Summer 8-2020

The Determinants of Physical Activity, Self-Monitoring of Blood Glucose, and Poor Glycemic Control Among Individuals Diagnosed With Type 2 Diabetes in Saudi Arabia: A Cross-Sectional Study Based on the Saudi Health Interview Survey (SHIS)

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THE DETERMINANTS OF PHYSICAL ACTIVITY, SELF-MONITORING OF BLOOD GLUCOSE, AND POOR GLYCEMIC CONTROL AMONG INDIVIDUALS DIAGNOSED WITH TYPE 2 DIABETES IN SAUDI ARABIA: A CROSS-SECTIONAL STUDY BASED ON THE SAUDI HEALTH INTERVIEW SURVEY (SHIS)

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A Dissertation Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

HEALTH SERVICES RESEARCH

OLD DOMINION UNIVERSITY
August 2020

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ABSTRACT

THE DETERMINANTS OF PHYSICAL ACTIVITY, SELF-MONITORING OF BLOOD GLUCOSE, AND POOR GLYCEMIC CONTROL AMONG INDIVIDUALS DIAGNOSED WITH TYPE 2 DIABETES IN SAUDI ARABIA: A CROSS-SECTIONAL STUDY BASED ON THE SAUDI HEALTH INTERVIEW SURVEY (SHIS)

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The prevalence of diabetes and poor glycemic control in Saudi Arabia has increased that contributed to the growing number of deaths in Saudi Arabia. It is known that type 2 diabetes (T2DM) can be prevented but there is a lack information about the magnitude of the of diabetes at national level as well as the risk factors for physical activity (PA), self-monitoring of blood glucose (SMBG), and poor glycemic. Thus, through utilizing Health promotion model (HPM), the aims are to examine the personal factors, cognitive-perceptual, and behavioral determinants of three outcomes; physical activity, SMBG, and poor glycemic control. A secondary data (Saudi health interview survey-2013) was used with two sample sizes for examining PA and SMBG (808 participants who reported to have T2DM and were 18 year or older) and poor glycemic control (391 participants who reported to have T2DM and had data about their blood glucose level) outcomes. Bivariate and multivariate logistic regression were conducted to address the research questions at alpha level of 0.05.

The results showed that the prevalence of physical activity, SMBG, and poor glycemic control, were 9.1%, 55.4%, and 34%, respectively. Younger age (Adjusted odds ratio [AOR] = 2.84), and higher education (AOR = 3.14) were associated with PA, while health professional support for treatment (HPST) was inversely associated with PA (AOR = 0.35). Factors associated with SMBG were obesity (Adjusted prevalence ratio [APR] = 1.20), middle (APR =

1.30) and higher (APR =1.49) education, while shorter diabetes duration (AOR = 0.78 for < 5 years and 0.78 for 5-9 years) and Eastern region (AOR = 0.66) were inversely associated with SMBG. For poor glycemic control, the only predictor was Eastern region (AOR = 1.55) compared to the Central region. Further analysis showed that region of residence, education, diabetes duration, and age were prominent predictors of all cognitive-perceptual and behavioral outcomes. The study suggested individualizing plan of care for diabetic patients due to disparity in the personal factors. The study supported the urgent change in the healthcare system to adapt healthcare professional team-based care. Finally, longitudinal studies at both national and regional levels are needed to determine the causal relationship focusing on both personal and psychological factors.

ACKNOWLEDGEMENTS

I would like to sincerely express my appreciation for the support I gained from several individuals who have contributed to my success in the doctoral program at Old Dominion University. First, I thank my advisor Dr. Qi Zhang (Harry) for his support and guidance throughout my journey in the doctoral program. I also had the privilege to work with him in several projects where he demonstrated passion, knowledge, and patience that was reflected positively on me. He is a valued mentor and colleague.

I would also like to thank my other committee members, Dr. Mishoe and Dr. Durgampudi, for their support and assistance during the dissertation process. Dr. Mishoe was kind enough to join the committee after a former member left the university. Her expertise in health administration and policy added value to the dissertation. Dr. Durgampudi for his epidemiological expertise that contributed to my understanding about diseases. All the committee members were always supportive.

I also extend my sincere gratitude to Dr. Benjamin, doctoral program director, for her guidance and support from the day I joined the program until my graduation. She was always available whenever I need assistance. I admire her leadership skills. I would also like to thank Dr. Elawad, Dr. Fatima, and Ms. Dala form the Ministry of Health for providing me with the SHIS data.

I must also express my appreciation to my family; my mother, Munirah, my father, Abdulrahman, and my sisters and brothers for their continuous support. A special thanks to my wife, Nourah, for the time, sacrifice, and care that she has given to me and our children. Her enduring patience and understanding have helped in achieving my goal. I also thank my little daughter, Lama, and son, Ibrahim, for bringing joy into my life.

LIST OF ABBREVIATIONS

ADA	American Diabetes Association
AOR	Adjusted odds ratio
APR	Adjusted prevalence ratio
BMI	Body Mass Index
CI	Confidence interval
DV	Dependent variable
FVC	Fruit and vegetable consumption
HAB	House activity barriers
HPSL	Healthcare professional support for lifestyle change
HPST	Healthcare professional support for treatment
IDF	International Diabetes Federation
IV	Independent variable
MHP	Multiple healthcare providers
MOH	Ministry of Health
OR	Odds ratio
PAB	Physical activity barriers
PHS	Perceived health status
PR	Prevalence ratio
RCV	Regular clinic visits
RVHP	Recent visit to health professional
SA	Saudi Arabia
SHIS	Saudi Health Interview Survey
SMBG	Self-monitoring of blood glucose
T2DM	Type 2 Diabetes Mellitus
VAB	Vigorous activity barriers
WHO	World Health Organization

TABLE OF CONTENTS

Page

LIST OF TABLES x

LIST OF FIGURES xi

Chapter

I. INTRODUCTION 1
   BACKGROUND 1
   STATEMENT OF THE PROBLEM 3
   THE HEALTH PROMOTION MODEL 4
   SIGNIFICANCE OF THE STUDY 8
   AIMS OF THE STUDY 10

II. SYSTEMATIC REVIEW OF THE LITERATURE 14
   INTRODUCTION 15
   METHOD 17
      LITERATURE SEARCH STRATEGY 17
      SELECTION CRITERIA FOR STUDIES 19
      SELECTION OF STUDIES AND DATA EXTRACTION 19
      QUALITY ASSESSMENT OF STUDIES 20
      STATISTICAL ANALYSIS 20
   RESULTS 21
      STUDY SELECTION 21
      QUALITY APPRAISAL 23
      PREVALENCE OF POOR GLYCEMIC CONTROL 23
      RISK FACTORS ASSOCIATED WITH GLYCEMIC CONTROL 25
   DISCUSSION 29

III. METHODOLOGY 34
   STUDY DESIGN 34
   DATA SOURCE 34
   SHIS INSTRUMENT 35
   STUDY POPULATION 36
   PROTECTION OF HUMAN SUBJECTS 36
   KEY STUDY VARIABLES 37
   STATISTICAL ANALYSIS 42

Chapter Page

IV. RESULTS 46
OVERVIEW OF T2DM STATUS IN SAUDI ARABIA 46
MISSING DATA AND MULTIPLE IMPUTATION 48
DESCRIPTIVE STATISTICS 52
BIVARIATE ANALYSIS 53
HYPOTHESIS AND MODEL TESTING 57

V. DISCUSSION 71
OVERVIEW OF THE PREVALENCE OF POOR GLYCEMIC CONTROL, PHYSICAL ACTIVITY, AND SMBG 71
OVERVIEW OF THE MAIN FINDINGS 74
LIMITATIONS 91
IMPLICATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH ..92

VI. CONCLUSIONS 94

REFERENCES 95

APPENDICES 125
A. DEFINITION OF TERMS INCLUDED IN THE STUDY 125
B. SUMMARY OF THE INCLUDED STUDIES RELATED TO POOR GLYCEMIC CONTROL AMONG T2DM INDIVIDUALS IN SAUDI ARABIA 126
C. QUALITY ASSESSMENT OF THE INCLUDED STUDIES IN ACCORDANCE WITH MODIFIED STROBE CHECKLIST 134
D. DETAILS OF THE MEASURES INCLUDED IN THE STUDY OBTAINED FROM THE SHIS MANUAL 136
E. EQUATIONS USED IN THE SAMPLING WEIGHTS FOR SHIS'S HOUSEHOLD AND LAB DATA 144
F. FLOWCHART OF THE PROCESS OF ANALYZING THE SHIS DATA DEVELOPED BY THE AUTHORS 145
G. NUMBERS AND PERCENTAGES OF MISSING VALUES IN EACH VARIABLE AND ARRANGED FROM HIGHEST TO LOWEST 146
H. CHARACTERISTICS OF MISSING DATA FOR DIABETES DURATION, INCOME, AND FAMILY HISTORY ACROSS SEVERAL PERSONAL FACTORS—PRESENTED IN PERCENTAGES 147
I. SEVERAL PERSONAL CHARACTERISTICS OF THOSE WITH MEASURED HBA1C 148
J. PERSONAL, COGNITIVE-PERCEPTUAL, AND BEHAVIORAL CHARACTERISTICS OF PHYSICAL ACTIVITY, SELF-MONITORING OF BLOOD GLUCOSE, AND GLYCEMIC CONTROL AMONG SAUDIS WITH T2DM 149

Page

K. CHARACTERISTICS, PREVALENCE RATIO, AND P VALUE FROM BIVARIATE ANALYSIS OF THE ASSOCIATION BETWEEN THE RISK FACTORS AND POOR GLYCEMIC CONTROL AMONG WOMEN AND MEN WITH T2DM 152

VITA 154

LIST OF TABLES

Table Page

II.1 Database Search Strategy for Poor Glycemic Control among T2DM Individuals in Saudi Arabia (Date of Last Search 11/08/2018)........ 18

II.2 List of Predictors Related to Poor Glycemic Control in T2DM from 19 Observational Studies........ 26

IV.1. Characteristics of Personal, Cognitive-perceptual, and Behavioral Factors in the Original and Completed Data 50

IV.2. Odds Ratio or Prevalence Ratio, 95% Cis, and P Values from Bivariate Analysis of The Association Between Risk Factors and Physical Activity, Self-Monitoring of Blood Glucose and Poor Glycemic Control Among Saudis with T2DM 54

IV.3. Adjusted Odds Ratio, 95% CIs, and P Values from Multivariate Analysis of The Association Between Personal, Cognitive-Perceptual Factors and Physical Activity Among Saudis with T2DM 59

IV.4. Adjusted Prevalence Ratio, 95% CIs, and P Values from Multivariate Analysis of the Association Between Personal, Cognitive-Perceptual Factors and Self-Monitoring of Blood Glucose Among Saudis with T2DM 61

IV.5. Adjusted Prevalence Ratio (APR), 95% CIs, and P Values from Multivariate Analysis of the Association Between Personal, Cognitive-Perceptual, Behavioral Factors and Poor Glycemic Control Among Saudis with T2DM........ 63

IV. 6. Prevalence Ratio (PR), 95% CI, and P Value from Bivariate Analysis of the Association Between Some Personal Factors and Both Psychological and Cognitive-Perceptual as Outcomes Among Saudis with T2DM........ 66

IV. 7. Prevalence Ratio (PR), 95% CI, and P Value from Bivariate Analysis of the Association Between Some Personal Factors and Both Behavioral and Obesity as Outcomes Among Saudis with T2DM 69

LIST OF FIGURES

Figure Page

I.1. Estimated Prevalence of Diabetes (a), Undiagnosed Diabetes (b), Deaths Due to Diabetes (c), and Cost of Diabetes (d) in Saudi Arabia for 2010-2017 According to IDF 2

I.2. Proposed Model for Risks Associated with Physical Activity, Self-Monitoring Blood Glucose, and Poor Glycemic Control Adapted from Pender's Health Promotion Model 13

II.1. Selection Process for Including Studies in the Systematic Review and Meta-Analysis in Accordance with PRSMA Flowchart 22

II.2. Pooled Prevalence of Poor Glycemic Control Among T2DM Population in Saudi Arabia - Metanalysis of 11 Cross-sectional Studies 24

IV.1. Distribution of Weighted Percentages for 808 Saudi Participants with T2DM Across 13 Administrative Regions in Saudi Arabia - Based on SHIS 2013 47

IV.2. Status of Poor Glycemic Control Among 391 Saudis with T2DM Participated in the Laboratory Test Module Across 13 Administrative Regions in Saudi Arabia - Based on SHIS 2013 48

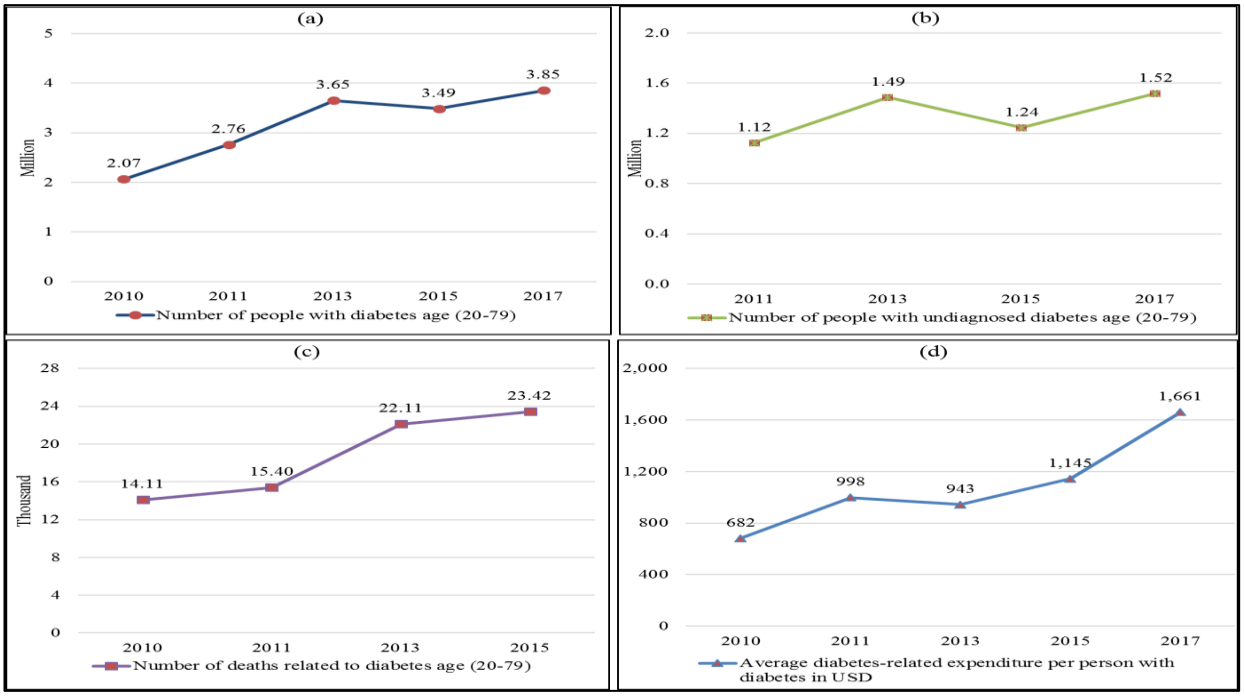
CHAPTER I

INTRODUCTION

Background

Diabetes is a non-communicable disease that causes a tremendous burden affecting millions of people worldwide, especially in the developing countries (see Appendix A for definitions and B for abbreviations). According to the International Diabetes Federation (IDF)[1] and the World Health Organization (WHO)[2], type 2 diabetes mellitus (T2DM) accounted for around nine-tenths of all diabetes cases. From 2010 to 2017, the prevalence of diabetes in Saudi Arabia (SA) had increased by 86 percent (see Figure I.1a) with an estimated 3.85 million people suffering from diabetes.[1,3-6] If this trend continues, the number of individuals with diabetes is expected to double by 2025. Also of importance is the fact that the IDF estimated that undiagnosed cases of diabetes had reached 1.5 million in 2017, a 35.7 percent increase since 2011 (see Figure I.1b).[1,4] In 2015, diabetes-related deaths accounted for 19 percent of 116,934 crude deaths, a 66 percent increase since 2010 (see Figure I.1c).[3,6] Thus, diabetes was ranked fourth as a leading cause of death in SA according to the Institute for Health Metrics and Evaluation (IHME).[7] The estimated cost of treating a Saudi diabetic person was $1,661 (see Figure I.1d) and the cost had significantly increased, almost tripling since 2010. The current economic burden of diabetes was estimated at $6.39 billion.[1]

Figure I.1. Estimated Prevalence of Diabetes (a), Undiagnosed Diabetes (b), Deaths Due to Diabetes (c), and Cost of Diabetes (d) in Saudi Arabia from 2010-2017 According to the International Diabetes Federation (IDF).[1]



With the alarming prevalence of diabetes in SA, the uncontrolled blood glucose levels among the diabetic population is another evolving issue. Several studies revealed a high prevalence—between 33 and 91 percent—of poor glycemic control among Saudi people diagnosed with diabetes. Among these studies, only six reported the prevalence of uncontrolled T2DM,[8-13] while the majority did not specify the type of diabetes—taking into consideration that the common type of diabetes is T2DM. The previous studies clearly indicated that a significant portion of the population with T2DM did not maintain their blood glucose at normal levels. In addition, people with poor glycemic control are typically at a higher risk of developing macro

[1] The Graph was created by the author and the data was retrieved from the International Diabetes Federation atlas for the years of 2010, 2011, 2013, 2015, and 2017 (IDF, 2010; 2011; 2013; 2015; 2017)[1,3-6]

and microvascular complications, including neuropathy, nephropathy, retinopathy, and heart-related diseases.[14-20]. Some studies found that among Saudi diabetic patients with poorly controlled blood glucose, many had microvascular complications related to neuropathy, retinopathy, nephropathy, and coronary heart disease.[21-24] Controlling blood glucose is critical in the prevention of microvascular complications and mortality.[25]

Statement of the Problem

Based on the prior studies, there was insufficient investigation into risk factors associated with health behaviors (e.g., physical activities and fruit and vegetable consumptions), diabetes management, and glycemic control in Saudi individuals with T2DM. Furthermore, there were several issues found in the existing literature examining the determinants of poor glycemic control in Saudis with T2DM. First, and most importantly, no study had investigated the risk factors related to health behaviors, diabetes management, and glycemic control at the national level in Saudis with T2DM. To illustrate, the current nationally representative studies had limitations, such as unspecified type of diabetes and the fact that the definition of poor glycemic control was not based on well-known diabetes standards.[26] Furthermore, there was a lack of statistical analysis (i.e., analyzing the relationship between predictors and outcomes).[11-12] In some studies, the focus was not on glycemic control as the primary outcome variable.[8,27] Additionally, studies vary in the type of measures used to determine glycemic control (i.e., Al-Rowais[28] used HbA1c as a measurement of glycemic control while Alzaheb et al.[10] used fasting blood glucose).

Second, cognitive-perceptual factors, such as perceived barriers and healthcare provider support, were inadequately investigated, while there was more attention placed on clinical (e.g., cholesterol levels) and personal factors (e.g., gender, age, and education) associated with both health behaviors and glycemic control.[8,13] Third, no study has implemented a theoretical model to provide a structural pathway to the association between the risk factors and the outcomes to strengthen and provide rigor to the findings. For instance, Alzaheb et al.,[10] Alsulaiman,[29] Al-Elq,[11] Al-Hussein,[12] and Guzu et al.[13] did not utilize a theoretical framework to examine the relationship between health behaviors and glycemic control outcomes. The value of utilizing theories is to predict, explain, and understand the relationship between the predictors and the outcomes in a meaningful approach (e.g., direct verses indirect association); thus, they guide and set a foundation for designing the hypotheses and methodology for addressing a health problem.[30]

Consequently, it was crucial to conduct a systematic review and meta-analysis to address some of the limitations of reported studies, focusing on the prevalence of poor glycemic control in Saudis with diagnosed T2DM. There have been no previous systematic review related to glycemic control in SA. In addition, it is important to apply a theoretical approach to examine the risk factors associated with health behaviors, diabetes management, and glycemic control, from a among Saudis diagnosed with T2DM. Overall, by addressing some of the limitations of prior studies this dissertation to focus on generalizability of findings and explore the cognitive-perceptual factors based upon a theoretical framework: Health Promotion Model.[31]

The Health Promotion Model (HPM)

From a terminology standpoint, health behavior has been widely used in the past three decades, which helped in shifting the focus from prevention of disease to promoting a better quality of life. [31] The HPM was empirically tested in the early 90s by Pender and colleagues[32]. The initial purpose of the model was to provide support to nurses in recognizing the determinants of health behaviors that could be fundamental for health promotion change at the individual level.[31] The foundation of this model was based on two well-established theories; The Expectancy Value Theory[33] and Social Cognition Theory[34], and was differentiated by excluding threat factors as a direct influence on health behaviors and support for self-actualization rather than health protection. [31]

The theoretical basis for the HPM model focuses on major concepts: individual characteristics and experience, behavior-specific cognitions and affect, and behavioral outcomes.[31] Individual characteristics and experience including prior behaviors asserts that there are differences among individuals and these differences influence their perceptions, beliefs, decisions, and actions. Commitment to engage in a behavior directly relies on an individual's perceived benefit. Oppositely, commitment to engage in a behavior can be restricted by perceived barriers which eventually affect the individual in performing the intend behavior. When the individual has greater perceived confidence in their ability, it will increase the possibilities of performing the behavior directly and indirectly through decreasing the perceived barriers.[31] Commitment to engage in and perform the intended behavior increases when the individual has a positive emotion, which also increases perceived confidence and vice versa. Social network including families, friends, and healthcare providers are source of influence, either positively or negatively, on the individual perception and belief toward the intended behavior. Also, in theory the individual who has low control over competing demands (e.g., work), the likelihood of performing the intended behavior will decrease. The individual has the capability to change perception, belief, and surrounding environment (physical or interpersonal) that initiate self-motivation toward healthy behavior.[31]

The HPM model has several constructs. The individual characteristics includes two main constructs: prior related behaviors and personal factors. Prior related behaviors according to

Pender et al.[31] is related to the individual recurring behavior that can be identified as a habit and this habit varies in its strength. The relationship between prior related behaviors and the intended behavior is suggested to be indirect through cognitive-perceptual factors (i.e., perceived barriers and benefits, self-efficacy, and related activity affect).[31] For example, self-efficacy is driven by prior behaviors that acts as a main source of information to determine the level of confidence in doing the intended behavior. Similarly, personal factors are part of the individual characteristics and experience. As previously mentioned, individuals are different from each other and these differences can be direct or indirect influence on the intended behavior. For instance, different people have different educational level, and this may directly affect their perception and therefore determine their engagement in healthy behaviors. Personal factors are psychological (e.g., perceived health status), sociocultural (e.g., education), and biological (e.g., gender). The importance of the personal factors varies according to the type of behavior.[31]

In addition, the HPM model has six measurable cognitive-perceptual constructs for changing individuals' behaviors to improve their health or manage their chronic diseases. The six constructs are perceived benefits of action, barriers to action, self-efficacy, activity-related affect, and interpersonal and situational influence.[31] Perceived benefits of action is defined as the expected benefits from performing a specific behavior. For example, a person might think that quitting smoking will save him/her some money. Perceived barriers to action is related to any perceived obstacle that may hinder a person from doing a specific behavior. For instance, longer time is taken to go to the gym or cost of taxi to go to the gym. Perceived self-efficacy is pertaining to what a person thinks about his/her skills or capabilities in performing a specific behavior. Activity-related affect is related to the feelings of the individual before, during and after performing a specific behavior, and can be positive or negative depending on the characteristic of the behavior. Interpersonal influences refer to other peoples' perception, belief, and behavior which may positively or negatively influence the individual perception. Social support and social norm are forms of interpersonal influences. Situational influences can be described as a perception of a given circumstances (e.g., stress) that allow or prevent from doing a specific behavior. Finally, these constructs are considered critical because they can be altered through intervention.[31]

There are three constructs related to the behavioral outcomes: immediate competing demands and preferences, commitment to plan of action, and health- promoting behavior. Immediate competing demands and preferences simply are factors that either under or out of control by an individual that may impact performing other behaviors. For example, competing demand such as working for longer hours, where a person has low control over his/her job, may prevent the person from performing other behaviors. Commitment to plan of action refers to the intention and planning toward performing a specific behavior and is considered the final step that leads to the specific behavior. Finally, the performance of the actual health behavior and the results associated with it. Therefore, the HPM model was created to support people to have better maintenance of their health.[31]

According to Pender et al.[31] individuals have a crucial role in maintaining their own health and behaviors; therefore, the HPM provides several assumptions. First, behavioral change requires individual initiative to manage and control behaviors proactively. Second, how much someone values their own health is a predictor of behavior. Third, individuals are capable of being self-assured, which involves assessing their own skills. Fourth, individuals, with their unique and complex characteristics, interact with the environment, and both change each other throughout time. Finally, as a part of the interpersonal influences, health professionals have impact on individuals' outcomes over the course of their lives. These assumptions guide both people with diseases and healthcare professionals in gaining more knowledge about what factors drive health behaviors.

The HPM has been adapted in health research to investigate several health issues and evaluate health promotion programs. For example, the HPM model has been applied to studies of exercise and diet among adolescents and adults with chronic disease and injury,[35-39] and to specifically assess healthy behaviors in people with diabetes.[40-44] Shin et al.[45] applied the constructs of the HPM to identify factors associated with promotional behaviors (e.g., physical activity, nutrition spiritual growth, and stress management) among elderly women with low income in Korea and were able to develop a statistical model that was able to explain more than 70 percent of the variance.

This dissertation will focus on predicting physical activity, self-monitoring of blood glucose, and glycemic control among people with T2DM guided by Pender's health promotion model.[31] The model will help in establishing a foundation for and explaining the association between personal, cognitive-perceptual, and behavioral factors with the outcomes among Saudi diabetic individuals. Since the study uses a secondary data (SHIS), several variables in the HPM model will not be tested due to unavailability of the data. The excluded variables from the study are perceived benefits of action, perceived self-efficacy, activity related affect, situational influence, immediate competing demands and preferences, and commitment to plan of action.

Significance of the Study

There were several innovative aspects of the dissertation. First, this study used nationally representative data so that the findings can be generalized, to and give a true inference about the entire population of Saudi Arabia. Thus, this was the first-known study that explored the issue of

T2DM at a national level in SA. Second, the study followed international standards in defining outcomes (i.e., glycemic control and physical activity follows American Diabetes Association [ADA][46-47] standards). Following international standards increases the precision and credibility of the findings. Third, the dissertation used the theoretical framework (HPM) as a guide to conduct the study, through data collection, analysis and interpretation. The model improves thoroughness and adds value in understanding the link between variables and outcomes.[48,49] Which eventually inform healthcare providers of the importance of considering such factors in their treatment plan for diabetic patients.

Fourth, the study had included specific cognitive-perceptual factors (e.g., perceived barrier and health provider support) that the previous studies did not adequately address. The perceived barriers and health provider support factors may increase our understanding of the cognitive-perceptual aspects of Saudi individuals with T2DM. Therefore, health care providers could be expected to take into consideration these cognitive factors when treating diabetic patients. From a cost-effectiveness perspective, it may help in designing appropriate intervention programs considering these factors prior to or in line with treatment of hyperglycemia. Certainly, the study was the first known in using the HPM to examine the variables among the targeted population. Finally, the majority of diabetic patients were classified as T2DM. The WHO[2] indicated that T2DM is the dominant type of diabetes, affecting millions of people around the world. In Saudi Arabia, Alotaibi[50] showed that the number of T2DM patients was dramatically growing. In addition, it is known that T2DM can be avoided, in the majority of the cases, by maintaining a healthy lifestyle, such as exercising and eating healthy foods.[51] Therefore, the unique aspect of this project will focus on the type 2 diabetic patients that represent the largest portion of all diabetic cases in SA. Generally, all aspects mentioned above may contribute to the quality and trustworthiness of the overall outcome of this study.

The overall objective of this proposed study was to understand personal and cognitive-perceptual predictors' concomitant with health behavior, diabetes management, and poor glycemic control in Saudis with diagnosed T2DM, utilizing the Health Promotion Model (HPM) as a conceptual framework. The rationale was to provide comprehensive knowledge about T2DM by closing the gap in the current literature where limited attention has been given to several crucial aspects related to poor glycemic control. These were individuals' cognitive-perceptual factors, assessment of the healthy behaviors and poor glycemic control in people with T2DM at a national level, lack of a clear definition of glycemic control that follows international standards, and a theoretical approach to precisely guide in explaining the current burden of healthy behaviors and glycemic control in Saudis with diagnosed T2DM.

Aims of the Study

Aim 1. To explore the association between personal factors (psychological, biological, and sociocultural), perceived activity barriers (vigorous, house, and physical), and healthcare provider support (treatment, lifestyle change, and multiple healthcare providers) and physical activity (DV) among Saudis diagnosed with T2DM (see Figure I.2). Several studies showed physically active individuals with T2DM tended to be younger in age,[52-57] men,[54,57-58] had higher education,[54-55,57] had high income,[54-55,57,59] had normal weight,[54-55] had good perceived health,[55-56] had lack of social support including health providers,[53-54,56,60] and had low activity barriers[53,61,62,57]. Therefore, the following hypotheses are proposed.

Hypothesis ($H_{1.1}$): Younger individuals, men, higher education, high income, not obese and perceived good health will be significantly associated with physical activity.

Hypothesis ($H_{1.2}$): Low vigorous activity barriers (VAB), low house activity barriers (HAB), low physical activity barriers (PAB), and health professional support for lifestyle change (HPSL) will be significantly associated with physical activity after controlling for personal factors.

Aim 2. To examine the relationship between personal factors, perceived activity barriers, healthcare provider support and self-monitoring of blood glucose (SMBG) (DV) among Saudis diagnosed with T2DM (see Figure I.2). Studies found that younger men [63-67] with higher education,[8,65-66,68-71] longer duration of diabetes,[66,70-73] had support for treatment,[65,69] and had multiple health providers[74-75] strong predictors of SMBG. Therefore, the following hypotheses are proposed.

Hypothesis ($H_{2.1}$): Younger individuals, men, higher education, and longer duration of diabetes will be significantly associated with SMBG.

Hypothesis ($H_{2.2}$): Health professional support for treatment (HPST) and MHP will have significant association with SMBG after controlling for personal factors.

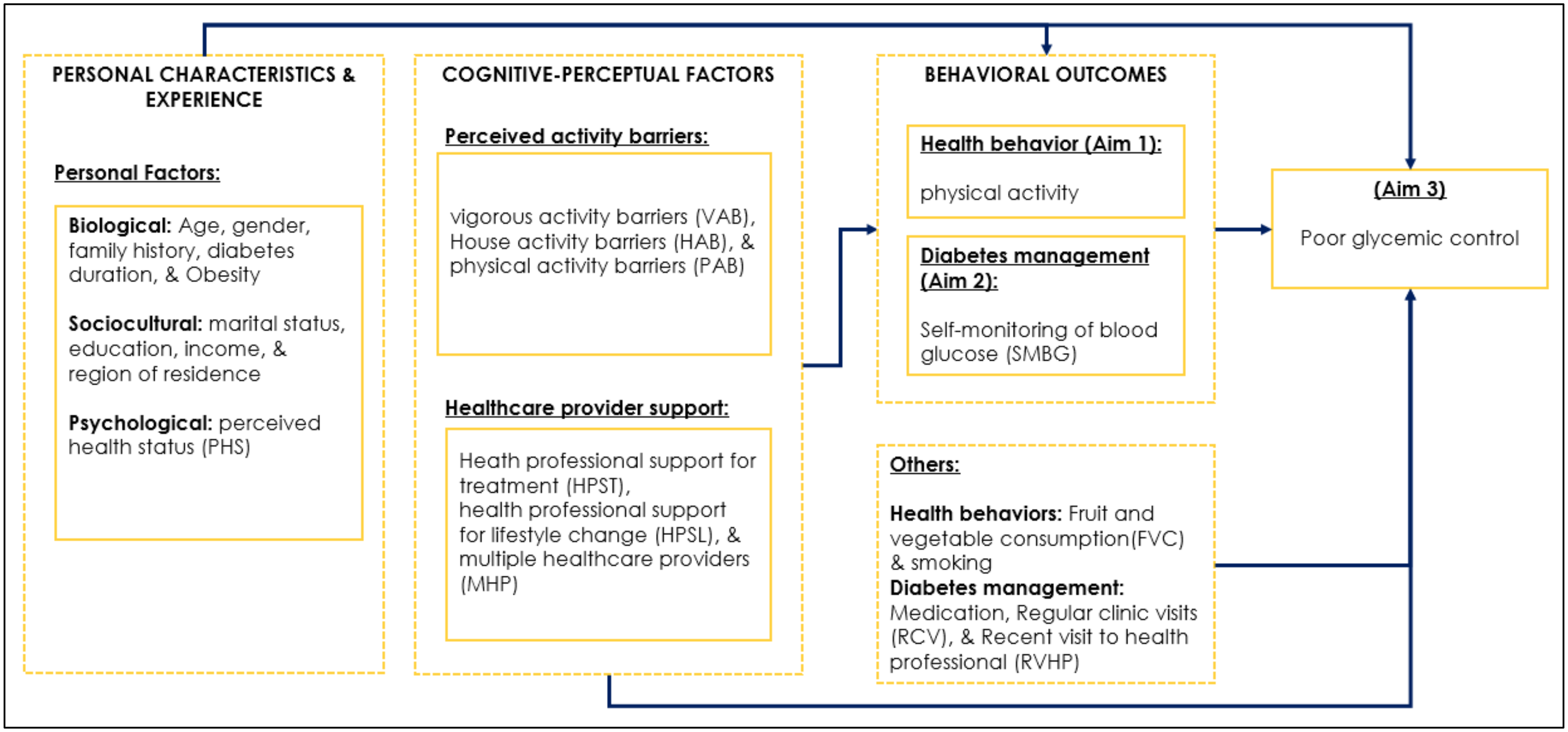
Aim 3. To investigate the association between personal factors, perceived activity barriers, healthcare provider support, health behaviors, diabetes management, and poor glycemic control (DV) among people diagnosed with T2DM in Saudi Arabia (see Figure I.2). Studies revealed that younger age,[76-77] women,[27,78] low education,[77-78] poor perceived health,[79-80] obesity,[10,77,81] longer diabetes duration,[10,76-77,82-83] perceived barriers,[84-86] health professional support,[87-88] physical inactivity,[10,76,81] poor diet,[10,76-77,81,89] smoking,[77,90,91] low adherence to SMBG,[10,76,81] and no adherence to medication [81,92] were related to poor glycemic control. Thus, the following hypotheses were proposed.

Hypothesis ($H_{3.1}$): Younger individuals, women, low education, perceived poor health, obese, and longer diabetes duration will be significantly associated with poor glycemic control.

Hypothesis ($H_{3.2}$): High VAB, High HAB, High PAB, no HPST, no HPSL, and no MHP will be significantly associated with poor glycemic control after controlling for personal factors.

Hypothesis ($H_{3.3}$): Not using medication, not physically active, inadequate fruit and vegetable consumption, smoker, no SMBG, no regular clinic visits (RCV), and no recent visit to a health professional (RVHP) will be significantly related to poor glycemic control after adjusting for personal factors, perceived activity barriers, and healthcare provider support.

Figure I.2. Proposed Model for Risks Associated with Physical Activity, Self-Monitoring Blood Glucose, and Poor Glycemic Control Adapted from Pender's Health Promotion Model.[31]



CHAPTER II

REVIEW OF THE LITERATURE

The study aimed to use meta-analysis to estimate the prevalence of poor glycemic control among type 2 diabetes mellitus (T2DM) patients and to conduct a systematic review of its associated risk factors in Saudi Arabia (SA). We followed the PRISMA flowchart and searched, from May to November 2018, the Scopus, PubMed, PsycINFO, Web of Science, and CINAHL Plus databases. The main search terms were T2DM, glycemic control, and SA. The inclusion criteria were: observational studies conducted in T2DM patients in SA; with reported prevalence or/and personal, psychological or behavioral predictors; and published after 2005. Articles were assessed by using a modified STROBE tool. Studies included in the meta-analysis defined uncontrolled T2DM as HbA1c ≥ 7% (53 mmol/mol), and reported results were based on a random effects model. Nineteen articles met the inclusion criteria comprised of three retrospective cohort studies, one case-control study, and 15 cross-sectional studies. The quality of the studies varied based on the application of The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist as high (3 studies), moderate (7 studies), and low (9 studies). The pooled prevalence of uncontrolled T2DM in SA was 77.7%, with a 95% confidence interval [CI]:71.2%, 84.2%. In these studies, the most consistent predictors related to poor glycemic control included diabetes duration, treatment modality, self-efficacy, fruits and vegetables intake, diet, SMBG, and treatment settings. This meta-analysis further documents the poor glycemic control among Saudi diabetic patients is prevalent, as documented in the meta-analysis. More high-quality studies and national data are needed to estimate this prevalence more accurately. Future studies should address the psychological and behavioral factors related to poor glycemic control in SA.

PROJECT: A META-ANALYSIS OF UNCONTROLLED T2DM AND A SYSTEMATIC REVIEW OF ITS DETERMINANTS IN SAUDI ARABIA

Introduction

Of the more than 400 million adults living with diabetes worldwide, three-fourths of them live in low-to-middle income countries.[1,93] The global diabetic population could increase by 48 percent by 2045, if the current trend continues.[1] In addition, according to the International Diabetes Federation (IDF), the global estimates of cases of prediabetes and undiagnosed diabetes in the world's population are 352 and 212 million, respectively.[1] Diabetes does not occur suddenly; specifically, in type 2 diabetes mellitus (T2DM) cases, it is suggested that the onset of insulin resistance may start at an early age, creating a higher risk of diabetes development.[94-95] If left undiagnosed for too long, T2DM may lead to the progressive damage of bodily organs.[96-97]

In addition to the genetic factors associated with diabetes, other factors play vital role in the development of diabetes, including personal factors such as age, gender, and education; psychological factors such as depression and anxiety; behavioral factors such as smoking, diet, and physical activity; and environmental factors, such as access to healthcare services.[98-107] The consequences of untreated diabetes are drastic, since diabetes is one of the top ten leading causes of disability and mortality.[7,82,108] Complications from diabetes can lead to microvascular and macrovascular diseases, with the estimated global health expenditure for diabetes reaching over $700 billion in 2017.[1,109-113]

The rate of diabetes in Saudi Arabia (SA) has significantly increased in the last decade. In 2010, the total diabetic population was 2.1 million, and by 2017 it had reached 3.85 million, an 86 percent increase.[1,3] If the upward trend in diabetes prevalence remains, the total diabetic population is expected to reach six million by 2025. In addition, the number of undiagnosed diabetes cases was estimated to be 1.5 million, and the number of annual deaths caused by diabetes-related complications in 2017 had grown to 14,665.[1] Cerebrovascular disease, foot ulcers, myocardial infarctions, renal failure, retinopathy, and neuropathy were found to be the most common diseases associated with diabetes in SA, while the complications, including retinopathy, nephropathy, and macrovascular diseases, were often found to lead to mortality in SA.[24,26,114-116] In 2017, the diabetes-associated cost in SA was estimated to exceed $1,661 per capita annually.[1]

Despite the fact that there has been an increase in the prevalence of diabetes cases in SA, there continues to be a lack of attention to glycemic control for those who are diagnosed with T2DM.[11] According to the American Diabetes Association (ADA), the ideal glycemic control is defined as glycated hemoglobin (HbA1c) < 7% (53 mmol/mol) for adults, excluding pregnant women.[46] While it is known that T2DM is the most common type of diabetes, and that it can be prevented through lifestyle changes, several studies have shown a high rate of comorbidities among those in SA with T2DM, despite the fact that around 80 percent of the Saudi population is under the age of 45.[21,23,117-118]

Saudi Arabia's ability to understand the prevalence of uncontrolled T2DM and its determinants will provide a basis for the government's intervention to reduce the burden of diabetes. At present, there is no national data available that estimates the prevalence of uncontrolled T2DM annually. In addition, there is no systematic review of the factors that contribute to the poor glycemic control among T2DM patients in SA. Therefore, the objective of this study is to estimate the prevalence of uncontrolled T2DM and to identify personal, psychological, and behavioral risk factors for poor glycemic control in T2DM in SA.

Methods

Literature Search Strategy

A systematic literature search was developed and conducted by utilizing the following databases: CINAHL Plus, PsycINFO, Web of Science, Scopus, and PubMed. The search focused on three main concepts: glycemic control, type 2 diabetes mellitus, and Saudi Arabia, according to the objective of the systematic review. Synonyms were carefully identified via the Medical Subject Headings (MeSH) vocabulary, were used in the search to extract related studies, and were separated by Boolean operators (OR and AND). The terms were “diabetes mellitus, type 2” subject heading (SH) OR “hyperglycemia” (SH) OR “type 2 diabetes” OR “Noninsulin-Dependent” OR “NIDDM” OR “non insulin dependent” OR “non-insulin-dependent” OR “insulin resistance” OR “type II diabetes” OR “T2DM” OR “T2D” AND “glycemic control” OR “diabetic control” OR “glucose” OR “blood sugar” OR “Glycated Hemoglobin” OR “hemoglobin A1c” OR “Hb A1c” OR “HbA1c” OR “A1c” AND “Saudi” OR “KSA.” The search was restricted to the title and abstract. In addition, a search technique was utilized in each database to break down the search into two steps: terms with OR were searched separately and then were combined with AND (see Table II.1). The searching began on May 10, 2018 and ended on November 8, 2018. Results from the studies were summarized (see Appendix B). If blood glucose was measured with more than one test, only one test was presented in the summary, and priority was given for HbA1c test as a criterion standard.[119]

Table II.1. Database Search Strategy for Poor Glycemic Control among T2DM Individuals in Saudi Arabia (date of last search 11/08/2018).

Search no.	Search Terms	CINAHL Plus	PsycINFO	Web of Science	Scopus	PubMed	Total
S1	"diabetes mellitus, type 2" OR "hyperglycemia" OR "type 2 diabetes" OR "Noninsulin-Dependent" OR "NIDDM" OR "non insulin dependent" OR "non-insulin-dependent" OR "insulin resistance" OR "type II diabetes" OR "T2DM" OR "T2D"	55,076	11,168	292,592	372,090	201,273	932,199
S2	"glycemic control" OR "diabetic control" OR "glucose" OR "blood sugar" OR "Glycated Hemoglobin" OR "hemoglobin A1c" OR "Hb A1c" OR "HbA1c" OR "A1c"	61,480	19,716	565,187	857,977	469,965	1,974,325
S3	"Saudi" OR "KSA"	3,873	4,115	31,379	52,036	17,107	108,510
S4	“S1” AND “S2” AND “S3” with filter (date 2005-2018)	32	12	267	358	194	863

Selection Criteria for Studies

All relevant studies were selected if they: (1) reported prevalence and/or examined personal, psychological, or behavioral risk factors associated with glycemic control; (2) were conducted in SA on a population diagnosed with T2DM; (3) were observational studies (e.g., cross-sectional, case-control, and retrospective/prospective cohort); and (4) were published in peer-reviewed journals and in English. Studies were excluded if any of the following criteria were met: (1) the study focused on other types of diabetes (e.g., type 1 and gestational diabetes); (2) there was a specific study population, such as admitted patients or patients who had specific comorbidity; (3) the study reported only genetic, biochemical (e.g., vitamins, medication, serum), and environmental pollution (e.g., chemical and radiation) risk factors; (4) the study also excluded other types of publications, including intervention (e.g., RCT), qualitative, review, pilot studies, letters, commentaries, abstract, dissertation, and editorials; and (5) the study was published before 2005. The reasons for restricting the data search to 2005 and after is to address the issue of uncontrolled diabetes during the past decade and to ensure both that the search yielded enough articles for inclusion and that the articles maintained relevance to the current state of glycemic control in SA.[120] Cross-sectional studies that followed the ADA standards of adequate glycemic control, HbA1c < 7% (53 mmol/mol) for nonpregnant adults, or partially followed ADA standards but failed to report pregnant women were included in the quantitative data synthesis of prevalence (meta-analysis) in this study.[46]

Selection of Studies and Data Extraction

The articles selected from the databases were transferred into Microsoft Excel (Office 365) for analysis, including author, year of publication, title, and abstract. Two researchers (M.A. and S.A.) independently searched the databases, screened the titles and abstracts for eligibility, and reviewed the full texts to determine which articles would be included. In cases in which agreement of selection of any study could not be reached between the independent researchers applying the inclusion criteria, a third researcher (Q.Z.) made the final decision. The study followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flowchart as a guide for proper selection of the relevant articles.[121]

Quality Assessment of Studies

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist was used to assess the quality of the included articles.[122] The tool had 22 items, including items such as an abstract which were deemed unnecessary in the assessment of the studies. Therefore, we followed a modified version, using only 15 of the items that were crucial in the assessment process.[123] Each study yielded a score ranging from one to 15 that was presented in percentages. The quality level of the studies was classified into low (< 60%), moderate (60 - 79%), and high (≥ 80%).[123] Two independent researchers, (M.A.) and (S.A.), evaluated the included studies and met to compare and to discuss them. Disagreements between the two researchers were settled by the third researcher (Q.Z.).

Statistical Analysis

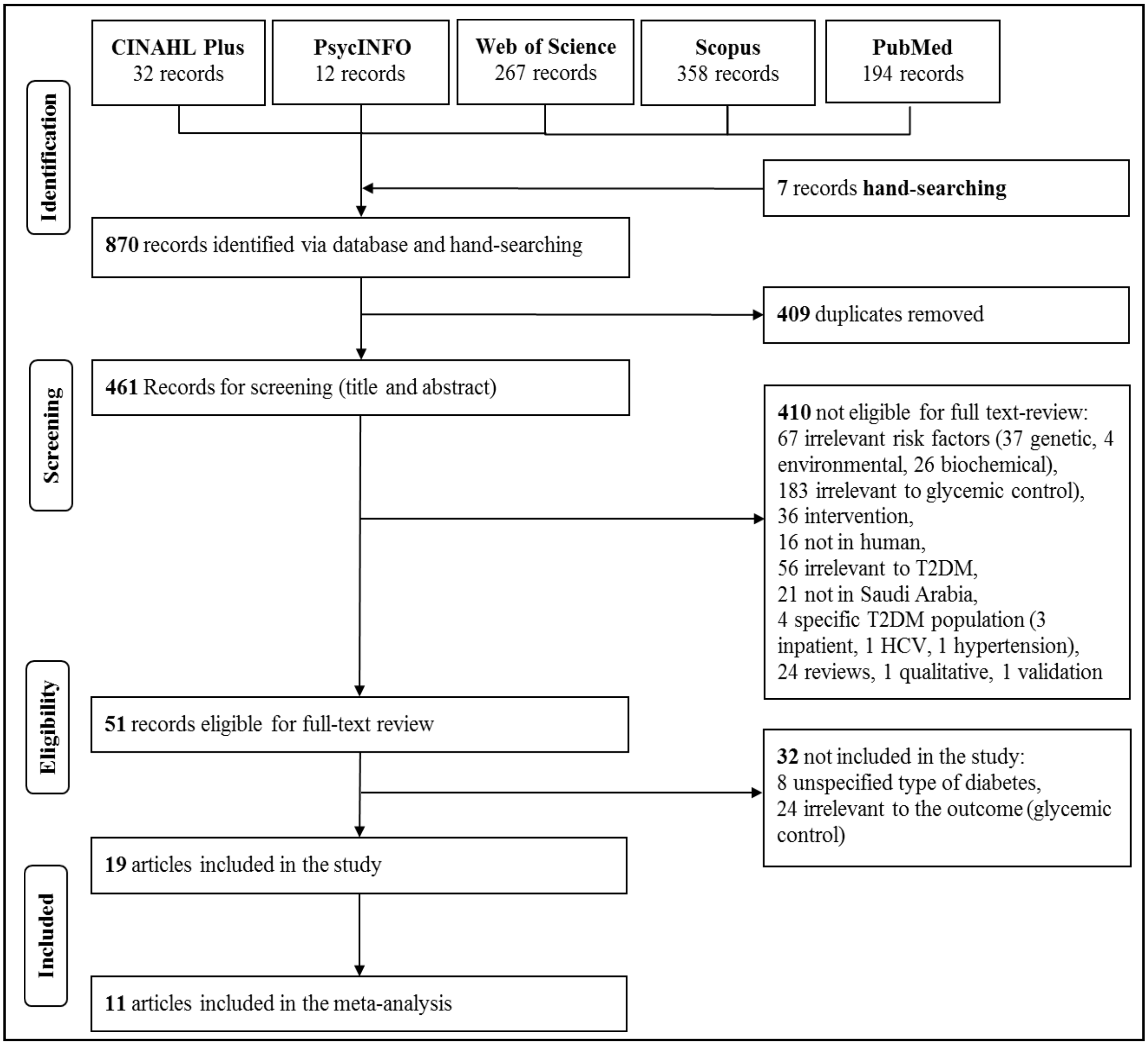
The study included a meta-analysis in order to report the pooled prevalence of uncontrolled T2DM patients in SA. A random effects model was applied by using a customized Microsoft Excel spreadsheet developed by Neyeloff et al.[124] A heterogeneity test (I^2) was conducted to determine the percentage of inconsistency between studies, where heterogeneity was considered high at ≥ 75%, moderate at 50%, and low at 25%.[125] The results were presented in a forest plot.[84]

Results

Study Selection

The search yielded 870 articles (32 CINAHL, 12 PsycINFO, 267 Web of Science, 358 Scopus, 194 PubMed, and 7 hand-searching), 409 of which were found to be duplicates. A total of 461 articles were screened for eligibility, and only 51 were determined to be eligible, as shown in Figure II.1. The reasons for the exclusion of articles (N = 410) included 67 irrelevant risk factors (67 articles: genetic factors, 37; environmental factors, 4; and biochemical factors, 26), 183 irrelevant to glycemic control, 36 intervention studies, 16 studies which subjects were not human, 56 studies irrelevant to T2DM, 21 studies not in SA, 4 narrowly-defined T2DM population (three studies involving inpatient, one study targeting patients with hepatitis C virus, and one study targeting hypertension), 24 review articles, one qualitative study, and one instrument validation. Among the 51 eligible studies, only 19 were included in the systematic review. The excluded studies included eight studies discussing an unspecified type of diabetes and 24 studies found to be irrelevant to the glycemic control. The search yielded 15 cross-sectional studies, [9-13, 27,76-78,81,83,89,126-128] three retrospective cohort studies,[129-131] and one case-control study,[132] as summarized in Appendix B. Furthermore, 11 cross-sectional studies were included in the meta-analysis that highlighted prevalence of poor glycemic control in SA, based on the inclusion criteria.

Figure II.1. Selection Process for Including Studies in the Systematic Review and Meta-analysis of Prevalence in Accordance with PRSMA Flowchart.



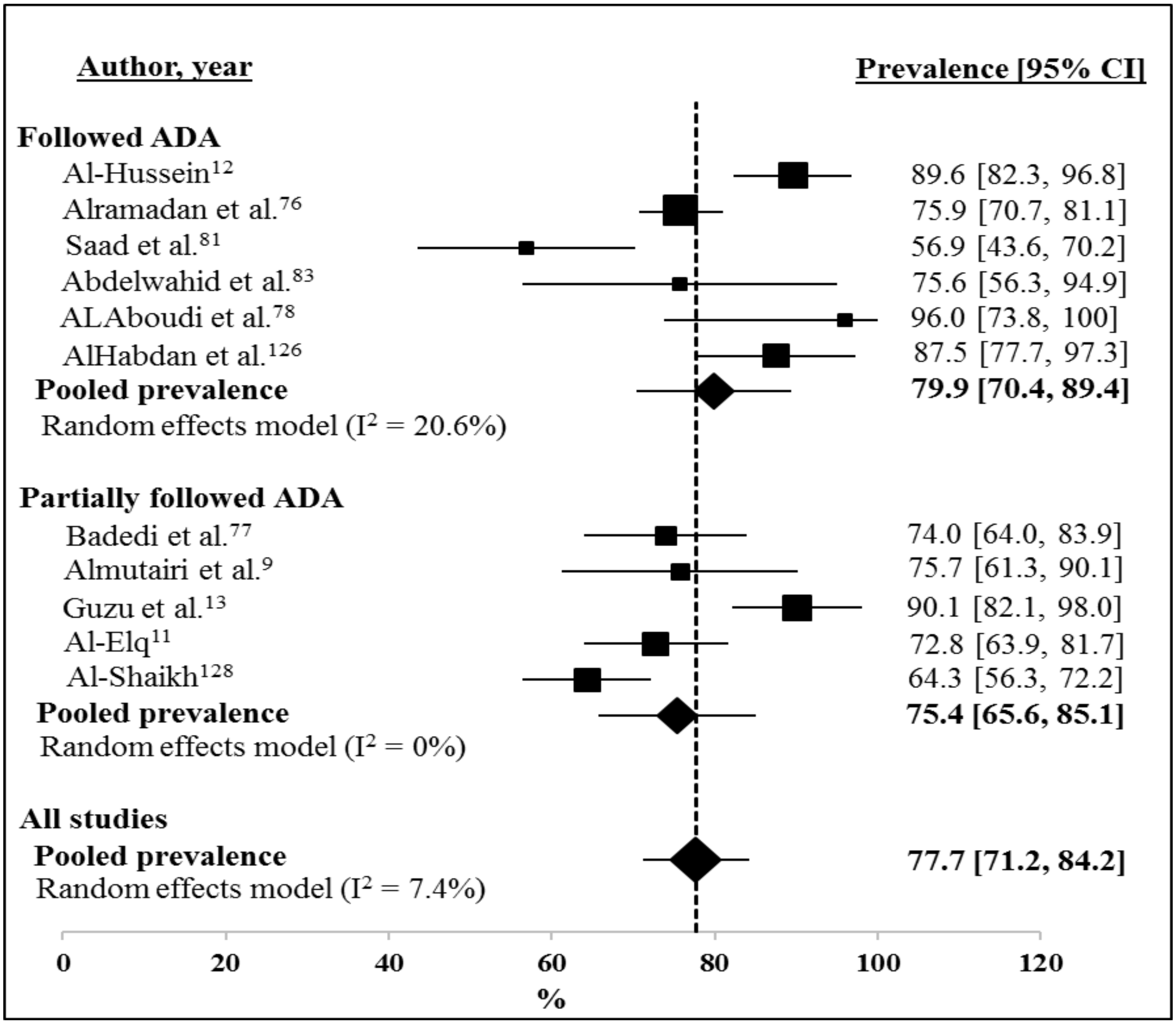
Quality Appraisal

The authors (M.A. & S.A.) agreed on 94% of the studies out of 285 evaluated items; any disagreements were settled after discussion. The results of the assessment revealed that there were nine low,[9,12,27,77,128-132] seven moderate,[13,78,81,83,89,127-128] and three high quality studies[10-11,76] to be considered. In addition, the studies' scores ranged from 3 (20%) to 13 (86%), with a median score of 9 (60%), as presented in Appendix C.

Prevalence of Poor Glycemic Control

The meta-analysis showed that the overall pooled prevalence of poor glycemic control among individuals with T2DM in SA was 77.7 % (95% confidence interval [CI]:71.2%, 84.2%) after applying the random effects model (see Figure 2). The I^2 was 7.4%, which indicated low heterogeneity. Further subgroup analysis was conducted according to the ADA criteria. The pooled prevalence of the studies that completely and partially followed ADA were 79.9% (95% CI: 70.4%, 89.4%) and 75.4% (95% CI: 65.6%, 85.1%), respectively. Moreover, the pooled mean age (standard deviation) of the sample studies included (one study did not report age) in the study was 54.2 years (SD = 4.3 years).

Figure II.2. Pooled Prevalence of Poor Glycemic Control among Saudis with T2DM - Metanalysis of 11 Cross-sectional Studies.



ADA = American Diabetes Association.

Risk Factors Associated with Poor Glycemic Control.

The results of this systematic review about the risk factors associated with poor glycemic control were presented in Table II.2 and Appendix B. These included personal, psychological, and behavioral factors. Among the personal factors, younger age groups (46-60 and <46 years) were more likely to have poor glycemic control compared to older age groups (>60 years) (OR = 1.9, 95% CI [1.3, 2.8]) and (OR = 3.1, 95% CI [1.7, 5.5]), respectively.[76] Badedi et al.[77] also found that, based on a bivariate analysis, younger diabetic patients (ages 28-49) had a higher mean HbA1c (mean = 9) compared to older patients in 50-64 years (mean = 8.7) and 64-83 (mean = 7.7) with *P*-value equal to .011.

Gender was also addressed in 11 studies of glycemic control in persons having.[9-10,12,27,76-78,81,83,127,130] Alaboudi et al.[78] reported that men showed a significantly lower median value of HbA1c (median = 9.04) compared to women (median = 10.01) with *P*-value equal to .005. Similarly, Habib[27] investigated 1,000 participants and found that men had lower mean (SD) HbA1c, 9.1 (3.3), compared to women, 9.6 (2.8) with *P*-value equal to .0075. In contrast, Alsulaiman et al.[127] conducted a study with a large sample size of patients with T2DM (n = 1,632) and found that men were 1.4 times more likely to have poor glycemic control compared to women (95% CI [1.2, 1.8]).

The association between education and HbA1c was examined in seven studies. Of these, one study showed that participants with low education ($\beta = -0.38$) were associated with having higher blood glucose levels.[78] In addition, one study indicated that education had a strong negative association with the mean HbA1c ($P = .032$).[77] However, there was no post-hoc analysis to determine the differences among the sub-categories (e.g., illiterate, read and write, elementary, intermediate, secondary, and university).

TABLE II.2. List of Predictors Related to Poor Glycemic Control in T2DM from 19 Observational Studies.

	Predictor	N studies	Statistically significant association			
			n studies	Direction of association		n studies accounted for cofounders
				Positive (+)	Negative (-)	
Personal	Age	10	2	0	2	1
	Gender	11	3	NA	NA	0
	Education	7	2	0	2	1
	Income	4	0	-	-	-
	marital status	5	1	NA	NA	0
	Employment status	6	1	NA	NA	0
	Diabetes duration	7	6	6	0	5
	Family history	4	2	2	0	2
	Location of residence	3	2	NA	NA	1
	Treatment settings	5	3	NA	NA	0
	Waist-hip ratio	1	1	1	0	0
	BMI	7	3	3	0	1
	Physical health	1	1	0	1	0
	Hypoglycemia events	1	1	0	1	1
	EDS	1	0	-	-	-
Psychological	Family support	2	1	0	1	0
	Physician-patient relationship	1	1	0	1	0
	HbA1c Awareness, knowledge, & education	4	2	0	2	1
	Self-efficacy	3	3	0	3	2
	Anxiety	2	0	-	-	-
	Depression	3	1	1	0	0
	Stress	1	1	1	0	0
	Cognitive function	1	0	-	-	-
Behavioral	Physical activity	6	3	0	3	2
	Sedentary lifestyle	1	0	-	-	-
	Diet	5	3	NA	NA	1
	Fruits & vegetables intake	2	2	1	1	1
	SMBG	5	3	1	2	0
	Smoking	4	1	1	0	0
	Medication adherence	4	1	0	1	1
	Treatment modality	8	6	NA	NA	3
	Follow-up visits	2	0	-	-	-
	foot care	2	1	0	1	1

N = total number of studies examined each predictor; NA = not applicable; EDS = excessive daytime sleepiness; SMBG = self-monitoring of blood glucose.

Diabetes duration was considered a crucial factor in relation to glycemic control. Alramadan et al.[76] found that those with a diabetes duration of greater than ten years were 1.9 times more likely to have poor glycemic control compared to those with less than or equal to ten years (95% CI [1.4, 2.8]). Alzaheb et al.[10] reported that patient groups with a diabetes duration of 5 to 10 years and those with greater than 10 years were 2.3 and 5.2 times more likely to have poor glycemic control, compared to patients with fewer than five years' duration (95% CIs [1.1, 4.8], [2.5, 10.7] respectively). Abdelwahid et al.[83] applied a multiple regression model and found that an increase in diabetes duration was related to an increase in HbA1c level ($\beta = 0.06$, $P = .019$). Another study similarly found that an increase in diabetes duration was associated with increased HbA1c level ($\beta = 0.31$, $P < .05$).[78] Badedi et al.[77] showed that patients with diabetes duration of greater than or equal to seven years had higher mean HbA1c ($M = 9.1$) compared to patients with diabetes duration less than seven years ($M = 7.5$), $P < .001$.

Body mass index (BMI) was examined in several studies, of which three established correlation with glycemic control. One study indicated that obesity (AOR = 5.4, 95% CI [2.7, 12.6]), and being overweight (AOR = 3.8, 95% CI [2, 7.2]) were associated with poor glycemic control, compared to being of normal weight, after adjusting for self-monitoring of blood glucose (SMBG), diet, exercise, diabetes duration, and family history of diabetes.[10] Another study found BMI to be positively associated with mean HbA1c ($P = .01$); obese individuals had higher HbA1c levels compared to those who were overweight, of normal weight, and under-weight.[77] A third study had also confirmed the same findings: that BMI was positively associated with glycemic control.[81]

Treatment settings were also reported in five studies.[76,83,126,128,131] Higher proportions of poor glycemic control were reported among individuals who visited primary health care or diabetes centers, compared to those who visited hospitals ($P = .019$).[76] A retrospective cohort study compared two treatment settings and found that patients who visited diabetes centers had a higher mean HbA1c, compared to those who visited primary healthcare centers (PHCC) for all five follow-up visits ($P < .05$).[131] Al-Shaikh[128] revealed that the percentage of patients with T2DM treated in a private hospital with HbA1c < 7% was significantly higher (58.5%) than the percentage of those treated in government-run hospitals (11.5%). Moreover, two studies found that diabetic patients with family history of diabetes were more likely to have poor glycemic control compared to those with no family history with OR, at 7.3 and 3.4, according to Alzaheb et al.[10] and Almutairi et al.[9], respectively.

Location of residence was also found to be an independent predictor of poor glycemic control; the odds of poor glycemic control for patients living in a remote location were 3.2, compared to those of urban patients (95% CI [1.2, 8.6]).[76] In contrast, people living in urban areas were 2.1 times more likely to have poor glycemic control compared to urban (95% CI [1.3, 3.4]), although the relationship between residence and the glycemic control was not significant in their adjusted model.[10] One study showed that marital status was associated with HbA1c, indicating that divorced individuals had higher mean of HbA1c compared to single, widowed, and married, $P = .005$.[77]

Few psychological factors were examined in the included studies. The psychological factors examined included self-efficacy, self-confidence, depression and stress. Self-efficacy related to blood sugar monitoring was negatively associated with HbA1c levels ($\beta = -0.4$, $P < .05$).[78] Badedi et al.[77] showed that patients who lacked confidence in managing self-care behaviors were more prone to have poor glycemic control, compared to those who could perform self-care with confidence (OR = 4, 95% CI [1.5, 10.6]). Saad et al.[81] reported the same findings.

In addition, one study found that depression and stress were associated with higher HbA1c ($P < .001$).[77]

The relationship between behavioral risk factors and glycemic control were reported in three studies that revealed a negative association between physical activity and HbA1c.[10,76,81] Moreover, an unhealthy diet was shown to be a strong predictor in poor glycemic control.[10,76-77,81,89] The use of oral medication as the treatment modality was significantly associated with glycemic control, compared to the use of insulin.[9,76,78,81,89] Additionally, low self-monitoring of blood glucose levels was significantly related to poor glycemic control.[10,76,81]

Overall, there were 32 risk factors identified in the study (i.e., 14 personal, eight psychological, and ten behavioral risk factors) (see Table II.2). No studies that examined income, anxiety, cognitive function, sedentary lifestyle, and follow-up visits found an association with HbA1c.[9-10,12,76,81,126,132] On the other hand, all the other variables were associated with HbA1c. The studies' findings varied from one variable to another in terms of the number of studies that investigated individual variables and the number that established associations between independent and outcome variables. In addition, the measured outcome differed across all the studies, where some studies used HbA1c as a continuous variable and others as used it as categorical (e.g., controlled vs. uncontrolled HbA1c).

Discussion

Despite the variation in the definitions of poor glycemic control, a robust estimate of the prevalence of uncontrolled diabetes in SA, which is similar to the prevalence in neighboring countries such as United Arab Emirates, Bahrain, and Oman.[133-135] The prevalence of uncontrolled diabetes in China was 11.6% and in the U.S. was around 41%,[136-137] which may be less than what other have indicated as incidence in SA.

In this review, the risk factors of poor glycemic control were examined in their varying frequencies in the literature, with gender as the most studied risk factor, followed by age, treatment modality, education, diabetes duration, diet or fruits and vegetables intake, BMI, physical activity, employment status, marital status, and treatment settings (see Table II.2). In contrast, the least examined factors were depression, self-efficacy, anxiety, family support, physician/patient relationship. Diabetes duration, treatment modality, self-efficacy, fruits and vegetables intake, diet, SMBG, and treatment settings were the most consistent predictors of HbA1c.[9-10,13,27,76-78,81,83,89,126,132] On the other hand, inconsistent predictors of poor glycemic control were age, gender, education, employment status, depression, smoking, physical activity, and BMI.[10,76-78,81,127] For instance, only two studies out of ten established evidence that age was related to HbA1c.[76-77] Similarly, gender was found to be associated with HbA1c in the bivariate analyses of only three of 11 studies.[27,78,127] There was no explanation provided in the studies as to why age and gender were not significant. This was presumably due to the low quality of evidence that the highest proportion of the studies found age and gender, as common risk factors, not related to HbA1c. Income, anxiety, a sedentary lifestyle, and follow-up visits were not predictors of HbA1c.[9-10,12,76,81,126,132] Noticeably, some studies reported large odds ratio values which may indicate a bias in their results. For example, one study reported that physical inactivity was associated with poor glycemic control, with an odds ratio of 19,[10] while another study showed an odds ratio of 1.48.[76] The estimated odds ratio of 19 (95% CI [6.23, 58.06]) was possibly not a reliable value; this could be because there was a lack of information to fit the model (i.e., low events per variable). The use of alternative statistical tools, such as Bayesian logistic regression, may improve the quality of the reported outcomes.[138]

While these factors are well known predictors of HbA1c, the between-study variations were evident. The variations could be related to the distinct measurement tools of the outcome and to the use of independent variables (e.g., definitions of glycemic control), low statistical power, and poor statistical methods. Regarding the definition of variables, some studies defined blood glucose level in their analyses as a continuous variable (e.g., AlHabdan et al.[126] and Al Harbi.[129]), and others as a binary indicator, such as poor glycemic control of HbA1c ≥ 7% (e.g., Alramadan et al.[76]) or > 8% (e.g., Mirghani et al.[132]). Similarly, there were variations in the definition of the independent variables as well. For example, AlAboudi et al.[78] used an education variable as an ordinal variable with four levels in the bivariate analysis but as a continuous variable in the regression. Due to these variations and few studies, it was difficult to conduct a meta-analysis of predictors related to uncontrolled diabetes in order to objectively assess the direction and strength of the association.

The presence of underpowered studies (e.g., those with a low sample size) was another issue that could have impacted some results. For instance, Abdelwahid et al.[83] used a sample-size technique and reached 78 participants in their study but failed to consider the type of statistical method and the number of predictors involved in their study in order to precisely determine the required sample. In their case, it was multiple regression with five predictors; therefore, they underestimated the required sample size, which may have affected the accuracy of the regression coefficient, according to Kelley and Maxwell.[139] Furthermore, some studies did not report their sample size technique (e.g., Mirghani et al.[132] and Almutairi et al.[9]).

With respect to poor statistical methods, some studies adopted only the significant variables from the bivariate analysis in the multi-variate regression (e.g., Saad et al.[81] and Alzaheb et al.[10]), while at the same time, multicollinearity was not checked. This approach was criticized by Wang and colleagues, since including a non-significant variable from the bivariate logistic regression into the multiple logistic regression may show significance and vice versa (e.g., AlAboudi et al.[78]).[140] Therefore, the model specification should follow a better approach, such as Schwarz' Bayesian and Akaike's information criteria.[140] It is noteworthy to mention that most studies did not consider confounding factors in the analysis to accurately identify independent predictors and to address the complexity of diseases. For example, Habib only examined the relationship between gender and HbA1c, but did not account for other covariates.[27]

Apparently, one study implemented a hierarchical regression that first included behavioral factors (e.g., exercise) and then the psychological factors (e.g., self-efficacy related to exercise) in its model.[78] However, no explanation was provided by the author about this approach, nor was a theoretical framework followed. This points to the fact that the value of behavioral theories relied upon by a researcher, in order to make proper decisions about how to approach and understand the nature of a problem or situation, cannot be understated.[30]

We should note the limitations of this study. First, the overall quality of the included studies was low to moderate. Second, studies with small samples were included in the meta-analyses, which could increase sampling error.[141] Third, all of those in the included sample population were individuals in government healthcare settings, while other populations that did not have access to governmental healthcare or who used private healthcare settings were not represented. Fourth, only one study included individuals from different regions in SA, while the others focused on the major cities (e.g., Riyadh), which may not produce an accurate estimation of the national prevalence in SA. Thus, the results should be interpreted with caution. Additionally, the systematic review only included observational studies, so no causal inference could be interpreted from the results.

In conclusion, the high prevalence of uncontrolled diabetes in Saudi Arabia raises a concern. With all the examined risk factors associated with increased blood glucose, the need remains to address the management of diabetes at the personal and community levels, following a theoretical approach, in order to better understand the complexity of the disease within the context of Saudi culture. In addition, disparity in healthcare delivery is another important factor that may play an important role in the management of diabetes. More attention is needed, in future research, to improve the evidence related to HbA1c through conducting studies that target the diabetic population utilizing household-level data instead of merely utilizing hospital data. Also, more attention should be paid to the psychological factors that were not sufficiently investigated, and this can be done through using health-related behavior theories (e.g., the Health Promotion Model)[31]. These future directions may give substantive evidence and a broader perspective about uncontrolled diabetes in Saudi Arabia. Collaboration between government, healthcare providers, and health researchers is needed, to address this issue in an effective manner and at a national level, in order to lessen the burden of a disease that may impact both the economy of the country and the well-being of the Saudi population.

CHAPTER III

METHODOLOGY

Study Design

A cross-sectional study was performed using secondary data from the Saudi Health Interview Survey (SHIS) that was obtained from the Ministry of Health (MOH) in Saudi Arabia.[142] The study provided descriptive, bivariate, and multivariate analysis to give an overview of the characteristics of the study population and to address the specific aims. Pender's HPM was used to guide the study because it is considered to be a comprehensive model that can support the predictive power of the model through utilizing all possible independent variables and their relation to the outcome variables. Personal and cognitive-perceptual and health behaviors and diabetes management factors were utilized as independent variables in the study. In addition, there were three distinct outcome variables (dependent): physical activity (PA), self-monitoring of blood glucose (SMBG), and glycemic control. It is important to note that both PA and SMBG was used as independent variables along with the other health behaviors and diabetes management variables, in the analysis of the third aim. This design was based on a theoretical framework, which enabled the researchers to efficiently utilize the SHIS data and describe the relationship between the independent and dependent variables.

Data Source

The Saudi Health Interview Survey (SHIS) is nationally representative data. There were 10,827 participants, with a 90 percent response rate. There were 5,941 individuals involved in laboratory measurement, 55 percent response rate.[142] In 2013, the SHIS data was the first national health care survey conducted by the MOH in collaboration with researchers from the Institute of Health Metrics and Evaluation (IHME), which provided support in survey design and training. The survey was part of a major project in Saudi Arabia to establish a population-based surveillance system for monitoring chronic diseases. The survey included data that covers socioeconomic and health-related risk factors, inpatient-outpatient, and intervention-related information.[142] The SHIS covered all regions of Saudi Arabia for individuals age 15 and up, using a stratified multistage sampling technique.

The SHIS adapted the sample selection methodology established by the Saudi General Authority for Statistics,[118] and split the country into units, with each unit having 140 households, on average. The units were selected randomly from the 13 administrative regions, and 14 households were selected randomly from each unit. Subjects were selected randomly from each household after an initial interview with the head of household. Then, formulas were developed to weight each participant based on the stratification procedure mentioned above for those participated in the survey interview and laboratory test (see Appendix E for the formulas). Finally, professional and trained staff from MOH (one supervisor and 20 surveyors for each unit) conducted the survey, including the household interviews and lab measurements.

SHIS Instrument

The survey was designed to incorporate four modules. The first module was general information about the head of the household. The second module was about the questionnaire and anthropometric measures (e.g., weight and height). The third module, called “disposition coding,” was used to record the participation and follow-up rate, and worked as a reference code when there was a temporary pause during data collection. The fourth module was the laboratory measures where the blood samples were collected in specific clinics. All collected blood samples were sealed and coded, then sent to the main hospital in Riyadh for analysis.[142] Lenovo notebooks and DatStat software were used in the data collection process to help surveyors and to ensure consistency and quality of the collected data. In addition, the name of the anthropometric and biochemical instruments used in the survey is presented in the section detailing dependent and independent variables. In this study, the researchers assumed that the quality of the data was maintained during and after the data collection process (i.e., data were entered according to the participants' responses and no manipulation occurred to the data after the collection process).

Study Population

The study population used a secondary data obtained from the SHIS dataset. There were two inclusion criteria. First, the criterion specified for aims one and two was all subjects age 18 and above who were reported to have T2DM. The second criterion specified for aim three was all subjects age 18 and above who were reported to have T2DM and have undergone laboratory testing (biochemical analysis) to measure their blood glucose level for the reason that the data were weighted for nonresponse bias to be representative to the general population. The final sample size for aim 1 and two was 808 and for aim three was 391. All sample sizes were determined after obtaining the data and IRB approval. In order to maximize the sample size and enhance predictive power of the model, all participant records that met the inclusion criteria were included.

Protection of Human Subjects

The Ministry of Health directly oversaw the implementation and monitoring of the SHIS. Subjects who agreed to participate in the SHIS were asked to sign informed consent.[142] Participants in the survey had a unique identifier (HHID) to conceal their identity at the beginning of the survey. In order to obtain the data, a request letter was addressed to the National Diabetes Prevention and Control Program at the MOH. In addition, authorization to utilize SHIS data in this study was obtained from Institutional Review Board (IRB) at Old Dominion University.

Key Study Variables

There were 24 variables that were included in the analysis of the study. These variables were categorized into independent variables (e.g., personal, perceived activity barriers, and healthcare provider support), health behaviors (e.g., Physical Activity [PA], fruit and vegetable consumption [FVC], and smoking) and diabetes management (medication, regular clinic visits [RCV], and recent visit to health professional [RVHP]). The dependent variables were PA (aim1), SMBG (aim2), and poor glycemic control (aim3) (see Figure I.2). Both PA and SMBG were also be used as independent variables in aim 3. The following is a descriptive list of the variables that were utilized in the study. In addition, Appendix D has further details related to the classification and coding of the variables.

Personal Factors

These factors were characterized as biological, sociocultural, and psychological. These factors were used as independent variables in the study. First, biological factors included age, gender, family history, diabetes duration, and obesity. *Age*. The SHIS had reported that the participants' ages were 18 and above. The age factor was categorized into two groups: ≥54 and < 54 according to the meta-analysis presented in chapter 3. *Gender*. Both women and men were included in the study. The proportion of men to women was depending on the specified sample size that was extracted from the SHIS dataset utilizing sampling weight. *Family history*. This variable described whether each participant had a family member who were diagnosed with diabetes including parents, children, brothers, and/or sisters. Family history was categorized into two levels in the study: Yes and No. *Diabetes duration*. According to the SHIS, participants were asked about their age when they first received a diagnosis of diabetes.[108] The researchers calculated the age of the disease in year by subtracting the current age of the participant from their age when first diagnosed with diabetes (i.e., diabetes duration = year of diagnosis - survey year in Hijri calendar). Then, the diabetes duration was classified into three groups: (< 5 years.), (5 – 9 years), and (≥ 10 years).[143] *Obesity*. In order to determine whether the participants obese or not, first body mass index (BMI) was calculated using height and weight provided by the SHIS data (i.e., BMI = weight in kg/ height in M^2). Then, it was classified into two groups: Yes, obese (BMI ≥ 30) and No, not obese (BMI < 30) using index of weight for height.[144] The instrument used in the SHIS to measure weight was Omron HN286. This variable was utilized as independent factor.

Second, sociocultural factors were considered in the study, including marital status, education, income, and Region of residence. *Marital status*. Subjects were asked to report their marital status. The researchers classified the answers into two groups: married and others (e.g., never married, separated, divorced, or widowed). *Education*. This variable determined the level of education of the individuals with type 2 diabetes. Education was categorized into three levels: low (primary school or below), middle (intermediate or high school), and high (college degree or higher). *Income*. This variable referred to measuring the economic status of the participants where the SHIS broke down household income in Saudi Riyal (SR) per month into eight groups; therefore, for the convenience of the study, income was reclassified into three groups: low (< 5000 SR), middle (≥ 5,000 SR to < 15,000 SR), and high (≥15,000 SR).[2] *Region of residence*. According to the SHIS, the living area indicates whether a participant resides in a village or city which could be further classified into urban and rural. However, the obtained data was limited to

[2] SR = 0.27 USD.

the 13 administrative regions. Consequently, the data was classified into five groups instead: central (i.e., Riyadh and Qaseem), northern (i.e., Tabouk, Haiel, Northern borders, AlJouf, and Quriat), southern (i.e., Asir, Bisha, AlBaha, Najran, Jizan), eastern (i.e., Damam), western regions (Jeddah & ALMadina Almonawra). *Perceived Health status (PHS)*. The SHIS asked the participants a single question to rate their health in general. It was measured using a 5-point Likert scale (excellent, very good, good, fair, and poor). In the study, a median split technique was used to reclassify the variable into two groups: Poor (fair, and poor) and Good (excellent and very good, and good).

Cognitive-perceptual Factors

It is the perception of individual about behaviors, beliefs or attitude of others to engaging in health behaviors.[31] The study included perceived activity barriers and healthcare provider support, which were utilized as independent variables. First, perceived activity barriers which includes vigorous activity barriers (VAB), house activity barriers (HAB), and physical activity barriers (PAB). *VAB.* Participants were asked whether their current health limits them from doing vigorous activities, such as running or participating in strenuous sports.[142] The answers were based on a 5-point Likert scale (not at all, very little, somewhat, quite a lot, and cannot do). The variable was reclassified into two groups: Low (not at all, and very little) and High (somewhat, quite a lot, and cannot do). *HAB*. This was a single question about whether participants' current health hinders them from performing work or household activities. The answers were measured using 5-point Likert scale (without any difficulty, with a little difficulty, with some difficulty, with much difficulty, and unable to do). In the study, the variable also was reclassified into two groups: Low (without difficulty, and with a little difficulty) and High (with some difficulty, with much difficulty, and unable to do). *PAB*. Participants were asked whether their current health hinders them from doing activities such as standing from a seated position, standing and for a long time, and/or stair climbing. The answers were measured in 5-point Likert scale (without any difficulty, with a little difficulty, with some difficulty, with much difficulty, and unable to do). In the study, the variable followed the above classification process: Low (without difficulty and with a little difficulty) and High (with some difficulty, with much difficulty, and unable to do). Second, healthcare provider support includes health professional support for treatment (HPST), and lifestyle change (HPSL), and multiple healthcare providers (MHP). *HPST.* Diabetic participants were asked two questions about treatment or advice prescribed by health professionals related to insulin and medication. These two questions were combined into single variable with two levels: Yes (any treatment or advice was given – insulin or medication) and No (no treatment or advice was given). *HPSL*. Diabetic participants were asked two questions about treatment or advice prescribed by health professional related to lifestyle change (i.e., four separate questions for stop smoking, lose weight, diet, and exercise). These four questions were combined into a single variable with two levels: Yes (any treatment or advice was given related to one of the above specified lifestyle change) and No (no treatment or advice was given). *MHP*. Participants were asked a single question about one or more providers they regularly go to when they are sick or need advice. The answers were separated into two levels: Yes (more than one provider) and No (one provider or no provider).

Behavioral Outcomes and Other Factors

The behavioral outcomes include health behaviors and diabetes management. First, health behaviors include PA, FVC, and smoking. *PA.* The SHIS defined moderate activity as small increases in breathing or heart rate for at least 10 consecutive minutes while at work and/or leisure, while vigorous activity was defined as large increases in breathing or heart rate for at least 10 consecutive minutes while at work and/or leisure.[142] The researchers followed the ADA guidelines to classify PA of individuals with T2DM into two groups: high physical activity (i.e., perform at least 150 minutes per week of moderate to intensive activity and the activity is spread over at least three days per week) and low physical activity (i.e., less than 150 minutes per week of moderate to intensive activity or activity is spread over less than three days per week).[47] The PA data in the SHIS were collected in days per week, and hours and minutes per day. The data was computed to get minutes per week by converting hours into minutes (for those who answered in hours), then multiplying minutes per day by days per week. *FVC.* This involved the consumption of recommended foods, specifically vegetables and fruits (including 100 percent fruit juice) in adequate serving sizes. The participants in the survey were asked three questions related to the consumption of each category that includes number of days per week and number of servings per day of fruits, drinking 100 percent juice, and vegetables. The variable was measured by calculating the total average consumption of fruits, juice, and vegetables per day (i.e., average FVC = number of servings per day * number of days per week / seven). Juice was combined with fruit then FVC was categorized into two levels: adequate FVC (i.e., at least ≥ 1.5 servings of fruits and ≥ 2 servings of vegetables per day for adult women and ≥ 2 servings of fruits and ≥ 2.5 servings of vegetables per day for adult men) and inadequate FVC (i.e., < 1.5 servings of fruits and/or < 2 servings of vegetables per day for women and < 2 servings of fruits and/or < 2.5 servings of vegetables per day for men) based on the 2015–2020 Dietary Guidelines for Americans.[145] *Smoking.* Subjects in the SHIS were asked if they smoke any tobacco products. Smoking was classified into two levels: Yes (smoke) and No (do not smoke or previously smoke). Second, diabetes management includes SMBG, medication, regular clinic visits (RCV), and recent visit to health professionals (RVHP). *SMBG*. Participants were asked if they monitor their blood sugar level at home. The answers will be classified into Yes (monitor) and No (do not monitor). SMBG was also utilized as a dependent variable in aim 2 and an independent variable in aim 3. *Medication*. Participants were asked if they used medication for diabetes in the past 30 days or since the diagnosis of diabetes. The answers were reclassified into two levels: Yes, currently using medication and No, previously or never used medication. *RCV*. Participants in the SHIS where asked if they regularly visit a diabetes clinic. This was a dichotomous variable (two levels): Yes and No. *RVHP*. Participants were asked if they have visited a doctor or health professional in the past 30 days for diabetes management. Answers were classified into Yes and No.

Glycemic Control

This was a primary outcome as a dependent variable in the study and was measured by Glycated Hemoglobin (HbA1c). The HbA1c in the SHIS was analyzed using the COBAS INTEGRA400 plus instrument for all those who participated in the clinical module. In the study, HbA1c was classified into good and poor glycemic control. Good glycemic control was defined as those who have HbA1c < 7% (53 mmol/mol), and poor glycemic control with HbA1c ≥ 7% (53 mmol/mol).[46] The researchers assumed that the definition of glycemic control according to the ADA standards is universally accepted.

Statistical Analysis

All variables included in the study were identified, cleaned, altered, and recoded according to the study design. Answers with "don't know" or "decline to respond" were treated as missing values in the study design. All binary categorical variables were coded with '0' and '1' (e.g., gender: '0' = men and '1' = women) and categorical variables with more than two groups were coded incrementally starting from '1' (e.g., 1, 2, 3, … n). Variables related to survey design were included in the analysis (i.e., sampling weight and strata while cluster was missing) see Appendix E.

Missing Data

Multiple-imputation (MI) method was used to replace missing data.[146-147] The procedure that was followed in the MI was called fully conditional specification (FCS) approach with the assumption that the missing data was missing at random (MAR). The FCS deals with missing cases in multiple variables with different forms (e.g., continuous and discrete); therefore, it allowed for each variable to have imputation model in the imputation sequence.[148-149] At least all variables in the study were included in the MI to avoid bias in the parameter estimation because the relationship between the variables were maintained after MI.[150-153]

Although five imputations were sufficient according to Rubin[147], the number of imputations in this study was determined on the basis of the percentage of missing cases as a rule of thumb.[149] In this study, the percentage of missing cases was around 50%; therefore, 50 imputed datasets were used in the final analysis. Pooled imputed data was utilized in the final analysis. Imputed datasets were visually inspected to assess variation with the original data following some recommendation provided by Sterne et al.[154]

Descriptive Analysis and Multivariate Modeling

The SHIS data was a national dataset using multistage stratified sampling technique, so the selected sample reflects the whole population of Saudi Arabia. Therefore, the study used weighted data in the analysis.

Three types of analysis were performed for each aim. First, descriptive statistics was conducted to give a general overview of the characteristics of the independent and dependent variables, which was presented in numbers and weighted percentages. Second, weighted bivariate analysis (for non-parametric test) was used to determine the level of significant association between each independent and the outcome variable for each aim, and the results were presented in Prevalence Ratio (PR) or Odds Ratio (OR) , 95% confidence interval (CI) and *p* value.

Third, a weighted multivariate analysis (i.e., more than one independent variable in the analysis for non-parametric test) was used in order to address each specific hypotheses in each aim and determine the predictive margin of the outcome in association with the related predictors. In order to test the hypotheses in each aim, the weighted multivariate analysis involved several steps and each step was considered as one block in the model. Following the HPM, the first block (model) included personal factors (biological, sociocultural, and psychological) to test the first hypothesis in each aim. The second block included perceived activity barriers (VAB, HAB, and PAB) and healthcare provider support (HPST, HPSL, and MHP) to test the second hypothesis in each aim. The third aim included an additional block that contains health behaviors (PA, FVC, and smoking) and diabetes management (medication, SMBG, RCV, and RVHP) to test the third hypothesis. The results were presented in PR or OR, 95% CI, and *p* value.

In addition, two sampling weights (e.g., household and laboratory) were utilized in the analysis to weight the sample of the study for correct interpretation of the data and to maintain generalizability of the results to the Saudi population. For instance, the laboratory sampling weight was used in the analysis of the third aim to investigate risk factors for poor glycemic control, and the household sampling weight was used in the analysis of the first and second aims when analyzing risk factors related to PA and SMBG. See Appendix F for the procedures that was followed to deal with the SHIS data in the study.

The alpha level of statistical significance was set at 0.05. OR and PR were obtained from logistic and log-binomial regression, respectively. OR was used when the event of the outcome was less than 10%, and the opposite for PR where the event was common because OR overestimate PR.[155-157] When there was a convergence issue in the analysis, Poisson regression was used instead of log-binomial regression to obtain the PR.[157] The assumption of multicollinearity was assessed using variance inflation factor (VIF) and tolerance tests.[158] Due to complexity of the statistical analysis (i.e., multiple imputation and complex survey design) only the Receiver Operating Characteristic (ROC) for model accuracy and Wald test for model fit were used.[159-160] Two software were used for the study were SPSS 26 (IBM Corp.)[161] and Stata 16 (Stata Corp.)[162]. For preparing variables for analysis, data were merged, converted, recoded, computed, and imputed via SPSS. For final data analysis, Stata was utilized because of its capability to deal with multiple imputed data with complex survey design (i.e., command code: “mi estimate: svy: logistic or glm”).

CHAPTER IV

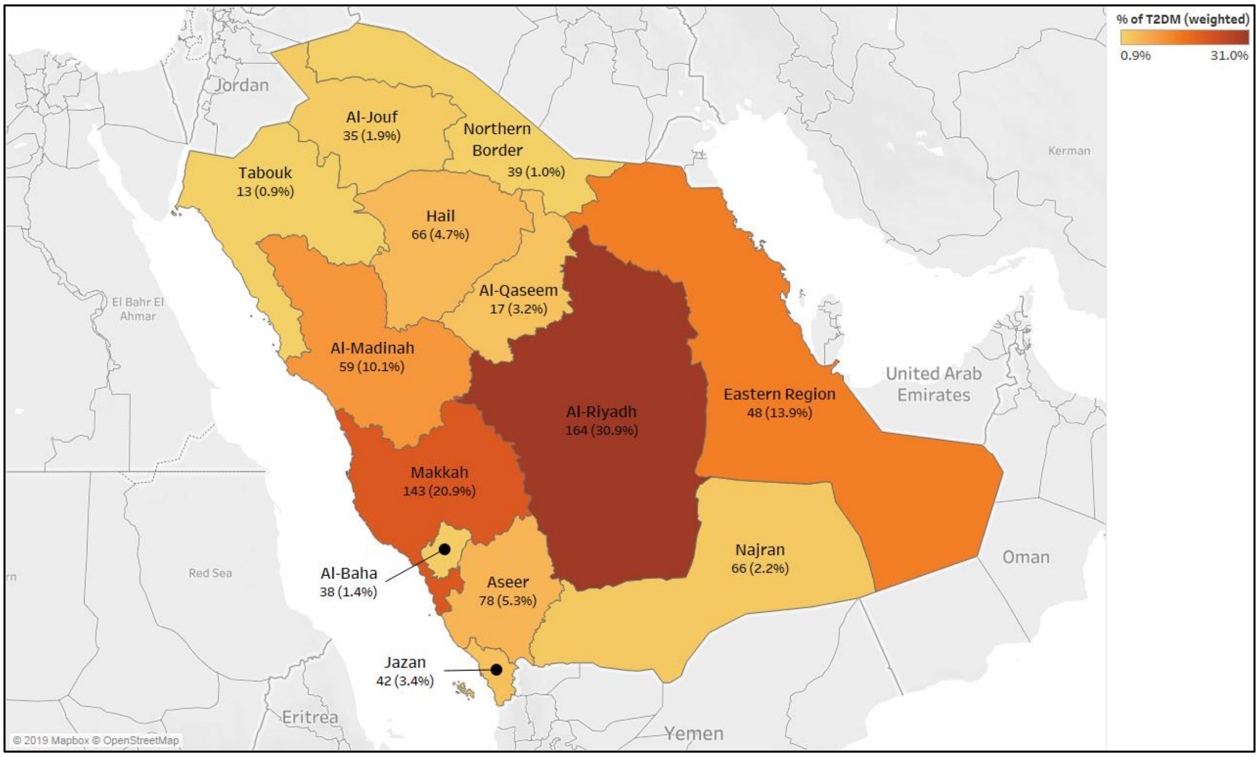
RESULTS

Overview of T2DM Status in Saudi Arabia

There were 808 participants reported to have T2DM included in the study. The number of participants in this study was equivalent to ≈ 7.5% of the total sample size (10,827) who participated in the SHIS. The weighted data showed the prevalence of Saudis with T2DM was more than 0.7 million in 2013. The 808 participants were used in the analysis of the physical activity (aim 1) and self-monitoring of blood glucose (aim 2) outcomes. In addition, the number of individuals with T2DM who completed the laboratory tests with valid records were 391 (response rate of ≈ 48.4% from the 808 participants), and the weighted data showed 589,482 of total population. The sample size of 391 was used in the analysis of poor glycemic control outcome (aim 3). The number of participants who had poor glycemic control (HbA1c ≥ 7%) were 164 with weighted percentage equal to 34.3 and was equivalent to more than one third of the total T2DM population that participated in laboratory test.

The distribution of T2DM across all the administrative regions in Saudi Arabia were reported (see Figure IV.1). The highest proportion of all T2DM cases was found in Al-Riyadh region and the lowest was in Tabouk with weighted percentage of 30.9 and 0.9, respectively. Additionally, the analysis showed that T2DM was more frequent in urbanized regions. For example, the major regions such as Al-Riyadh, Makkah, and Eastern region had the highest percentages of T2DM while other regions like Tabouk, Northern Border, Al-Jouf, Najran had the least percentages.

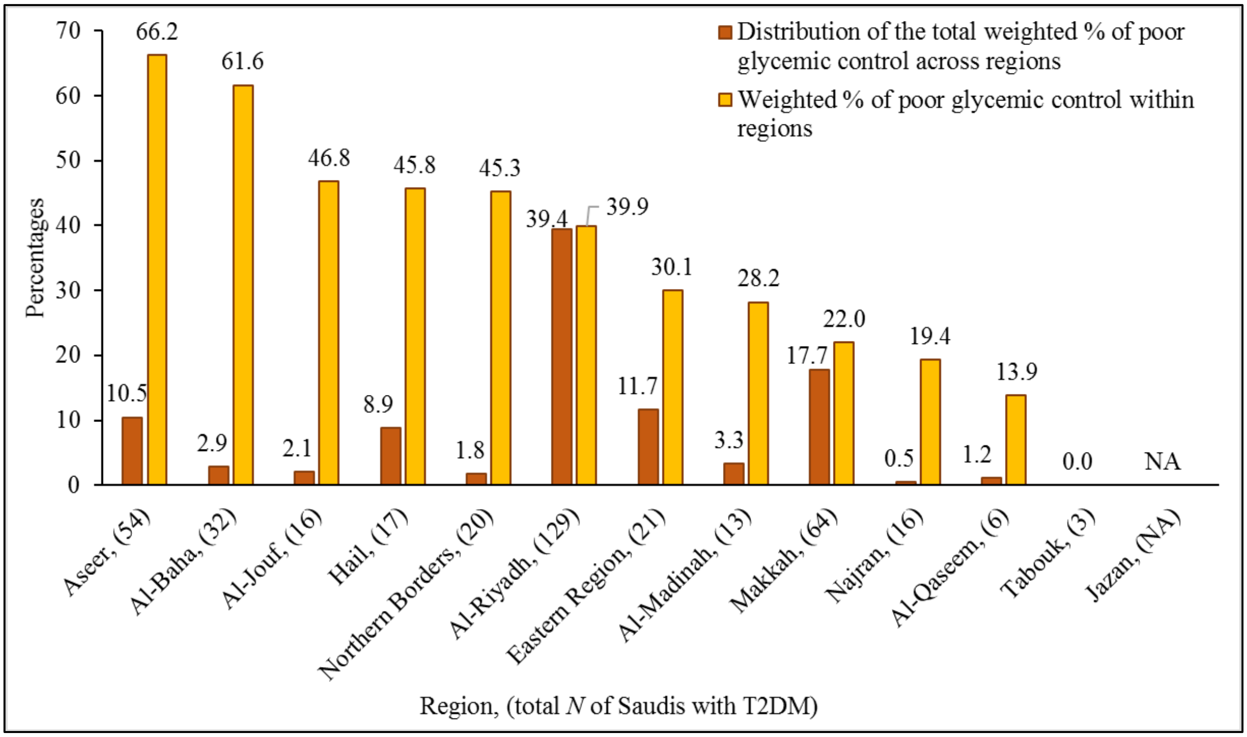
Figure IV.1. Distribution of Weighted Percentages for 808 Saudi Participants with T2DM Across 13 Administrative Regions in Saudi Arabia - Based on 2013 SHIS data.[3]



Similarly, the status of uncontrolled T2DM in Saud Arabia across and within regions were shown in Figure IV.2. The distribution of the total percentage of poor glycemic control across regions was highest in Al-Riyadh (39.4%) followed by Makkah (17.7%) while the least prevalent was Tabouk (0%) and Najran (0.5%). However, when the data was analyzed within region, the results revealed that Asser and Al-Baha had the highest prevalence of uncontrolled T2DM with weighted percentage of 66.2 and 61.6, respectively. Note that participants from Jazan region did not complete laboratory test module and due to missing data; therefore, information about the status of uncontrolled T2DM in this region cannot be determined.

[3] Map was created via Tableau (V. 2019.3.0).

Figure IV.2. Status of Poor Glycemic Control among 391 Saudis with T2DM Participated in the Laboratory Test Module Across 13 Administrative Regions in Saudi Arabia - Based on 2013 SHIS data.



Missing Data and Multiple Imputation

All variables included in the study were analyzed for missing data. The results showed that out of 24 assessed variables, only two had complete data (e.g., gender, region of residence). The percentages of incomplete data for cases and values were 51.6% and 3.4%, respectively. The highest variable with missing data was diabetes duration (21.7%), income (17.2%), and family history (15.2%) while the lowest was physical activity (0.1%), as shown in Appendix G. Diabetes duration, income, and family history were further assessed for missingness because of high percentage of missing data. The findings showed that age group of ≥ 54 years, low education, and central region had the highest missing values in diabetes duration, income and family history. Men group had the highest missing values in diabetes duration and family history while women had the highest missing data for income variable (see Appendix H). The trend of missingness was assumed to be missing at random (MAR). Therefore, 50 imputations were conducted according to the percentage of missing cases.

After multiple imputation, the complete data was compared with the original data (e.g., data with missing values) to address any possible variation (See Table IV.1). The results showed no sign of differences between the original and the completed data across the variables except for diabetes duration. Due to large number of missing values in diabetes duration, there was slight decrease in the proportion of those with <5 years group for the imputed data compared to the original data. However, this variation is minute and does not cause problem to the analysis.

Although the Saudi Health Interview Survey (SHIS) accounted for the response bias via sampling weight (i.e., lab weight), for those who underwent laboratory test to obtain their HbA1c levels, it was necessary to determine if there were differences between those who had records or did not have records of HbA1c. The results showed the prevalence of those with measured HbA1c where higher in middle and high income participants compared to low income (Prevalence ratio [PR] = 1.25 and 1.27, respectively). Also, region of residence was a predictor for those with measured HbA1c. Compared with central region we found that the PR were 0.51, 0.59, 0.49, 0.61 for Western, Eastern, Norther, and Southern, respectively. Other socio-demographic factors did not show any significance (see Appendix I).

Table IV.1. Characteristics of Personal, Cognitive-Perceptual, and Behavioral Factors in the Original and Completed Data.

Variable	Original data *n* (weighted %)	Completed data Aim 1 & 2 *n* (weighted %)	Completed data Aim 3 *n* (weighted %)
Sample size		808	391
Age			
<54 years	321 (47.9)	324 (47.9)	152 (49.1)
≥54 years	481 (52.1)	484 (52.1)	239 (50.9)
Gender			
Women	331 (38.7)	331 (38.7)	160 (33.5)
Men	477 (61.3)	477 (61.3)	231 (66.5)
Family history			
Yes	483 (70.8)	556 (69.7)	280 (72.3)
No	202 (29.2)	252 (30.3)	111 (27.7)
Diabetes duration			
<5 years	211 (36.2)	245 (32.9)	131 (37.3)
5-9 years	164 (25.9)	207 (26.7)	99 (26.1)
≥ 10 years	258 (37.9)	356 (40.4)	161 (36.6)
Obesity			
Yes	409 (53.1)	419 (53.2)	208 (54.9)
No	381 (46.9)	389 (46.8)	183 (45.1)
Marital status			
Married	619 (81.5)	621 (81.5)	298 (83.9)
Others	187 (18.5)	187 (18.5)	93 (16.1)
Education			
Low	477 (52.8)	477 (52.7)	241 (54.8)
Middle	221 (34.1)	221 (34.0)	105 (32.8)
High	108 (13.2)	110 (13.3)	45 (12.4)
Income			
Low	274 (34.8)	326 (34.8)	145 (32.1)
Middle	304 (49.5)	364 (49.1)	181 (49.2)
High	91 (15.7)	118 (16.1)	65 (18.7)
Region of residence			
Central	181 (34.2)	181 (34.2)	135 (36.8)
Western	202 (31.0)	202 (31.0)	77 (31.7)
Eastern	48 (13.9)	48 (13.9)	21 (13.4)
Northern	153 (8.6)	153 (8.6)	56 (10.1)
Southern	224 (12.3)	224 (12.3)	102 (8.0)
PHS			
Poor	179 (17.5)	179 (17.5)	94 (17.0)
Good	627 (82.5)	629 (82.5)	297 (83.0)

Table IV.1. Continued.

Variable	Original data n (weighted %)	Completed data Aim 1 & 2 n (weighted %)	Aim 3 n (weighted %)
Sample size		808	391
VAB			
Low	366 (50.6)	374 (50.6)	174 (50.5)
High	426 (49.4)	434 (49.4)	217 (49.5)
HAB			
Low	538 (72.3)	555 (72.1)	268 (72.1)
High	241 (27.7)	253 (27.9)	123 (27.9)
PAB			
Low	576 (76.6)	580 (76.4)	279 (78.3)
High	225 (23.4)	228 (23.6)	112 (21.7)
HPST			
Yes	705 (87.8)	707 (87.8)	346 (88.5)
No	101 (12.2)	101 (12.2)	45 (11.5)
HPSL			
Yes	732 (92.3)	740 (92.0)	363 (95.3)
No	65 (7.7)	68 (8.0)	28 (4.7)
MHP			
Yes	326 (41.5)	338 (41.2)	166 (47.1)
No	444 (58.5)	470 (58.8)	225 (52.9)
Physical Activity			
Active	66 (9.1)	66 (9.1)	31 (8.3)
Inactive	741 (90.9)	742 (90.9)	360 (91.7)
FVC			
Adequate	60 (9.9)	65 (9.9)	26 (8.2)
Inadequate	710 (90.1)	743 (90.1)	365 (91.8)
Smoking			
Yes	114 (17)	114 (17.0)	43 (15.6)
No	691 (83)	694 (83.0)	348 (84.4)
SMBG			
Yes	448 (55.4)	450 (55.4)	231 (59.3)
No	357 (44.6)	358 (44.6)	160 (40.7)
Medication			
Yes	742 (92.7)	742 (92.3)	361 (92.7)
No	64 (7.3)	66 (7.7)	30 (7.3)
RCV			
Yes	622 (80)	627 (80.2)	315 (81.1)
No	181 (20)	181 (19.8)	76 (18.9)
RVHP			
Yes	687 (86.8)	690 (86.8)	340 (88.0)
No	117 (13.2)	118 (13.2)	51 (12.0)
Glycemic control (HbA1c)			
Poor	164 (34.3)	-	164 (34.3)
Good	227 (65.7)	-	227 (65.7)

PHS = Perceived health status; VAB = vigorous activity barriers; HAB = house activity barriers; PAB = physical activity barriers; HPST = health professional support for treatment; HPSL = health professional support for lifestyle change; MHP = Multiple healthcare providers; FVC = fruit and vegetable consumption; SMBG = self-monitoring of blood glucose; RCV = regular clinic visits; RVHP = Recent visit to health professional.

Descriptive Statistics

Table IV.1 also provided a general overview of personal, cognitive-perceptual, and behavioral characteristics of Saudi population with T2DM based on the imputed data, which were used in the analysis of aim 1 and 2. With regards to personal characteristics, the majority of T2DM population were 61.3% men, 52.1% had age of 54 years old or older, 81.5% married, 53.2% obese, 52.8% had low education, 49.5% had middle income, 34.2% living in the central region, 69.7% had family history of diabetes, and 40.4% had diabetes duration ≥ 10 years, and 82.5% had good perceived health. The results also showed the characteristics of cognitive-perceptual factors and found few percentages of T2DM population had high activity-related barriers, where 27.9% had high house activity barriers (HAB) and 23.6% had high physical activity barriers (PAB), while it was almost half of T2DM had high vigorous activity barriers (VAB). In addition, the majority received health professional support for treatment ([HPST], 87.8%) and health professional support for lifestyle change ([HPSL], 92%), while 58.8% had no multiple healthcare providers (MHP). The characteristics of behavioral factors were 90.9% physically inactive, 90.1% had inadequate fruit and vegetable consumption (FVC), 83% non-smoker, 55.4% had self-monitoring of blood glucose (SMBG), 92.3% use medication, 80.2% had regular clinic visits (RCV), and 86.8% had recent visit to a healthcare professional (RVHP).

In addition, Table IV.1 showed the characteristics of complete data that were used for the analysis of the third aim (poor glycemic control). For the personal characteristics, there were 66.5% men, 50.9% in the age group of 54 years old or older, 83.9% married, 54.9% obese, 54.8% had low education, 49.3% had middle income, 36.9% living in the central region, 72.3% had family history of diabetes, and 36.6% had diabetes duration ≥ 10 years, and 83% had good perceived health. For the characteristics of cognitive-perceptual factors, it was found that almost half of participants had high VAB while fewer percentages 27.9% and 21.7% had high HAB and PAB, respectively. In addition, the majority received HPST with 87.8% and HPSL with 92%, while 58.8% had no MHP. The characteristics of behavioral factors were 90.9% physically inactive, 90.1% had in adequate FVC, 83% non-smoker, 55.4% had SMBG, 92.3% use medication, 80.2% had RCV, and 86.8% had RVHP.

Bivariate Analysis

A bivariate analysis was conducted to address the relationship between personal, cognitive-perceptual factors and physical activity and SMBG according to the health promotion model. In addition, poor glycemic control was also addressed via measuring the association of personal, cognitive-perceptual, and behavioral factors with the outcome. The results are presented in table IV. 2. Additionally, further descriptive statistics of each aim with the predictors can be found in Appendix J.

Physical Activity (aim 1)

In the analysis of physical activity, the results found that among personal factors, under the age of 54 years (OR = 4.03, 95% CIs [2.03, 8.02]), diabetes duration less than 5 years (OR = 2.25, 95% CIs [1.01, 5.02]), middle level of education (OR = 3.07, 95% CIs [1.41, 6.69]), high level of education (OR =6.15, 95% CIs [2.60, 14.54]), and high income (OR = 4.19, 95% CIs [1.75, 10.01]), were significantly associated with physically active Saudis with T2DM. In addition, cognitive-perceptual factors that were found to be associated with physically active Saudis with T2DM were low VAB (OR = 0.46, 95% CIs [0.23, 0.93]), low HAB (OR = 0.22, 95% CIs [0.07, 0.72]), and received HPST (OR = 0.42, 95% CIs [0.19, 0.91]). The relationship of the other personal (gender, family history, obesity, marital status, region of residence, and PHS) and cognitive-perceptual (PAB, HPSL, and MHP) factors were not statistically significant with physical activity.

Table IV.2. Odds Ratio or Prevalence Ratio, 95% CIs, and P Values from Bivariate Analysis of the Association Between Risk Factors and Physical Activity, Self-Monitoring of Blood Glucose and Poor Glycemic Control among Saudis with T2DM.

Variable	Physical Activity			SMBG			Poor glycemic control		
	OR	95% CI	*P* Value	PR	95% CI	P Value	PR	95% CI	P Value
Age < 54 years old	**4.03**	**[2.03, 8.02]**	**<0.001**	0.98	[0.83, 1.16]	0.807	1.06	[0.73, 1.53]	0.778
Men	1.77	[0.84, 3.74]	0.130	1.01	[0.85, 1.20]	0.915	0.97	[0.67, 1.39]	0.854
Family history (yes)	1.89	[0.89, 4.02]	0.096	**1.25**	**[1.00, 1.55]**	**0.048**	0.99	[0.63, 1.59]	0.988
Diabetes duration <5 years	**2.25**	**[1.01, 5.02]**	**0.049**	0.86	[0.70, 1.06]	0.156	0.81	[0.52, 1.26]	0.354
Diabetes duration 5-9 years	1.75	[0.71, 4.35]	0.227	0.81	[0.63, 1.03]	0.081	0.75	[0.44, 1.28]	0.293
Obese	1.49	[0.79, 2.82]	0.220	**1.22**	**[1.02, 1.45]**	**0.026**	1.00	[0.69, 1.45]	0.992
Married	2.15	[0.92, 5.04]	0.078	1.17	[0.93, 1.47]	0.190	1.18	[0.76, 1.84]	0.450
Middle education	**3.07**	**[1.41, 6.69]**	**0.005**	**1.26**	**[1.04, 1.53]**	**0.017**	0.89	[0.59, 1.34]	0.576
High education	**6.15**	**[2.60, 14.54]**	**<0.001**	**1.55**	**[1.28, 1.88]**	**<0.001**	0.86	[0.48, 1.53]	0.608
Middle income	1.90	[0.90, 4.03]	0.094	**1.30**	**[1.05, 1.61]**	**0.015**	1.21	[0.78, 1.87]	0.390
High income	**4.19**	**[1.75, 10.01]**	**0.001**	**1.55**	**[1.21, 1.98]**	**0.001**	1.10	[0.61, 1.97]	0.752
Western region	1.27	[0.58, 2.80]	0.550	0.89	[0.73, 1.09]	0.259	0.60	[0.35, 1.05]	0.076
Eastern region	0.32	[0.07, 1.56]	0.161	**0.63**	**[0.41, 0.96]**	**0.034**	0.80	[0.38, 1.68]	0.550
Northern region	0.50	[0.20, 1.22]	0.130	0.91	[0.74, 1.13]	0.396	1.14	[0.69, 1.89]	0.599
Southern region	1.10	[0.46, 2.59]	0.835	0.85	[0.69, 1.04]	0.120	**1.58**	**[1.14, 2.20]**	**0.006**
Good PHS	1.31	[0.51, 3.38]	0.575	1.02	[0.82, 1.27]	0.843	0.90	[0.58, 1.40]	0.649
high VAB	**0.46**	**[0.23, 0.93]**	**0.030**	0.91	[0.76, 1.08]	0.257	1.20	[0.83, 1.75]	0.335
High HAB	**0.22**	**[0.07, 0.72]**	**0.012**	0.83	[0.68, 1.01]	0.067	0.90	[0.59, 1.39]	0.639
High PAB	0.52	[0.20, 1.32]	0.168	0.97	[0.79, 1.18]	0.757	1.20	[0.81, 1.79]	0.364
HPST (yes)	**0.42**	**[0.19, 0.91]**	**0.027**	**1.42**	**[1.10, 1.99]**	**0.043**	1.62	[0.81, 3.26]	0.175
HPSL (yes)	1.16	[0.43, 3.17]	0.766	1.30	[0.87, 1.94]	0.208	0.80	[0.45, 1.40]	0.426
MHP (yes)	1.19	[0.62, 2.29]	0.604	1.09	[0.92, 1.30]	0.311	1.24	[0.84, 1.81]	0.275

Table IV.2. Continued.

Variable	Physical Activity			SMBG			Poor glycemic control		
	OR	95% CI	*P* Value	PR	95% CI	*P* Value	PR	95% CI	*P* Value
Physically Active	-	-	-	-	-	-	1.17	[0.67, 2.06]	0.576
Adequate FVC	-	-	-	-	-	-	1.12	[0.59, 2.11]	0.730
SMBG (yes)	-	-	-	-	-	-	1.09	[0.74, 1.60]	0.650
Smoker	-	-	-	-	-	-	1.01	[0.58, 1.73]	0.985
Medication (yes)	-	-	-	-	-	-	1.55	[0.71, 3.38]	0.272
RCV (yes)	-	-	-	-	-	-	1.49	[0.87, 2.56]	0.150
RVHP (yes)	-	-	-	-	-	-	1.01	[0.59, 1.71]	0.981

Reference categories for categorical predictors are: Age (≥ 54 years); Gender (women); Family history (no); Diabetes duration (≥ 10 years; obesity (no); Marital status (others); Education (low); Income (low); Region of residence (central); PHS (poor); VAB (low); HAB (low); PAB (low); HPST (no); HPSL (no); MHP (no); Physical activity (inactive), FVC (inadequate); SMBG (no); Smoking (no); Medication (no); RCV (no); RVHP (no).
PHS = Perceived health status; VAB = vigorous activity barriers; HAB = house activity barriers; PAB = physical activity barriers; HPST = health professional support for treatment; HPSL = health professional support for lifestyle change; MHP = Multiple healthcare providers.

SMBG (aim 2)

The results showed five personal factors were significantly associated with SMBG among Saudis with T2DM: family history (PR = 1.25, 95% CIs [1.00, 1.55]), obesity (PR = 1.22, 95% CIs [1.02, 1.45]), middle level of education (PR = 1.26, 95% CIs [1.04, 1.53]), high level of education (PR = 1.55, 95% CIs [1.28, 1.88]), middle income (PR = 1.30 , 95% CIs [1.05, 1.61]), high income (PR = 1.55, 95% CIs [1.21, 1.98]), live in Eastern region (PR = 0.63, 95% CIs [0.41, 0.96]). Furthermore, only those who received HPST (PR = 1.42, 95% CIs [1.01, 1.99]), as a cognitive-perceptual factor, found to be associated SMBG among Saudis with T2DM. The HPST indicated that T2DM individuals who got support from healthcare providers for treatment (e.g., medicine or insulin) monitor their blood glucose level more than those who did not get the support for treatment. The relationship of the other personal (age, gender, diabetes duration, marital status, and PHS) and cognitive-perceptual (VAB, HAB, PAB, HPSL, and MHP) factors were not statistically significant with SMBG.

Poor glycemic control (aim 3)

The results showed only one personal factor associated with poor glycemic control. Saudis with T2DM living in Eastern region had increased prevalence ratio of poor glycemic control compared to the central region (APR = 1.58, 95% CIs [1.14, 2.20]). Other personal, cognitive-perceptual, and behavioral factors were not significantly associated with poor glycemic control. Therefore, further sub-population (e.g., gender) analysis was conducted to detect if there any association between these factors and poor glycemic control. In the women sub-population analysis, only those who had HPST (APR = 8.03, 95% CI [2.65, 24.28]) and medication (APR = 4.32, 95% CI [1.19, 15.66]) were associated with poor glycemic control. However, there were no significant factors associated with poor glycemic control among men sub-population.

Hypothesis and Model Testing

A multivariate analysis was conducted to answer the hypotheses from each aim. In the first aim related to physical activity, two hypotheses were tested that were related to the personal and cognitive-perceptual factors. In the second aim related to self-monitoring of blood glucose (SMBG), two hypotheses were tested, one for personal factors and the other for cognitive-perceptual factors. In the third aim related to poor glycemic control, three hypotheses were tested for personal, cognitive-perceptual, and behavioral factors. The area under the ROC curve (AUC) and Wald F test were performed for each hypothesis to determine the accuracy and fit of the analyzed model. The reference group for each variable in the model analysis were as followed: age ≥ 54 years, women, no family history of diabetes, diabetes duration ≥ 10 years, not obese, other marital status, low education, low income, central region, poor PHS, low VAB, low HAB, low PAB, no HPST, no HPSL, no MHP, physically inactive, inadequate FVC, no SMBG, no mediation, no RCV, and no RVHP. No indication of multicollinearity among the predictors were noticed (i.e., the variance inflation factor was < 3 and tolerance test > 0.4).

Hypothesis 1.1

Logistic regression was performed to directly predict the odds ratio of physical activity from the personal factors. The results presented in Table IV.3. The area under the ROC curve (AUC) was 0.78 indicating fair model accuracy and the Wald test showed adequate fit to the data of the model-1, $F(16, 791.6) = 3.53$, $p < .001$. The results found that age and education were the only factors associated with physical activity. Younger Saudis with T2DM whose age < 54 years old had 2.84 greater odds of being physically active compared to those age ≥ 54, 95% CI (1.25, 6.45). In addition, the odds of those who had higher education were 3.14 times greater to be physically active compared to low educated Saudis with T2DM. Other personal factors were not statistically significant predictors of physical activity.

Hypothesis 1.2

The logistic regression model was conducted to determine the direct association between cognitive-perceptual factors (model 2 in Table IV.3) and physical activity after adjusting for the personal factors. The AUC was 0.81 showing good model accuracy and the Wald test of model fit was not significant indicating inadequate fit to the data, $F(6, 789.1) = 1.74$, $p > .05$. In addition, only health professional support for treatment (HPST) was a predictor of physical activity, where receiving HPST appears to decrease the odds of being physically active compared to not receiving HPST in Saudis with T2DM after adjusting for personal factors (AOR = 0.35, 95% [.14, .85]). No other cognitive-perceptual factors found to be significant. It was important to mention that younger age (< 54 years) remained independent predictor of physical activity in the final model (AOR = 2.77, 95% [1.18, 6.51]).

Table IV.3. Adjusted Odds Ratio, 95% CIs, and P Values from Multivariate Analysis of the Association Between Personal, Cognitive-Perceptual Factors and Physical Activity among Saudis with T2DM.

	Model-1			Model-2		
Variable	AOR	95% CI	*P* Value	AOR	95% CI	*P* Value
Age < 54 years old	**2.84**	**[1.25, 6.45]**	**0.013**	**2.77**	**[1.18, 6.51]**	**0.019**
Men	1.57	[0.67, 3.68]	0.304	1.68	[0.71, 3.95]	0.234
Family history (yes)	1.55	[0.69, 3.50]	0.293	1.53	[0.68, 3.45]	0.305
Diabetes duration <5 years	1.40	[0.60, 3.29]	0.442	1.17	[0.48, 2.85]	0.738
Diabetes duration 5-9 years	1.56	[0.56, 4.33]	0.390	1.53	[0.52, 4.48]	0.438
Obese	1.44	[0.75, 2.79]	0.272	1.54	[0.77, 3.09]	0.221
Married	1.19	[0.44, 3.18]	0.734	1.14	[0.43, 3.01]	0.788
Middle education	2.23	[0.92, 5.40]	0.075	2.02	[0.85, 4.81]	0.112
High education	**3.14**	**[1.02, 9.71]**	**0.047**	2.88	[0.97, 8.57]	0.058
Middle income	0.96	[0.40, 2.31]	0.930	0.92	[0.37, 2.30]	0.854
High income	1.83	[0.65, 5.12]	0.251	1.85	[0.66, 5.20]	0.245
Western region	1.45	[0.58, 3.60]	0.428	1.28	[0.50, 3.31]	0.604
Eastern region	0.39	[0.08, 1.99]	0.258	0.30	[0.05, 1.61]	0.159
Northern region	0.80	[0.31, 2.06]	0.643	0.83	[0.31, 2.25]	0.718
Southern region	1.49	[0.58, 3.86]	0.411	1.19	[0.48, 2.98]	0.707
Good PHS	0.67	[0.27, 1.71]	0.405	0.57	[0.19, 1.77]	0.335
High VAB				0.77	[0.33, 1.81]	0.547
High HAB				0.27	[0.06, 1.23]	0.090
High PAB				2.56	[0.54, 12.14]	0.235
HPST (yes)				**0.35**	**[0.14, 0.85]**	**0.021**
HPSL (yes)				0.68	[0.22, 2.11]	0.499
MHP (yes)				1.02	[0.47, 2.19]	0.960
AUC	0.78			0.81		
Wald test	$F(16, 791.6) = 3.53, p < .001$			$F(6, 789.1) = 1.74, p > .05$		

Reference categories for categorical predictors are: Age (≥ 54 years); Gender (women); Family history (no); Diabetes duration (≥ 10 years); obesity (no); Marital status (others); Education (low); Income (low); Region of residence (central); PHS (poor); VAB (low); HAB (low); PAB (low); HPST (no); HPSL (no); MHP (no). Model-1 = only personal factors were included in the analysis; Model-2 = personal and cognitive-perceptual factors were included in the analysis; AUC = Area under ROC curve; AOR = adjusted odds ratio; CI = Confidence Interval; PHS = Perceived health status; VAB = vigorous activity barriers; HAB = house activity barriers; PAB = physical activity barriers; HPST = health professional support for treatment; HPSL = health professional support for lifestyle change; MHP = Multiple healthcare providers.

Hypothesis 2.1

Log-binomial regression was performed to directly predict self-monitoring of blood glucose (SMBG) from personal factor. The results of model-1 presented in Table IV.4. the AUC was 0.69 with poor model accuracy and the Wald test of model-1 indicated adequate fit to the data, $F(16, 789.9) = 3.54$, $p < .001$. The results showed four variables were associated with SMBG. The prevalence ratio of those with shorter diabetes duration (i.e., < 5 years and 5-9 years) to perform SBMG were less compared to those with longer diabetes duration (i.e., ≥ 10 years), (APR =0.78, 95% CI [0.63, 0.97], and APR = 0.78, 95% CI [0.62, 0.99], respectively). Obese Saudis with T2DM had a prevalence of SMBG that was 0.22 times greater than non-obese, 95% CI (1.04, 1.44). Those with middle and higher education had a prevalence of SMBG that was 0.32 and 0.54 greater than those, 95% CI ([1.8, 1.62] and [1.20, 1.98], respectively) . the prevalence of performing SMBG among Saudis with T2DM was less in the Eastern region compared to the Central region (APR = 0.64, 95% [0.43, .095]). Other personal factors were not significantly associated with SMBG.

Hypothesis 2.2

Log-binomial regression was performed to directly predict self-monitoring of blood glucose (SMBG) from cognitive-perceptual factors after adjusting for personal factors. The results of model-2 presented in Table IV.4. The AUC of model accuracy was 0.71, and the Wald test of model-2 indicated inadequate fit to the data, $F(6, 790.5) = 1.35$, $p > .05$. The results showed no evidence of association between cognitive-perceptual factors and SMBG. On the other hand, it was found that diabetes duration of 5-9 years (APR = 0.78), middle and higher education (APR = 1.30 and 1.49, respectively), and Eastern region (APR = 0.66) were consistent predictors of SMBG.

Table IV.4. Adjusted Prevalence Ratio, 95% CIs, and P Values from Multivariate Analysis of the Association Between Personal, Cognitive-Perceptual Factors and Self-monitoring of Blood Glucose among Saudis with T2DM.

	Model-1			Model-2		
Variable	APR	95% CI	P Value	APR	95% CI	P Value
Age < 54 years old	0.86	[0.72, 1.02]	0.085	0.84	[0.71, 1.00]	0.055
Men	0.92	[0.76, 1.12]	0.424	0.91	[0.76, 1.10]	0.350
Family history (yes)	1.21	[0.98, 1.48]	0.074	1.21	[0.99, 1.50]	0.068
Diabetes duration <5 years	**0.78**	**[0.63, 0.97]**	**0.027**	0.80	[0.64, 1.00]	0.052
Diabetes duration 5-9 years	**0.78**	**[0.62, 0.99]**	**0.039**	**0.78**	**[0.62, 0.98]**	**0.034**
Obese	**1.22**	**[1.04, 1.44]**	**0.017**	**1.20**	**[1.01, 1.41]**	**0.034**
Married	1.07	[0.83, 1.37]	0.618	1.09	[0.85, 1.39]	0.518
Middle education	**1.32**	**[1.08, 1.62]**	**0.007**	**1.30**	**[1.06, 1.59]**	**0.012**
High education	**1.54**	**[1.20, 1.98]**	**0.001**	**1.49**	**[1.17, 1.89]**	**0.001**
Middle income	1.13	[0.90, 1.41]	0.294	1.12	[0.89, 1.41]	0.316
High income	1.31	[0.99, 1.72]	0.057	1.31	[0.99, 1.73]	0.060
Western region	0.92	[0.75, 1.12]	0.397	0.91	[0.74, 1.12]	0.390
Eastern region	**0.64**	**[0.43, 0.95]**	**0.026**	**0.66**	**[0.44, 0.98]**	**0.042**
Northern region	1.03	[0.83, 1.28]	0.761	1.03	[0.82, 1.29]	0.810
Southern region	0.93	[0.75, 1.15]	0.498	0.92	[0.74, 1.15]	0.485
Good PHS	1.02	[0.83, 1.26]	0.847	1.04	[0.83, 1.29]	0.748
High VAB				0.93	[0.77, 1.12]	0.445
High HAB				0.83	[0.61, 1.12]	0.216
High PAB				1.22	[0.92, 1.60]	0.163
HPST (yes)				1.36	[0.98, 1.90]	0.064
HPSL (yes)				1.03	[0.71, 1.50]	0.869
MHP (yes)				1.06	[0.90, 1.26]	0.464
AUC	0.69			0.71		
Wald test	$F(16, 789.9) = 3.54$, $p < .001$			$F(6, 790.5) = 1.35$, $p > .05$		

Reference categories for categorical predictors are: Age (≥ 54 years); Gender (women); Family history (no); Diabetes duration (≥ 10 years); obesity (no); Marital status (others); Education (low); Income (low); Region of residence (central); PHS (poor); VAB (low); HAB (low); PAB (low); HPST (no); and HPSL (no); MHP (no). Model-1= only personal factors were included in the analysis; Model-2 = personal and cognitive-perceptual factors were included in the analysis; AUC = area under the curve; APR = adjusted prevalence ratio; CI = Confidence Interval; PHS = Perceived health status; VAB = vigorous activity barriers; HAB = house activity barriers; PAB = physical activity barriers; HPST = health professional support for treatment; HPSL = health professional support for lifestyle change; MHP = Multiple healthcare providers.

Hypothesis 3.1

Log-binomial regression was conducted to determine the relationship between the personal factors and poor glycemic control (see Table IV.5). The accuracy of the model was poor (AUC = 0.67), and the Wald test of the model-1 fit was significant, $F(16, 376.3) = 1.81$, $p < .05$. The results obtained from model-1 analysis found that only Southern region was significantly associated with poor glycemic control compared to the central region (APR = 1.55, 95% [1.09, 2.08]). Other personal factors were not statistically significant.

Hypothesis 3.2

Model-2 was analyzed using log-binomial regression to determine if there was a relationship between the cognitive-perceptual factors and poor glycemic control after adjusting for personal factors. AUC was 0.71 indicating fair model accuracy and the Wald test of the model-2 fit was not significant, $F(6, 375.7) = 1.46$, $p > .05$. All factors in the model-2 were not statistically significant at $p < .05$ were not statistically significant except the prevalence poor glycemic control in Western region was less compared to central region (APR = 0.53, 95% [.29, 0.98]).

Hypothesis 3.3

Model-3 was analyzed using log-binomial regression to determine if there was a relationship between the behavioral factors and poor glycemic control after adjusting for personal and cognitive-perceptual factors. The AUC was 0.71 indicating fair model accuracy and the Wald test of the model-3 fit was not significant, $F(7, 376.7) = 0.46$, $p > .05$. All factors in the model-3 were not statistically significant except the prevalence of poor glycemic control in Western region was less compared to central region (APR = 0.53, 95% [.29, 0.98]).

Further gender sub-group analysis was carried out to inspect if there was any association each personal, cognitive-perceptual, behavioral and poor glycemic control among men and women.

Table IV.5. Adjusted Prevalence Ratio (APR), 95% CIs, and P Values from Multivariate Analysis of the Association Between Personal, Cognitive-Perceptual, Behavioral Factors and Poor Glycemic Control among Saudis with T2DM.

	Model 1			Model 2			Model 3		
Variable	APR	95% CI	P Value	APR	95% CI	P Value	APR	95% CI	P Value
Age < 54 years old	1.10	[0.74, 1.62]	0.653	1.11	[0.75, 1.66]	0.596	1.11	[0.74, 1.68]	0.610
Men	1.08	[0.73, 1.61]	0.701	1.02	[0.68, 1.52]	0.932	1.01	[0.66, 1.56]	0.949
Family history (yes)	0.90	[0.56, 1.45]	0.652	0.84	[0.52, 1.34]	0.459	0.78	[0.46, 1.28]	0.337
Diabetes duration <5 years	0.80	[0.51, 1.26]	0.329	0.89	[0.57, 1.39]	0.597	0.89	[0.56, 1.41]	0.613
Diabetes duration 5-9 years	0.72	[0.43, 1.21]	0.216	0.73	[0.43, 1.22]	0.225	0.74	[0.44, 1.27]	0.273
Obese	0.97	[0.68, 1.39]	0.865	0.94	[0.66, 1.34]	0.722	0.96	[0.67, 1.38]	0.838
Married	1.13	[0.71, 1.79]	0.605	1.14	[0.72, 1.79]	0.576	1.17	[0.74, 1.84]	0.502
Middle education	0.76	[0.50, 1.15]	0.191	0.79	[0.52, 1.18]	0.245	0.77	[0.51, 1.17]	0.222
High education	0.72	[0.39, 1.33]	0.303	0.72	[0.39, 1.36]	0.314	0.71	[0.38, 1.40]	0.337
Middle income	1.24	[0.80, 1.95]	0.334	1.25	[0.80, 1.96]	0.341	1.23	[0.77, 1.96]	0.379
High income	1.22	[0.64, 2.29]	0.546	1.19	[0.62, 2.27]	0.603	1.22	[0.63, 2.39]	0.556
Western region	0.57	[0.32, 1.03]	0.062	0.56	[0.31, 1.01]	0.053	**0.53**	**[0.29, 0.98]**	**0.044**
Eastern region	0.74	[0.36, 1.50]	0.397	0.72	[0.35, 1.50]	0.381	0.26	[0.31, 1.42]	0.287
Northern region	1.09	[0.66, 1.80]	0.729	0.89	[0.53, 1.50]	0.665	0.25	[0.51, 1.54]	0.664
Southern region	**1.55**	**[1.09, 2.08]**	**0.014**	1.42	[0.99, 2.05]	0.055	1.32	[0.88, 1.97]	0.177
Good PHS	0.99	[0.66, 1.50]	0.97	1.10	[0.73, 1.65]	0.664	1.06	[0.69, 1.61]	0.798
high VAB				1.10	[0.74, 1.65]	0.639	1.13	[0.75, 1.69]	0.559
High HAB				0.64	[0.36, 1.12]	0.117	0.66	[0.37, 1.17]	0.154
High PAB				1.62	[0.92, 2.88]	0.097	1.57	[0.88, 2.82]	0.129
HPST (yes)				1.72	[0.85, 3.52]	0.134	1.41	[0.60, 3.36]	0.437
HPSL (yes)				0.78	[0.47, 1.31]	0.344	0.80	[0.46, 1.38]	0.421
MHP (yes)				1.31	[0.88, 1.93]	0.180	1.33	[0.89, 1.99]	0.167

Table IV.5. continued.

	Model 1			Model 2			Model 3		
Variable	APR	95% CI	P Value	APR	95% CI	P Value	APR	95% CI	P Value
Physically Active							1.27	[0.70, 2.30]	0.434
Adequate FVC							1.05	[0.57, 1.93]	0.881
SMBG (yes)							0.91	[0.63, 1.32]	0.627
Smoker							0.98	[0.54, 1.78]	0.936
Medication (yes)							1.56	[0.59, 4.09]	0.369
RCV (yes)							1.30	[0.72, 2.36]	0.382
RVHP (yes)							0.79	[0.43, 1.45]	0.446
AUC	0.67			0.71			0.71		
Wald test	*F*(16, 376.3) = 1.81, *p* < .05			*F*(6, 375.7) = 1.46, *p* > .05			*F*(7, 376.7) = 0.46, *p* > .05		

Reference categories for categorical predictors are: Age (≥ 54 years); Gender (women); Family history (no); Diabetes duration (≥ 10 years); obesity (no); Marital status (others); Education (low); Income (low); Region of residence (central); PHS (poor); VAB (low); HAB (low); PAB (low); HPST (no); and HPSL (no); MHP (no); physically inactive; inadequate FVC; SMBG (no); Medication (no) ;RCV (no); RVHP (no). Model-1= only personal factors were included in the multivariate analysis; Model-2 = personal and cognitive-perceptual factors were included in the analysis; Model-3 = personal, cognitive-perceptual, and behavioral factors included in the analysis; AUC = area under the ROC curve; APR = adjusted prevalence ratio; CI = Confidence Interval; PHS = Perceived health status; VAB = vigorous activity barriers; HAB = house activity barriers; PAB = physical activity barriers; HPST = health professional support for treatment; HPSL = health professional support for lifestyle change; MHP = Multiple healthcare providers; FVC = fruit and vegetable consumption; SMBG = self-monitoring of blood glucose; RCV = regular clinic visits; RVHP = Recent visit to health professional.

Due to small sample size in the sub-group analysis, only bivariate log-binomial regression was conducted in the analysis of poor glycemic control. The results showed evidence of association in women sub-group but was not of much value because of small size and bivariate analysis (see Appendix K). The prevalence ratio was 8.03 for HPST and 4.32 for medication indicating that receiving HPST and using medication were related to poor glycemic control. For men sub-group analysis, there were no evidence of association between all factors and poor glycemic control.

Due to lack evidence in the association between the predictors and aim 3 related to poor glycemic control, another approach was taken to address the association of common personal factors with cognitive-perceptual and behavioral factors among Saudi with T2DM. For example, the study analyzed the association between age across several outcomes such as VAB, HAB, FVC, and smoking. At least this analysis would help identify the most important predictive variables for perceptions and behaviors in T2DM individuals. Factors associated with psychological and cognitive-perceptual outcomes were separately analyzed and presented in prevalence ratio (see Table IV.6). Age < 54 years old found to be a predictor of good PHS (1.19), high VAB (0.55), high HAB (0.32), and high PAB (0.28) outcomes. Male gender was only a predictor of high HAB (0.62) and high PAB (0.60). Being married was a predictor of high HAB (0.60), high PAB (0.53) and HPSL (1.15). Middle education was a predictor of good PHS (1.21), high VAB (0.60), high HAB (0.30), high PAB (0.29). Similarly, higher education was a predictor of good PHS (1.31), high VAB (0.38), high HAB (0.22), high PAB (0.26). Middle income was a predictor of high HAB (0.66), high PAB (0.70), and HPSL (1.09). High income was a predictor of good PHS (1.13), high HAB (0.55), and high PAB (0.44). Western region was a predictor of HPSL (0.95) and MHP (1.89). Likewise, Eastern region with 0.84 and 1.63 for HPSL and MHP, respectively. Northern region was a predictor of High VAB (1.35), High HAB (1.49), and MHP (1.95), while Southern region only predicted HPSL (0.90).

Table IV.6. Characteristics, Prevalence Ratio (PR), 95% CI, and P Value from Bivariate Analysis of the Association Between Some Personal Factors and Both Psychological and Cognitive-Perceptual as Outcomes among Saudis with T2DM.

	Good PHS		High VAB		High HAB		High PAB	
Variable	PR [95% CI]	P Value	PR [95% CI]	P Value	PR [95% CI]	P Value	PR [95% CI]	P Value
Age < 54 years old	**1.19 [1.10, 1.30]**	**< .001**	**0.55 [0.44, 0.69]**	**< .001**	**0.32 [0.22, 0.47]**	**< .001**	**0.28 [0.18, 0.44]**	**< .001**
Men	1.07 [0.98, 1.17]	0.151	0.94 [0.78, 1.14]	0.541	**0.62 [0.47, 0.84]**	**0.002**	**0.60 [0.43, 0.84]**	**0.002**
Married	1.06 [0.96, 1.18]	0.235	0.97 [0.77, 1.23]	0.816	**0.60 [0.44, 0.80]**	**0.001**	**0.53 [0.38, 0.73]**	**< .001**
Middle education	**1.21 [1.10, 1.33]**	**< .001**	**0.60 [0.47, 0.77]**	**< .001**	**0.30 [0.19, 0.47]**	**< .001**	**0.29 [0.17, 0.48]**	**< .001**
High education	**1.31 [1.21, 1.41]**	**< .001**	**0.38 [0.25, 0.57]**	**< .001**	**0.22 [0.11, 0.44]**	**< .001**	**0.26 [0.13, 0.49]**	**< .001**
Middle income	1.06 [0.96, 1.17]	0.272	0.89 [0.72, 1.10]	0.266	**0.66 [0.48, 0.92]**	**0.013**	**0.70 [0.49, 1.00]**	**0.050**
High income	**1.13 [1.00, 1.27]**	**0.049**	0.74 [0.53, 1.05]	0.089	**0.55 [0.30, 0.99]**	**0.049**	**0.44 [0.22, 0.87]**	**0.019**
Western region	0.95 [0.85, 1.06]	0.320	0.94 [0.73, 1.21]	0.630	1.21 [0.81, 1.80]	0.345	1.25 [0.81, 1.93]	0.317
Eastern region	1.07 [0.93, 1.22]	0.340	0.96 [0.66, 1.40]	0.836	1.51 [0.88, 2.57]	0.131	1.35 [0.70, 2.63]	0.372
Northern region	0.96 [0.86, 1.07]	0.473	**1.35 [1.08, 1.68]**	**0.007**	**1.49 [1.00, 2.20]**	**0.048**	1.70 [1.11, 2.61]	0.015
Southern region	0.90 [0.80, 1.01]	0.063	0.92 [0.71, 1.19]	0.502	1.20 [0.80, 1.80]	0.375	1.42 [0.92, 2.18]	0.113
Diabetes duration <5 years	**1.22 [1.10, 1.34]**	**< .001**	**0.61 [0.46, 0.81]**	**0.001**	**0.57 [0.38, 0.86]**	**0.008**	**0.48 [0.30, 0.77]**	**0.003**
Diabetes duration 5-9 years	**1.14 [1.02, 1.29]**	**0.027**	0.86 [0.67, 1.09]	0.212	0.83 [0.56, 1.23]	0.357	0.85 [0.55, 1.30]	0.446

Reference categories for categorical predictors are: Age (≥ 54 years); Gender (women); Diabetes duration (≥ 10 years); Marital status (others); Education (low); Income (low); Region of residence (central). PR = prevalence ratio; CI = Confidence Interval; PHS = Perceived health status; VAB = vigorous activity barriers; HAB = house activity barriers; PAB = physical activity barriers ; HPST = health professional support for treatment; HPSL = health professional support for lifestyle change; MHP = Multiple healthcare providers.

Table IV.6. Continued.

	HPST		HPSL		MHP	
Variable	PR [95% CI]	P Value	PR [95% CI]	P Value	PR [95% CI]	P Value
Age < 54 years old	0.97 [0.91, 1.04]	0.379	0.99 [0.95, 1.06]	0.870	0.94 [0.75, 1.18]	0.589
Men	1.01 [0.95, 1.09]	0.703	1.05 [0.98, 1.12]	0.151	1.14 [0.90, 1.44]	0.270
Married	0.95 [0.89, 1.01]	0.105	**1.15 [1.04, 1.28]**	**0.008**	1.25 [0.92, 1.68]	0.149
Middle education	0.98 [0.91, 1.06]	0.618	1.04 [0.98, 1.10]	0.241	0.97 [0.74, 1.26]	0.799
High education	0.97 [0.87, 1.09]	0.640	0.98 [0.89, 1.08]	0.668	1.25 [0.94, 1.67]	0.129
Middle income	0.98 [0.91, 1.07]	0.696	**1.09 [1.01, 1.17]**	**0.025**	0.99 [0.76, 1.30]	0.960
High income	0.98 [0.88, 1.10]	0.765	1.08 [0.97, 1.21]	0.138	1.23 [0.88, 1.72]	0.232
Western region	0.94 [0.87, 1.02]	0.163	0.95 [0.90, 1.00]	0.063	**1.89 [1.36, 2.63]**	**< .001**
Eastern region	0.89 [0.76, 1.04]	0.145	**0.84 [0.71, 0.99]**	**0.038**	**1.63 [1.03, 2.56]**	**0.036**
Northern region	0.99 [0.92, 1.08]	0.924	0.96 [0.91, 1.02]	0.200	**1.95 [1.40, 2.71]**	**< .001**
Southern region	0.95 [0.88, 1.03]	0.224	**0.90 [0.84, 0.97]**	**0.006**	1.32 [0.92, 1.89]	0.129
Diabetes duration <5 years	**0.88 [0.80, 0.97]**	**0.008**	0.99 [0.92, 1.08]	0.927	0.99 [0.75, 1.32]	0.970
Diabetes duration 5-9 years	1.02 [0.94, 1.11]	0.635	1.06 [0.99, 1.12]	0.080	0.86 [0.62, 1.20]	0.377

Reference categories for categorical predictors are: Age (≥ 54 years); Gender (women); Diabetes duration (≥ 10 years); Marital status (others); Education (low); Income (low); Region of residence (central). PR = prevalence ratio; CI = Confidence Interval; HPST = health professional support for treatment; HPSL = health professional support for lifestyle change; MHP = Multiple healthcare providers.

Table IV.7 showed the results of the factors associated with behavioral and obesity outcomes and were presented in prevalence ratio. Men was a predictor of obesity (0.70) and smoking (7.20). Being married was associated with smoking (4.18). Higher education was associated with adequate FVC (4.46). High income was a predictor of adequate FVC (4.17), smoking (1.82), and RVHP (1.12). With regards to region of residence, it was found that Western region was associated with adequate FVC (2.82), RCV (0.78), and RVHP (0.87). Eastern region was associated with adequate FVC (11.35) and medication use (1.09). Northern region was associated with adequate FVC (3.02), RCV (0.85), and RVHP (0.92), while Southern region was associated with adequate FVC (3.65) and RVHP (0.91). Diabetes duration of < 5 years was associated with less medication use (0.90).

Table IV.7. Characteristics, Prevalence Ratio (PR), Odds Ratio (OR), 95% CI, and P Value from Bivariate Analysis of the Association Between Some Personal Factors and Both Behavioral and Obesity as Outcomes among Saudis with T2DM.

	Obesity		Adequate FVC		Smoking	
variable	PR [95% CI]	P Value	OR [95% CI]	P Value	PR [95% CI]	P Value
Age < 54 years old	1.10 [0.92, 1.31]	0.303	1.10 [0.55, 2.19]	0.781	1.16 [0.75, 1.79]	0.504
Men	**0.70 [0.59, 0.82]**	**< .001**	0.53 [0.26, 1.04]	0.065	**7.20 [2.51, 20.63]**	**< .001**
Married	1.03 [0.83, 1.29]	0.768	0.94 [0.42, 2.15]	0.890	**4.18 [1.42, 12.31]**	**0.009**
Middle education	1.01 [0.83, 1.23]	0.933	2.24 [0.97, 5.18]	0.060	1.16 [0.71, 1.88]	0.550
High education	0.96 [0.74, 1.25]	0.762	**4.46 [1.96, 10.16]**	**< .001**	1.23 [0.71, 2.15]	0.461
Middle income	1.08 [0.88, 1.33]	0.476	2.34 [0.89, 6.15]	0.084	1.04 [0.62, 1.76]	0.878
High income	1.18 [0.91, 1.54]	0.206	**4.17 [1.43, 12.12]**	**0.009**	**1.82 [1.02, 3.26]**	**0.043**
Western region	0.80 [0.64, 1.01]	0.061	**2.82 [1.02, 7.80]**	**0.046**	0.93 [0.55, 1.57]	0.788
Eastern region	0.98 [0.72, 1.34]	0.921	**11.35 [3.58, 35.98]**	**< .001**	1.34 [0.67, 2.69]	0.410
Northern region	0.98 [0.79, 1.22]	0.847	**3.02 [1.00, 9.09]**	**0.049**	0.67 [0.37, 1.21]	0.186
Southern region	0.83 [0.66, 1.04]	0.099	**3.65 [1.27, 10.5]**	**0.016**	0.64 [0.33, 1.22]	0.171
Diabetes duration <5 years	1.15 [0.92, 1.44]	0.209	1.05 [0.48, 2.29]	0.905	1.27 [0.71, 2.25]	0.421
Diabetes duration 5-9 years	1.02 [0.78, 1.32]	0.897	0.42 [0.16, 1.06]	0.067	1.39 [0.73, 2.62]	0.314

Reference categories for categorical predictors are: Age (≥ 54 years); Gender (women); Diabetes duration (≥ 10 years); Marital status (others); Education (low); Income (low); Region of residence (central). PR = prevalence ratio; CI = Confidence Interval; FVC = fruit and vegetable consumption.

Table IV.7. Continued.

	Medication		RCV		RVHP	
variable	PR [95% CI]	P Value	PR [95% CI]	P Value	PR [95% CI]	P Value
Age < 54 years old	0.95 [0.9, 1.00]	0.056	0.99 [0.9, 1.08]	0.762	0.94 [0.88, 1.01]	0.111
Men	0.99 [0.94, 1.04]	0.765	0.99 [0.9, 1.09]	0.829	1.02 [0.95, 1.09]	0.597
Married	0.97 [0.92, 1.01]	0.111	0.97 [0.88, 1.06]	0.498	1.02 [0.95, 1.10]	0.593
Middle education	1.03 [0.97, 1.08]	0.343	0.96 [0.87, 1.07]	0.457	0.99 [0.92, 1.07]	0.858
High education	1.02 [0.94, 1.11]	0.617	0.98 [0.86, 1.12]	0.756	0.97 [0.86, 1.09]	0.597
Middle income	1.03 [0.97, 1.09]	0.347	0.99 [0.90, 1.11]	0.988	1.08 [0.99, 1.18]	0.095
High income	0.99 [0.91, 1.09]	0.865	1.04 [0.91, 1.19]	0.558	**1.12 [1.01, 1.24]**	**0.025**
Western region	1.04 [0.97, 1.12]	0.276	**0.78 [0.69, 0.88]**	**< .001**	**0.87 [0.80, 0.94]**	**0.001**
Eastern region	**1.09 [1.01, 1.17]**	**0.023**	0.89 [0.74, 1.06]	0.180	0.86 [0.74, 1.00]	0.050
Northern region	1.04 [0.96, 1.13]	0.316	**0.85 [0.76, 0.96]**	**0.007**	**0.92 [0.84, 0.99]**	**0.041**
Southern region	1.04 [0.96, 1.12]	0.307	0.91 [0.82, 1.00]	0.056	**0.91 [0.84, 0.98]**	**0.015**
Diabetes duration <5 years	**0.90 [0.84, 0.97]**	**0.003**	0.95 [0.85, 1.07]	0.411	0.96 [0.88, 1.05]	0.398
Diabetes duration 5-9 years	0.97 [0.9, 1.04]	0.378	0.99 [0.87, 1.12]	0.839	0.98 [0.89, 1.08]	0.643

Reference categories for categorical predictors are: Age (≥ 54 years); Gender (women); Diabetes duration (≥ 10 years); Marital status (others); Education (low); Income (low); Region of residence (central). PR = prevalence ratio; CI = Confidence Interval; RCV = regular clinic visits; RVHP = Recent visit to health professional.

CHAPTER V

DISCUSSION

Overview of the Prevalence Poor Glycemic Control, Physical Activity, and SMBG

The prevalence of T2DM among Saudi population, as shown by the analysis, was more than 0.72 million in 2013, which represents a significant proportion of Saudi population. Unfortunately, there was no comparative study found in the literature that estimated the prevalence of Saudis with T2DM at regional nor country level. The only sources that predict the magnitude of diabetes in general were the International Diabetes Federation (IDF)[5] and two published studies (e.g., El Bcheraoui et al.[26] and Al-Quwaidhi[163]) for the same year. For example, in 2013 the IDF estimated the diabetes in general to be 3.65 million in Saudi Arabia.[5] However, these studies estimated the burden of diabetes in general for all those living (e.g., citizen and non-citizen) in Saudi Arabia. The study is first to be known to highlight the magnitude of T2DM in Saudi Arabia with accurate estimation including estimation of poor glycemic control, physical activity and self-monitoring of blood glucose (SMBG) of the year 2013.

This study further demonstrates that the prevalence of T2DM varies across regions (see Figure IV.1). The results indicated that those regions with urbanized cities have higher prevalence of diabetes. For instance, Riyadh region is the most urbanized city (i.e., the capital city) having the highest prevalence of T2DM compared to less urbanized regions. The degree of urbanization also applied to the Makkah and Eastern regions where T2DM ranked second and third after the Riyadh region with 20.9% and 13.9%, respectively. Other related studies in Saudi Arabia have established the association between urbanization and diabetes in Saudi Arabia.[164-165] For instance, Al-Rubeaan et al.[165] showed that odds of diabetes were 1.23 higher in urban compared to rural residence. A systematic review at a global level suggested that urbanization was directly associated with T2DM in upper middle income countries, while indirectly via other risk factors such as physical activity in high income countries.[166] Urbanization has tripled since the early 90's where Riyadh, Makkah, and Eastern regions are the most populated regions and have the fastest urban growth in Saudi Arabia.[167,168] Thus, this an indication that uncontrolled urbanization may lead to unhealthy lifestyle, lack of access to health services due to capacity, and environmental pollution which may impose a great challenge especially for a fast growing country like Saudi Arabia.[169]

The focal point of this study was to determine the magnitude of poor glycemic control among Saudis with T2DM. The prevalence of poor glycemic control in Saudi Arabia was 34.30% compared to 77.7% that was previously reported by the meta-analysis of prevalence presented in Chapter II, Figure 2. The SHIS data showed lower prevalence compared to the meta-analysis with about 43% in difference. The overestimation of poor glycemic control in the meta-analysis and the large variation between the two findings could be explained by the differences in the study design. For instance, most of the included studies in the meta-analysis were conducted at local level utilizing hospital data, while the SHIS was at national level utilizing household data (i.e., multistage stratified random sampling of households). The hospital data may lack the generalizability where individuals with T2DM who did not have access to health care or were healthy may be neglected. Therefore, the majority of those visited hospitals may have had healthcare issues.

The study also suggested variation in the prevalence of glycemic control between regions. In general, the highest total percentage of poor glycemic control cases was 39.4% in Riyadh region compared to other regions. On the other hand, Aseer (66.2%), Al-Bahaa (61.6%), Al-Jouf (46.8%), Hail (45.8%), and Northern Border (45.3%) regions had the highest percentages of poor glycemic control as a proportion of their T2DM populations (see Figure IV.2). These regions can be described as unurbanized and located in Southern and Northern part of Saudi Arabia. Despite the variation in the prevalence of poor glycemic control between regions, a plausible answer for the substantial increase in the prevalence could be attributed to lack access to healthcare and lack of knowledge and awareness about diabetes.[170-175] In addition, these high percentages raise a concern regarding the increase in morbidity and mortality due to diabetes. For example, one study showed that diabetes was the leading cause of years lived with disability (YLDs) in Saudi Arabia in 2013.[108]

The results also showed very low percentages (9.1%) were physically active Saudis with T2DM, which was measured according to the American Diabetes Association (ADA)[47] recommendations. This result was consistent with previous studies showing low physical activity among diabetic Saudis.[53-54] For instance, Alramadan et al.[54] revealed that only 30% of T2DM Saudis adhere to the recommend physical activity (≥ 150 min/week) in four diabetic centers in Hofuf, Jeddah, and Riyadh. Another study showed similar results where only 38% adhered to physical activity.[53] However, our study was representative to the whole Saudi diabetic population compared to these studies. In addition, the issue of lack of physical activity can be seen not only on diabetic people but also extends to the general Saudi population.[176-178] While it is known that physical activity is a risk for chronic diseases, the low prevalence of physical activity raises a concern about the need for effective methods of promoting healthy behaviors.[179-180]

Prevalence of those who monitor their blood glucose (SMBG) was 55.4% which means significant proportion of Saudis with T2DM do not take self-care practices and do not record their blood glucose which eventually could lead to lack of maintaining healthy behaviors.

Several local studies were conducted in Saudi Arabia showed variation in the prevalence of SMBG that ranges from 22% to 90%.[63,73,181-183] Sabbah and colleagues[181] conducted their study in a family medicine clinics in Al-Taif city and found only around one-fifth of the patients with T2DM adhered to SMBG. Another study conducted in diabetes clinic in the Eastern region showed 62% of diabetic patients adhered to SMBG.[182] Similar study was conducted in primary healthcare center in Makkah found two-third of the participating patients adhere to SMBG.[63] The highest adherence to SMBG (90%) found in AlBarrak et al.[183] study and was carried out in a university hospital in Riyadh. These studies were local and conducted in different cities in Saudi Arabia. Generally, few patients adhere to SMBG as part of diabetes self-care while SMBG is highly recommended by the American Diabetes Association especially for those on insulin treatment.[46]

Overview of the Main Findings

A total of seven hypotheses were tested in this study. These were determined via the health promotion model (HPM) and were related to three outcomes including physical activity, SMBG, and poor glycemic control. The investigated risk factors were personal, cognitive-perceptual, and behavioral.

Physical Activity

Hypothesis 1.1 stated that younger individuals, men, higher education, high income, not obese and perceived good health will be significantly associated with physical activity. However, the analysis partially supported the hypothesis where only younger age and higher education had association with physically active Saudi with T2DM. Although there were few studies examining risk factors for physical activity among diabetic patient in Saudi Arabia,[52-54] the findings were consistent with these studies.

The results of this study showed older people with T2DM were not physically active. Similarly, Alzahrani et al.[53] conducted a study on small number of subjects with T2DM (250) at three primary healthcare clinics in Jeddah and found the mean age ($M = 54$) for physically active individuals were significantly lower compared to those inactive ($M = 58.7$). Another study examined factors associated with physical activity among T2DM individuals in three diabetic centers in Hofuf, Jeddeh, and Riyadh on more than 1000 sample size, and found younger individuals significantly adhere to physical activity compared to older individuals.[54] Elbur[52] also conducted his study on men with diabetes at a hospital in Taif city showed the odds of adhering to physical activity was 1.8 times higher in the younger age (< 50 year) compared to the older age. The findings of our study suggested that exercise among older population was low and despite the importance of other factors such as BMI, muscle quality in elderly people could be an important predictor of physical function.[184-185] Therefore, a specific exercise regimen designed for elderly is needed that focuses on improving muscle quality without compromising their health.[186] Unfortunately, the initiatives to promote physical activity among elderly in Saudi Arabia remain unclear. A recent systematic review that focuses on geriatric research in Saudi Arabia showed few studies that conducted on elderly and none of these studies were interventional or introduced a health promotion program to improve physical activity among the vulnerable population and the study suggested high quality research that impact development of policies and care for elderly people.[187] Another study pointed out that there was lack of literature about promoting physical activity in Saudi Arabia, and also questioned the effectiveness of the governmental initiatives to promote physical activity as they were on a short-term and their outcomes were not objectively assessed.[179]

Higher education was another independent factor that directly associated with physical activity among T2DM individuals and was consistent with other studies. One study showed higher education associated with physical activity.[54] In addition, Elbur[52] found the odds of those with secondary education or higher were 2.3 greater in adhering to physical activity compared to lower than secondary education. The study suggested that those with lower education and elderly can be targeted through designed educational programs that promotes awareness about healthy behaviors.[188]

Hypothesis 1.2 stated that low vigorous activity barriers (VAB), low house activity barriers (HAB), low physical activity barriers (PAB), and health professional support for lifestyle change (HPSL) will be significantly associated with physical activity after controlling for personal factors. However, the analysis did not support the hypothesis and only health professional support for treatment (HPST) was found to be negatively associated with physically active Saudis who had T2DM. In addition to HPST, only age remained a consistent and independent predictor of physical activity after complete model analysis. The findings from the study suggested that those who were advised to take medication may avoid exercise since the medicine may provide adequate results for lowering blood glucose level. Furthermore, patients with T2DM who had combined treatment (i.e., medication, especially insulin, with exercise) were at higher risk of experiencing hypoglycemic events.[189] Thus, it is crucial for the healthcare providers to balance between treatment and lifestyle modifications the types of treatment given to patients with T2DM. Other studies showed the relationship between physician support and self-care management in different forms. Ramadhan et al.[54] revealed that poor education about diabetes given by the healthcare providers was associated with lower physical activity. Another study showed higher percentage of patients with T2DM believed that their physicians had influence on the management of diabetes.[190] Furthermore, the role of physician on perceived autonomy support was related to physical activity.[56,191] Therefore, the role of healthcare providers is vital in patient's self-care management, and the more the healthcare providers discuss and share the decision of the treatment with their patients, the more the patients tend to adhere to the treatment and eventually had better self-care management including physical activity.[192]

There were several personal and cognitive-perceptual factors found to be significant in the bivariate analysis but not in the model testing of hypothesis 1.1 and 1.2. Among personal factors associated with physical activity, there were diabetes duration < 5 years, middle education, and high income. The findings were consistent with several studies.[52-54] For instance, Ramadan et al.[54] showed in their bivariate analysis that low income, and longer diabetes duration were associated with physical inactivity among diabetic Saudis. Also, older age, lower education and low income were found to relate with lack physical activity among the general Saudi population.[193] Personal factors, such as education and age, played a significant role in predicting physical activity. Among cognitive-perceptual factors, high VAB (OR = 0.46) and high HAB (OR = 0.22), were associated with physical inactivity. Several studies supported the association between perceived barriers, utilizing different measurement tools, and physical inactivity in Saudi Arabia and other coutnries.[53,57,77,60-62,194] For example, Alzahrani et al.[53] indicated that lack of energy and fear of injury were associated with physical inactivity. Also, Badedi et al.[77] found correlation between high barriers to exercise (e.g., inability to exercise, shortness of breath, and pain) and adherence to exercise among T2DM patients in Jazan city. In a study conducted in neighboring country, Oman, had similar results to that of Alzahrani et al.,[53] and both studies reported study participants having lack of energy and fear of injury were physically inactive.[60]

The perceived barriers were not disease-specific and can predict physical inactivity in the general population of Saudi Arabia.[176] However, in this study, the results may implies that VAB and HAB barriers were not dependent predictors of physical activity and this could be related to older diabetic individuals may perceive higher barriers toward physical activity compared to younger individuals, or it could be related to other unknown factors.

Some of the important predictors were found not significant with physical activity includes gender, obesity, perceived health status (PHS) and health professional support for lifestyle change (HPSL). Regarding gender, although there was a noticeable difference in the proportion of men being more physically active compared women, the analysis did yield significant results. Similarly, two studies did not establish the association between gender and physical activity in Saudi diabetic patients.[190,194] On the other hand, Ramadan et al.[54] showed women were significantly less active compared to men. Another study revealed that women had higher self-care management score including exercise when compared to men, indicating better self-care management among women.[8] Although there were variations in the findings from the existing literature examining physical activity among diabetic patients in Saudi Arabia, a systematic review supported the fact that women were less active compared to men in the general population but not specifically diabetic individuals.[176] Cultural barriers could explain a part of the puzzle where women have lack access to designated areas that ensures privacy and comfort for women to exercise.[195-197] Another aspect could be related to the cultural norms where women spends most of their time at home taking care of their families and they may not find adequate time and place to perform physical activity.[198-199] In addition, the initiatives for promoting physical activity are insufficient for women and fewer than men.[179] Therefore, considering gender differences in the process of promoting healthy behaviors are crucial in Saudi Arabia.

Obesity was also found not significantly associated with physical activity in our study. There were two studies that examined BMI and physical activity among diabetic individuals in Saudi Arabia.[54,194] Aldukhayel[194] did not find BMI as a predictor of physical activity, while Ramadan et al.[54] found those with lower BMI were more physically active. In addition, mean BMI was significantly higher in physically inactive men and women in Saudi Arabia but when categorizing BMI into three level (e.g., normal, over, and obese weight) it did not yield significant results.[193] Moreover, a Canadian study found inverse relationship between BMI and physical activity ($ß$ = - 0.11, $p < .001$).[57] Nevertheless, it is possible that the association between BMI and physical activity was mediated by another factor such as HPSL. For instance, physicians may encourage their obese patients to engage in physical activity. Another example suggested mediation effect of BMI on intention to perform physical activity via perceived behavioral control and attitude.[200] Therefore, it is necessary to take into consideration complexity of the associated between risk factors with physical activity behavior among diabetic individuals, even if it is known that cross-sectional studies do not provide causal inference between factors.

The health provider support for lifestyle change (HPSL) variable was not found as a significant predictor of physical activity. The non-significance could be related to the way HPSL variable was operationally defined. For instance, HPSL was created on the basis of four components including advise for diet, exercise, lose weight, and quit smoking. However, if the variable was measured by only using the exercise component then it may yield more accurate results. Due to complexity of the study design that involved 24 variables that were tested in three aims, it was not feasible to break down the HPSL variable into sub-variables. Several studies showed the importance of healthcare provider in promoting healthy behaviors which was previously mentioned.[53-54,56,60] Physicians may become a role model for their patient by believing in and adhering to healthy lifestyle. For instance, a systematic review showed that physically active healthcare providers were more likely to advise their patients to practice exercise.[201] In addition, not only an advice is given to patients to practice physical activity but there should be well designed program that fit the needs of each diabetic individual.[202]

Overall, physical activity is one of important healthy behaviors that prevent chronic diseases. However, a large proportion of Saudis with T2DM were physically inactive. Several factors played a major role in determining physical activity including younger age, higher education, and no HPST as well as diabetes duration < 5 year, high income, education, and low VAB and HAB. Diabetes treatment plans and health promotion programs should consider the personal and cognitive-perceptual differences among individuals with T2DM in Saudi Arabia.

Self-monitoring of Blood Glucose

Hypothesis 2.1 stated that younger individuals, men, higher education, and longer duration of diabetes will be significantly associated with self-monitoring of blood glucose (SMBG). Nevertheless, the adjusted model analysis partially supported the hypothesis and only obesity, higher education and middle education were associated with adherence SMBG while shorter diabetes duration (<5 and 5-9 years groups) and Eastern region were associated with no adherence to SMBG.

Obesity was an independent predictor of SMBG showing that higher proportion of obese Saudis with T2DM adhered to SMBG compared to non-obese. Although several studies conducted in Saudi Arabia did not address the association between obesity or BMI with SMBG,[8,63,181] it is known that obesity is one of the main risk factors for type 2 diabetes and uncontrolled HbA1c, and it is highly recommended to be treated.[203] Therefore, some randomized trial studies suggested that increase of self-monitoring of blood glucose level among obese patients improved both dietary habit and reduction in weight.[204-205] The possible explanation in this study is that those who were obese may experience higher HbA1c levels and may need to reduce their BMI but this requires constant monitoring of their blood glucose level to assess and prevent possible hypoglycemic event when doing exercise or having strict diet.

Education is also considered as an independent predictor of SMBG where Saudis with T2DM who had high level of education adhered to SMBG compared to low level of education. This finding is supported by Mansouri et al.[63] study when they examined non-insulin T2DM patients attending primary healthcare clinic center in Makkah city. Their results showed those who had higher education significantly associated with adherence to SMBG. In addition, Abdel Gawwad et al.[86] conducted a study on patients with T2DM attending diabetic clinic at university hospital in Riyadh, and they revealed that the odds of patients with higher education was 2.89 times higher to use SMBG compared to those with lower education. Another study in Al Madinah region found diabetic patients with formal education had higher mean SMBG score compared to those with no formal education (mean difference = 0.67).[8] It is suggested that individuals with higher level of education may have higher knowledge about disease. For example, two studies found knowledge about DM increase the adherence to SMBG.[181,206]

The proportion of diabetes duration for the group < 5 and 5 to 9 years were less compared to > 10 years group in adhering to SMBG, which indicates that Saudis with T2DM who had longer duration of diabetes use SMBG for their HbA1c management. Although, one study supported these findings (e.g., ALzahrani et al.[73]), several studies did not find duration of diabetes to be associated with SMBG.[8,63,181] This could be due to variation between studies. For instance, one study only explored the association between diabetes duration and SMBG on non-insulin group.[63] Individuals with T2DM for longer time may experience more complications, so diabetic individuals may potentially gain benefits from using SMBG in maintaining their health.[207-208]

Regional differences were observed in the analysis. Eastern region had low adjusted prevalence ratio in using SMBG compared to Central region. A study was conducted in Eastern region showed nearly 43% had high misconception score about diabetes, and high misconception about diabetes was significantly associated with low adherence to SMBG.[182] Therefore, it may indicated that there were lack of educational programs that increases awareness about diabetes in the Eastern region when considering the high percentage (30.1%) of poor glycemic control in that region. Further investigation is vital to know what contributes to the differences between regions.

Hypothesis 2.2 stated that Health professional support for treatment (HPST) and multiple healthcare providers (MHP) will have significant association with SMBG after controlling for personal factors. Nonetheless, the analysis did not support the hypothesis and no relationship found between cognitive-perceptual factors and SMBG. On the other hand, personal factors that were significant in the hypothesis 2.1, such as obesity, education, diabetes duration, and region of residence, remained strong predictors of SMBG.

Factors that were seen to be significant only in the bivariate analysis were family history, income, and HPST. For instance, Saudis with T2DM who had family history of diabetes had a prevalence of 25% higher in using SMBG compared to those with no family history. This may indicate that it is more likely for a diabetic patient who had a family member affected by diabetes to have better knowledge and experience about diabetes compared those do not have. Therefore, they may better adhere to self-management practices including SMBG. Income also another predictor that may have association but not independently with SMBG, where diabetic patients with middle and high income had higher prevalence ratio in using SMBG compared to low income. Although Ministry of Health (MOH) dispenses devices for SMBG to their diabetic patients,[209] it may not be sufficient because there are diabetic patients who had less access to healthcare as well as the availability of associated supplies with the devices such as strips, batteries, and calibration which are costly. For example, in the United States, the cost of SMBG devices and peripherals reached nearly half a billion dollar in 2002.[210] Therefore, those who are in a good economic status may be able to purchase the device and perform SMBG compared with poor economic status. HPST factor was also associated with SMBG, showing Saudis with T2DM who got advice from healthcare providers for treatment had higher prevalence ratio (1.42) in using SMBG compared with those do not have support. The results suggested indirect association between HPST and SMBG through supporting those with elevated blood glucose level to take treatment, especially insulin, where continuous monitoring is needed. However, the previous mentioned factors did not show association with SMBG in the presence of other variables suggesting these predictors were of less importance in the study.

The study also did not find age, gender, and MHP associated with SMBG. Although age was not significantly related to SMBG, there was a variation in the existing literature of the association between age and SMBG in Saudi Arabia, where two studies found younger age associated with adherence to SMBG (e.g., ALzahrani et al.[73] and Mansouri et al.[63]), while other studies showed no relationship (e.g., Al Johani[8] and Alyaemni[67]). The findings may suggest further sub-group analysis to see whether age is associated with SMBG; however, it is difficult due to large number of variables and not large sample size. Gender was also not found to be significant predictor of SMBG suggesting that gender differences do not play a major role in the adherence to SMBG. Different findings were observed among existing studies showing more men adhere to SMBG compared to women (e.g., Mansouri et al.[63] and Alyaemni[67]), and one study showed opposite association (e.g., Al Johani[8]) but some others did not establish that association (e.g., Abdel Gawwad et al.[68] and ALzahrani et al.[73]). Furthermore, multiple healthcare providers (MHP) was not associated with SMBG indicating that diabetic patient with access to more than one healthcare provider did not associate with better self-management. However, from the descriptive analysis, it was shown that high proportion of Saudis with T2DM did not adhere to healthy behaviors (e.g., physical activity, fruit and vegetable consumption and SMBG) while the majority had regular clinic visits and recent visits to healthcare providers which raise a question about the healthcare system in Saudi Arabia. The healthcare system is a physician-driven and having multiple physicians may not be effective as having a diverse team.[211-212] Quality of healthcare system especially for diabetes management remained a critical issue in Saudi Arabia.[11,76,129] Al-Elq[11] demonstrated the gap between the implementation of diabetes guidelines and the actual practice by showing that 15% of diabetic patients attending primary healthcare had a good glycemic control based on a clinical judgment from physicians while their actual HbA1c level based on laboratory records showed poor glycemic control. Another study supports the previous study and suggested low compliance in the implementation of diabetes guidelines from the healthcare providers in family healthcare centers despite the increased trend of glycemic control in the follow-up periods.[129] Furthermore, a limitation was presented in a study showing medical records for patients did not have information about HbA1c level targets that need to be achieved by each patient which may impact the management of diabetes.[76] Al-Rubeaan[212] showed the majority of diabetic cases were seen by general practitioners while nearly one percentage were seen by two physicians in endocrinology and internal medicine, and saw urgency in improving the diabetes management system via including different health care disciplines. The existence and role of multidisciplinary healthcare team (e.g., physician, nurse, and dietitian) in the management of chronic disease including diabetes is vital for a holistic approach to manage T2DM.[74-75] Additionally, implantation of specific key performance indicators such as JCAT[213] via health quality protocols and diabetes guidelines should help in providing effective management of diabetes.[214]

Finally, continuous monitoring of glucose monitoring has benefit toward controlling poor glycemic control, especially for those who had fluctuating HbA1c levels.[215] Therefore, the more data that healthcare providers have about their patients, the more accurate treatment plans are given to them. In this study, several personal factors showed strong association with SMBG including obesity, longer diabetes duration, high educational level, high income, and family history while Eastern region was associated with no SMBG. Other personal and cognitive-perceptual factors did not show relationship with SMBG. Personal factors remain strong predictors of SMBG, and the focus on individualized treatment including appropriate educational programs is fundamental to promote healthy behaviors among Saudis with T2DM. However, the focus should extend to address cognitive-perceptual factors that may play a major role in the treatment process. For example, perceived barriers (e.g., cost of device and pertaining supplies, lack of knowledge on how to use the device, and pain associated the use of the device) and self-efficacy of SMBG were important in the self-management behavior.[63,77-78] In addition, SMBG may vary in benefits from insulin and obese group to those on non-insulin regimen group. Hence, a better collaboration between the healthcare providers will ensure effective promotion of healthy behaviors among diabetic patients.

Poor Glycemic Control

Hypothesis 3.1 stated that younger individuals, women, low education, perceived poor health, obese, and longer diabetes duration will be significantly associated with poor glycemic control. However, the analysis did not support the hypothesis and there was no evidence of association between personal factors and poor glycemic control. The analysis showed region of residence as the only predictor of poor glycemic control, where Saudis with T2DM reside in Southern region had higher prevalence ratio of poor glycemic control compared to those living in the Central region. This finding does not necessarily suggest that urbanization had a role in this issue; however, as previously mentioned that the issue could be related to access (e.g., Southern region known for harsh terrain where people live in mountains) or quality of healthcare provided. For example, a study showed that only eight percentage of the primary healthcare centers in Aseer region had health educator professionals and two-thirds of physicians did not attend diabetes training program.[216] Another study from the same region showed high percentages of patients attending primary healthcare complained from longer weighting time and shortage of specialized clinics.[217] This assumption is supported by the finding from the bivariate analysis between region of residence and recent visit to healthcare providers (RVHP), where the results suggested that diabetic individuals live in Southern region were less prevalent (PR = 0.91) to have RVHP compared to those in Central region, which means longer period of time to see healthcare providers. Furthermore, a study conducted in Southern regions showed low percentages of people had controlled blood glucose level indicating the need for diabetes educators to be involved in the primary healthcare centers to support patients.[218]

Hypothesis 3.2 stated that High VAB, High HAB, High PAB, no HPST, no HPSL, and no MHP will be significantly associated with poor glycemic control after controlling for personal factors. Nevertheless, the study did not show any significance between cognitive-perceptual factors and poor glycemic control. Similarly, Hypothesis 3.3 stated that not using medication, physically inactive, inadequate fruit and vegetable consumption, smoker, no adherence to SMBG, no regular clinic visits (RCV), and no recent visit to a health professional (RVHP) will be significantly related to poor glycemic control after adjusting for personal factors, perceived activity barriers, and healthcare provider support. However, the results did not show any association between the behavioral factors and poor glycemic control.

It is obvious that the analysis of poor glycemic control did not show evidence of association with risk factors because of the limited sample size and low response rate, which was 48% for those who participated in the laboratory test module in the Saudi Health Interview Survey (SHIS) survey. The high percentages of nonresponse rate may introduce a bias in the data and lack of inference withdrawn from the analysis even if the variation in the represented population was corrected via weighted analysis.[219] Furthermore, less respondents completed the laboratory test in four regions compared to the Central region (see Appendix I) showing regional variations. In addition, no data available from Jazan administrative region showing zero participants compared to the data used for aims 1 and 2. Therefore, the results related to the poor glycemic control should be interpreted with caution. For example, when there is available data about Jazan region which is part of Southern region, the analysis may yield different results. In addition, the association did not remain significant between Southern region and poor glycemic control in the third hypothesis when behavioral factors were included.

Further investigation was carried out to predict the relationship between some of the personal factors (e.g., age, gender, and income) and both cognitive-perceptual and behavioral factors as shown in Table IV.6 and IV.7. The findings suggested the most prominent predictors were region of residence, diabetes duration, education, income, and age. On the other hand, gender and marital status were the least factors in predicting cognitive-perceptual and behavioral factors.

Region of residence was a strong predictor and the following results were compared with the Central region. The findings showed Southern region was associated with poor glycemic control. Eastern region was associated with no adherence to SMBG. Northern region was associated with High VAB and High HAB. Eastern regions were associated with no HPSL and Medication. Eastern, Western, and Northern regions were associated with MHP. Eastern, Western, Northern, and Southern regions were associated with adequate FVC. Western and Northern regions were associated with no RCV. Northern and Southern regions were associated with no RVHP. The results indicated variation among the regions, and this could be due to unforeseen differences in urbanization, terrain, social values, and access to healthcare.[169,220] Therefore, further analysis at regional level is needed to precisely determine risk factors contributing to poor glycemic control and other behavioral factors.

Income was another strong predictor and the results showed low income was associated with high HAB, high PAB compared to middle and high income. Also, middle income was associated with HPSL and SMBG compared to low income. Diabetic Saudis with high income had good PHS, adequate FVC, physical activity, smoking, SMBG, and RVHP compared to low income. The findings suggested those with better economic status had healthy lifestyle except that it may promote unhealthy behaviors such as smoking. In addition, healthcare providers and public health professionals should focus more on those with low economic status as they are vulnerable to unhealthy lifestyle and diabetes.[165]

Shorter diabetes duration (<5 & 5-9 years) was associated with good PHS and PA(bivariate), while longer diabetes duration (>10 years) was associated with high VAB, high HAB, high PAB, HPST, Medication and SMBG. the results of diabetes duration showed that the onset of diabetes is critical in the management of the disease. In addition, a national study on children and adolescents with diabetes (age between 7-18 years) found that 16% among known cases with diabetes had T2DM, and newly cases accounted for 4% but did not specify the type of diabetes.[221] Therefore, early onset of diabetes may lead to comorbidity at early age and impose a burden on the diabetic individuals and the healthcare system in Saudi Arabia.[222] Early detection and treatment could lower the impact of diabetes. In addition, the prevalence of undiagnosed diabetes was estimated to be 1.5 million.[1] This issue could be explained by the lack of routine medical follow-up by middle aged and older Saudis.[223-224]

Low education was found to be associated with high VAB, high HAB and high PAB, while high education was associated with good PHS, adequate FVC, physical activity, and SMBG. These findings suggest high educational level is linked with the healthy behaviors and indirectly associated with glycemic control, although several studies did not establish a direct association between education and diabetes in Saudi Arabia including our study.[9,10,76,81] The study also supports the focus on educational programs provided to diabetic individuals with low education to increase knowledge and awareness about the healthy practices that improves the control of their disease.

Age is a non-modifiable factor that was strongly associated with several cognitive-perceptual and behavioral factors. Younger Saudis with T2DM (< 54 years) were physically active, had good PHS and low perceived barriers (e.g., VAB, HAB, and PAB) compared to older individuals (≥ 54 years). There is a lack of information about the characteristic of elderlies in

Saudi Arabia.[187,225] Therefore, understanding the elderly population with diabetes is fundamental through development and implementation of geriatric care guidelines, which will help in the management of diabetes.

Gender differences were also associated with several factors. Women were more obese and had high HAB and PAB than men, while men had higher prevalence of smoking. The study suggested the existence of individual differences supporting customized health promotion programs where focus could be more on losing weight for women while smoking cessation for men. Furthermore, high prevalence of smokers was found to be married. Similar findings were found in another study where married men had higher prevalence of smoking in Saudi Arabia.[226] This raises a concern about the passive role of family in supporting their diabetic individual to quit smoking especially in a country known for a strong social bonds.[227] However, due to complexity of diabetes, the analysis of the personal factors should be interpreted with caution as the interaction between variables was not assessed and further mediation analysis is suggested to determine the indirect association of personal factors and the outcomes for poor glycemic control.

The current literature is lacking regarding adequate implementation and assessment of interventional programs provided to diabetic patients in Saudi Arabia. A recent systematic review showed only four interventional studies were conducted in Saudi Arabia and even if these studies showed promising results, they had several limitations including inappropriate design (i.e., studies were not randomized control trial) and lack of theoretical approach .[228] Evaluation of intervention programs are needed to address the effectiveness of the current efforts in managing the burden of diabetes in Saudi Arabia including the cost-effective analysis of these programs to assess their economic benefits.

All in all, poor glycemic control remained a major issue among Saudis with T2DM. The results of the third aim, related to poor glycemic control, did not yield promising results due to small sample size. Another approach was taken to address the most common personal factors that relates to cognitive-perceptual and behavioral factors. The findings suggested personal factors play a major role either positively or negatively in the control of diabetes. Consequently, this study supports the individualized treatment approach, while taking into consideration other physiological factors that were not addressed in this study such as stress, depression, and self-efficacy.[78,81,229] Variation in the quality of the services provided by primary healthcare were addressed in another study that supports having attention to effectively tackle the issue of diabetes among Saudis with T2DM.[220]

Limitations

There were some limitations in the study. First, the study was based on a cross-sectional data, so causal inference cannot be assumed. Second, according to the ADA definition of poor glycemic control,[45] pregnant women should be excluded. However, due to unavailability of data related to pregnant women, we were not able to exclude them. Third, the study did not address the differences between those on insulin versus non-insulin regimen due to unavailability of pertaining data. Fourth, the generalizability of the findings remained questionable because the cluster variable (primary sampling unit) was missing from the data to account for sampling design, which may underestimate the standard errors and impact the parameter estimate. Fifth, the results were based on data collected in 2013. However, this is the only available data at national level and no data was collected afterward by the MOH. Sixth, nonresponse rate was high in the assessment of poor glycemic control which possibly introduced bias in the analysis and lack of evidence in the results due to small sample size. As an alternative, further investigation was conducted to address the role of personal factors on other outcomes. Finally, the analysis only addressed factors at personal and inter-personal level because the Health promotion Model focuses on these levels. In addition, the study did not address other important perceptual factors such as stress due to limited data.

Implications and Recommendations for Future Research

While it is known that T2DM can be prevented and despite the country's efforts in managing the burden of diabetes, high prevalence of Saudis with T2DM had poor glycemic control and poor healthy behaviors. Although it is the sole responsibility of diabetic individuals to control their diseases, standardized treatment and health education provided by the healthcare professional may not be sufficient for patient's adherence. The study suggested variations in several personal and perceptual factors including age (e.g., elderly diabetic people), regional differences, education, income, and barriers toward healthy behaviors that need to be addressed for effective healthcare system. Being cognizant of these factors by healthcare professionals, increases the awareness about the patient's stated and implied need and can be valuable in individualizing treatment and health promotion plans for those with T2DM. In addition, collaboration among healthcare professionals including physicians, dietitian, and nurses is vital via promoting positive and diminishing negative attributes related to the diabetic individuals.

Further longitudinal research is needed to address causality within the complex nature of diabetes in Saudi Arabia including psychological factors. Utilization of theoretical models (e.g., health promotion model) may supports healthcare providers in identifying factors that positively and negatively contributes to healthy practices in individuals with T2DM. Technology (e.g., applications and non-invasive SMBG devices) can be beneficial in tracking and recording patient's data in a timely manner. Finally, there is a need for a reform in the healthcare system to adapt healthcare professional team-patient relationship rather than only physician-patient relationship, specifically in counseling and treatment.

CHAPTER VI

CONCLUSIONS

With the increase in the prevalence of T2DM, poor glycemic control, and comorbidity of T2DM can be prevented. The study suggested that several personal and cognitive-perceptual factors could play a major role in determining the engagement in healthy practices (e.g., physical activity and SMBG) among Saudis with T2DM. The most prominent factors were region of residence, education, income, diabetes duration, and age. The findings indicate an urgent need for healthcare providers to adapt personalized treatment for diabetic patients instead of applying the general standards on all patients. Health promotion model (HPM) provides a useful tool that helps identify personal and inter-personal factors contributing to the disease when designing an intervention program. Although some limitation presented in the study, further investigation is needed to determine the causal effect of the personal and cognitive-perceptual factors through longitudinal studies. Finally, healthcare system in Saudi Arabia should adapt team-based patient care rather than just physician-based care.

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Appendix A

Definition of Terms Included in the Study

Diabetes	Excess glucose in the blood stream. It has different types that develop differently based on the clinical diagnosis. These are type 1, type 2, and other types. The most common type is type 2, diabetes mellitus (T2DM) that is characterized by a combination of both insufficient production of insulin from the pancreas, as well as the body's resistance to insulin, wherein body cells do not respond normally to insulin.	(IDF[1], WHO[2])
uncontrolled diabetes	Elevated blood glucose above the recommended level (i.e., HbA1c $\geq$ 7%) for those who previously diagnosed with T2DM. In addition, it can be called uncontrolled blood glucose level, poor glycemic control, uncontrolled T2DM, and hyperglycemia. Note. Studies have different recommended level.	(ADA[46])
HbA1c	*Glycated hemoglobin* is a biochemical measure to determine the level of glucose in the bloodstream.	(ADA[46])
Physical activity	*"Physical activity is a general term that includes all movement that increases energy use and is an important part of the diabetes management plan."*	(ADA[49])

Appendix B

Summary of the Included Studies Related to Poor Glycemic Control among T2DM Individuals in Saudi Arabia.

Author, year	Study period, City	Design, sampling technique	*N* (% men)	Mean age (SD) or (range)	Poor GC measure, definition	Data source	Risk Factors assessed	Main results
Al-Hussein[12]	2003-2004, Riyadh	Cross-sectional, Simple random sampling	651 (45.5)	53.2 (11.7)	HbA1c, ≥ 7% (53 mmol/mol)	MRR	Age, gender, FUV	- No significance found
Alramadan et al.[76]	2017, Hofuf, Riyadh, Jeddah	Cross-sectional, Systematic random sampling	1,092 (35.1)	57.6 (11.1)	HbA1c, ≥ 7% (53 mmol/mol)	MRR, interview questionnaire	Age, gender, education, LR, nationality, ES, income, region, FH, Eating habit, FVI, PA, SH, smoking, DD, TM, MA, FUC, FS (diet & PA), BMI, WHR, KH, depression, anxiety, CF, GU, HE	- Predictors of poor GC: Age group 40-60 years (OR = 1.9, 95% CI [1.3, 2.8]) & < 46 years (OR = 3.1, 95% CI [1.7, 5.5]), living in remote area (OR = 3.2, 95% CI [1.2, 8.6]), ↓ FVI (OR = 1.6, 95% CI [1.1, 2.3]), ↓ PA (OR = 1.5, 95% CI [1, 2.1]), ↓ KH (OR = 1.9, 95% CI [1.3, 2.7]), DD > 10 years (OR = 1.9, 95% CI [1.4, 2.8]), injectable TM (OR = 4.1, 95% CI [2.5, 6.9]) & both oral and injectable TM (OR = 6.8, 95% CI [3.9, 11.9]), HE ≥ 60 times last month (OR = 0.5, 95% CI [0.2, 0.9]).

Author, year	Study period, City	Design, sampling technique	*N* (% men)	Mean age (SD) or (range)	Poor GC measure, definition	Data source	Risk Factors assessed	Main results
Saad et al.[81]	2013, Riyadh	Cross-sectional, Convenience sampling	123 (72.4)	61.97 (NR)	HbA1c, ≥ 7% (53 mmol/mol)	MRR, interview questionnaire	Gender, age, income, education, smoking, DD, PDE, MS, ES, BMI, TM, self-efficacy (diet, exercise, SMBG, medical treatment, & foot care, SCB (diet, exercise, SMBG, medication, & foot care).	- Predictors of GC in univariate regression: OHA use (OR = 0.181), diet self-efficacy (OR = 0.115), exercise self-efficacy (OR = 0.275), SMBG self-efficacy (OR = 0.321), diet (OR = 0.087), exercise (OR = 0.308), SMBG (OR = 0.219), BMI (OR = 1.8) were associated with glycemic control. - Predictors of GC in multivariate regression: Diet & oral medication.
Sami et al.[89]	2017, Almajmaah	Cross-sectional, Systematic random sampling	350 (57.7)	(40 - 51)	HbA1c, > 7.5% (58 mmol/mol)	MRR, questionnaire	DMK, DK, DA, DP	- DP mediate relationship b/w HbA1c level & DMK, DK, and DA. - DP positively associated with HbA1c. - DMK had significant total effect (0.481) on HbA1c, followed by DK (0.434) and DA (0.240), P < 0.001.

Author, year	Study period, City	Design, sampling technique	*N* (% men)	Mean age (SD) or (range)	Poor GC measure, definition	Data source	Risk Factors assessed	Main results
Alzaheb et al.[10]	2016-2017, Tabuk	Cross-sectional, Convenience sampling	423 (52.7)	NR	FBG, > 130 mg/dL	MRR, interview questionnaire	Age, gender, education, MS, residence, ES, income, region, FH, diet, PA, DD, TM, SMBG, FS, BMI	- Predictors of poor GC: FH (AOR = 7.38 , 95% CI [4.09, 13.31]), 5–10 years DD (AOR = 2.33, 95% CI [1.14, 4.78] and >10 years DD (AOR = 5.19, 95% CI [2.50, 10.69]), ↓ PA (AOR: 19.02, 95% CI 6.23–58.06), overweight (AOR = 3.79, 95% CI [2.00–7.18]), & (obesity AOR =5.35, 95% CI [2.72–12.59]).
Abdelwahid et al.[83]	2016, Jazan	Cross-sectional, Systematic random sampling	78 (47.4)	54.6 (13)	HbA1c, ≥ 7% (53 mmol/mol)	Interview questionnaire, lab test	Gender, MS, HT, LR, FT, SHC, FH, smoking, TM, BMI, DD	- DD (B = 0.06) independent predictors of HbA1c level.
AlHabdan et al.[126]	2013-2014, Riyadh	Cross-sectional, Systematic random sampling	352 (42.6)	50.5 (8.9)	HbA1c, ≥ 7% (53 mmol/mol)	MRR	TS, age, DD, FUV	- No significant difference in mean HbA1c b/w family medicine clinic (M = 9.01, SD = 1.75) & Endocrine clinic (M = 8.93, SD = 1.98). - % of patients achieved GC: 15.9% in endocrine clinic versus 9.11% in family medicine clinic.

Author, year	Study period, City	Design, sampling technique	*N* (% men)	Mean age (SD) or (range)	Poor GC measure, definition	Data source	Risk Factors assessed	Main results
ALAboudi et al.[78]	2012, Riyadh	Cross-sectional, NR	75 (77.5)	54 (9.2)	HbA1c, ≥ 7% (53 mmol/mol)	Interview questionnaire, lab test	Age, gender, DD, education, MS, JT, TM, KH, Self-efficacy (diet, exercise, SMBG, medication, foot care), SCB (diet, exercise, SMBG, medication, foot care)	- Predictors of HbA1c level in bivariate analysis: gender (women, M = 10.1, vs. men, M = 9.04), type of treatment (diet, M = 9.96 vs. oral, M = 8.92 vs insulin only, M = 9.12 vs oral & insulin M = 9.84). - Predictors of ↓ HbA1c in multiple regression: Shorter DD (B = 0.385), ↑ education level (B = -0.385), ↑ foot care (B = -0.354), ↑ SMBG self-efficacy (B = - 0.395).

Author, year	Study period, City	Design, sampling technique	*N* (% men)	Mean age (SD) or (range)	Poor GC measure, definition	Data source	Risk Factors assessed	Main results
Badedi et al.[77]	NR, Jazan	Cross-sectional, Stratified cluster sampling	288 (49.7)	54.6 (10.9)	HbA1c, ≥ 7% (53 mmol/mol)	Interview questionnaire, anthropometric and Lab test.	Age, gender, MS, education, ES, smoking, DD, DMK, SCBA (FMP, taking medication, exercise, SMBG, FMP&M, FMP&E, FMPME&T, M&TM), NM, TM, FS, PPR, CMSCB, PH, depression, stress, BMI	- Predictors of ↑ HbA1c level in bivariate analysis: younger age (28-49), Lack education, polypharmacy, and DD ≥ 7 years, smoker, divorced, not comply with diet or medications, no FS, no PPR, no DMK, no CMSCB, depression, stress, ↑ BMI. - Predictors of poor GC in logistic regression: low adherence taking medication (OR = 4.1, 95% CI [1.3, 12.3]), number of medications (OR = 7.49, , 95% CI [3.5, 16.3]), DD ≥ 7 years (OR = 4.6, , 95% CI [1.9, 11.7]), no CMSCB (OR = 4.6, , 95% CI [1.9, 11.7]).
Alsulaiman et al.[127]	2011-2015, Riyadh	Cross-sectional, Convenience sampling	1,632 (44.5)	(18 - 59)	HbA1c, ≥ 8 mmol/l	MRR	Age, gender	- Men were more likely to have uncontrolled diabetes OR = 1.44, CI [1.18, 1.76]

Author, year	Study period, City	Design, sampling technique	*N* (% men)	Mean age (SD) or (range)	Poor GC measure, definition	Data source	Risk Factors assessed	Main results
Habib[27]	NR, Riyadh	Cross-sectional, NR	1,000 (50.1)	53.9 (NR)	HbA1c, ≥ 7.5% (58 mmol/mol)	MRR, lab test	Gender	- Poor GC was significantly more in Women (M = 9.63, SD = 2.78) compared to men (M=9.10, SD = 3.34) (P < .01) based on bivariate analysis.
Almutairi et al.[9]	NR, Al-madinah	Cross-sectional, Systematic random sampling	140 (33.6)	NR	HbA1c, ≥ 7% (53 mmol/mol)	MRR, self-administered questionnaire	Obesity, PA, DI, age, gender, income, ES, FH, education, TM	- Predictors of poor GC: FH (OR = 3.5), and oral medication & both (oral and diet) (OR = 78.14).
Guzu et al.[13]	2011, Al-Kharj	Cross-sectional, Consecutive sampling	543 (36.3)	57 (12)	HbA1c, ≥ 7% (53 mmol/mol)	MRR	TM	- The mean HbA1c lowest among patients controlled by diet only (M = 7.3, SD = 1.7) compared with oral (M = 9, SD = 1.8), insulin (M = 10.3, SD = 2) , or combined (M = 10.2, SD = 1.7) (P < 0.001).
Al-Elq[11]	2006, Nationwide	Cross-sectional, NR	353 (NR)	51.6 (10.8)	HbA1c, ≥ 7% (53 mmol/mol)	case report form by physician	TM	- 32% on oral medication alone, 19% of on oral and insulin achieved GC target.

Author, year	Study period, City	Design, sampling technique	*N* (% men)	Mean age (SD) or (range)	Poor GC measure, definition	Data source	Risk Factors assessed	Main results
Al-Shaikh[128]	NR, Jeddah	Cross-sectional, NR	400 (51)	46.2 (NR)	HbA1c, ≥ 7% (53 mmol/mol)	MRR	TS	- Mean HbA1c higher in patients treated in governmental hospital (M = 9.9) compared to private hospital (M = 7.1), *P* = 0.001. - % of patients reached target GC higher in private (58.5%) compared to governmental hospital (11.5%), P = 0.001.
Mirghani et al.[132]	2015, Tabuk	Case-control, Systematic random sampling	278 (NR)	47.6 (12.32)	HbA1c, > 8% (64 mmol/mol)	Interview questionnaire, lab test	Depression, anxiety, EDS	- No significance found.
Ferwana et al.[131]	2011-2015, Riyadh	Retrospective cohort, NR	446 (47.1)	52.9 (NR)	HbA1c, > 7% (53 mmol/mol)	MRR	TS	- ↑ mean change of HbA1c from first to last visit in the PHCC (M = 0.248, SD = 1.67) compared to CDC (M = 0.204, SD = 1.38). - Mean HbA1c for CDC was higher for each year of all 5 years follow-ups compared to PHCC, P = .001, .004, .04, .004, .009.

Author, year	Study period, City	Design, sampling technique	*N* (% men)	Mean age (SD) or (range)	Poor GC measure, definition	Data source	Risk Factors assessed	Main results
Ferwana et al.[130]	2006-2009, Riyadh, Qassim, Arar, Rafha, Najran	Retrospective cohort, Stratified simple random sampling	778 (37.3)	55 (11.4)	HbA1c, > 7% (53 mmol/mol)	MRR	Age, gender, education, BMI	- Improvement in % of patients achieving HbA1c target, from 12.6% in 2006 to 16.6% in 2009 (P < .001). education was associated with HbA1c level for the year 2007 and 2008.
Al Harbi et al.[129]	2010-2011, Riyadh	Retrospective cohort, NR	450 (44.2)	48.5 (12.2)	HbA1c, > 7% (53 mmol/mol)	MRR	Trend of HbA1c, TM	- ↑ in trend of patients achieving GC throughout the four follow-up visits (*P* = .003). - In all 4 visits, mean HbA1c level was significantly lower among those on oral medications compared with insulin alone or combined with oral medications (P < .001).

↑ = increase; ↓ = decrease; GC = glycemic control; OR = odds ratio; AOR = adjusted odds ratio; NR = not reported; MRR = medical record review; FUV = follow-up visit; LR = location of residence; ES = employment status; FH = family history; FVI = fruits and vegetables intake; PA = physical activity; SH = sitting hours; DD = diabetes duration; TM = treatment modality; MA = medication adherence; FUC = follow-up center; FS = family support; BMI = body mass index; WHR = waist-hip ratio; KH = knowledge of HbA1c; CF = cognitive function; GU = glucometer use; HE = hypoglycemia events; PDE = pre-diabetes education; MS = marital status; ES = employment status; SMBG = self-monitoring blood glucose; DMK = diabetes mellitus knowledge; DK = dietary knowledge; DA = dietary attitude; DP = dietary practice; HT = house type; FT = family type; JT = job type; SCB = self-care behaviors; SCBA = self-care behavior's adherence; FMP = following a meal plan; FMP&M = following a meal plan & medication; FMP&E = following a meal plan & exercise; FMPME&T = following a meal plan, medication, exercise, & testing blood glucose; PPR = physician-patient relationship; NM = Number of medication; CMSCB = confidence in ability to manage self-care behavior; M&TM = medication and treatment modality; PH = physical health; TS = treatment setting; EDS = excessive daytime sleepiness; DI = dietary intake; DM = diabetes management; PHCC = primary health care center; CDC = community diabetic center.

Appendix C

Quality Assessment of the Included Studies in Accordance with Modified STROBE Checklist.

Items	Al-Hussein[12]	Alramadan et al.[76]	Saad et al.[81]	Sami et al.[89]	Alzaheb et al.[10]	Abdelwahid et al.[83]	ALAboudi et al.[78]	Badedi et al.[77]	AlHabdan et al.[126]	Alsulaiman et al.[127]
1.Study design	1	1	1	1	1	1	1	1	1	1
2.Setting	1	1	1	1	1	1	1	0	1	1
3.Participants	0	1	1	1	1	1	1	1	1	1
4.Variables	1	1	1	0	1	0	1	1	1	0
5.Measurement	1	1	1	1	1	0	1	1	1	1
6.Bias	0	0	0	0	0	0	0	0	0	0
7.Study size	0	1	0	1	1	1	0	0	1	0
8.Statistical methods	0	0	1	0	1	1	1	1	0	0
9.Discriptive data	0	0	1	1	1	1	1	1	1	1
10.Outcome data	1	1	1	1	1	1	1	1	1	1
11.Main results	1	1	1	1	1	1	1	1	1	1
12.Key Result	0	1	0	0	0	0	0	0	0	0
13.Limitations	1	1	1	1	1	1	1	0	1	1
14.Interpretation	0	1	0	0	1	1	0	0	1	1
15.Generalizability	0	1	0	0	0	0	0	0	0	0
Total score (%)	7 (46.7)	12 (80)	10 (66.7)	9 (60)	12 (80)	10 (66.7)	10 (66.7)	8 (53.3)	11 (73.3)	9 (60)
Quality level	low	high	moderate	moderate	high	moderate	moderate	low	moderate	moderate

1 = Yes, 0 = No

Items	Mirghani et al.[132]	Ferwana et al.[131]	Ferwana et al.[130]	Al Harbi et al.[139]	Habib[27]	Almutairi et al.[9]	Guzu et al.[13]	Al-Elq[11]	Al-Shaikh[128]
1.Study design	1	1	1	1	1	1	1	1	1
2.Setting	1	1	1	1	0	0	1	1	0
3.Participants	1	0	1	1	1	1	1	1	0
4.Variables	1	0	0	0	0	0	0	1	0
5.Measurement	1	0	0	0	0	0	0	1	0
6.Bias	0	0	0	0	0	0	0	0	0
7.Study size	0	1	1	1	0	0	1	1	0
8.Statistical methods	0	0	1	0	0	1	1	1	0
9.Discriptive data	0	1	0	0	1	0	1	1	0
10.Outcome data	1	1	1	1	1	1	1	1	1
11.Main results	1	1	1	1	1	0	1	1	1
12.Key Result	0	1	1	1	1	0	1	0	0
13.Limitations	1	0	0	1	0	0	1	1	0
14.Interpretation	0	0	0	0	0	0	1	1	0
15.Generalizability	0	0	0	0	0	0	0	1	0
Total score (%)	8 (53.3)	7 (46.7)	8 (53.3)	8 (53.3)	6 (40)	4 (26.7)	11 (73.3)	13 (86.7)	3 (20)
Quality level	low	low	low	low	low	low	moderate	high	low

1 = Yes, 0 = No

Appendix D

Details of the Measures Included in the Study Obtained from the SHIS Manual.[142]

Variable name	Role	Level of measurement	Description based on SHIS	Classification based on the study	Note/ Reference
Personal (biological)					
Age	independent	Ordinal	18 and above	'0' = (≥54) and '1' = (<54)	Chapter 3
Gender	independent	Nominal	1) Male & 2) Female	‘0’ = Women and ‘1’ = Men	
Family history	independent	Nominal	"Do your parents (father or mother), children, brothers, or sisters suffer from diabetes?" 0) No & 1) Yes answers	‘0’ = No & ‘1’ = Yes	
Diabetes duration	independent	Ordinal	" In what year did you first receive this diagnosis?" this variable was described as the onset of diabetes and is measured in years (Hijri calendar)	Step1: Diabetes duration = year of diagnosis - Survey year. Step2: Classified into three groups: ‘1’ = (< 5), ‘2’ = (5-9) and ‘3’ = (≥ 10)	Pan et al.[143]
Obesity	independent	Ordinal	Wight (kg) and height (cm)	Step1: calculate BMI = weight /(height/100)^2 Step2: BMI is classified into two groups: ‘0’ = not obese (< 30) and ‘1’ = Obese (≥ 30)	WHO[144]
Personal (sociocultural)					
Marital status	independent	Nominal	“1) Never married, 2) Currently married, 3) Separated, 4) Divorced, & 5) Widowed”	‘0’ = Others (1, 3, 4, & 5) and ‘1’ = Married	
Education	independent	Ordinal	“1) Can’t read or write, 2) Can read and write, 3) Primary school completed, 4) Intermediate school completed, 5) High school completed, 6)	‘1’ = Low (1, 2, & 3), ‘2’ = Middle (4 & 5), and ‘3’ = High (6 & 7)	

Variable name	Role	Level of measurement	Description based on SHIS	Classification based on the study	Note/ Reference
			College/University completed, & 7) Post graduate degree"		
Income	independent	Ordinal	Monthly household income: "1) Less than 3000 Riyal, 2) 3000 Riyal to less than 5000 Riyal, 3) 5000 Riyal to less than 7000 Riyal, 4) 7000 Riyal to less than 10000 Riyal, 5) 10000 Riyal to less than 15000 Riyal, 6) 15000 Riyal to less than 20000 Riyal, 7) 20000 to less than 30000, & 8) 30000 Riyal or more."	'1' = Low (1 & 2), '2' = Middle (3, 4 & 5), and '3' = High (6, 7, & 8)	Note. 1 Riyal = 0.27 USD.
Region of residence	independent	Nominal	13 regions: 1) Riyadh, 2)Western Region, 3) ALMadina Almonawra, 4) Qaseem, 5) Eastern Region, 6) Aseer/Bisha, 7) Tabouk, 8) Haiel, 9) Northern Borders, 10) Jazan, 11) Najran, 12) AlBaha, 13) AlJouf/Quriat	Classified 13 regions into 5 groups: '1' = Central (1 & 4), '2' = Western (2 & 3), '3' = Eastern (5), '4' = Northern (7, 8, 9, & 13), '5' = Southern (6, 10, 11, & 12)	
Personal (psychological)					
Perceived health status (PHS)	independent	Ordinal	self-reported assessment of individual's health (in general): "1) excellent, 2) very good, 3) good, 4) fair, and 5) poor"	Two groups: '0' = Poor (4, & 5) and '1' = Good (1, 2, & 3)	
Cognitive-perceptual (Perceived activity barriers)					
Vigorous activity barriers (VAB)	independent	Ordinal	"Does your health now limit you in doing vigorous activities, such as running, lifting heavy objects, or participating in strenuous sports?": 1) Not at all, 2) Very little, 3) Somewhat, 4) Quite a lot, & 5) Cannot do	Two groups: '0' = Low (1& 2) and '1' = High (3, 4 & 5)	

Variable name	Role	Level of measurement	Description based on SHIS	Classification based on the study	Note/ Reference
House activity barriers (HAB)	independent	Ordinal	"During the past 30 days, how difficult was it to perform your work or house activities?": 1) Without any difficulty, 2) With a little difficulty, 3) With some difficulty, 4) With much difficulty, & 5) Unable to do	Two groups: ‘0’ = Low (1& 2) and ‘1’ = High (3, 4 & 5)	
Physical activity barriers (PAB)	independent	Ordinal	"During the past 30 days, how difficult was it to perform any of the following activities: walking a short distance, standing from a seated position, standing for a short period of time, climbing one step of stairs?": 1) Without any difficulty, 2) With a little difficulty, 3) With some difficulty, 4) With much difficulty, & 5) Unable to do	Two groups: ‘0’ = Low (1& 2) and ‘1’ = High (3, 4 & 5)	
Cognitive-perceptual (Healthcare provider support)					
Health professional support for treatment (HPST)	independent	Nominal	"Are you currently receiving any of the following treatments / advice for diabetes prescribed by a doctor or other health professional?" Two items: Insulin (A): 1) Yes & 0) No Medication (B): 1) Yes & 0) No	‘0’ = No (if A & B = 0) and ‘1’ = Yes (if A or B = 1)	
Health professional support for lifestyle change (HPSL)	independent	Nominal	"Are you currently receiving any of the following treatments / advice for diabetes prescribed by a doctor or other health professional?" four items: Diet (A): 1) Yes & 0) No. Lose weight (B): 1) Yes & 0) No. Quit smoking (C): 1) Yes & 0) No. Exercise (D): 1) yes & 0) no	‘0’ = No (if A, B, C, & D = 0) and ‘1’ = Yes (if A, B,C, or D = 1)	

Variable name	Role	Level of measurement	Description based on SHIS	Classification based on the study	Note/ Reference
Multiple healthcare providers (MHP)	independent	Nominal	"Is there a clinic, doctor's office, or other place that you usually go to when you are sick or need advice about your health care?" 0) No, 1) One place, & 2) More than one place	'0' = No (0 or 1) and '1' = Yes (2)	
Health behaviors					
Physical activity (PA)	-	Ratio	Vigorous work activity (VWA). Q1: "Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like [carrying or lifting heavy loads, digging or construction work] for at least 10 minutes continuously?": 1)Yes & 0)No. Q2: "In a typical week, on how many days do you do vigorous-intensity activities as part of your work?" 1) Number of days. Q3: "How much time do you spend doing vigorous-intensity activities at work on a typical day?" 1) Hours per day, 2) Minutes per day	Step1: For those who reported in hours, transform Q3:1 from hours per day to minutes (mins) per day (Q3:1=hours*60 mins). Step2: multiply minutes by number of days per week (VW=Q3:1*Q2:1 and Q3:2 * Q2:1). Note, those who reported with No in Q1 will have '0' value and results in Step 2 will be added in the final calculation for PA.	
	-	Ratio	Moderate Work activity (MWA). Similar to VWA questions but related to "work that causes small increases in breathing or heart rate such as brisk walking [or carrying light loads] for at least 10 minutes continuously"	Similar to VWA procedures.	

Variable name	Role	Level of measurement	Description based on SHIS	Classification based on the study	Note/ Reference
	-	Ratio	Vigorous recreational activity (VRA). Similar to VWA questions but related to "vigorous-intensity sports, fitness or recreational (leisure) activities that cause large increases in breathing or heart rate like [running or football] for at least 10 minutes continuously"	Similar to VWA procedures.	
	-	Ratio	Moderate recreational activity (MRA). Similar to VWA questions but related to "fitness or recreational (leisure) activities that cause a small increase in breathing or heart rate such as brisk walking, [swimming, volleyball] for at least 10 minutes continuously"	Similar to VWA procedures.	
	dependent (aim 1) & independent (aim3)	Nominal	The sum of physical activity in minutes per week (results of step 2 in VW, MW, VRA, and MRA) and if Q2 = 3 days in any of the following: VW, MW, VRA, or MRA	'0' = Inactive (< 150 minutes/week or spread over < 3 days per week) and '1' = Active (≥ 150 minutes/week & spread over ≥ 3 days per week)	ADA[47]
Fruit and vegetable consumption (FVC)	-	Ratio	Two items about fruit: A) "In a typical week, on how many days do you eat fruit? Include fresh, frozen, or canned fruit. For example, figs, grapes, oranges, bananas, or apples. Do not include juices, blended fruits, or dried fruits." B) "How many servings of fruit do you eat on one of those days?"	average fruit consumption per day = (B * A) / 7	

Variable name	Role	Level of measurement	Description based on SHIS	Classification based on the study	Note/ Reference
	-	Ratio	Two items about juice: A) "In a typical week, on how many days do you drink 100% fruit juices, including blended fruits? Do not include nectars." B) "How many servings of 100% fruit juices do you drink on one of those days?"	average juice consumption per day = (B * A) / 7	
	-	Ratio	Two items about vegetable: A) "In a typical week, on how many days do you eat vegetables? Include raw, cooked, canned, or frozen vegetables. Do not include rice, potatoes, or cooked dried beans such as kidney beans, pinto beans, or lentils." B) "How many servings of vegetables do you eat on one of those days?"	average vegetable consumption per day = (B * A) / 7	
	Independent	Nominal	The Sum of fruit and juice then compare the results of fruit/juice and vegetable with the recommended daily consumption	'0' = Inadequate (fruit including juice < 1.5 &/or vegetable < 2 servings per day for women and fruit including juice < 2 &/or vegetable < 2.5 servings per day for men) and '1' = Adequate (fruit including juice ≥ 1.5 & vegetable ≥ 2 servings per day for women and fruit including juice ≥ 2 & vegetable ≥ 2.5 servings per day for men)	HHS and USDA[145]

Variable name	Role	Level of measurement	Description based on SHIS	Classification based on the study	Note/ Reference
Smoking	Independent	Nominal	Two items about smoking: A)"Have you ever smoked any tobacco products, such as cigarettes, cigars or pipes or Shisha?" 1) Yes and 0) No B) "Do you currently smoke any tobacco products, such as cigarettes, cigars, pipes or Shisha?" 1) Yes and 0) No	'0' = No (non-smoker & previous smoker) and '1' = Yes (current smoker)	
diabetes management					
Self-monitoring of blood glucose (SMBG)	Dependent (aim 2) and Independent (aim3)	Nominal	"Do you test your blood sugar at home?" 1) Yes and 0) No	'0' = No and '1' = Yes	
Medication	Independent	Nominal	"During the past 30 days, or since your diagnosis, have you ever taken medication for this condition? 0) No, never took medication, 1) Yes, currently taking medication, & 2) Yes, previously took medication, but not currently"	'0' = No (0 & 2) and '1' = Yes (1)	
Regular clinic visits (RCV)	Independent	Nominal	"Do you visit the diabetes clinic or your doctor for diabetes on a regular basis?" 1) Yes and 0) No	'0' = No and '1' = Yes	
Recent visit to health professional (RVHP)	Independent	Nominal	"In the last month did you visit a physician or other health professional for the management of your diabetes?" 1) Yes and 0) No	'0' = No and '1' = Yes	

Variable name	Role	Level of measurement	Description based on SHIS	Classification based on the study	Note/ Reference
Primary outcome					
Glycemic control	Dependent (aim3)	Nominal	HbA1c measured in percentage.	‘0’ = Good glycemic control (HbA1c < 7% [53 mmol/mol]) and ‘1’ = Poor glycemic control (HbA1c ≥ 7% [53 mmol/mol])	ADA[46]

Appendix E

Equations Used in the Sampling Weights for SHIS's Household and Lab Data.[142]

Household data

$$p_{selection} = \frac{N_{individuals,sampled,strata}}{N_{households,total,strata}\, N_{individuals,total,household}}$$

$$w_{person} = \frac{1}{p_{selection}}$$

$$w_{person,post-stratified} = w_{person} \frac{\%\ pop_{Saudi,age,sex}}{\%\ pop_{sample,age,sex}}$$

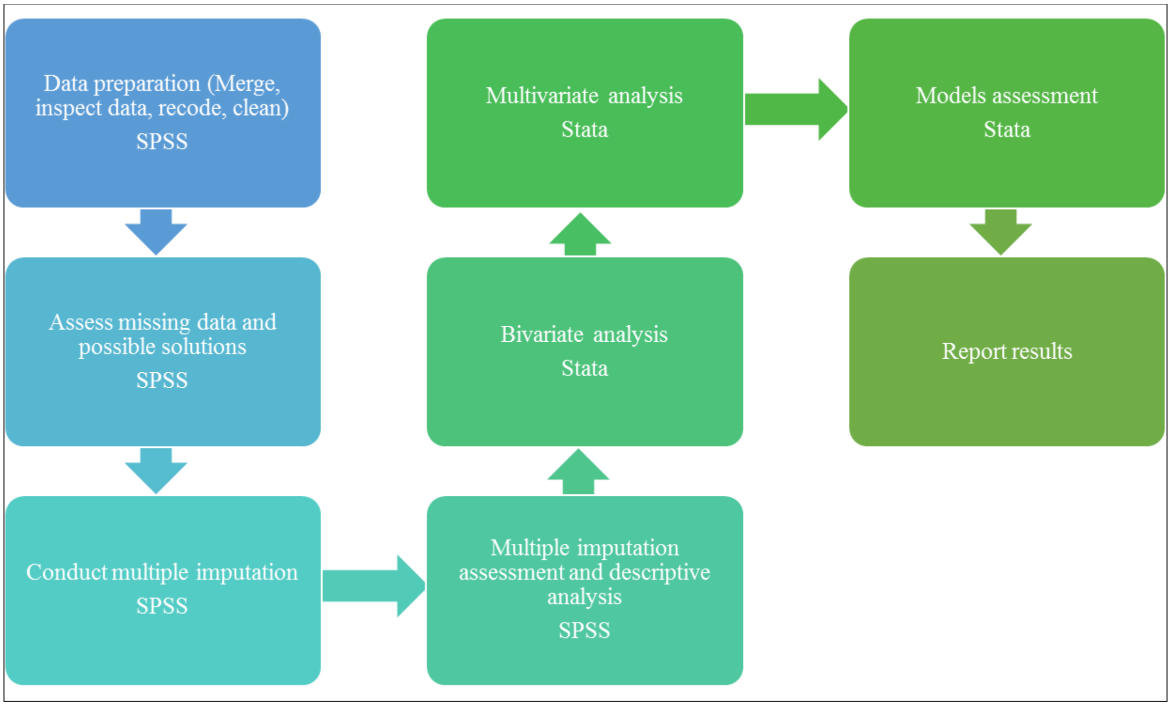
Lab data

$$w_{lab} = \frac{N_{individuals,sampled,strata}}{N_{individuals,Mod\ 4,strata}}\, w_{person}$$

$$w_{lab,post-stratified} = w_{lab}\, p_{logistic} F \frac{\%\ pop_{householdSamplevariables}}{\%\ pop_{Mod\ 4,variables}}$$

Appendix F

Flowchart of the Process of Analyzing the SHIS Data Developed by the Authors.



Appendix G

Numbers and Percentages of Missing Values in Each Variable and Arranged from Highest to Lowest.

Variable	Missing *n* (%)
Diabetes duration	175 (21.7)
Family history	123 (15.2)
Income	139 (17.2)
FVC	38 (4.7)
MHP	38 (4.7)
HAB	29 (3.6)
Obesity	18 (2.2)
HPSL	11 (1.4)
VAB	16 (2.0)
PAB	7 (0.9)
age	6 (0.7)
RCV	5 (0.6)
RVHP	4 (0.5)
Smoking	3 (0.4)
SMBG	3 (0.4)
Marital status	2 (0.2)
Education	2 (0.2)
PHS	2 (0.2)
HPST	2 (0.2)
Physical Activity	1 (0.1)
Medication	2 (0.2)
Gender	0 (0)
Region of residence	0 (0)

PHS = Perceived health status; VAB = vigorous activity barriers; HAB = house activity barriers; PAB = physical activity barriers; HPST = health professional support for treatment; HPSL = health professional support for lifestyle change; MHP = Multiple healthcare providers; FVC = fruit and vegetable consumption; SMBG = self-monitoring of blood glucose; RCV = regular clinic visits; RVHP = Recent visit to health professional.

Appendix H

Characteristics of Missing Data for Diabetes Duration, Income, and Family History Across Several Personal Factors—Presented in Percentages.

Variable		Diabetes duration	Income	Family history
		%	%	%
age				
	≥54 years	14.3	11.1	12.1
	<54 years	7.1	6.1	3.1
Gender				
	Men	11.5	6.7	9.5
	Women	10.1	10.5	5.7
Education				
	Low	14.8	12.9	12.0
	Middle	5.5	3.3	2.9
	High	1.2	0.7	0.2
Region of residence				
	Central	6.8	5.1	4.7
	Western	3.2	2.8	3.3
	Eastern	2.2	1.5	0.6
	Northern	2.6	3.5	4.0
	Southern	6.8	4.3	2.6

Note. age and education had missing values of 6 and 2 respectively.

Appendix I

Several Personal Characteristics of those with Measured HbA1c.

Variable		Having HbA1c Yes n, (%)	No n, (%)	Total	PR	P Value
Unweighted sample		391 (48.39)	417 (51.61)	808		
age	≥54 years	239 (49.4)	245 (50.6)	484	Ref.	
	<54 years	152 (46.9)	172 (53.1)	324	0.95	0.52
Gender	Women	231 (48.4)	246 (51.6)	477	Ref.	
	Men	160 (48.3)	171 (51.7)	331	1.0	0.98
Education	Low	241 (50.5)	236 (49.5)	477	Ref.	
	Middle	105 (47.5)	116 (52.5)	221	0.94	0.46
	High	45 (41.3)	64 (58.7)	109	0.82	0.10
Income	Low	145 (44.6)	180 (55.4)	325	Ref.	
	Middle	181 (49.7)	183 (50.3)	364	1.12	0.20
	High	65 (55.1)	53 (44.9)	118	1.23	0.06
Region of residence	Central	135 (74.6)	46 (25.4)	181	Ref.	
	Western	77 (38.1)	125 (61.9)	202	0.51	< 0.001
	Eastern	21 (43.7)	27 (56.3)	48	0.59	0.002
	Northern	56 (36.6)	97 (63.4)	153	0.49	< 0.001
	Southern	102 (45.5)	122 (54.5)	224	0.61	< 0.001

Appendix J

Personal, Cognitive-perceptual, and Behavioral Characteristics of Physical Activity, Self-monitoring of Blood Glucose, and Glycemic Control Among Saudis with T2DM.

Variable	Physical Activity		SMBG		Glycemic control	
	Active *n* (%)	Inactive *n* (%)	Yes *n* (%)	No *n* (%)	Poor *n* (%)	Good *n* (%)
Unweighted sample	66 (8.17)	742 (91.83)	450 (55.69)	358 (44.31)	164 (41.94)	227 (58.06)
Weighted sample	65,763 (9.08)	658,611 (90.92)	401,490 (55.43)	322,884 (44.57)	202,217 (34.30)	387,265 (65.70)
Age						
≥54 years	18 (4.05)	466 (95.95)	266 (55.99)	218 (44.01)	99 (33.41)	140 (66.59)
<54 years	48 (14.55)	276 (85.45)	184 (54.82)	140 (45.18)	65 (35.23)	87 (64.77)
Gender						
Women	16 (6.38)	315 (93.62)	178 (55.11)	153 (44.89)	66 (35.08)	94 (64.92)
Men	50 (10.78)	427 (89.22)	272 (55.62)	205 (44.38)	98 (33.91)	133 (66.09)
Family history						
No	15 (5.83)	237 (94.17)	123 (47.35)	129 (52.65)	46 (34.44)	64 (65.56)
Yes	51 (10.49)	505 (89.51)	327 (58.93)	229 (41.07)	118 (34.25)	163 (65.75)
Diabetes duration						
<5 years	31 (12.31)	214 (87.69)	124 (52.78)	121 (47.22)	49 (32.16)	82 (67.84)
5-9 years	17 (9.89)	190 (90.11)	111 (49.54)	96 (50.46)	40 (29.89)	59 (70.11)
≥ 10 years	18 (5.91)	338 (94.09)	215 (61.46)	141 (38.54)	75 (39.63)	85 (60.37)
Obesity						
No	26 (7.36)	363 (92.64)	203 (49.69)	186 (50.31)	80 (34.27)	103 (65.73)
Yes	40 (10.59)	379 (89.41)	247 (60.47)	172 (39.53)	84 (34.33)	124 (65.67)
Marital status						
Married	56 (10.02)	565 (89.98)	357 (56.94)	264 (43.06)	130 (35.18)	168 (64.82)
Others	10 (4.92)	177 (95.08)	93 (48.77)	94 (51.23)	34 (29.72)	59 (70.28)

Variable	Physical Activity		SMBG		Glycemic control	
	Active *n* (%)	Inactive *n* (%)	Yes *n* (%)	No *n* (%)	Poor *n* (%)	Good *n* (%)
Education						
Low	17 (4.21)	460 (95.79)	231 (47.66)	246 (52.34)	107 (36.26)	134 (63.74)
Middle	29 (11.87)	192 (88.13)	139 (60.23)	82 (39.77)	39 (32.22)	66 (67.78)
High	20 (21.26)	90 (78.74)	80 (73.93)	30 (26.07)	18 (31.19)	27 (68.81)
Income						
Low	18 (4.98)	308 (95.02)	152 (44.84)	174 (55.16)	57 (30.59)	88 (69.41)
Middle	32 (9.07)	332 (90.93)	220 (58.36)	144 (41.64)	75 (36.98)	106 (63.02)
High	16 (17.99)	102 (82.01)	78 (69.40)	40 (30.6)	32 (33.63)	33 (66.37)
Region of residence						
Central	14 (9.53)	167 (90.47)	113 (62.41)	68 (37.59)	57 (37.77)	78 (62.23)
Western	24 (11.82)	178 (88.18)	114 (55.57)	88 (44.43)	20 (22.80)	57 (77.20)
Eastern	2 (3.28)	46 (96.72)	17 (39.18)	31 (60.82)	7 (30.09)	14 (69.91)
Northern	11 (4.99)	142 (95.01)	91 (56.97)	62 (43.03)	22 (43.21)	34 (56.79)
Southern	15 (10.35)	209 (89.65)	115 (52.99)	109 (47.01)	58 (59.75)	44 (40.25)
PHS						
Poor	8 (7.37)	171 (92.63)	95 (54.44)	84 (45.56)	38 (37.29)	56 (62.71)
Good	58 (9.44)	571 (90.56)	355 (55.64)	274 (44.36)	126 (33.69)	171 (66.31)
VAB						
Low	51 (12.13)	323 (87.87)	223 (58.13)	151 (41.87)	74 (31.18)	100 (68.82)
High	15 (5.95)	419 (94.05)	227 (52.65)	207 (47.35)	90 (37.49)	127 (62.51)
HAB						
Low	62 (11.51)	493 (88.49)	318 (58.23)	237 (41.77)	121 (35.26)	147 (64.74)
High	4 (2.80)	249 (97.2)	132 (48.19)	121 (51.81)	43 (31.82)	80 (68.18)
PAB						
Low	59 (10.17)	521 (89.83)	321 (55.83)	259 (44.17)	122 (32.85)	157 (67.15)
High	7 (5.56)	221 (94.44)	129 (54.11)	99 (45.89)	42 (39.52)	70 (60.48)

Variable	Physical Activity		SMBG		Glycemic control	
	Active *n* (%)	Inactive *n* (%)	Yes *n* (%)	No *n* (%)	Poor *n* (%)	Good *n* (%)
HPST						
No	15 (17.12)	86 (82.88)	39 (40.52)	62 (59.48)	16 (22.15)	29 (77.85)
Yes	51 (7.96)	656 (92.04)	411 (57.49)	296 (42.51)	148 (35.89)	198 (64.11)
HPSL						
No	6 (7.98)	62 (92.02)	30 (43.59)	38 (56.41)	13 (42.68)	15 (57.32)
Yes	60 (9.17)	680 (90.83)	420 (56.46)	320 (43.54)	151 (33.89)	212 (66.11)
MHP						
No	39 (8.48)	431 (91.52)	251 (53.40)	219 (46.60)	94 (30.88)	131 (69.12)
Yes	27 (9.93)	311 (90.07)	199 (58.31)	139 (41.69)	70 (38.15)	96 (61.85)
Physical Activity						
inactive	-	-	-	-	148 (33.82)	212 (66.18)
active	-	-	-	-	16 (39.69)	15 (60.31)
FVC						
Inadequate	-	-	-	-	153 (33.97)	212 (66.03)
Adequate	-	-	-	-	12 (38.04)	15 (61.96)
SMBG						
No	-	-	-	-	66 (32.52)	94 (67.48)
Yes	-	-	-	-	98 (35.53)	133 (64.47)
Smoking						
No	-	-	-	-	147 (34.28)	201 (65.72)
Yes	-	-	-	-	17 (34.45)	26 (65.55)
Medication						
No	-	-	-	-	11 (22.75)	19 (77.25)
Yes	-	-	-	-	153 (35.21)	208 (64.79)
RCV						
No	-	-	-	-	25 (24.57)	51 (75.43)
Yes	-	-	-	-	139 (36.57)	176 (63.43)
RVHP						
No	-	-	-	-	22 (34.12)	29 (65.88)
Yes	-	-	-	-	142 (34.33)	198 (65.67)

% = weighted percentage; PHS = Perceived health status; VAB = vigorous activity barriers; HAB = house activity barriers; PAB = physical activity barriers; HPST = health professional support for treatment; HPSL = health professional support for lifestyle change; MHP = Multiple healthcare providers; FVC = fruit and vegetable consumption; SMBG = self-monitoring of blood glucose; RCV = regular clinic visits; RVHP = Recent visit to health professional.

Appendix K

Characteristics, Prevalence Ratio, and P Value from Bivariate Analysis of the Association Between the Risk Factors and Poor Glycemic Control Among Women and Men with T2DM.

	Poor glycemic control among women			Poor glycemic control among men		
Variable	PR	95% CI	P Value	PR	95% CI	P Value
age <54 years	1.04	[0.60, 1.80]	0.885	1.06	[0.65, 1.72]	0.814
Family history	0.91	[0.47, 1.79]	0.792	1.04	[0.56, 1.93]	0.907
Diabetes duration 5-9 years	0.83	[0.39, 1.74]	0.613	0.72	[0.37, 1.41]	0.341
Diabetes duration <5 years	0.63	[0.33, 1.21]	0.165	0.93	[0.53, 1.65]	0.809
Obese	0.96	[0.55, 1.70]	0.899	1.02	[0.63, 1.65]	0.943
Married	1.23	[0.71, 2.13]	0.462	1.29	[0.50, 3.35]	0.597
Middle education	1.36	[0.76, 2.40]	0.297	0.77	[0.45, 1.32]	0.343
High education	0.26	[0.06, 1.17]	0.078	1.10	[0.61, 2.00]	0.752
Middle income	1.27	[0.67, 2.43]	0.463	1.18	[0.67, 2.08]	0.570
High income	0.95	[0.34, 2.63]	0.920	1.17	[0.57, 2.39]	0.674
Western region	0.62	[0.26, 1.47]	0.272	0.60	[0.30, 1.21]	0.151
Eastern region	Omitted	Omitted	Omitted	1.04	[0.49, 2.22]	0.911
Northern region	1.44	[0.73, 2.83]	0.292	0.93	[0.45, 1.94]	0.852
Southern region	1.72	[1.06, 2.79]	0.027	1.47	[0.93, 2.32]	0.098
Good PHS	0.66	[0.38, 1.15]	0.140	1.14	[0.60, 2.16]	0.688
High VAB	1.59	[0.92, 2.76]	0.096	1.04	[0.64, 1.69]	0.870
High HAB	0.92	[0.51, 1.67]	0.792	0.88	[0.49, 1.60]	0.679
High PAB	1.08	[0.60, 1.93]	0.806	1.29	[0.77, 2.17]	0.335
HPST	**8.03**	**[2.65, 24.28]**	**<0.001**	0.87	[0.43, 1.78]	0.710
HPSL	0.99	[0.40, 2.46]	0.986	0.65	[0.32, 1.34]	0.244
MHP	1.12	[0.63, 1.99]	0.704	1.32	[0.79, 2.18]	0.286
Physically active	0.75	[0.18, 3.08]	0.684	1.33	[0.73, 2.43]	0.353
Adequate FVC	1.20	[0.36, 3.98]	0.760	1.09	[0.51, 2.34]	0.830
SMBG	1.36	[0.78, 2.38]	0.276	0.98	[0.59, 1.61]	0.927

Variable	Poor glycemic control among women			Poor glycemic control among men		
	PR	95% CI	P Value	PR	95% CI	P Value
Smoker	Omitted	Omitted	Omitted	1.07	[0.60, 1.89]	0.829
Medication	**4.32**	**[1.19, 15.66]**	**0.026**	1.08	[0.46, 2.53]	0.854
RCV	1.23	[0.58, 2.65]	0.587	1.67	[0.80, 3.48]	0.173
RVHP	0.87	[0.42, 1.81]	0.703	1.10	[0.53, 2.32]	0.793

Omitted = no calculation was performed because zero cell; PHS = Perceived health status; VAB = vigorous activity barriers; HAB = house activity barriers; PAB = physical activity barriers; HPST = health professional support for treatment; HPSL = health professional support for lifestyle change; MHP = Multiple healthcare providers; FVC = fruit and vegetable consumption; SMBG = self-monitoring of blood glucose; RCV = regular clinic visits; RVHP = Recent visit to health professional.

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UNPUBLISHED WORK

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