43.3</td>
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<tr>
<td>Race/Ethnicity (%)</td>
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<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Mexican American</td>
<td>6.7</td>
<td>5.6</td>
<td>4.4</td>
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<tr>
<td>Other Hispanic</td>
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Table 8—Continued

<table>
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<th>Non-Hispanic White</th>
<th>Non-Hispanic Black</th>
<th>Other Race (including multi-racial)</th>
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<td></td>
<td>66.4</td>
<td>66.8</td>
<td>73.9</td>
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<tr>
<td>Less than high school</td>
<td>40.3</td>
<td>37.0</td>
<td>29.6</td>
</tr>
<tr>
<td>High school diploma (including GED)</td>
<td>28.3</td>
<td>10.1</td>
<td>29.0</td>
</tr>
<tr>
<td>More than high school</td>
<td>31.4</td>
<td>52.9</td>
<td>41.4</td>
</tr>
</tbody>
</table>

Relationships with HbA1c Values

Relationships between HbA1c and six key variables were analyzed. Key variables included physical activity variables and covariates. Figures 1 through 7 illustrate the relationships between A1c and METs, diabetes status, BMI, Ethnicity, age, and gender. These results were in response to the first seven research questions outlined in Table 5 (Chapter 3). Each individual relationship between a variable and A1c was then explored through the multivariable regression, which addressed the relationship between physical activity (METs) and A1c while controlling for the other variables.

The key research question sought to determine if increasing levels of physical activity were associated with lower HbA1c levels. METs was used as the primary variable to represent physical activity and was plotted against A1c values. As anticipated, increasing physical activity (METs) was related to lower levels of HbA1c ($R^2 = .009; p = < .001$). Other physical activity variables used in the study included duration and number of activities.
Although physical activity was the key variable of interest for in terms of its impact on HbA1c, other variables (covariates) can impact HbA1c levels, including but not limited to, diabetes status, BMI, ethnicity, age, and gender. Each of the individual relationships between these covariates and HbA1c levels were investigated and the results are displayed in the following set of figures.

Figure 2 shows the mean HbA1c levels for two diabetes status groups: Diabetes vs. No Diabetes. The Diabetes group represented in this figure included subjects with self-reported type 2 diabetes and self-reported borderline diabetes. The mean value of A1c for the Type 2 Diabetes group was 7.03% (± 1.37) while the mean value of A1c for
the No Diabetes group was 5.42% (± .42) (p < 0.001). In this analysis, the Type 2 Diabetes group had 5,387,829 subjects and the No Diabetes group had 45,689,249 subjects (Ns represent weighted number of cases).

Figure 2. A1c as a Function of Diabetes Status

Using the two groups of BMI categories, Low BMI and High BMI, the mean A1c levels of these two different BMI groups were compared. As is shown in Figure 3, subjects in the Low BMI group had a correspondingly lower mean A1c level (5.44% ± .61) compared to subjects in the High BMI group (5.75% ± .89). The mean A1c levels were significantly different between the two groups (p < 0.001). The sizes of the two groups were similar, with the low BMI group having 26,050,613 subjects and the high BMI group having 25,026,465 subjects (total weighted N = 51,077,078).
Figure 3. A1c as a Function of BMI Status

Figure 4 reveals that subjects in the Ethnic group had a significantly higher ($p < 0.001$) mean HbA1c level (5.94% ± 1.07) compared to subjects in the Not Ethnic group (5.52% ± .67). The Ethnic group contained 8,687,783 subjects and the Not Ethnic group contained 42,389,295 subjects (total weighted N = 51,077,078).

Figure 4. A1c as a Function of Ethnic Status
Figure 5 illustrates that subjects in the Low Age group had a significantly lower 
\((p < 0.001)\) mean HbA1c level \((5.48\% \pm .69)\) compared to subjects in the High Age group 
\((5.71\% \pm .83)\). The Low Age group contained 26,074,407 subjects and the High Age 
group contained 25,002,671 subjects (total weighted \(N = 51,077,078\)).

![Figure 5. A1c as a Function of Age Status](image)

Figure 6 illustrates the mean HbA1c levels for subjects in two groups of MET 
levels, Low METs and High METs. There was a statistically significant difference in the 
mean HbA1c levels between the two groups with a mean HbA1c of 5.62\% \((\pm .81)\) for the 
Low METs group compared with a mean of 5.57\% \((\pm .74)\) for the High METs group \((p < 
0.001)\). The Low METs group contained 25,638,659 subjects and the High METs group 
contained 25,438,419 subjects.
The differences in mean HbA1c levels between Males and Females was investigated. The findings indicated that Males had a statistically significant higher mean HbA1c percentage (5.66% ± .84) compared to Females (5.52% ± .69) ($p < 0.001$). There were 25,805,932 weighted subjects in the Males group and 25,271,146 weighted subjects in the Female group (total weighted N = 51,077,078).
Regression Analysis

The results of the multivariable regression are described below. The model for the multivariable regression examined the combined effects of the previous six variables (diabetes status, BMI, Ethnicity, age, METs, and gender) on A1c. The model was designed to examine the effect of physical activity, as defined by METs, on A1c while controlling for the other variables. Table 9 shows that although diabetes status was the biggest predictor of A1c, the other covariates, including METs, remained factors in predicting A1c.

The column $\beta$ represents the independent contribution of each independent variable to the prediction of A1c (the dependent variable). The contribution of METs was nearly 5%. The contribution of METs showed a negative correlation, indicating that the smaller the number of METs, the greater the A1c. The other covariates had positive correlations indicating that the higher the value of the variable (i.e. BMI), the higher the A1c. The $R^2$ value (.45) indicated that about 45% of the variability in A1c could be explained by this model.

<table>
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<th>$SE\ B$</th>
<th>$\beta$</th>
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<td>(3.165-04)</td>
<td>7.165-07</td>
<td>-0.05 *</td>
</tr>
<tr>
<td>Diabetes Status</td>
<td>1.46</td>
<td>2.735-04</td>
<td>0.58 *</td>
</tr>
<tr>
<td>Gender</td>
<td>0.07</td>
<td>1.629-04</td>
<td>0.04 *</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>0.25</td>
<td>2.191-04</td>
<td>0.12 *</td>
</tr>
<tr>
<td>Age</td>
<td>0.01</td>
<td>7.830-06</td>
<td>0.09 *</td>
</tr>
<tr>
<td>BMI</td>
<td>0.02</td>
<td>1.549-05</td>
<td>0.13 *</td>
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Table 9—Continued

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<th>(constant)</th>
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Note. $R^2 = .45$

* $p < .001$

**Physical Activity and Diabetes Status Analyses**

The following three figures illustrate the relationship between two diabetes status groups (Diabetes vs. No Diabetes) and three different physical activity variables: METs, duration (in minutes), and number of activities.

When the mean MET values between the two groups of diabetes status were compared, it was found that the mean value among subjects in the No Diabetes group was higher ($127.56 \pm 114.53$) compared to subjects in the Type 2 Diabetes group ($105.56 \pm 102.08$) ($p < 0.001$). On average, both groups accumulated more than 100 METs/hour/month of physical activity. The results of this analysis are shown in Figure 8.

![Figure 8. Mean METs as a Function of Diabetes Status](image)

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Another physical activity variable of interest was the duration of activity achieved in the 30-day period prior to the interview (in minutes). As shown in Figure 9, subjects in the Type 2 Diabetes group had a lower mean number of minutes of physical activity during the 30-day period prior to the interview compared to the No Diabetes group (1051.49 ± 1204.47 minutes vs. 1248.52 ± 1152.34 minutes, respectively) ($p < 0.001$). It was also anticipated that the No Diabetes group would have a higher mean value of minutes compared to the Type 2 Diabetes group. The mean number of minutes for the Type 2 Diabetes group (1051.49) corresponds to approximately 35 minutes of physical activity per day for a 30-day period while the mean number of minutes for the No Diabetes group (1248.52) corresponds to approximately 42 minutes of physical activity per day for a 30-day period.

![Figure 9. Mean Minutes of Activity as a Function of Diabetes Status](image-url)
The third physical activity variable of interest was the number of different activities. The No Diabetes group had a significantly higher ($p < 0.001$) mean number of activities (2.26 ± 1.44) compared to the Type 2 Diabetes group (1.70 ± .99).

Figure 10. Mean Number of Activities as a Function of Diabetes Status
CHAPTER 5
DISCUSSION

Introduction

Exercise, along with diet and medication, has been considered one of the three cornerstones of diabetes therapy (Boulé, et al., 2001) and exercise interventions have been found to play a role in lowering HbA1c values (Boulé at al., 2001; Di Loreto et al., 2006; Snowling & Hopkins, 2006). The primary aim of this study was to show that HbA1c values were inversely proportional to higher levels of physical activity among subjects of all diabetes statuses (type 2 diabetes, borderline diabetes, and no diabetes). Through the data analyses, this aim was supported.

Primary Hypothesis

Multivariable Regression

A multivariable regression model demonstrated the independent effect of physical activity, as defined by METs, on HbA1c levels while controlling for diabetes status, gender, age, BMI, and ethnicity. In support of the primary hypothesis, METs were a contributing factor to HbA1c values. The covariates, including diabetes status, gender, age, BMI, and ethnicity also contributed to the HbA1c values, but METs accounted for nearly 5% of the shared variance. However, a much larger proportion of the variance was shared between diabetes status and HbA1c values.
The covariates investigated in the model included diabetes status, gender, age, BMI, and ethnicity. With the exception of BMI, and to some extent diabetes status, the other covariates (gender, age, and ethnicity) are elements that are beyond an individual’s control. However, physical activity is an area that individuals can largely control. Regardless of the relatively small contribution of physical activity, as defined by METs, to HbA1c values, the important aspect is that physical activity does have a relationship to HbA1c values (higher METs are associated with lower HbA1c values). This finding lends support to public health recommendations for physical activity and physical activity recommendations by the American Diabetes Association for individuals with diabetes. Despite risk factors and genetics, physical activity has an association with improved health outcomes, particularly with HbA1c values, as was shown in this study.

Relationship between Covariates and HbA1c

While the multivariable regression model examined the combined effects of physical activity and the covariates on HbA1c values, the individual relationships between these covariates and HbA1c values were also investigated. Two groups were created for each of the covariates so that the mean HbA1c values could be compared. In the case of gender, the two groups already existed as male and female. However, for other covariates such as diabetes status, age, BMI, and ethnicity, certain conventions were applied to collapse the data into two groups (i.e. Low Age group vs. High Age group).

It was expected that lower mean HbA1c levels would correspond with subjects who did not have type 2 diabetes, were in the Low Age group, were in the Low BMI
group, were Not Ethnic, and were female. The results of these ANOVA analyses revealed the anticipated results. Additionally, METs was divided into a Low METs group and a High METs group and through the ANOVA analyses it was found that the High METs group had a lower mean HbA1c value compared to the Low METs group (5.57% vs. 5.62%). Furthermore, a scatterplot of METs and HbA1c revealed a negative correlation between these two variables, meaning that as METs increased, HbA1c values decreased.

Several findings from the current study support results reported in the literature. Specifically, the relationships between HbA1c values and two of the covariates, age and ethnicity, yielded results consistent with previous findings. Increasing age has been associated with decreased glucose tolerance, even in non-diabetics (Elahi & Muller, 2000). The present study found that subjects in the high age group, which combined type 2 diabetics, borderline diabetics, and non-diabetics, had a higher mean HbA1c level compared to the subjects in the low age group. With respect to ethnicity, higher HbA1c levels have been found in certain ethnic groups compared to Whites. Specifically, higher levels of A1c have been found among African-American subjects compared to White Americans (Agurs-Collins et al., 1997). The present study also found that the group of ethnic subjects had a higher mean HbA1c compared to the group of not-ethnic subjects.

Physical Activity Levels

The differences in physical activity behaviors were investigated between the group of subjects with type 2 diabetes and the group of subject with no diabetes. METs were the primary variable used to define physical activity and was used to represent physical activity in the multivariable regression. However, two other variables, 30-day
cumulative minutes of activity and the total number of different activities performed in the 30-day period prior to the interview were also used as measures of physical activity. With all three physical activity variables, subjects in the no diabetes group had higher levels of physical activity compared to subjects in the type 2 diabetes group.

These findings are consistent with other findings reported in the literature. Previous research has reported that a larger proportion of non-diabetic adults (31% - 39%) achieve the recommended amounts of physical activity per week compared to adults with diabetes (28%-31%) (Morrato, Hill, Wyatt, Ghushchyan, & Sullivan, 2006; Resnick, Bardsley, Foster, & Ratner, 2006; Nelson, Reiber, Boyko, 2002). The recommended level of physical activity is five or more episodes of moderate physical activity per week or three or more episodes of vigorous physical activity per week.

In other studies, participants have been found to overestimate time spent on physical activity (Tzetis, Avgerinon, Vernadakis & Kioumourtzoglou, 2001). Based on this finding, the number of different activities performed over the 30-day period prior to the interview was used as an independent variable for physical activity. It was assumed that subjects would be more likely to recall if they did or did not do a specific type of activity within the 30-day reference period compared to their ability to be able to accurately recall and report the frequency, duration, or intensity of each exercise session.

The impact of increased exercise intensity on A1c is still unclear. A recent meta-analysis evaluated the effects of different modes of exercise on HbA1c values (Snowling & Hopkins, 2006). Their findings indicate a reduction in A1c as a result of any mode of exercise (aerobic exercise, resistance training, or combined aerobic exercise and
resistance training) (Snowling & Hopkins, 2006). This finding was considered surprising given that most physiological adaptations to exercise are sensitive to intensity (Snowling & Hopkins, 2006). Di Loreto et al. (2005) found that energy expenditures greater than 10 METs/hour/week were associated with health benefits such as decreased body weight, decreased waist circumference, improved HbA1c, and improved blood pressure, but that levels closer to 27 METs/hour/week were even more beneficial for previously sedentary subjects with type 2 diabetes.

Demographics

Since the hypothesis examined physical activity and HbA1c values, subjects needed to have these data elements present to be included in the analysis. Unfortunately, once these criteria were applied, nearly half (46.3%) of the subjects were excluded due to the lack of physical activity and HbA1c data. This substantial dropout rate prompted the exploration for differences between the two groups (those included in the analysis vs. those excluded from the analysis). Additionally, a comparison was made between the group of subjects that was used for the analyses and the group of all subjects.

Compared to the group of subjects that was excluded from the analysis, the group of subjects included in the analysis appeared to be slightly younger (across all groups except those with borderline diabetes), appeared to have slightly lower BMI levels (all groups), appeared to have a higher level of education (across all groups except those with borderline diabetes), appeared to be somewhat less ethnic, and appeared to have a higher proportion of males. These differences were nearly parallel to those seen between the
group of subjects that were analyzed compared to all subjects overall, with the exception of gender. The group of all subjects had a relatively even split of males vs. females.

The characteristics of the group of subjects analyzed (subjects with physical activity and HbA1c data), were consistent with other findings that report on the demographics of those who are more likely to participate in physical activity. For example, physical activity tends to decline with age (Pate et al., 1995), and race/ethnicity is also associated with lower levels of physical activity (Hays & Clark, 1999).

The group of subjects that was analyzed represented only 53.7% of the overall group of subjects, a key limitation of the current study. These subjects appeared to be somewhat younger than the group of subjects that was excluded and somewhat younger than the overall group of subjects. Furthermore, the group of subjects that was analyzed appeared to be not only younger, but also appeared to have lower BMI levels, higher education levels and less ethnicity. Given that the analyses captured only slightly more than half of the overall group of subjects, there is a potential bias of the results given that these characteristics were present in the analyses and that subjects who were older, had lower levels of education, higher BMI levels, and were more ethnically diverse were excluded. It is assumed that a large proportion of the 46.3% of subjects that did not have physical activity data, and thus were excluded from the analyses, did not have this data because they are inactive, have physical disabilities or other health conditions that prohibit them from exercising, or that the data were not provided by the respondent for any number of reasons.
Limitations

The results of the current research support the concept that many factors, in addition to physical activity, were associated with HbA1c levels. As was shown in this study, diabetes status, gender, age, and BMI all contributed to HbA1c levels. However, the multivariable regression model was only able to explain about 42% of the relationship with HbA1c values. Therefore, there are other variables (covariates) that likely are related to A1c.

One of the key variables not addressed in the current research was the use of glucose lowering drugs. It is likely that glucose lowering drugs play a substantial role in influencing HbA1c values, particularly among the subjects with type 2 diabetes and/or borderline diabetes. Other possible covariates include smoking status, income, education, nutrition and duration of diabetes. Increasing duration of diabetes generally results in progressively higher A1c levels (Benoit et al, 2005).

With respect to physical activity, the current study had several other limitations. The actual self-reported duration of each activity was not included in the calculation of METs. It was assumed that the METs represented one-hour. However, this assumption may be an over or under-estimation of the actual 30-day cumulative MET score if subjects did not exercise for a full hour each session or if they exercised more than one hour per session.

Additionally, in many analyses, including the regression model, the groups of diabetes status were not assessed separately, which limits the ability to generalize to specific populations (type 2 diabetics vs. non-diabetics) or to make specific physical
activity recommendations. Furthermore, since the physical activity variables were representative of a 30-day period, it is not practical to compare the findings to current physical activity recommendations which follow a per-week structure. Future research of this nature should be designed so that results can be compared to or put into context with Federal guidelines for physical activity and/or other findings on the health outcomes of physical activity.

Finally, this study looked at data collected at one point in time, therefore any change in HbA1c levels could not be evaluated. Most of the literature on exercise and change in HbA1c values is based on exercise interventions of at least 12 weeks to allow for changes in HbA1c as a result of the intervention to be assessed. These methodological differences limit the ability to directly compare the findings of this study to the literature. Future studies should use longitudinal data in order to be able to capture changes in HbA1c values in relation to physical activity behaviors.

Despite the limitations, the results of this study support the association between physical activity and lower HbA1c levels among older adults of all diabetes statuses. Furthermore, higher levels of exercise, as defined by METs, are associated with lower HbA1c levels. While METs are considered a valuable measure of physical activity because they address duration and intensity of exercise, the impact of the true value of METs in relation to health outcomes is still in question.

One study found that both moderate intensity and high intensity exercise were equally effective in reducing insulin resistance when at least 400 calories were expended per session (O’Donovan et al., 2006). Another study found that exercise programs
consisting of approximately 170 minutes of exercise per week improved insulin sensitivity more substantially than exercise programs consisting of approximately 115 minutes of exercise per week, regardless of exercise intensity and volume (Houmard, et al., 2004). Additionally, a 2001 report, Boulé et al. found that although HbA1c was significantly lower in their exercise group compared to the control group, exercise intensity (METs) was not associated with the post-intervention reduction in A1c. A 2003 report by Boulé et al. concluded that exercise intensity in terms of VO$_2$ max was a better predictor of post-intervention difference in HbA1c compared to exercise volume (METs/hour/week) (Boulé et al., 2003).

**Future Research and Conclusions**

The results lead to many more questions which could be explored through additional research. Looking at the multivariable regression model for only subjects with type 2 diabetes should be a priority in order to add clarity to the relationship between physical activity and HbA1c values found in this study. Additionally, as mentioned previously, there are many other covariates such as smoking status, nutrition and income that could impact the results. Future research should include these covariates when investigating physical activity behaviors and diabetes status. Specifically, studies that examine the behaviors of older adults should consider income as an important element as fixed incomes of the elderly may influence the results.

Overall the body of research, including this study, continues to build support for the role of physical activity in maintaining or improving health. Physical activity is a behavior that individuals can control and therefore continued efforts should be made by
public health professionals to increase the proportion of the population that achieves at least the recommended amounts of physical activity per week. Since having diabetes was such a strong factor in the multivariable regression in determining a person’s HbA1c level, care should be taken to adopt healthily lifestyle behaviors, including physical activity, that aim to prevent, delay, or manage diabetes.
## APPENDIX A

### Table A1. Data Files and Variables Used

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<td>DIQ060U</td>
<td>Unit of Measure</td>
<td>1 = Months 2 = Years 7 = Refused 9 = Don't know</td>
</tr>
<tr>
<td>PAQIAF</td>
<td>PADACTIV</td>
<td>What vigorous/moderate activities?</td>
<td>10 = Aerobics 23 = Jogging……etc.</td>
</tr>
<tr>
<td>PAQIAF</td>
<td>PADLEVEL</td>
<td>Reported intensity level of activity</td>
<td>1 = Moderate 2 = Vigorous</td>
</tr>
<tr>
<td>PAQIAF</td>
<td>PADTIMES</td>
<td>Number of times done activity in past 30 days?</td>
<td>Enter number</td>
</tr>
<tr>
<td>PAQIAF</td>
<td>PADDURAT</td>
<td>Average duration of activity (minutes)</td>
<td>Enter number</td>
</tr>
<tr>
<td>Weight History</td>
<td>WHD010</td>
<td>Current Self-Reported Height (inches)</td>
<td>Enter number</td>
</tr>
<tr>
<td>Weight History</td>
<td>WHD020</td>
<td>Current Self-Reported Weight (pounds)</td>
<td>Enter number</td>
</tr>
<tr>
<td>Glycohemoglobin (LAB10)</td>
<td>LBXGH</td>
<td>Glycohemoglobin (%)</td>
<td></td>
</tr>
</tbody>
</table>

*Codebooks can be found at: http://www.cdc.gov/nchs/about/major/nhanes/nhanes01-02.htm

**PAQIAF = Physical Activity Individual Activity File
REFERENCES


U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics. (2006). *National Health and Nutrition Examination Survey* [Data file and associated documentation, and analytic guidelines]. Available from Centers for Disease Control and Prevention,

