PREDIABETES: TRANSLATING PRACTICAL INTERVENTIONS FOR THE TREATMENT OF PRIMARY CARE PATIENTS

by

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STATEMENT OF DISSERTATION APPROVAL

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ABSTRACT

Several studies have demonstrated an association between prediabetes (preDM) and the incidence of Type II Diabetes Mellitus (T2DM). Many preventable factors can contribute to this association, namely behavioral and environmental conditions that lead to physiological changes and symptomology. Earlier identification of disease through combining common laboratory studies that demonstrate an elevated fasting glucose may be one mechanism to identify the vast majority of patients who are unaware of their preDM condition. Also, it has been widely demonstrated that T2DM can be effectively prevented or delayed with interventions geared towards weight management, physical activity, goal setting, and stress management. However, it is not entirely known whether education provided within a healthcare delivery system is effective in supporting patients to reach a 5% weight loss while reducing their overall incidence of T2DM disease. Furthermore, study is needed to evaluate such health interventions beyond effectiveness, to better identify effect and transferability through measuring the reach, adoption, and implementation. The objective of this dissertation was to determine: (a) the risk of T2DM among patients with confirmed and unconfirmed preDM relative to an at-risk group; (b) the association of a 5% weight loss with participation in the Intermountain Healthcare (IH) Diabetes Prevention Program (DPP); and, subsequently, (c) the reach, effectiveness, adoption, and implementation of the IH DPP intervention. The IH Enterprise Data Warehouse was utilized to evaluate these objectives. Patients with unconfirmed preDM

(HR 1.74; CI 1.59, 1.91; $p<0.0001$) and confirmed preDM (HR 2.77; CI 2.38, 3.23; $p<0.0001$) were more likely to develop T2DM when compared to at-risk patients. DPP participants were more likely to achieve a 5% weight loss within 6 months (OR 1.72; 95% CI 1.29, 2.34; $p<0.001$) and less likely to have incident T2DM (OR 0.45; 95% CI 0.24, 0.84; $p=0.012$) when compared to the no-DPP group. Lastly, DPP-based lifestyle interventions deployed within IH's delivery system demonstrated moderate effectiveness in the short term, yet the proportion of patients (8%) who enrolled was low. Broad adoption across regions by providers and leadership revealed organizational buy-in (194 providers at 53 clinics referred patients), while demonstrating that much of the clinical effect was seen when patients participated in interventions that were far less resource intensive (only 2.3 DPP counseling encounters on average). In conclusion, confirmed and unconfirmed preDM was associated with T2DM, however when patients participated in a DPP-based intervention, there was significant weight loss and reduction in T2DM incidence. Finally, the IH DPP demonstrated encouraging potential when evaluating organizational adoption and short-term effectiveness, yet may benefit from leveraging technology to scale these established interventions for those at risk for disease.

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CHAPTER 1

INTRODUCTION

Diabetes is a major cause of morbidity, disability, and mortality, affecting over 27 million persons.[1-3] In the United States, approximately 1.7 million individuals are newly diagnosed every year.[3] The World Health Organization has predicted a global increase in diabetes prevalence by 39% between the years 2000 and 2030 and suggests that the number will increase to 366 million people by the year 2030.[4] Diabetes can lead to heart disease and stroke, blindness, kidney disease, amputation, and eventually death when not properly managed.[5] In 2010, it was the seventh leading cause of death in the United States.[5]

In additional to the millions of diabetic individuals, there are 86 million persons identified with prediabetes (preDM) who are at increased risk for type II diabetes mellitus (T2DM).[6] The majority of individuals with preDM are unaware that they have it, and a quarter of those with preDM will develop diabetes within 3 to 5 years of detection.[7]

Two groups of patients have emerged in the recent literature with the highest susceptibility of being associated with incident disease: (a) at-risk patients defined by American Diabetes Association (ADA) criteria including body mass index (BMI) $\geq$25 kg/m^2 and one additional risk factor: high risk ethnicity, first degree relative with diabetes, elevated triglycerides or blood pressure, low HDL, diagnosis of gestational

diabetes or polycystic ovary syndrome, or birth of a baby weighing >9 lbs), and (b) patients who meet the preDM criteria through laboratory testing of HbA1c (A1c 5.7-6.49%) or fasting plasma glucose (FPG 100-125 mg/dL).[2,3]

Of those with only risk factors for disease, gestational diabetes and polycystic ovarian syndrome tend to carry additional risk of T2DM as compared to other risk factors recognized by the ADA.[8,9] In a systematic review of the literature, an A1c range of 5.7–6.49% had a 5-year risk of developing diabetes between 25–50% and a relative risk 20 times higher compared with an A1C of 5.0%.[10] In addition, observational evidence suggests that there is an association between preDM and complications of diabetes such as early nephropathy, small fiber neuropathy, early retinopathy, and risk of macrovascular disease.[11] Within a community-based study of adults without diabetes, preDM was a stronger predictor of subsequent cardiovascular events and incident diabetes diagnosis.[12]

A third group, patients with preDM who are unaware of their condition,[1,3] is emerging as a vital target population for identification and intervention. Patients with unidentified or unconfirmed preDM may be identified by pairing several laboratory studies that are routinely ordered in clinical practice: a fasting lipid panel accompanied by a chemistry panel on the same day that documents a glucose level between 100-125 mg/dL. While studies have evaluated the incremental risk of T2DM for patients with confirmed preDM or risk factors for disease, there is little report on the clinical course for patients who are unaware of their condition and their risk trajectory for T2DM.

Diabetes results from a combination of genetic predisposition, behavioral and environmental risk factors that demonstrate a diminished quality of life while leading to

many other subsequent chronic diseases.[4] However, there is strong evidence that such modifiable risk factors such as bad health behaviors, nutrition, obesity, and physical inactivity are the main behavioral or environmental determinants of the disease.[4] General consensus among practitioners is that to combat diabetes, we must first undergo measures to prevent it.

Several prominent studies have demonstrated that strategies to support weight loss and weight loss maintenance are the key to preventing the development of diabetes in those at-risk for disease.[13-18] More importantly, the Diabetes Prevention Program (DPP) Outcomes Study demonstrated that the prevention or delay of diabetes with lifestyle intervention or metformin can persist for over ten years.[19] DPP strategies have been reproduced and modeled in many other countries and clinical settings, and with differing populations,[14,17-23] yet much less evidence exists on pragmatic lifestyle interventions deployed within health systems for patients diagnosed with preDM.

Studies have shown that DPP-based lifestyle interventions are efficacious, and furthermore, these interventions are readily accessible with the potential for substantial clinical and public health impact.[18] However, to date, only a few health systems have deployed interventions aimed at weight loss and physical activity for prevention of T2DM.[24,25] While studies have shown moderate levels of weight loss and clinical benefit from DPP-based strategies, the reach into target population tends to be meager, and there is little evidence regarding the organizational adoption or fidelity to the intervention as intended.[26,27]

In early 2013, Intermountain Healthcare (IH) deployed a modified form of the National Diabetes Prevention Program[17] across its system to uniquely identify patients

with preDM, provide a mechanism for provider referral into the program and included 3 different pathways for participation. The primary purpose of the DPP was to support patients in attaining a 5% weight loss within 6 months of enrollment shown to be most effective at reducing the incidence of T2DM.[14]

Determination of T2DM risk for patients with confirmed and unconfirmed preDM relative to those at-risk for disease would be beneficial to provide clinical guidance to physicians on who should be referred for lifestyle interventions. Additionally, if the DPP was able to demonstrate sufficient reach into our at-risk population, achievement of a 5% weight loss and a reduction in the incidence of T2DM, wide organizational adoption, and overall implementation fidelity, then such a program could be translated across the care continuum while providing greater health and value to patients and the delivery system alike.

This dissertation addressed the following specific aims:

1. Determine the incidental risk of Type II diabetes mellitus among patients with confirmed and unconfirmed prediabetes relative to an at-risk group receiving care from primary care physicians over a 5-year period.
2. Evaluate the short-term effectiveness of the Intermountain Healthcare Diabetes Prevention Program for patients with prediabetes deployed within primary care clinics.
3. Evaluate the reach, effectiveness, adoption, and implementation of the Intermountain Healthcare Diabetes Prevention Program utilizing the RE-AIM framework among patients identified with prediabetes deployed within primary care clinics.

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CHAPTER 2

INCIDENTAL RISK OF TYPE II DIABETES MELLITUS AMONG PATIENTS WITH CONFIRMED AND UNCONFIRMED PREDIABETES[1]

Abstract

Objective

To determine the risk of type 2 diabetes (T2DM) diagnosis among patients with confirmed and unconfirmed prediabetes (preDM) relative to an at-risk group receiving care from primary care physicians over a 5-year period.

Study Design

Utilizing data from the Intermountain Healthcare (IH) Enterprise Data Warehouse (EDW) from 2006–2013, a retrospective analysis was performed using discrete survival analysis to estimate the time to diagnosis of T2DM among groups.

Population Studied

All adult patients who had at least one outpatient visit with a primary care physician (family medicine, internal medicine, or geriatric specialty) during 2006–2008 at an IH clinic and subsequent visits through 2013 were included. Patients were further selected for the study if they met criteria for (a) at-risk for diabetes (BMI ≥ 25 kg/m2 and

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one additional risk factor: high risk ethnicity, first degree relative with diabetes, elevated triglycerides or blood pressure, low HDL, diagnosis of gestational diabetes or polycystic ovarian syndrome, or birth of a baby weighing >9 lbs); or (b) confirmed preDM (HbA1c ≥ 5.7–6.49% or fasting blood glucose 100–125 mg/dL); or (c) unconfirmed preDM (documented fasting lipid panel and glucose 100-125 mg/dL on the same day).

Principal Findings

Of the 33,388 patients who were eligible for study, 57.0% were considered at-risk, 38.4% had unconfirmed preDM, and 4.6% had confirmed preDM. Average age was 51.1 years and 45.9% were females. Those with unconfirmed and confirmed preDM tended to be Caucasian (88.0%; 89.6%; 81.2%, respectively) and a greater proportion were obese (66.0%; 67.0%; 52.14%, respectively) as compared to those at-risk for disease. Patients with unconfirmed and confirmed preDM tended to have more prevalent high blood pressure (31.1%; 35.2%; 30.4%, respectively) and depression (18.6%; 27.4%; 17.4%, respectively) as compared to the at-risk group. Based on the discrete survival analyses, patients with unconfirmed preDM (HR 1.74; CI 1.59, 1.91; $p<0.0001$) and confirmed preDM (HR 2.77; CI 2.38, 3.23; $p<0.0001$) were more likely to develop T2DM when compared to at-risk patients.

Conclusions

Unconfirmed and confirmed preDM is strongly associated with the development of T2DM as compared to patients with only risk factors for disease. As IH transitions from the current episodic, volume-driven model of disease management to one that rewards value and promotes population health through prevention and wellness, these findings solidify the need to develop systems of care that proactively identify and assess

the health needs of our target population while coordinating services to improve the health of that population.

Introduction

Type 2 diabetes mellitus (T2DM) is one of the most costly diseases due to the size of the population at risk and the fact that diabetes is a risk factor for almost all other chronic diseases.[1,2] The World Health Organization has predicted a global increase in diabetes prevalence by 39% between the years 2000 and 2030, representing a global increase to 366 million people by the year 2030.[3] In additional to the millions of individuals with T2DM, there are an estimated 86 million Americans identified with prediabetes (preDM) who are at increased risk for the development of T2DM over time, yet only 14% of individuals are aware of their condition.[4]

Two groups of patients have emerged in the recent literature with the highest susceptibility of being associated with incident diabetes: (a) at-risk patients defined by American Diabetes Association (ADA) criteria including body mass index (BMI) ≥25 kg/m^2 and one additional risk factor: high risk ethnicity, first degree relative with diabetes, elevated triglycerides or blood pressure, low HDL, diagnosis of gestational diabetes or polycystic ovary syndrome, or birth of a baby weighing >9 lbs); and (b) patients who meet the preDM criteria through laboratory testing of HbA1c (A1c 5.7-6.49%) or fasting plasma glucose (FPG 100-125 mg/dL).[4-6]

When evaluating the effect of individual risk-factors for T2DM, patients with gestational diabetes and polycystic ovary syndrome have the highest rates of newly diagnosed diabetes.[7] A handful of studies have shown that a quarter of those with confirmed preDM will develop diabetes within 3 to 5 years of detection.[8] Observational

evidence suggests that there is an association between confirmed preDM and complications of diabetes such as early nephropathy, small fiber neuropathy, early retinopathy, and risk of macrovascular disease.[9] Beginning in the early 1990s, several prominent studies have demonstrated that strategies to support weight loss and weight loss maintenance are the key to preventing development of T2DM in the prediabetic or those at-risk for disease.[10-15]

Patients who have undiagnosed or unconfirmed preDM have also been identified as a vital target population, yet to date, there has been little data collected on how to identify this population and the trajectory of illness that a patient with unconfirmed preDM might face.[16] As postulated by this study, unconfirmed preDM patients were identified by pairing laboratory studies that are routinely ordered in clinical practice: a fasting lipid panel accompanied by a chemistry panel on the same day that documents a glucose level between 100–125 mg/dL. Patients meeting this "unconfirmed" criteria may not have any evidence of preDM documented in their medical record since their provider was unaware of the condition and furthermore, these patients may not have been treated using evidence-based therapies such as metformin to impede disease progression. Nevertheless, these patients do in fact meet the ADA criteria for preDM and may have increased risk of developing T2DM in the future.

While previous research provides an informative perspective on the health outcomes faced by patients with confirmed preDM and those with risk factors for disease, the clinical course among patients with unconfirmed preDM has yet to be determined. To address this gap in knowledge, the primary purpose of this paper is to determine the incremental risk of T2DM among patients with confirmed and

unconfirmed prediabetes relative to an at-risk group receiving care from primary care physicians over a 5-year period.

Methods

A longitudinal, closed cohort design was utilized to determine the association of T2DM over time among three groups of patients considered at higher risk for disease.

Study Subjects and Practice Attribution

Subjects

A source population of adult patients (≥18 years of age) who had at least one outpatient visit with a primary care physician (Family Medicine, Internal Medicine, or Geriatric specialty) during 2006–2008 and received continued treatment through 2013 were identified in IH's Enterprise Data Warehouse (EDW). Patients meeting source inclusion criteria were further delineated for study if they did not have a known death or prevalent T2DM. As defined in Table 2.1, patients were included for study if they met criteria for (a) at-risk for diabetes or (b) confirmed preDM or (c) unconfirmed preDM. This study was approved by the IH Institutional Review Board.

Patient Attribution

To adjust for practice variation, we attributed patients to a primary care provider and practice who provided the plurality of qualifying services (Current Procedural Terminology codes for outpatient office visit, preventive medicine visit, or wellness visit: 9920x, 9921x, 99385-87, 99395-97, G0101, G0402, G0438) in a given calendar year, with most recent service date breaking any ties.

Table 2.1. Definition of Study Groups

Study group	Definition
At-risk for diabetes	BMI ≥ 25 kg/m2 + one additional risk factor: • High risk ethnicity (Asian, African Americans, Hispanic, Native Americans) • 1st degree relative with Diabetes • HDL <35 mg/dL • Triglycerides >250 mg/dL • Hypertension >140/90 mmHg • Gestational Diabetes diagnosis • Polycystic Ovary Syndrome diagnosis • Baby weighing >9lbs
Unconfirmed prediabetes	Chemistry Panel (with Glucose 100-125 mg/dL) on same day as Fasting Lipid Panel
Confirmed prediabetes	HbA1c 5.70-6.49% or..... Fasting Plasma Glucose 100-125 mg/dL

Study Measurement

Baseline Characteristics

As determined by clinical health characteristics, patients with differing levels of disease were compared to assess whether differences in patient demographics, social factors, as well as clinical and practice characteristics existed prior to diagnosis. Baseline demographics included age, sex, and race/ethnicity. Clinical characteristics for the study cohort included the proportion of patients with chronic conditions prior to study enrollment including: depression, coronary heart disease, congestive heart failure, atrial fibrillation, and high blood pressure. Criteria for chronic conditions are different for each condition; however, they are based on diagnosis codes and encounter data, and are approved by an internal expert committee of practicing providers (Table 2.2). Also included were the medication classes that were ordered (anti-hypertensive, atypical-neuroleptics, metformin, and statins) as well as weight (kilograms) and body mass index class (underweight, normal, overweight, or obese) at baseline. Data on other potential confounders were collected at varying points in time when a patient touched the delivery system: the specialty type of primary care provider (Family Medicine, Internal Medicine, or Geriatrics) and panel size of practice. The geographical region where services were provided was also included.

Study Endpoints

Time to diagnosis of T2DM was the primary outcome of interest. T2DM was defined by the National Committee for Quality Assurance (NCQA) through the Healthcare Effectiveness Data and Information Set (HEDIS) specifications.[17,18] These specifications require only one of the following to be met along with a diagnosis code of

Table 2.2. Definitions of Chronic Conditions

Chronic condition	Diagnoses (ICD-9-CM)[a]	Encounters (CPT)[a]	Exclusions
High blood pressure	360.42, 362.11, 401, 401.0, 401.1, 401.9, 402, 402.0, 402.00, 402.01, 402.1, 402.10, 402.11, 402.9, 402.90, 402.91, 403, 403.0, 403.00, 403.1, 403.10, 403.9, 403.90, 404, 404.0, 404.00, 404.01, 404.1, 404.10, 404.11, 404.90, 404.9, 404.91, 405, 405.0, 405.01, 405.09, 405.1, 405.11, 405.19, 405.9, 405.91, 405.99, 437.2	Outpatient visit with either: 99201-05, 99211-15, 99241-45, 99341-50, 99381-87, 99391-97, 99401-04, 99411-12, 99420, 99429, 99455-56	No documentation of renal transplant
Atrial fibrillation	427.31	Inpatient admission with either: 3734, 3726-28	none
Coronary artery disease	410.xx, 411.0, 411.1, 411.81, 411.89, 412.0, 413.0, 413.9, 414.0, 414.01, 414.02, 414.03, 414.04, 414.05, 414.06, 414.07, 414.11, 414.80, 414.90	none	none
Heart failure	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 428.0, 428.1, 428.20, 428.21, 428.22, 428.23, 428.30, 428.31, 428.32, 428.33, 428.40, 428.41, 428.42, 428.43, 428.9	none	none
Depression	296.2, 296.20, 296.21, 296.22, 296.23, 296.24, 296.25, 296.26, 296.3, 296.30, 296.31, 296.32, 296.33, 296.34, 296.35, 296.36, 296.82, 296.90, 298, 298.0, 300.4, 309.1, 309.28, 311	Hospital admission or... Emergency Department Visit or… Outpatient visit with either: 99201-05, 99211-15, 99241-45, 99341-50, 99381-87, 99391-97, 99401-04, 99411-12, 99420, 99429, 99455-56	none

Note. ICD-9-CM: The International Classification of Diseases, Ninth Revision, Clinical Modification; CPT: Current Procedural Terminology

[a] To be identified with a chronic condition, specifications require at least one CPT and ICD-9-CM code to be paired on the same day

diabetes (ICD-9 code: 250): (a) two outpatient encounters on different dates of service; (b) one acute inpatient encounter; (c) one emergency department visit; or (d) patients who were dispensed insulin or hypoglycemic/anti-hyperglycemics on an ambulatory basis. Other outcomes included the number who converted to T2DM. All outcomes were assessed thru December 31, 2013. For patients who were censored or did not develop T2DM disease, the last IH encounter was used as the censor date.

Statistical Analysis

Summary statistics were computed which included means, medians, standard deviations, and ranges to describe the study population characteristics. Continuous variables were compared between study groups using analysis of variance followed by adjustment for multiple comparisons using a Tukey pairwise analysis. Chi-square analysis was used to determine differences in proportions for categorical variables.

Discrete survival analysis modeling was utilized to test the null hypothesis that time to T2DM diagnosis was no different among patients with differing levels of disease. Patients categorized as at-risk for diabetes were considered the referent group. Hazard ratios were generated after adjustment for static and time-varying variables including demographic, clinical characteristics, and practice variation that are well known to affect the risk of diabetes. Due to the intrinsically discrete intervals of interest for a provider, the time-to-event data were divided into intervals of 6-month increments and the model was further adjusted for the number of times a patient visited the delivery system. The interval of care (180 days) was selected because evidence-based guidelines suggest twice yearly follow up with a provider for patients at increased risk for T2DM.[19] Nonadjusted Kaplan-Meier survival curves were used to visually compare T2DM risk across the

groups.

The effect of any interaction between age and study group was also assessed. Patients were categorized into two age groups based on the screening recommendation from the American Diabetes Association[4,6]: (a) < 45 years and (b) ≥45 years. These age groupings, along with the study group, created an interaction term that could be studied to determine the impact on time to T2DM.

For all analyses, a *p*-value ≤0.05 was considered statistically significant. All data were analyzed using Stata 12.0 (Stata Corp, College Station, TX).

Results

As documented in Figure 2.1, 631,174 patients who received at least one outpatient visit with a primary care physician (Family Medicine, Internal Medicine, Geriatric specialty) within the IH Delivery system during 2006–2008 were identified. Of these, 352,304 were excluded because they had no known increased risk for T2DM. An additional 213,138 patients were excluded because their age at time of study enrollment was <18 years of age. Another 31,894 patients were excluded because they had a known date of death during the study. Of the study population that remained, 8.76% (n=33,838) patients were identified as: at-risk (57.0%; n=19,288), unconfirmed preDM (38.4%; n=13,005) and those with confirmed preDM (4.6%; n=1,545). For patients within the at-risk group, 100% had a body mass index ≥ 25 kg/m^2; 37.4% were diagnosed with hypertension (blood pressure >140/90); 33.1% had an HDL <35mg/dL; 21.5% had triglycerides >250 mg/dL; 13.4% were of high-risk ethnicity; 2.9% had a baby weighing over >9lbs; 1.7% had a first degree relative with diabetes; 1.3% were diagnosed with gestational diabetes; and 0.7% were diagnosed with polycystic ovary syndrome (patients

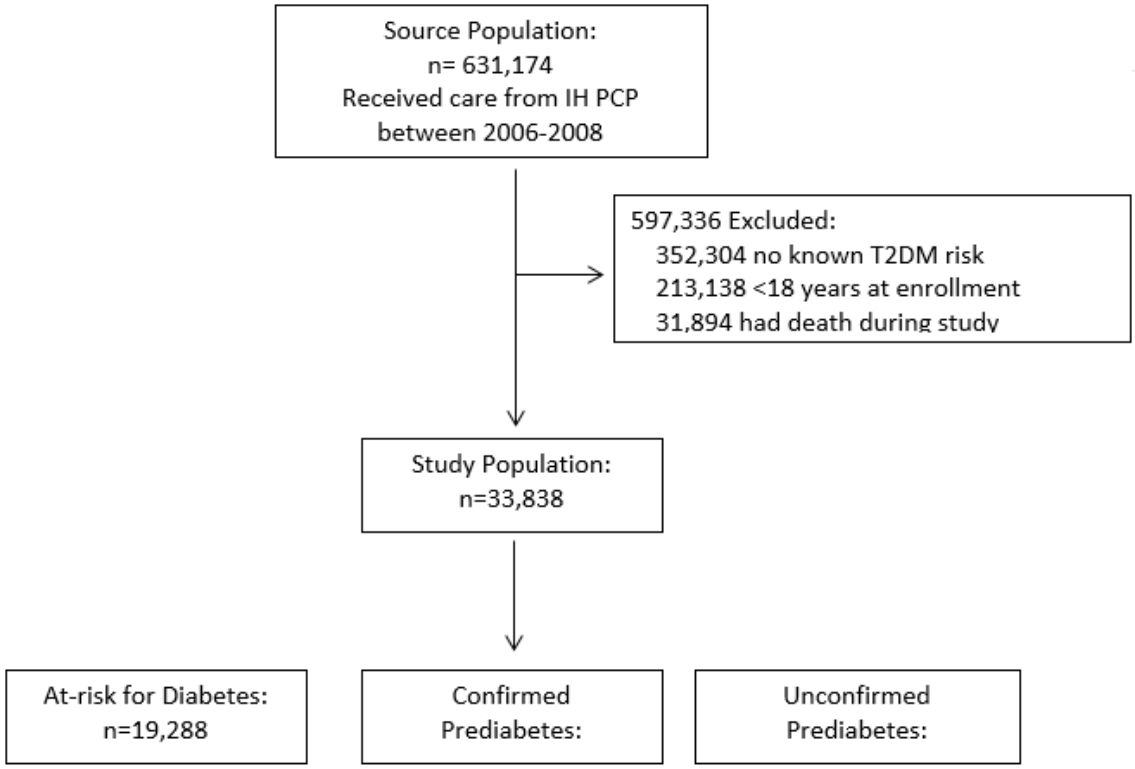

Figure 2.1. Study Criteria for Inclusion.

could have multiple indications for risk, and thus the proportion among the group does not add up to 100%).

Baseline demographic and clinical characteristics are summarized in Table 2.3. Over half (59.38%) of the unconfirmed preDM group were male compared to 51.01% and 48.87% in the at-risk and confirmed preDM group. Patients tended to be older in both the unconfirmed and confirmed preDM groups as compared to the at-risk group (54.1, 54.1, and 48.7 years, respectively).

Patients with confirmed preDM tended to have more depression, coronary heart disease, congestive heart failure, atrial fibrillation, and high blood pressure ($p<0.001$) as compared to patients in the other groups. Similarly, patients with confirmed preDM tended to have more ordered medications at time of diagnosis ($p<0.001$) as compared to other study groups. Weight at baseline did not seem to differ clinically; however, the finding was statistically significant. Patients in the unconfirmed and confirmed preDM group tended to be categorized more commonly as obese rather than those at-risk (66.01%, 66.93%, and 52.14%; $p<0.001$).

Actuarial risk for T2DM is shown in Figure 2.2, demonstrating an increasing separation between the study groups across the entire study period ($p<0.0001$). There was also a significant difference at 3- and 5-year intervals for risk of T2DM when comparing the study groups ($p<0.001$). Overall 9% (n=2,883) had converted to T2DM within 5 years, 20% (n=302) in the confirmed preDM group, 11% (n=1,391) in the unconfirmed group, and 6.0% (n=1,190) in the at-risk group. The average study follow-up did not seem to differ clinically among the confirmed, unconfirmed and at-risk groups (4.9 years, 5.1 years, and 5.2 years; $p<0.001$); however, the finding was statistically

Table 2.3. Baseline Characteristics

Variables	At-risk for Diabetes n= 19,288 mean± SD or %	Unconfirmed Prediabetes n=13,005 mean± SD or %	Confirmed Prediabetes n=1,545 mean± SD or %	*p*
	Demographics			
Age at Study Enrollment, yrs	48.67±15.28	54.09± 11.99	54.10± 13.02	<0.000
Age categories, %				<0.000
18-29	15.06	3.65	5.31	
30-39	17.03	9.43	9.71	
40-49	18.65	21.04	17.99	
50-59	21.84	32.11	31.00	
60-69	18.69	24.93	24.40	
≥ 70	8.73	8.84	11.59	
Sex, %				<0.000
Male	51.01	59.38	48.87	
Female	48.99	40.62	51.13	
Race/ethnicity				<0.000
White	81.17	87.92	89.58	
Asian	2.86	1.60	1.68	
Black	2.31	0.57	0.39	
Hispanic	3.88	0.65	0.58	
Other	4.36	1.85	1.29	
Unknown	5.42	7.41	6.47	
	Clinical Characteristics			
Chronic conditions, %				
High blood pressure	37.40	31.13	35.15	0.0004
Depression	17.36	18.6	27.38	<0.000
Coronary heart disease	9.22	9.4	11.78	<0.000
Congestive heart failure	3.64	2.99	5.24	<0.000
Atrial fibrillation	3.02	2.01	3.50	<0.000
Medication class, %				
Anti-hypertensive	28.31	26.91	27.83	<0.000
Anti-neuroleptics	2.59	1.94	6.60	<0.000
Metformin	1.17	1.96	3.56	<0.000
Statin	15.09	24.94	26.08	<0.000
Weight at baseline, kg	93.01±23.39	94.50±24.18	94.25±23.34	<0.000
BMI class at baseline, %				<0.000
Underweight	0.0	0.65	0.91	
Normal	0.0	8.96	10.49	
Overweight	47.86	24.38	21.68	
Obese	52.14	66.01	66.93	
Follow-up time, yrs	5.23	5.14	4.94	<0.000

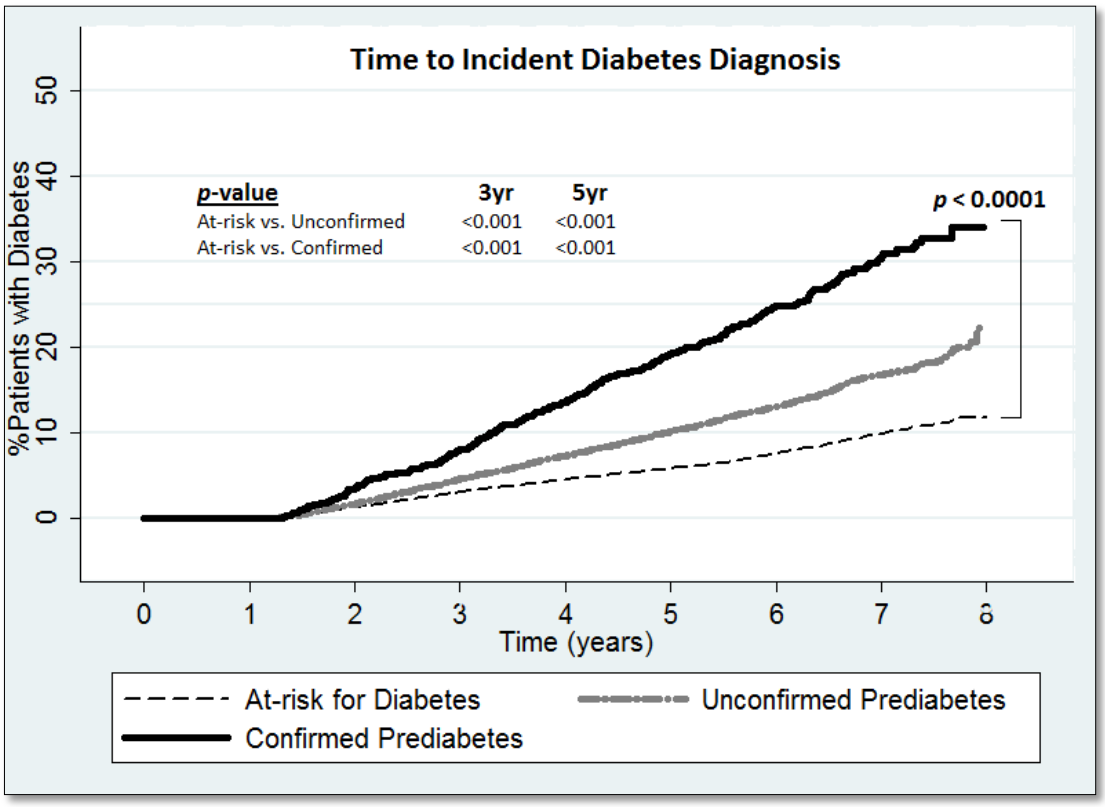

Figure 2.2. Kaplan-Meier Actuarial Survival Curve Showing Accumulated Diabetes Diagnosis Rates over Time among Study Groups

significant. When a group of healthy patients (criteria: no known risk of T2DM; at least 2 encounters to their provider during 2006–2008; no known death or prevalent T2DM) were included as the referent, there were no significant differences between that group and the at-risk group in terms of the incident risk of developing T2DM over time (Figure 2.3).

Utilizing discrete survival analyses adjusted for possible confounders, patients with unconfirmed preDM were 67% more likely to develop T2DM as compared to those at-risk (HR 1.67; CI 1.53, 1.83; $p<0.0001$). Patients with confirmed preDM had over a 2.5-fold increase of incident T2DM as compared to at-risk patients (HR 2.73; CI 2.37, 3.15; $p<0.0001$). Patients on metformin (HR 4.01; CI 3.37, 4.78; $p<0.0001$) and those with a diagnosis of high blood pressure at study enrollment (HR 1.16; CI 1.05, 1.27; $p=0.002$) tended to have significantly greater risk of developing T2DM while patients with depression showed a decreased risk of disease (HR 0.85; CI 0.77, 0.94; $p=0.001$). Patients with a BMI that was considered either overweight or obese were at higher risk for T2DM ($p<0.0001$). All multivariate results are documented in Table 2.4. Also, when assessing the interaction between age and study group, there was a significant association demonstrating a step-wise relationship in risk of developing T2DM with greater age and known preDM (Table 2.5.).

Discussion

Although a sizeable proportion of the study population did not develop incident disease over the 5-year study period, patients with confirmed and unconfirmed preDM showed a compelling association with risk of T2DM, even when adjusting for baseline characteristics. In a meta-analysis of prospective studies published between 1979 and

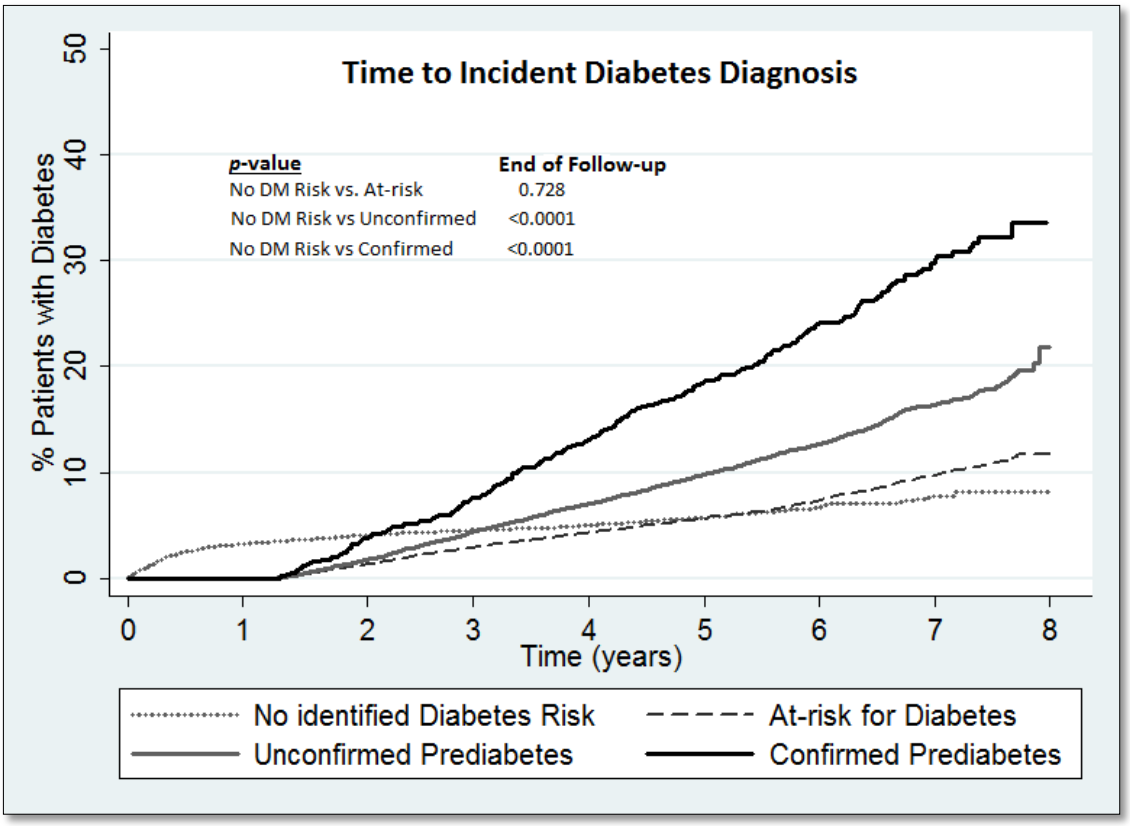

Figure 2.3. Kaplan-Meier Actuarial Survival Curve Showing Accumulated Diabetes Diagnosis Rates over Time among Patients with Confirmed and Unconfirmed Prediabetes, Those At-Risk for Diabetes, Relative to a Group with No Identified Diabetes Risk

Table 2.4. Incidental Risk of Type II Diabetes Mellitus among Patients with Confirmed and Unconfirmed Prediabetes as Compared to Those At-Risk for Disease

	Discrete survival analysis model				
Covariates	# pts	# with type II diabetes mellitus	Hazard ratio	95% *CI*	*p*
		Demographics			
Study Group					
At-risk for Diabetes	19,288	1,190	----	----	----
Unconfirmed prediabetes	13,005	1,391	1.67	1.53, 1.83	<0.000
Confirmed prediabetes	1,545	302	2.73	2.37, 3.15	<0.000
Age (years)					
18-29	3,462	47	----	----	----
30-39	4,662	203	2.34	1.55, 3.52	<0.000
40-49	6,612	413	3.07	2.07, 4.56	<0.000
50-59	8,867	882	3.96	2.68, 5.85	<0.000
60-69	7,223	921	3.92	2.65, 5.80	<0.000
≥ 70	3,012	417	3.67	2.46, 5.48	<0.000
Female sex	15,523	1,392	0.91	0.83, 0.98	0.018
Race					
Caucasian	28,474	2,598	----	----	----
Asian	786	64	2.24	1.74, 2.88	<0.000
Black	525	32	1.23	0.85, 1.77	0.278
Hispanic	841	8	0.84	0.38, 1.86	0.662
Other	1,102	79	1.53	1.19, 1.98	0.001
Unknown	2,110	102	1.11	0.89, 1.37	0.356
		Clinical Characteristics			
Chronic conditions					
Depression	6,190	646	0.85	0.77, 0.94	0.001
Coronary heart disease	3,183	374	1.10	0.96, 1.25	0.164
Congestive heart failure	1,173	142	0.91	0.74, 1.12	0.364
Atrial fibrillation	899	82	0.73	0.57, 0.94	0.014
High blood pressure	10,456	1,311	1.16	1.05, 1.27	0.002
Medication class					
Anti-hypertension	8,617	993	1.04	0.95, 1.15	0.370
Atypical-neuroleptics	854	85	0.86	0.68, 1.10	0.234
Metformin	535	190	4.01	3.37, 4.78	<0.000
Statin	6,556	746	0.96	0.87, 1.06	0.416
BMI class at baseline					
Normal	2,573	106	----	----	----
Underweight	175	13	2.53	1.36, 4.73	0.003
Overweight	11,414	527	1.39	1.11, 1.73	0.004
Obese	19,676	2,237	3.15	2.55, 3.88	<0.000

Table 2.5. Incidental Risk of Type II Diabetes Mellitus Associated with the Interaction of Study Group and Age Greater or Less than 45 years of Age among Study Patients

	Discrete Survival Analysis Model				
independent variables	#pts	# with type II diabetes mellitus	Hazard ratio	95% *CI*	*p*
Demographics					
Exposure group					
At-risk for diabetes and <45 years	7,828	238	----	----	----
At-risk for diabetes and ≥45 years	11,460	1,013	1.86	1.54, 2.25	<0.000
Unconfirmed prediabetes and <45 years	2,810	185	2.32	1.81, 2.99	<0.000
Unconfirmed prediabetes and ≥45 years	10,195	1,308	2.90	2.35, 3.57	<0.000
Confirmed prediabetes and <45 years	356	38	3.70	2.37, 5.77	<0.000
Confirmed prediabetes and ≥45 years	1,189	290	5.23	4.16, 6.58	<0.000
Female sex	15,523	1,392	1.00	0.86, 1.16	0.978
Race					
White	28,474	2,598	----	----	----
Asian	786	64	1.69	0.92, 3.11	0.093
Black	525	32	1.13	0.74, 1.73	0.560
Hispanic	841	8	0.78	0.25, 2.42	0.670
Other	1,102	79	1.46	1.07, 1.97	0.016
Unknown	2,110	102	1.24	0.98, 1.57	0.074
Clinical Characteristics					
Chronic conditions					
Depression	6,190	646	0.87	0.76, 0.99	0.042
Coronary Heart Disease	3,183	374	1.22	1.06, 1.42	0.007
Congestive Heart Failure	1,173	142	0.95	0.76, 0.99	0.042
Atrial Fibrillation	899	82	0.71	0.54, 0.93	0.014
High Blood Pressure	10,456	1,311	1.14	1.01, 1.29	0.043
Medication class					
Anti-hypertension	8,617	993	0.88	0.75, 1.03	0.114
Atypical-neuroleptics	854	85	0.32	0.10, 1.05	0.060
Metformin	535	190	3.78	3.09, 4.64	<0.000
Statin	6,556	746	1.09	0.94, 1.25	0.247
BMI class at baseline					
Normal	2,573	106	----	----	----
Underweight	175	13	2.47	1.24, 4.92	0.010
Overweight	11,414	527	1.30	1.02, 1.65	0.032
Obese	19,676	2,237	2.32	1.81, 2.97	<0.000

2004, annualized incidence rates of progression to diabetes in patients with various categories of glucose intolerance were comparable (15–25%) to results seen in this study.[20] In subsequent major studies, annual progression estimates were also similar: 11% in the Diabetes Prevention Program (DPP) outcomes study[21,22] and 9% in participants with impaired fasting glucose and 7% in those with HbA1c between 5.7–6.4% enrolled in a Japanese population-based study.[23]

The incidence rates detected within this study are clinically concerning and will be financially devastating to not only our transforming delivery system, but also to the patient and their families as we move into an accountable environment for care delivery. In the study, the majority of participants had not even reached a Medicare eligible age, demonstrating that those who develop chronic diseases will have to live with their disease for many years to come. In a series of rigorous cost analyses conducted over the past decade, the American Diabetes Association estimated that Americans with diagnosed diabetes have annual medical expenditures that are $7,900 more, or approximately 2.3 times higher, than they would be in the absence of diabetes ($13,700 vs. $5,800).[4] Therefore, it is important to identify not only the triggers that predispose progression but also potential interventions that could impede or slow incident disease over time.

Earlier identification of patients with preventable disease is one mechanism for redesigning healthcare within a transforming delivery system. While a large body of literature supports the effectiveness of intervening on a population of patients with a confirmed diagnosis of preDM or those with identifiable risk factors for disease, much less evidence exists about those who meet at-risk criteria.[21,24,25] Clinicians who suspect a

greater risk of T2DM can order laboratory tests such as FPG or HbA1c to confirm their suspicions. However, a significant number of patients (n= 13,005 in our study) are not yet on their radar, but were found to have elevated FPG from chemistry panels ordered while evaluating or screening for other conditions. This confirms our findings that patients with a confirmed or unconfirmed diagnosis of preDM demonstrated an incremental risk of developing T2DM in comparison to patients with only risk factors for disease. Identifying patients at greatest risk or those with the largest benefit will be one mechanism to manage the population's health in the future to delay or avoid diagnosis of T2DM.

The findings of this study clearly support previous work that demonstrate the increased risk of incident T2DM disease among exposed groups, yet also contributes to a limited body of knowledge surrounding methods to identify unconfirmed preDM and track outcomes over time. It should be noted that while confirmation of preDM increases the risk of T2DM, we also confirmed that increasing age also independently increases a person's chance of diagnosis. This finding lends evidence to the ADA criteria that recommends screening for T2DM and preDM in otherwise healthy individual's ≥45 years of age at least every 3 years.[4,7] Patients with depression at study entry seemed to have a protective effect for developing T2DM, which may be a mechanism of high functioning, multidisciplinary primary care teams to guide patients to care faster. This finding warrants further study.

Limitations

The study groups were carefully selected according to criteria found within the literature, but there may be inherent unaccounted differences due to data miscoding or

selection bias that still remain, affecting the results observed. Patients within the confirmed and unconfirmed preDM groups only had one documented laboratory test, although most clinical experts will require at least two tests to confirm suspicions of preDM. Patients within the at-risk study group may have variation in the ability to identify risk factors. When possible, validated IH registries were used to identify risk among patients (i.e., hypertension, polycystic ovary syndrome, gestational diabetes, and birth weights >9lbs); however, the ability to identify patients with family history of diabetes may be more difficult to classify because it relies on patient self-report and providers to document this in the medical record. Patients with prevalent T2DM diagnosis were excluded, yet there remains a possibility that their diagnosis was not identified due to the definition criteria or care that occurred outside of the IH system. The percentage of patients who were loss to follow-up was not defined or captured in this study. Patient encounters that occurred outside of the IH delivery system would not be captured within this analysis; however, IH does encompass roughly 60% of the care delivered within Utah. Since the IH Diabetes Registry does not distinguish between Type 1 or Type 2 diabetes mellitus, our primary outcome may still include both types of the disease. To account for these limitations, pediatric patients were excluded from the study population and the provider population was also limited to only primary care providers and did not consider those who delivered specialty care, such as endocrinologists and diabetologists. Female patients who consider their obstetrician or gynecologist as the provider who delivers their care primarily were not studied in this analysis and may warrant further study to determine their risk of T2DM. While the methodology used in this study attempted to account for practice variation across the IH clinics where the

patients received care, it might not account for all variation in practice which could affect the observed results. It should also be acknowledged that the study population was largely Caucasian and may not be generalizable to populations outside of IH. Patients from outside of the state of Utah do access the delivery system, yet are among the minority of IH encounters. Social determinants of health such as where the patient was born, their current living conditions, and education and income level have also been associated with health outcomes, but were not available for study.

Conclusions

Patients with unconfirmed and confirmed preDM had a higher risk of T2DM as compared to patients with only risk factors for disease. While early identification and risk stratification of T2DM is indispensable, the real opportunity lies with creating intensive lifestyle interventions that are attainable and affordable for patients, can sustain positive results over time, and can be scaled to meet the growing needs of our populations. While difficult to motivate these practices (e.g., proper nutrition, weight loss, physical activity), empowering patients with their risk status may activate them as partners in health. Coupling these interventions with integrative care management strategies, team-based care delivery, and payment reform geared towards value and service will only emphasize proactive identification and assessment for those at-risk for chronic disease progression and improve the overall health for most targeted populations, not just for patients at-risk for T2DM.

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CHAPTER 3

STEPPING BACK TO MOVE FORWARD: EVALUATING THE EFFECTIVENESS OF A DIABETES PREVENTION PROGRAM WITHIN A LARGE INTEGRATED HEALTHCARE DELIVERY SYSTEM[2]

Abstract

Objective

To evaluate the short-term effectiveness of the Intermountain Healthcare (IH) Diabetes Prevention Program (DPP) for patients with prediabetes (preDM) deployed within primary care clinics.

Study Design

A prospective, quasi-experimental study design was used to deploy the DPP within the IH system to identify patients with preDM, create a provider referral process to enroll patients within the DPP, standardize the counseling received, and to determine the short-term impact of a DPP-based intervention on patients with preDM targeting a primary goal of a 5% weight loss within 6 months of enrollment.

Study Population

An adult population aged ≥18-75 years who met the American Diabetes

[2] Kimberly D. Brunisholz, Elizabeth A. Joy, Mia Hashibe, Lisa H. Gren, Lucy A. Savitz, Jaewhan Kim.

Association criteria for preDM (HbA1c 5.7- 6.49% or Fasting Plasma Glucose 100-125mg/dL) were attributed to an IH primary care provider. Primary care providers were provided a list of their patients who met these laboratory criteria, and were encouraged to invite patients to participate in the DPP. Patients were excluded for study if they had been diagnosed with type II diabetes mellitus (T2DM) prior to or within 2 months of study enrollment, had a known death within the study period, or ever had weight loss surgery. Patients who attended DPP counseling between August 2013 and July 2014 were considered as the intervention (or DPP) group. The DPP group was matched using propensity scores at a 1:4 ratio with a control group of preDM patients who did not participate in DPP (no-DPP group).

Results

Of the 17,142 IH patients who were identified as meeting criteria for preDM, 6,842 had an in-person office with their provider. Patients receiving DPP education (n=573) were matched using patient demographics and clinical characteristics to the no-DPP group (n=2292). Average age was 58.4 years and 62% were female. Based on multivariate logistic regression, the DPP group was more likely to achieve a 5% weight loss within 6 months (OR 1.72; 95% CI 1.29, 2.34; $p<0.001$) and less likely to have incident T2DM (OR 0.45; 95% CI 0.24, 0.84; $p=0.012$) when compared to the no-DPP group.

Conclusions

DPP-based lifestyle interventions demonstrated significant reduction in body weight and incident T2DM when compared to nonenrollees.

Introduction

According to the American Diabetes Association (ADA), approximately 29.1 million Americans are diagnosed with Type II Diabetes Mellitus (T2DM) and there are over 1.7 million new cases diagnosed each year.[1-3] Even more overwhelming are the estimates that 37% of US adults have prediabetes (preDM) with a prevalence rate of greater than 75% in those aged 65 years and older.[1-3] However, roughly 86% of those with preDM are not aware of their condition.[1-5] Diabetes can lead to heart disease and stroke, blindness, kidney disease, amputation, and eventually death when not properly managed.[6] In 2010, it was the seventh leading cause of death in the United States.[6]

The ability to identify and intervene on populations at risk for T2DM represents an opportunity to reduce both the incidence and cost of disease over time. Extensive literature has demonstrated that intensive lifestyle interventions which focus on healthful nutrition, physical activity, weight management, and coping mechanisms are effective at decreasing the incidence of T2DM by as much as 58%.[7-11] Additional studies have shown that intensive lifestyle interventions outperform other medical management methods such as metformin.[5,7-12] Among patients who were recruited and enrolled from a primary care setting for DPP-based lifestyle interventions, 37% among coach-led groups and 35.9% among self-directed (as compared to 14.4% in the usual care group) were able to achieve a 7% weight loss goal.[11] Within a DPP-based intervention delivered by trained diabetic educators, over 40% of their population was able to achieve a 5% weight loss.[13] While these studies provide an informative perspective on the efficacy of lifestyle interventions, clinical effectiveness alone is not enough to demonstrate a broader public health impact.[14] Additional evidence supporting the external validity of interventions performed in real-world care delivery settings is needed to better inform and transform

decisions for clinical practice.[15]

Intermountain Healthcare (IH) began work in early 2013 to identify the population at-risk for diabetes; institute an expert clinical development team to create a care process for the identification and management of patients with preDM; analyze current organizational health promotion and disease prevention infrastructure; and to create an education and referral process for patients identified with preDM. Based on a modified form of the National Diabetes Prevention Program (NDPP),[10] IH piloted its Diabetes Prevention Program (DPP) in 5 primary care clinics and later deployed it system-wide as of January 2014. The IH DPP uniquely includes three different paths for participation: a two-hour introduction group class, individualized nutritional counseling, and an intensive lifestyle intervention.

It is unknown whether the IH DPP, implemented within a large integrated healthcare delivery system while utilizing multiple pathways for counseling, can support preDM patients in attaining a 5% weight loss within 6 months of enrollment. The purpose of this study is to evaluate the short-term impact of the DPP and determine the associated clinical outcomes and healthcare utilization patterns among enrolled patients as compared to patients with preDM who did not participate.

Methods

A prospective, quasi-experimental design was utilized to deploy the DPP within IH's delivery system. The primary outcome was to determine the association of a 5% weight loss at 6 months among patients who enroll in the DPP. Secondary outcomes of interest included incident diagnosis of T2DM, change in weight over the intervention period, and service utilization patterns among study groups.

Study Setting

Intermountain Healthcare (IH) is an integrated delivery system of 22 hospitals, a Medical Group with more than 185 ambulatory physician clinics and approximately 1,100 primary and secondary care physicians, and an affiliated health plan, that provides more than half of all healthcare services within Utah and southeastern Idaho.[16,17] IH's new mission, 'to help people live the healthiest lives possible', is actualized through a clinical integration structure (Clinical Programs) that is driven to optimize clinical work processes through a culture of accountable leadership, continuous quality improvement, and measurement of patient outcomes and delivery system costs.[16]

Diabetes Prevention Program

In early 2013, the Primary Care Clinical Program began work on the creation of a defined DPP to deploy within primary care clinics at IH. Previously, there was no systematic way to identify patients who met the criteria of preDM and there was no standardized way for providers to refer patients to existing wellness programs. This program identified patients who meet criteria for preDM (HbA1c 5.7-6.49% or Fasting Plasma Glucose 100-125mg/dL) and provided an introductory class focused on awareness and goal setting for patients, while leveraging existing wellness initiatives for intensive lifestyle and behavior change education demonstrated as effective in the peer-reviewed literature. Patients were then allowed to enroll in any or all of the three differing pathways that make up the DPP (Figure 3.1).

Prediabetes 101

An introductory, two-hour group class for preDM patients (Prediabetes 101) provided information on national standards for prevention of diabetes; healthy eating;

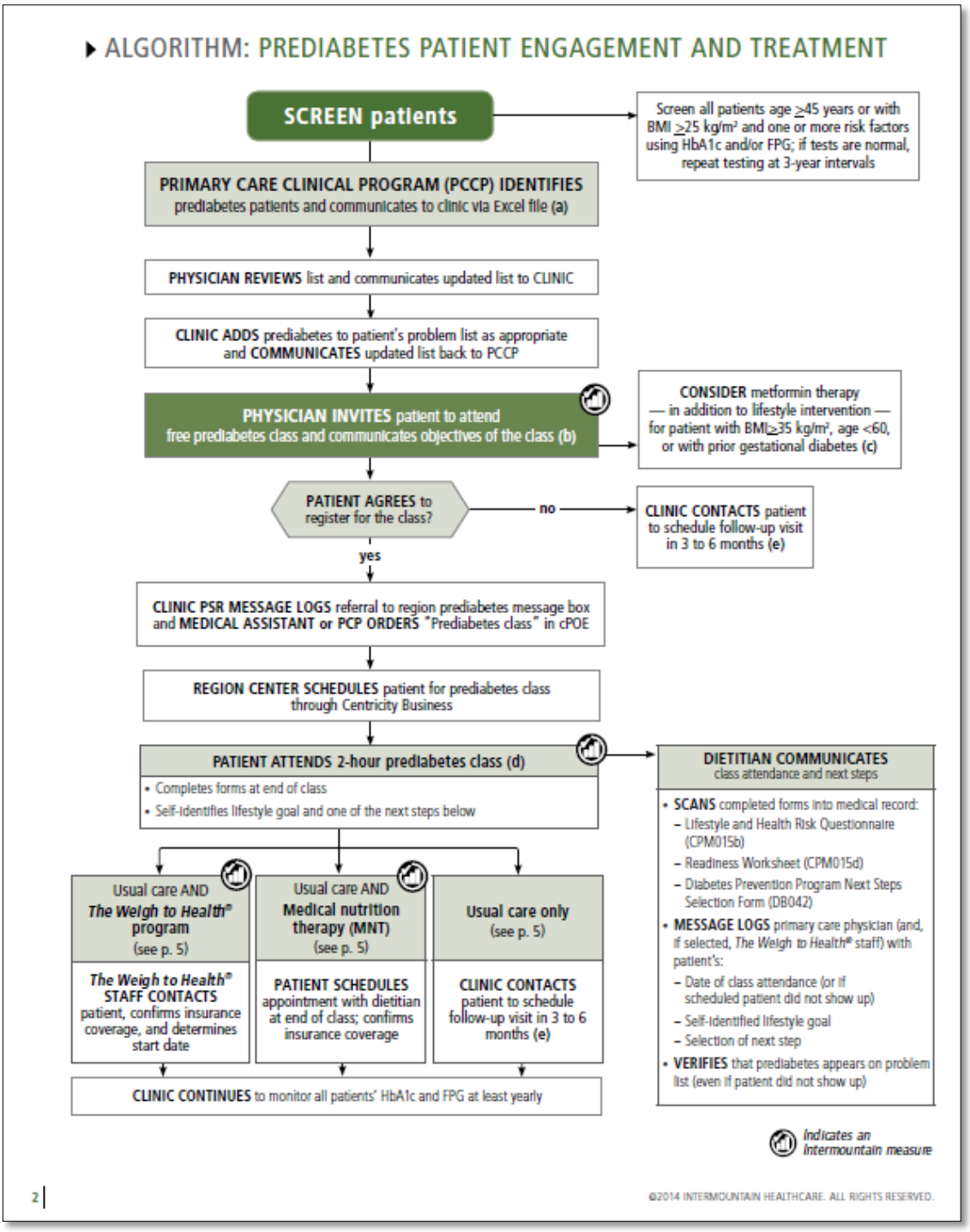

Figure 3.1. Intermountain Healthcare Diabetes Prevention Program (DPP) Flow Process. ©2014, Intermountain Healthcare. Used with permission. All other rights reserved.

being active and understanding the benefits of physical activity; problem solving to prevent short-term complications; healthy coping exercises to understand how preDM may affect emotional health; and reducing risks of long-term complications. Utilizing a group approach to instruction, this class was taught by dietitians who are certified diabetic educators and included components of goal setting and engagement/behavioral evaluation. Class participation was free of charge to patients within the IH system.

Medical Nutrition Therapy

Medical Nutrition Therapy (MNT), or nutrition counseling, includes individual sessions provided by Registered Dieticians. These sessions were highly individualized, catering materials and education to the needs of each patient. Patients were provided with a personalized eating plan and personalized support. In addition, dietitians were encouraged to provide patients with preDM structured educational content aimed at diabetes prevention. Three to five two-hour sessions per year are currently fully covered by several commercial health insurance plans as directed by the Affordable Care Act.[18-20]

Weigh to Health

The Weigh to Health (W2H) nutrition program is an IH hospital-based behavioral program offered over 12 class periods within a 6-month period for individuals who are overweight and obese. The program was: (a) constructed from current research and effective behavioral methods shown to promote and sustain weight loss and improve physical activity; (b) standardized across all IH hospitals; and (c) provided by Registered Dietitians with training and experience in weight management. For individuals that achieve attendance goals and lifestyle changes, some commercial health plans will fully reimburse for individual counseling and group courses. This program conducts education

through group and individual sessions and this curriculum most closely resembles education supported by the NDPP[10] (≥70% overlap), and caters to a majority of individuals that meet the preDM criteria.

Study Participants

A source population of adult patients (aged 18-75 years) who met criteria for preDM within the last 3 years was obtained through a query of IH's Enterprise Data Warehouse (EDW). Patients were attributed to a primary care provider who provided the plurality of qualifying services (Current Procedural Terminology codes for outpatient visit, preventive medicine visit, or wellness visit: 9920x, 9921x, 99385-87, 99395-97, G0101, G0402, G0438) in a given calendar year with most recent service date breaking any ties. Patient-level data were distributed to the providers and practice support staff so patients could be identified with preDM prior to arriving for their appointments. Providers were encouraged to invite eligible patients to participate in the DPP during their next in-person office visit. Patients were excluded for study if they had been diagnosed with diabetes prior or within 2 months of enrollment, had a known death within the study period, or ever had weight loss surgery. Patients who attended a Prediabetes 101 class, MNT, or W2H between August 2013 and July 2014 were considered as the intervention (DPP) group. Patients with preDM who were attributed to the same group of PCPs, and had the opportunity to enroll in the DPP, but did not, were considered as the control (no-DPP) group. This study was approved by the IH Institutional Review Board.

Study Measurement

Baseline Characteristics

As determined by clinical health characteristics, patients within the study groups were compared to assess whether differences in patient demographics and clinical characteristics existed prior to study enrollment. Baseline demographics included age, sex, race/ethnicity, and insurance status. Clinical characteristics for the study cohort included the proportion of patients with chronic conditions prior to study enrollment including: depression, coronary heart disease, congestive heart failure, atrial fibrillation, and high blood pressure. Criteria for chronic conditions are different for each condition; however, they are based on diagnosis codes and encounter data, and approved by an internal expert committee of practicing providers (see Table 2.2). The duration of preDM diagnosis was estimated based on the first documentation of laboratory values within the EDW system and was categorized into: less than 5 years duration, 5-9 years duration, and greater than 10 years of duration. The most recent (≤12 months prior to enrollment) clinical biometric measures were collected including: height, weight, body mass index class (underweight, normal, overweight, or obese), HbA1c, fasting plasma glucose, total cholesterol, High-Density Lipoprotein, and Low-Density Lipoprotein. Also included were the medications that were ordered prior to study enrollment and categorized as pertinent medication classes for study (anti-hypertensive, atypical-neuroleptics, metformin, and statins).

Study Outcomes

Achieving a 5% weight loss within a window of 5-12 months after study enrollment was the primary outcome of interest. This endpoint interval was selected

because evidence-based guidelines suggest semi-annual medical follow up for patients identified with preDM, and is paralleled to the outcome intervals within the literature.[7-11,21] Secondary outcomes included: incident diagnosis of T2DM, change in weight, and healthcare utilization (encounters with primary care physicians, specialty care physicians, lifestyle and weight management counseling, ED visits, and hospital admissions) among study groups assessed within a window of 5-12 months after enrollment.

Statistical Analyses

Roughly 17,142 patients were identified that met the preDM criteria within the IH system during the study period. Of these, 6,842 patients met the study criteria for enrollment. Expecting a 10% invitation rate among the eligible population (invited/eligible) and a 90% participation rate among those invited to participate (enrolled/invited), it was estimated that roughly 511 patients would participate. Those who did not participate were used as our control population. Because the control population available was much larger than the intervention population, patients were matched in a 1:4 ratio based on propensity score matching to their nearest neighbor to identify control patients that most likely resembled that of a DPP patient. Characteristics used for matching were: age; sex; race/ethnicity; duration of preDM; baseline weight; and prevalence of depression, high blood pressure, coronary artery disease, congestive heart failure, and atrial fibrillation. This weighting method produced an "average treatment effect on the treated" (ATT) estimates, answering the question: "Among control patients closely resembling the DPP patients, what outcomes were associated with the intervention".[22] Based on weight loss seen in previous DPP evaluation,[11] it was

estimated that enrollment of approximately 254 experimental subjects and 1016 control patients would provide > 80% power with alpha = 0.05 to detect a 5% weight loss.

To describe the similarities and differences among the study groups at baseline, a chi-square analysis was computed for categorical variables. Continuous variables were compared between study groups using a student's *t* test.

Conditional logistic regression modeling derived to test the null hypothesis that the association of achieving a 5% weight loss was no different among participants and nonparticipants. Patients categorized as no-DPP were considered the referent group. Odds ratios were generated after adjustment for baseline differences including demographic and clinical characteristics that are well known to affect the ability to achieve the 5% weight loss. Similarly, this method was used to determine the incidence of T2DM among groups.

For measurement of change in weight over the study period, difference-in-difference regression was used to identify the association and magnitude of weight loss among study groups from baseline to follow-up. Incidence rates (#events/patient-years) were utilized to test the association of DPP participation and specific healthcare utilization within the study period. An incidence rate ratio with corresponding 95% confidence intervals was computed to determine the probability of an event occurring among study groups.

For all analyses, a *p*-value ≤ 0.05 was considered statistically significant. All data were analyzed using Stata 12.0 (Stata Corp, College Station, TX).

Results

As documented in Figure 3.2, 17,142 patients were identified with the IH delivery system as meeting criteria for preDM within the last 3 years of the study period. Of these, 7,481 had an in-person office visit with their provider during the study period and had the opportunity to be invited to the DPP program. 639 patients were excluded from analysis (340 had T2DM prior or within 2 months of enrollment; 77 were invited but did not participate; 102 had miscoded data related to preDM diagnosis; 63 had medical condition not related to weight loss or diabetes prevention; 38 began education prior to DPP program initiation; 9 underwent weight loss surgery; 8 were <18 years old; and 2 died). Of those remaining (n=6,842), 573 subjects (8.4%) received DPP education. These case-patients were compared with no-DPP patients (n=2292) who served as the control group. Of the DPP group, 384 (67%) participated in the Prediabetes 101 class, 213 (37%) in MNT, and 54 (9%) in W2H (patients could participate in any of all of the different DPP pathways, and thus the proportion among the group does not add up to 100%). Only 63 patients participated in more than one DPP pathway, with all of them participating in the Prediabetes 101 and MNT classes combined.

Baseline demographic and clinical characteristics are summarized in Table 3.1. Due to the use of propensity score matching to select the control group, there were no statistical differences among patient characteristics used within the weighting (age; sex; race/ethnicity; duration of preDM; baseline weight; and prevalence of depression, high blood pressure, coronary artery disease, congestive heart failure, and atrial fibrillation). Of the other baseline characteristics considered, DPP patients were more likely to be uninsured/self-pay (11.1% vs. 6.0%; p=0.01), prescribed metformin (21.6% vs. 15.3%; p=0.01), and showed a reduced HbA1 level (5.9% vs 6.0%; p=0.02) compared to those

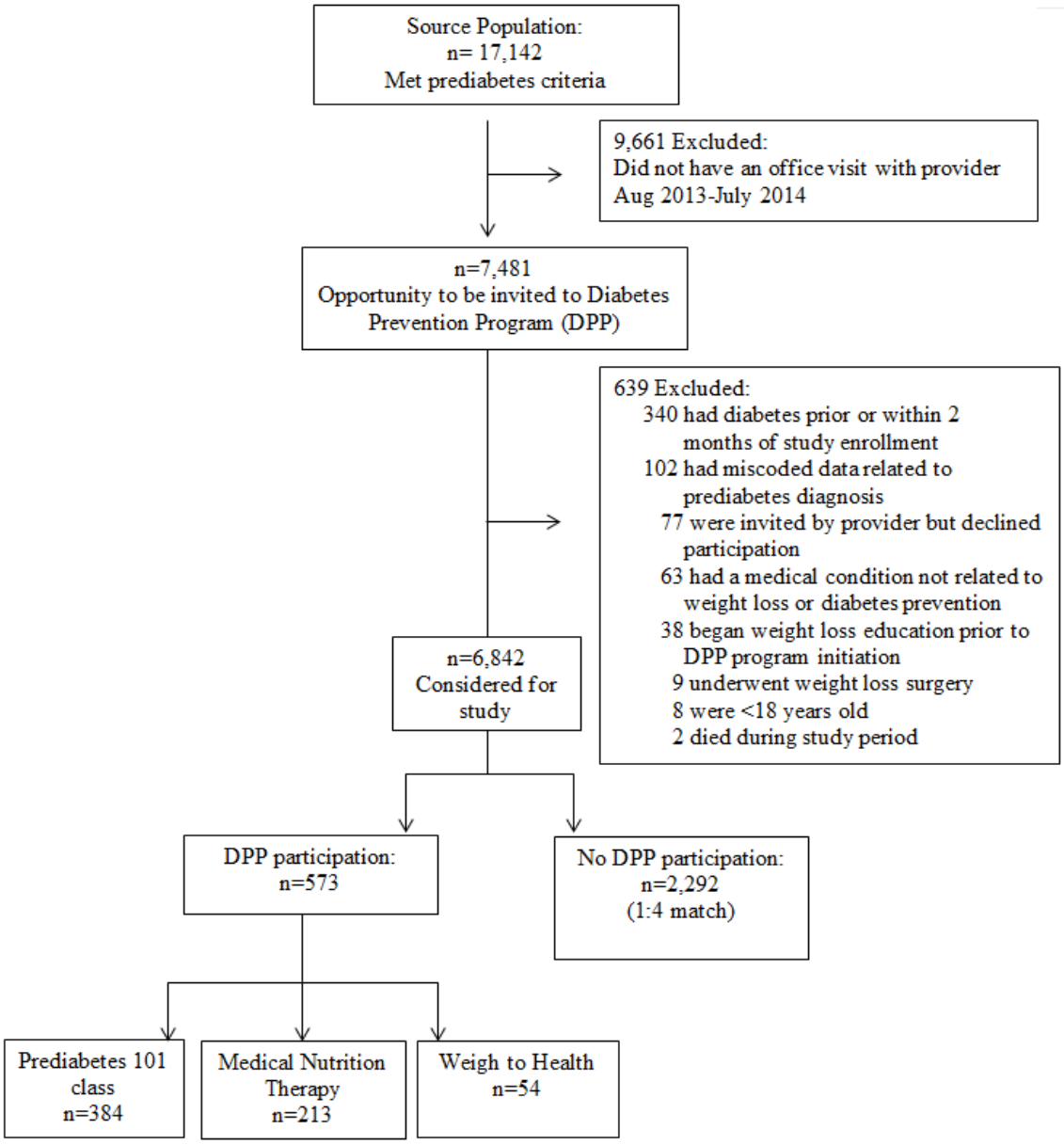

Figure 3.2. Inclusion Criteria for Study Enrollment

Table 3.1. Baseline Characteristics of the Study Population Stratified by Diabetes Prevention Program Participation

Variables	DPP Participants n = 573		Control Group n = 2292		
	n	$M \pm SD$ or %	n	$M \pm SD$ or %	p
Demographics					
Age at Study Enrollment, yrs	573	58.53±13.32	2292	58.38± 11.04	0.821
Gender, %					0.537
Male	212	37.12	886	38.66	
Female	356	62.88	1,406	61.34	
Race/ethnicity					0.786
White	506	88.43	1,984	86.56	
Hispanic	44	7.64	192	8.38	
Black	4	0.66	18	0.79	
Asian	10	1.75	44	1.92	
Other/Unknown	9	1.53	54	2.36	
Insurance					0.01
Commercial	294	51.31	1,252	54.62	
Medicare	194	33.84	816	35.60	
Medicaid	21	3.71	86	3.75	
Self-Pay/Uninsured	64	11.14	138	6.02	
Clinical Characteristics					
Prediabetes duration					0.606
<5 year	458	79.91	1,856	80.98	
5-9 years	100	17.47	392	17.10	
>10 years	15	2.62	44	1.92	
Chronic Conditions, %					
Depression	272	47.38	1,060	46.25	0.657
Coronary Heart Disease	114	19.87	444	19.37	0.806
Congestive Heart Failure	51	8.95	216	9.42	0.751
Atrial Fibrillation	45	7.86	156	6.81	0.419
High Blood Pressure	336	58.73	1,348	58.81	0.975
Medication class, %					
Anti-hypertensive	274	47.82	1,160	50.61	0.275
Anti-neurolyptics	55	9.61	204	8.90	0.630
Metformin	124	21.62	350	15.27	0.011
Statin	304	53.06	1,201	52.40	0.797
Weight, kg	573	98.81±25.37	2292	98.73±26.54	0.952
HbA1c, %	381	5.89±0.28	1431	5.96±0.52	0.015
LDL, mg/dL	392	106.41±35.02	1531	107.04±34.67	0.763
HDL, mg/dL	408	46.70±13.84	1568	46.41±13.54	0.723
Cholesterol, mg/dL	406	184.31±40.70	1569	185.63±39.67	0.578
Physical Activity, min/week	275	138.78±149.49	557	158.04±244.24	0.177
BMI Class, %					0.388
Underweight	2	0.44	13	0.58	
Normal	38	7.10	207	9.31	
Overweight	130	24.83	502	22.58	
Obese	355	67.63	1,501	67.52	

not enrolled. Physical activity (min/week) and other pertinent laboratory values (LDL, HDL, and cholesterol) did not significantly differ between groups at baseline.

After adjustment for all confounders listed in Table 3.2, patients in the DPP group were 70% more likely to achieve a 5% weight loss as compared to the control group (OR 1.70; 95%CI 1.29, 2.25; $p<0.001$). DPP patients were also less likely to have an incident diagnosis of T2DM during the study period (OR 0.49; 95%CI 0.28, 0.86; $p=0.012$). There was no statistical difference in the achievement of 5% weight loss when comparing the different DPP pathways (W2H vs Prediabetes 101: OR=0.65; 95%CI=0.24, 1.76; $p=0.40$; MNT vs Prediabetes 101: OR=1.39; 95%CI=0.76, 2.53; $p=0.28$; MNT/101 vs Prediabetes 101: OR=0.99; 95%CI=0.43, 2.28; $p=0.99$).

As documented in Table 3.3, there were greater rates (#events/patient year) of PCP visits (4.0 vs 3.6; $p=0.006$), visits to a specialty providers (4.8 vs1.3; $p<0.0001$), and lifestyle and weight management counseling attempts (3.1 vs 1.0; $p<0.0001$) that occurred in the DPP group as compared with the no-DPP group. There were no significant differences in acute care encounters among study groups.

DPP participants were more likely to have any weight loss (44.1% vs. 35.3%; $p<0.0001$) and the largest change in weight (-1.8kg vs -0.3 kg; $p=0.009$) when compared to no-DPP participants (Figure 3.2). After comparing the change in weight over time using difference in difference regression modeling, DPP participation showed a trend toward significance with a greater reduction in weight when compared to the no-DPP group (ß= -1.36; 95%CI -2.76, 0.05; $p=0.058$).

Table 3.2. Conditional Logistic Regression Modeling for Achievement of a 5% Weight Loss and Incidence of Type II Diabetes Mellitus Stratified by Diabetes Prevention Program Participation

		Achievement of 5% weight loss				Incidence of T2DM			
Independent variables	#pts	# with 5% weight loss	OR	95% *CI*	*p*	# with T2DM	OR	95% *CI*	*p*
Study Group									
Control group	2292	328	----	----	----	115	----	----	----
DPP participant group	573	128	1.70	1.29, 2.25	0.000	12	0.49	0.28, 0.86	0.012
Demographics									
Age, yrs	2865	456	1.00	0.99, 1.02	0.365	127	1.01	1.00, 1.03	0.174
Female sex	1762	294	1.03	0.84, 1.25	0.790	132	0.58	0.45, 0.76	0.000
Race									
White	2490	409	----	----	----	111	----	----	----
Asian	54	7	0.70	0.48, 1.02	0.066	10	0.99	0.61, 1.60	0.966
Black	22	3	0.43	0.10, 1.86	0.261	2	0.96	0.23, 4.08	0.954
Hispanic	236	21	1.06	0.53, 2.11	0.877	3	1.55	0.69, 3.47	0.289
Other/Unknown	63	16	1.46	0.81, 2.62	0.209	1	0.62	0.22, 1.74	0.368
Insurance									
Commercial	1546	233	----	----	----	66	----	----	----
Medicare	1010	161	1.07	0.84,	0.586	49	1.18	0.86,	0.314
Medicaid	107	30	1.90	1.35	0.001	5	1.22	1.62	0.569
Self-pay/Uninsured	202	32	1.39	1.28, 2.82 0.93, 2.08	0.110	7	0.65	0.62, 2.40 0.35, 1.22	0.180
Clinical Characteristics									
Prediabetes Duration, yrs									
<5 year	2314	358	----	----	----	108	----	----	----
5-9 years	492	82	0.95	0.76, 0.66	0.687	16	0.60	0.42, 0.84	0.003
>10 years	59	16	1.15	1.20, 2.01	0.611	3	0.76	0.34, 1.68	0.496
Chronic conditions									
Depression	1332	221	0.94	0.77, 1.15	0.557	49	0.82	0.62, 1.08	0.161
Coronary disease	558	79	0.80	0.62, 1.04	0.097	23	1.00	0.71, 1.41	0.990
Heart failure	267	53	1.25	0.90, 1.75	0.188	11	1.08	0.67, 1.76	0.855

Table 3.2. Continued

		Achievement of 5% weight loss				Incidence of T2DM			
Independent variables	#pts	# with 5% weight loss	OR	95% *CI*	*p*	# with T2DM	OR	95% *CI*	*p*
Atrial fibrillation	201	25	1.00	0.69, 1.43	0.979	4	0.83	0.48, 1.43	0.498
High blood pressure	1684	261	0.93	0.73, 1.18	0.544	79	0.93	0.67, 1.29	0.681
Medication class									
Anti-hypertension	1434	223	0.95	0.75, 1.20	0.641	71	1.30	0.94, 1.80	0.108
Atypical-neuroleptics	259	62	1.52	1.14, 2.01	0.004	5	0.91	0.55, 1.52	0.715
Metformin	474	87	0.97	0.76, 1.24	0.799	51	5.83	4.52, 7.53	0.000
Statin	1505	236	0.94	0.77, 1.14	0.506	70	1.03	0.79, 1.35	0.825
Baseline weight, kg	2865	456	1.01	1.00, 1.01	0.003	127	1.00	1.00, 1.01	0.345

Note. OR: Odds Ratio; CI: Confidence Interval; pts: patients; T2DM: Type II Diabetes Mellitus; DPP: Diabetes Prevention Program

[a] all covariates listed in the table were included in the model

Table 3.3. The Incidence Rate of Healthcare Utilization Encounters Stratified by Diabetes Prevention Program Participation

	DPP participants *n* = 573		Control group *n* = 2292				
	# events	#/ patient year	# events	# events/ patient year	Rate ratio	95% *CI*	*p*
# of visits to a PCP	1342	3.97	7210	3.66	1.09	1.02, 1.15	0.006
# of visits to a Specialist[a]	1626	4.82	7282	3.70	1.30	1.23, 1.38	<0.0001
# of Lifestyle and Weight Management counseling encounters[b]	1037	3.07	2063	1.05	2.93	2.72, 3.16	<0.0001
# of ED Visits	92	0.27	591	0.30	0.91	0.72, 1.13	0.39
# of hospital admissions	52	0.15	242	0.12	1.25	0.91, 1.70	0.14

Note. PCP: primary care physician; DPP: Diabetes Prevention Program; CI: confidence interval; ED: emergency department

[a] Number of visits to provider without primary care specialty designation

[b] Number of counseling encounters for either nutrition, physical activity, or the Diabetes Prevention Program classes

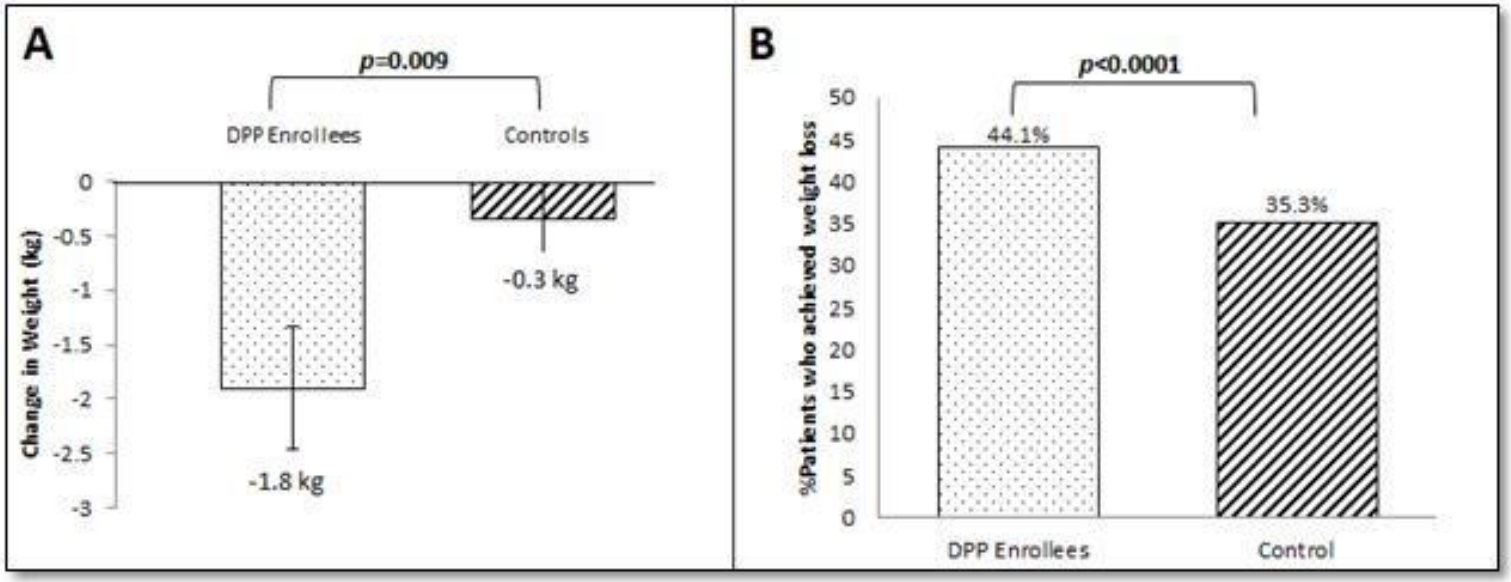

Figure 3.3. Secondary Outcomes of (a) Change in Weight (Kilograms) and (b) the Proportion of Patients Who Achieved Any Weight Loss Stratified by Diabetes Prevention Program Participation

Discussion

This primary-care-based pragmatic evaluation demonstrated that DPP-based lifestyle interventions led to significant reductions in body weight (measured by achievement of a 5% reduction in body weight and overall change in weight) and were accompanied by a significant reduction in T2DM incidence when compared to a patient group who did not enroll. DPP participants experienced an increased rate of follow up with primary and specialty care providers and increased lifestyle and weight management counseling as compared to patients with preDM who did not participate over a 6-month period. However, routine clinical follow-up according to evidence-based guidelines for this patient population could still improve (only 29% of study population had routine clinical biometrics such as physical activity per week and common laboratories documented within 5-12 months after participation). Also, when the different DPP pathways were compared, there seemed to be no statistical differences in outcomes, suggesting that patients may inherently gravitate towards counseling that best fits their individual needs.

While a large body of literature supports the internal validity of lifestyle and weight management counseling in improving outcomes related to weight loss and diabetes prevention,[7-11] much less evidence exist on outcomes associated with deployment of diabetes prevention efforts within a large integrated delivery system. The findings of this study support previous literature that demonstrate among patients who were recruited and enrolled from a primary care setting for DPP-based lifestyle interventions, 35-40% were able to achieve a clinically significant weight loss. [11,13] When compared to 2369 participants who participated in a nationwide, community-based

DPP led by the Centers for Disease Control and Prevention and the YMCA, 72% completed the 12-month program (compared to 68% in this study) and the average weight loss was 4.8%.[22] These studies lend credence to the effectiveness of deploying these strategies within pragmatic clinical or community-based settings while validating the results from this study.

However, even with this success, lifestyle change programs such as the IH DPP remain unavailable to most Americans with preDM, most notably those with Medicare and Medicaid insurance, who do not provide reimbursement for diabetes prevention programs, nor do they cover the cost of laboratory testing for diagnosis of preDM.[23] As evidenced by the large number of preDM patients identified with the IH system, the majority are at-risk for developing T2DM and could receive benefit from participating in nutritional and physical activity counseling. In a systematic review of over 3303 publications, Walden et al. present findings that suggest a range of trained interventionists, following structured protocols, from a variety of educational backgrounds could be considered for delivering weight loss therapy, rather than relying on the primary care practitioners to deliver such care.[23] In this study, we identified >17,000 patients who met the laboratory criteria of preDM, yet only a small proportion of this group was enrolled due to resource and clinical constraints within primary care teams.

DPP enrollment seemed to be one of only a few indicators of successful achievement of weight loss and the reduction in T2DM diagnosis after enrollment, even after adjustment for differences in patient characteristics among groups. Furthermore, DPP patients were more likely to be “touched” by the system, including more encounters

with PCPs, specialists, and those that were delivering lifestyle and weight management counseling. While these outcomes may reveal a patient population who is more engaged and accountable for their care, nevertheless, this may also be an indication that DPP participants are more likely to follow the established care process for preDM, contributing to their positive weight loss results. Both outcomes will warrant further longitudinal study to understand how efficiently the program can reach other patients groups and increase the ability to predict which patients are more likely to participate and achieve the desired weight loss goals.

Limitations

The study groups were carefully selected according to criteria found within the literature, but there may be inherent unaccounted differences due to data miscoding or selection bias that still remain affecting the results observed. Patients who enrolled with the DPP group may have been more "ready to change" than those that did not participate. However, the control group was carefully selected to only include those who had the opportunity to be invited by their PCP (but were not) and excluded patients who were invited but decided not to enroll. Female patients who consider their obstetrician or gynecologist as the provider who delivers their care primarily were not studied in this analysis and may warrant further study. Additional analyses will be needed to determine the patient characteristics of those who are more likely to participate and were outside of the scope of this current study.

Due to the different counseling pathways within the IH DPP, there may be unaccounted differences by evaluating them collectively. However, when these pathways were compared, there were no statistical differences in those that achieved a 5% weight

loss. Further longitudinal study will be needed to confirm this finding.

As demonstrated by some statistical differences among study groups in their baseline characteristics, DPP patients tended to be more likely to be prescribed metformin and have a lower HbA1c; however, these differences were accounted for in the regression models.

Since the IH Diabetes Registry does not distinguish between Type 1 or Type 2 diabetes mellitus, the primary outcome may still include both types of the disease. To account for this possibility, patients less than 18 years of age and those attributed to endocrinologists or diabetologists were not included for study. It should also be acknowledged that the study population was largely derived from patients who had visited a primary care provider within a large integrated healthcare system and may not be generalizable to populations outside of IH.

Data elements that include social determinants of health (income and education level, number of family members or dependents, and the contextual elements of the neighborhood or geographical location where the patient lives) have been shown to be predictive of positive outcomes in weight loss; however, these were not available for study. Other clinical biometrics (i.e., physical activity per week and common laboratories) were queried within the IH EDW, but very few patients (29%) in any of the study groups had these services performed at study completion. Quality improvements efforts are currently underway to ensure adherence to the care process for preDM and T2DM and will be studied in future analyses.

Conclusion

Within a pragmatic clinical setting, successful adaptation of DPP-based lifestyle interventions among preDM patients was associated with achievement of weight loss goals and a reduction in overall incidence of T2DM during the study period. Additional study is needed to determine the reach or representativeness of DPP participants; adoption or the number of providers and clinical settings who were willing to initiate the intervention; and the implementation, or fidelity to various elements of the IH DPP intervention. As demonstrated by the large population that was identified within this study, leveraging technology may be a key strategy to reach more affected populations and scale these established interventions for the masses. Finally, just as overall health does not arise from only a single factor, scalable interventions geared towards patient activation and accountability through structured behavior change practices will only emerge from concerted and collaborative efforts that stretch across the care continuum**.**

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CHAPTER 4

EVALUATION OF A DIABETES PREVENTION PROGRAM UTILIZING THE RE-AIM FRAMEWORK[3]

Abstract

Objective

Pragmatic evaluation of new interventions implemented in healthcare is one of the key issues addressing the gap between research and practice, but is seldom assessed in implementation studies. The aim of this study was to evaluate the reach, effectiveness, adoption, and implementation of a Diabetes Prevention Program (DPP) within a large, integrative delivery system among patients identified with prediabetes (preDM).

Methods

Using the Intermountain Healthcare (IH) Enterprise Data Warehouse (EDW), adult primary care patients (aged ≥18-75 years) who met the American Diabetes Association criteria for preDM (HbA1c 5.7- 6.49% or Fasting Plasma Glucose 100-125mg/dL) were attributed to a primary care provider (PCP) during 2013-2014. PCPs were provided a list of their patients who met these laboratory criteria and encouraged to invite patients during their next in-person office visit to participate in the DPP. Using the RE-AIM framework at 12 months post deployment, we evaluated: reach with data on

[3] Kimberly D. Brunisholz, Elizabeth A. Joy, Mia Hashibe, Lisa H. Gren, Lucy A. Savitz, Jaewhan Kim.

patient identification, participation, and representativeness; *effectiveness* with data on the odds of attaining a 5% weight loss; *adoption* with monitoring of organizational diffusion among providers/clinics; and implementation with the fidelity of the education as it was deployed throughout the delivery system.

Results

Roughly 8% of eligible patients were enrolled. Likelihood of participation was higher among patients who were: female, aged >70 years, overweight, had depression and higher baseline weight, and those prescribed metformin. Likelihood of participation was lower in patients with 5-9 years duration of preDM diagnosis. DPP participants were more likely to achieve a 5% weight loss within 6 months (OR 1.72; 95% CI 1.29, 2.34; $p<0.001$) when compared to a control group that did not participate. Providers from 7 of 8 regions referred patients to the DPP, with 174 providers at 53 clinics enrolling patients within the first 12 months of the program. There were on average 2.3 (range 1-16) DPP counseling encounters during follow-up.

Conclusions

DPP-based lifestyle interventions deployed within IH's delivery system demonstrated encouraging potential for patients identified with preDM and for the organization which provides their care. This study may inform pragmatic implementation of future evidence-based interventions for other health networks, physicians, and payers.

Introduction

It is estimated that 86 million adults, more than one-third of Americans aged 20 and over, have prediabetes (preDM) and are at high risk for developing Type II Diabetes

Mellitus (T2DM).[1] However, only one in 14 (7.1%) of adults in the US have been told by a healthcare provider that they have the condition.[1]

Diabetes results from a combination of genetic predisposition, as well as behavioral and environmental risk factors. However, there is strong evidence that such modifiable risk factors like bad health behaviors, nutrition, obesity, and physical inactivity are the main environmental determinants of the disease.[2] General consensus among practitioners is that to combat type II diabetes mellitus (T2DM), we must first undergo measures to prevent it.

Several randomized clinical trials have solidified the efficacy of intensive lifestyle interventions to support weight loss and weight loss maintenance as the key to preventing progression of diabetes for those at-risk for disease.[3-8] The Diabetes Prevention Program Outcomes Study (DPPOS) demonstrated that prevention or delay of diabetes with lifestyle intervention or metformin can persist for at least 10 years, showing that clinical improvements are not just transient effects.[9] While effective interventions may have a significant upfront investment, research using a simulation model projects that a nationwide prevention program would break even in 14 years and within 25 years, it would prevent or delay 885,000 cases of diabetes in US, producing a cost savings of $5.7 billion.[10]

While their study provides an informative perspective on the internal validity of targeted interventions, less evidence exists on similar interventions performed in real-world settings. In a study evaluating MOVE!, a weight management program from the Department of Veteran Affairs (VA), results showed a significant difference between the preintervention and postintervention slope of weight over time, suggesting that MOVE!

may prevent future weight gain.[11] However, later study revealed low participation among eligible veterans and low estimates of weight loss when translating their earlier successes into a program that used provider-based referrals.[12] Other Diabetes Prevention Program (DPP) translational efforts have piloted programs that demonstrate high attendance and low attrition when invited by a trusted health professional,[13] effective weight loss when delivered by trained diabetes educators,[14,15] and program sustainability when implemented within a community setting.[7,16-18] Most studies using the RE-AIM framework have largely focused on the reach and effectiveness of interventions and rarely report the level of operational adoption and implementation in their research evaluations.[19,20]

In early 2013, Intermountain Healthcare (IH) began work to identify the population at-risk for diabetes; institute an expert clinical development team to create a care process for the identification and management of patients with preDM; analyze current organizational health promotion and disease prevention infrastructure; and to create an education and referral process for patients identified with preDM. Based on a modified form of the National Diabetes Prevention Program (NDPP),[6] the IH Diabetes Prevention Program (DPP) uniquely identifies patients with preDM and includes three different options for participation: a two-hour introduction group class, individualized nutritional counseling, or an intensive lifestyle intervention.

Only a few health systems in the nation have identified those with preDM and intervened using evidenced-based programs for diabetes prevention. Little is known about diabetes prevention in regards to: the proportion or characteristics of eligible patients who participated, the overall effectiveness in achieving the 5% weight loss, the

level of organizational diffusion among providers/clinics, and the fidelity to the program as it was deployed. The purpose of this study was to evaluate the reach, effectiveness, adoption, and implementation of the IH DPP deployed within a large, integrative delivery system among patients identified with preDM.

Methods

We conducted an evaluation of the DPP program using the RE-AIM framework (reach, effectiveness, adoption, implementation, maintenance) for organizing our analysis, results, and interpretation to focus on all framework dimensions except for maintenance.[21-23] This framework emphasizes the need to evaluate health interventions beyond efficacy and effectiveness to include multiple criteria to better identify effect and transferability in a general population.[24,25]

Intermountain Healthcare's Diabetes Prevention Program

In early 2013, within an organizational culture of rapid cycle quality improvement, the Primary Care Clinical Program began work on the creation of a defined Diabetes Prevention Program to deploy within primary care clinics at IH. As described elsewhere,[26] this program identified patients who meet criteria for preDM (HbA1c 5.7-6.49% or Fasting Plasma Glucose 100-125mg/dL) for clinicians, provides an introductory class focused on awareness and goal setting for people with preDM, and leverages existing wellness initiatives for intensive lifestyle and behavior change education that have demonstrated effectiveness in the peer-reviewed literature.[26] Briefly, the DPP is comprised of three different pathways to participate: (a) an introductory, two-hour group class (Prediabetes 101); (b) individual, nutrition counseling sessions (Medical Nutrition Therapy, or MNT); and (c) a hospital-based behavioral program, offered over

12 class periods within a 6-month period (Weigh to Health, or W2H). Patients can enroll in any or all of the differing pathways that make up the DPP (see Figure 3.1).

Feasibility studies were conducted in five clinics between August 2013 and December 2013 to test the deployment of the Prediabetes 101 class. MNT and W2H were already in existence operationally throughout the system and were included as additional education pathways for DPP participants in August 2013. On the basis of the lessons learned during this testing, the DPP workgroup: revised the invitation process to participate by recommending an in-person invitation at the next PCP office visit rather than calling prospective patients; created distinct roles and responsibilities for the clinical and DPP teams; standardized the referral process and DPP documentation for all pathways in the electronic medical record; and engaged providers and clinical staff by performing regional trainings and clinical in-services for all impacted clinicians. IH medical and operational leadership issued a formal statement in January 2014 requiring that the Prediabetes 101 class would be free of charge to all patients and would be used as a patient engagement tool across the IH system. Medical Nutrition Therapy (MNT) and Weigh to Health (W2H) continued to require insurance coverage to be approved on a patient by patient basis. Full deployment throughout the IH delivery system of the Prediabetes 101 class occurred in January 2014.

Data Sources

In addition to routine clinical, administrative, and financial information about individual encounters, IH's Enterprise Data Warehouse (EDW) was queried for all data on patient demographics (age, sex, race/ethnicity and insurance status) and clinical biometric status (weight and body mass index class). Clinical characteristics for the study

cohort included the proportion of patients with chronic conditions prior to study enrollment including: depression, coronary heart disease, congestive heart failure, atrial fibrillation, and high blood pressure. Criteria for chronic conditions are different for each condition; however, they are based on diagnosis codes and encounter data, and approved by an internal expert committee of practicing providers (see Table 2.2). The duration of preDM diagnosis was estimated based on the first documentation of laboratory values within the EDW system. Medication use was collected at time of study enrollment (anti-hypertensive, atypical-neuroleptics, metformin, and statins). The institutional review board at Intermountain Healthcare approved this study.

Study Participants

A source population of adult patients (aged 18-75 years) who met criteria for preDM within the last 3 years was queried through IH's EDW for each clinic. Patients were attributed to a primary care provider who provided the plurality of qualifying services (Current Procedural Terminology codes for outpatient visit, preventive medicine visit or wellness visit: 9920x, 9921x, 99385-87, 99395-97, G0101, G0402, G0438) in a given calendar year with most recent service breaking any ties. Patient-level data were distributed to the providers and clinic support staff so patients could be identified prior to arriving for their appointments. Patients were excluded for study if they had been diagnosed with diabetes prior or within 2 months of enrollment, had a known death within the study period, or ever had weight loss surgery. Patients who attended a Prediabetes 101 introductory class, MNT, or W2H between August 2013 and July 2014 were considered as the DPP participant group. Patients who were eligible, or had the opportunity to enroll (had an office visit with their PCP during the study period) but did

not participate, were considered as the control group.

Assessment and Statistical Analyses of Reach

Reach was defined by the rate of participation in those that enrolled in the DPP (numerator) compared to those that were eligible to participate in the DPP (denominator). Due to possible DPP implementation variation, data was stratified by IH region. Representativeness was based on comparisons of participants to nonparticipants for key demographic and health-related characteristics. To determine the independent associations between DPP participation and patient characteristics, multivariable logistic regression modeling was utilized.

Assessment and Statistical Analyses of Effectiveness

To assess the *effectiveness* dimension, unpublished results from a recent comparative analysis were reported to determine the association of 5% weight loss and the incidence of T2DM among participants and nonparticipants. The results and the approach have been described in detail elsewhere.[26] Briefly, to determine which patients achieved a 5% weight loss, baseline weight was collected within 12 months of study enrollment and follow-up weight was collected within 5-7 months after enrollment. Change scores were calculated and a binary outcome of yes/no was computed if patients achieved a 5% weight loss from baseline. Incident diagnosis of T2DM (yes/no) was defined by the National Committee for Quality Assurance (NCQA) through the Healthcare Effectiveness Data and Information Set (HEDIS) specifications.[27,28] These specifications require only one of the following to be met along with a diagnosis code of diabetes (ICD-9 code: 250): (a) two outpatient encounters on different dates of service; (b) one acute inpatient encounter; (c) one emergency department visit; or (d) patients

who were dispensed insulin or hypoglycemic/anti-hyperglycemics on an ambulatory basis.

Conditional logistic regression modeling was utilized to obtain summary measures of relative risk for the study groups. Odds ratios were generated after adjustment for baseline differences including demographic and clinical characteristics that are well known to affect the ability to achieve the 5% weight loss. Similarly, this method was used to determine the incidence of T2DM among groups. Difference-in-difference modeling was used to measure the association and magnitude measurement of weight change from baseline to follow-up.

Assessment of Other RE-AIM Dimensions

To assess *adoption*, we calculated the number of providers and clinics that implemented the DPP in the first year that it was deployed. The range of patients referred per provider was also reported. To evaluate *implementation*, we used a proxy measure of adherence or fidelity to the DPP flow process. We assessed the average number of encounters per patient by each DPP pathway and the proportion of patients who only had only 1 encounter within the DPP. The proportion of patients who enrolled in the W2H pathway was assessed for completeness (≥12 encounters).

Results

Reach

17,142 people met the criteria for preDM during the study period (Figure 4.1). 6,862 were eligible because they met study criteria, had an office visit with their provider, and had the opportunity to be invited. 8.4% patients participated (n=573) with 384 (67%) participating in the 101 class, 213 (37%) in MNT, and 54 (9%) in W2H.

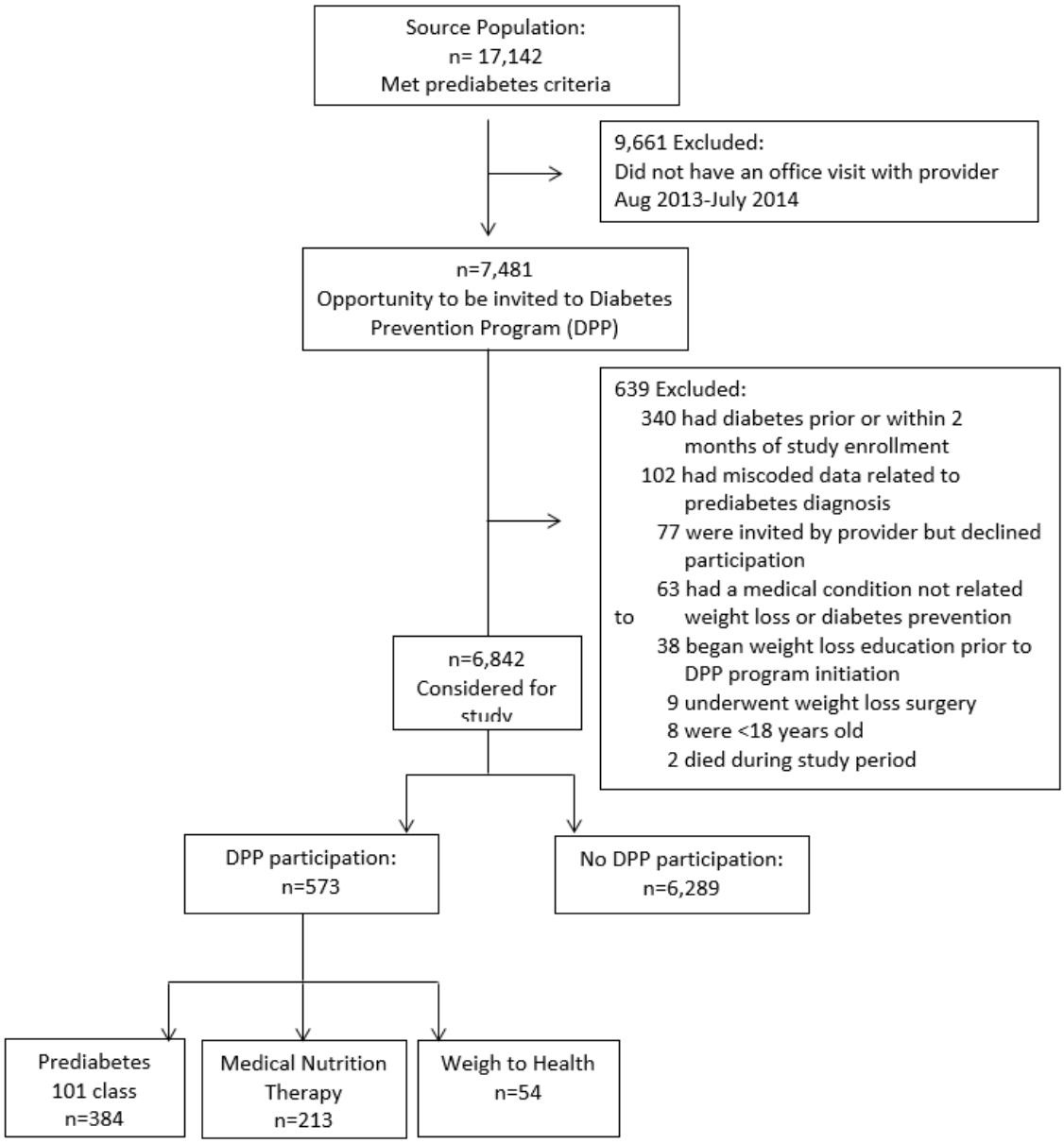

Figure 4.1. Inclusion Criteria for Study Enrollment

W2H (patients could participate in any of all of the different DPP pathways, and thus the proportion among the group does not add up to 100%). Only 63 patients participated in more than one DPP pathway, with all of them participating in the Prediabetes 101 and MNT classes combined. The DPP participation rate was greatest for regions 2, 5, and 6.

After adjusting for all factors listed in Table 4.1, the following characteristics were associated with an increased likelihood of participation: female sex, aged >70 years, overweight BMI category, depression, and those prescribed metformin. Likelihood of participation was lower in patients with 5-9 years (referent <5years) duration of preDM diagnosis. Additional analyses were completed to adjust for possible clinic implementation variation using mixed-effects logistic modeling, which confirmed that female sex, and those prescribed metformin were more likely to participate (Table 4.2).

Effectiveness

As documented in Figure 4.2, patients in the DPP group were 70% more likely to achieve a 5% weight loss as compared to the control group (OR 1.70; 95%CI 1.29, 2.25; $p<0.001$) after adjustment for possible confounders. DPP patients were also less likely to have an incident diagnosis of T2DM during the study period (OR 0.49; 95%CI 0.28, 0.86; $p=0.012$). After comparing the change in weight over time, DPP participation showed a trend toward significance with a greater reduction in weight when compared to the no-DPP group (ß= -1.36; 95%CI -2.76, 0.05; $p=0.058$).

Adoption

All measures related to the *adoption* dimension are documented in Table 4.3. Of the 8 regions within the IH system, the DPP was implemented in 7. One region was impacted substantially by extensive geography that would have made in-person

Table 4.1. Measurement of Reach: Characteristics and Associations of Patients Who Participated in the Diabetes Prevention Program

Variables	#pts	DPP participants *n* = 573		Nonparticipants *n* = 6289		Multivariable-adjusted associations of participation‡
		n	*M* ± *SD* or %	*n*	*M* ± *SD* or %	OR (95% *CI*)
Demographics						
Age categories, %						
18-29	174	19	3.32	155	2.47	---
30-39	506	39	6.81	467	7.44	0.69 (0.40, 1.17)
40-49	982	76	13.36	906	14.42	0.78 (0.44, 1.37)
50-59	1916	165	28.81	1,751	27.88	0.91 (0.53, 1.56)
60-69	2357	151	26.35	2,206	35.12	0.70 (0.40, 1.21)
≥ 70	919	123	21.47	796	12.67	1.75 (1.08, 2.83)*
Gender, %						
Male	3070	212	37.12	2,858	45.44	---
Female	3787	356	62.88	3,431	54.56	1.43 (1.09, 1.88)*
Race/ethnicity						
White	5947	506	88.43	5,441	86.52	---
Hispanic	575	44	7.64	531	8.44	0.73 (0.39, 1.35)
Black	57	4	0.66	53	0.84	0.80 (0.27, 2.35)
Asian	145	10	1.75	135	2.15	0.98 (0.70, 1.38)
Other	138	9	1.53	129	2.05	0.72 (0.46, 1.14)
Insurance						
Commercial	3967	294	51.31	3,673	58.40	---
Medicare	2208	194	33.84	2,014	32.02	0.92 (0.77, 1.09)
Medicaid	272	21	3.71	251	3.99	0.84 (0.51, 1.38)
Uninsured	415	64	11.14	351	5.58	2.21 (0.85, 5.74)
Clinical Characteristics						
Prediabetes duration, %						
<5 years	5389	458	79.91	4,931	78.41	---
5-9 years	1303	100	17.47	1,203	19.13	0.71 (0.56, 0.92)*
>10 years	170	15	2.62	155	2.46	0.86 (0.49, 1.49)
Chronic Conditions, %						
Depression	2808	272	47.38	2,536	40.32	1.15 (1.03, 1.28)*
Coronary Heart Disease	1234	114	19.87	1,120	17.81	1.13 (0.76, 1.70)
Heart Failure	516	51	8.95	465	7.39	0.93 (0.67, 1.29)
Atrial Fibrillation	416	45	7.86	371	5.90	1.28 (0.91, 1.81)
High Blood Pressure	3908	336	5873	3,572	56.80	1.12 (0.92, 1.35)
Medication class, %						
Anti-hypertensive	3322	274	47.82	3,048	48.47	0.81 (0.54, 1.21)
Anti-neurolyptics	576	55	9.61	521	8.28	1.02 (0.81, 1.29)
Metformin	1110	124	21.62	986	15.68	1.36 (1.01, 1.87)*
Statin	3497	304	53.06	3,193	50.77	0.97 (0.86, 1.11)
BMI class at baseline, %						
Underweight	40	2	0.38	38	0.63	0.81 (0.26, 2.49)
Normal	686	38	7.11	648	10.67	---
Overweight	1679	130	24.83	1,549	25.51	1.39 (1.02, 1.89)*
Obese	4193	355	67.63	3,838	63.20	1.21 (0.68, 2.13)

[a] all covariates listed in the table were included in the model.

*significance < .05

Table 4.2. Mixed-Effects Logistic Regression Modeling for Diabetes Prevention Program Participation

Variables	#preDM pts	#DPP participants	OR (95%CI)	*p*
		Demographics		
Age categories				
18-29	174	19	---	---
30-39	506	39	0.67 (0.36, 1.24)	0.21
40-49	982	76	0.79 (0.44, 1.40)	0.42
50-59	1916	165	0.85 (0.49, 1.49)	0.57
60-69	2357	151	0.67 (0.37, 1.21)	0.19
≥ 70	919	123	1.62 (0.85, 3.10)	0.14
Gender				
Male	3070	212	---	---
Female	3787	356	1.41 (1.15, 1.74)	0.001
Race/ethnicity				
White	5947	506	---	---
Hispanic	575	44	0.93 (0.64, 1.34)	0.68
Black	57	4	0.57 (0.19, 1.77)	0.34
Asian	145	10	1.22 (0.61, 2.46)	0.57
Other	138	9	0.74 (0.35, 1.58)	0.44
Insurance				
Commercial	3967	294	---	---
Medicare	2208	194	0.86 (0.65, 1.14)	0.29
Medicaid	272	21	0.77 (0.45, 1.29)	0.32
Uninsured	415	64	1.47 (0.97, 2.24)	0.07
		Clinical Characteristics		
Prediabetes duration				
<5 years	5389	458	---	---
5-9 years	1303	100	0.71 (0.55, 0.92)	0.01
>10 years	170	15	0.96 (0.53, 1.75)	0.90
Chronic Conditions				
Depression	2808	272	1.13 (0.93, 1.39)	0.23
Coronary Heart Disease	1234	114	1.02 (0.79, 1.33)	0.86
Heart Failure	516	51	0.93 (0.63, 1.36)	0.70
Atrial Fibrillation	416	45	1.30 (0.89, 1.89)	0.18
High Blood Pressure	3908	336	1.15 (0.89, 1.47)	0.28
Medication class				
Anti-hypertensive	3322	274	0.77 (0.60, 0.99)	0.04
Anti-neurolyptics	576	55	0.99 (0.71, 1.41)	0.99
Metformin	1110	124	1.32 (1.04, 1.68)	0.02
Statin	3497	304	1.03 (0.84, 1.26)	0.79
BMI class at baseline				
Underweight	40	2	0.61 (0.13, 2.92)	0.54
Normal	686	38	---	---
Overweight	1679	130	1.37 (0.94, 1.99)	0.09
Obese	4193	355	1.17 (0.79, 1.75)	0.43
		Clinic Characteristics		
# of paneled patients per clinic	6,862	573	1.00 (0.99, 1.00)	0.74
# of providers per clinic	6,862	573	0.99 (0.94, 1.04)	0.60

Table 4.2. Continued

Variables	#preDM pts	#DPP participants	OR (95%CI)	*p*
Urban location of clinic				
No	1,276	118	---	---
Yes	5,013	455	1.24 (0.56, 2.78)	0.60
Level of Medical Home Implementation				
None	1,083	147	---	---
Planning	449	27	0.57 (0.20, 1.63)	0.29
Adoption	1,733	115	0.48 (0.23, 1.01)	0.05
Routinized	3,024	284	0.59 (0.36, 0.98)	0.04

Note. preDM: prediabetes; DPP: Diabetes Prevention Program; OR: Odds Ratio; CI: Confidence Interval.

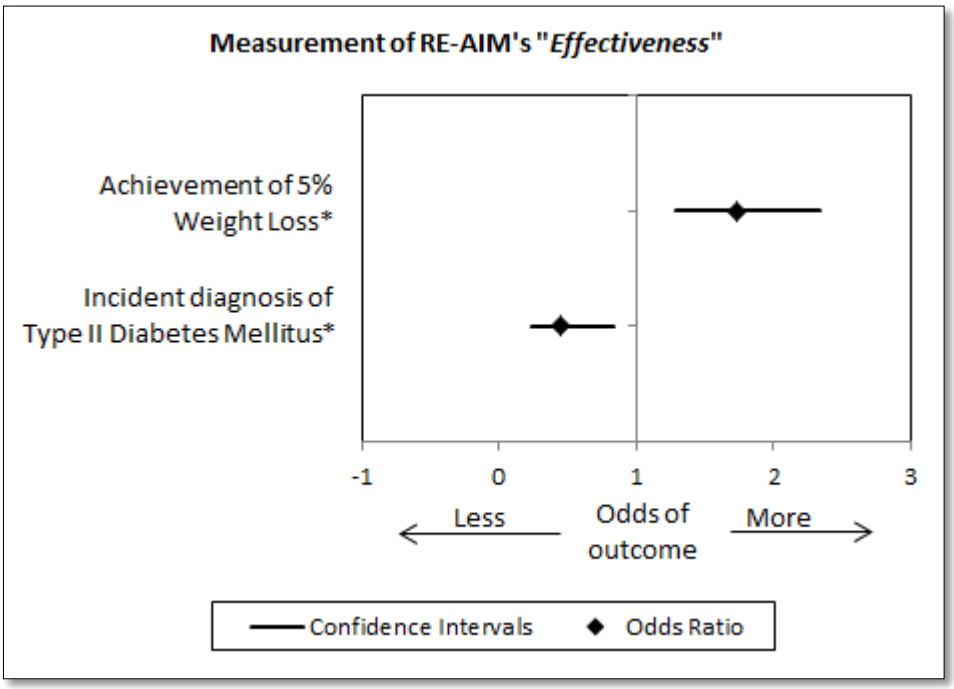

Figure 4.2. Measurement of Effectiveness: Association among Diabetes Prevention Program Participation and (a) Achievement of 5% Weight Loss and (b) Incident Diagnosis of Type II Diabetes Mellitus. *p<0.01, adjusted for age, female sex, race category (White, Asian, Black, Hispanic, or other/unknown), insurance plan at enrollment (Commercial, Medicare, Medicaid, or Uninsured/Self-pay), duration of prediabetes diagnosis (<5 years, 5-9 years, or ≥10 years), prevalence of chronic conditions (depression, coronary artery disease, heart failure, atrial fibrillation, high blood pressure), prescribed medication at enrollment (by drug class: anti-hypertensive, atypical-neuroleptics, metformin, statin), and baseline weight.

Table 4.3. Measures of Adoption and Implementation: Summary Results of Organizational Diffusion and the Fidelity to Implementation of the Program

	Intermountain Healthcare's Geographical Regions							
Measures	1	2	3	4	5	6	7	Total
				Adoption Dimension				
Eligible preDM patients, n	603	1,236	1,205	944	791	597	1,486	6,862
DPP Participants, n (%)	34 (5.6)	163 (13.2)	48 (4.0)	31 (3.3)	84 (10.6)	75 (12.6)	138 (9.3)	573 (8.4)
DPP referring clinics, n(%)	4 (80%)	8 (89%)	5 (56%)	9 (100%)	8 (88%)	10 (77%)	9 (100%)	53 (87%)
DPP referring providers, n	15	44	21	19	22	22	31	174
Range of patients referred per provider	1-5	1-32	1-5	1-4	1-12	1-14	1-16	1-32
				Implementation Dimension				
No. of DPP counseling encounters, mean (range)	2.1 (1-12)	2.7 (1-15)	3.3 (1-15)	2.3 (1-12)	2.5 (1-15)	1.5 (1-14)	1.9 (1-16)	2.3 (1-16)
DPP Participants with only 1 encounter, n (%)	26 (77%)	91 (56%)	28 (58%)	18 (51%)	44 (52%)	54 (72%)	117 (85%)	378 (66%)
W2H Participants with ≥ 12 encounters, n (%)	3 (75%)	13 (65%)	7 (78%)	2 (67%)	5 (72%)	1 (25%)	4 (57%)	35 (54%)

Note. preDM: prediabetes; DPP: Diabetes Prevention Program

counseling challenging and deferred participation during the first 12 months of the program. Within this primary care led intervention, 174 providers at 53 clinics referred patients to the DPP. The number of patients a provider referred for enrollment ranged from 1 to 32 and there was distinct variation among the differing regions on how many patients participated.

Implementation

As documented in Table 4.3, the mean number of DPP counseling encounters during follow-up was 2.3 and varied among regions (1-16). 66% of participants had only a single DPP counseling encounter (range across regions 51% to 85%), while for those that participated in W2H, roughly 54% had ≥ 12 encounters (range among regions 25% to 78%).

Discussion

Overall, the first year results from the IH DPP demonstrated encouraging potential for translating DPP-based interventions into primary care clinics within our large integrated, healthcare delivery system. While this study demonstrated that only a small proportion (8.4%) of patients with preDM participated in the program, for those that did participate, there was a significant association with achieving a 5% weight loss and reducing the incidence of T2DM when they were compared to a group who did not participate. Several patient characteristics emerged, such as older age, female sex, prevalent depression diagnosis, being overweight, and prescribed metformin, that were associated with a greater likelihood of participation. Medical and operational leadership supported this program, with broad adoption by clinics and providers across the IH system. While on average, the numbers of DPP participants was low per provider (48%

referred less than 5 patients), several providers emerged as clinical champions of the program. In terms of implementation fidelity, few patients participated in more than one intervention option and the majority received only one encounter during the program.

Results from this study support research from other DPP-based interventions deployed within comparable delivery systems such as Kaiser Permaneante Colorado[20] and the Department of Veteran Affairs (VA).[29,30] Preliminary results from a national model of diabetes prevention linking health insurers and community programs suggest that "large-scale prevention efforts can be effective, scalable and sustainable with collaboration, health information technology, community-based delivery of evidence-based interventions, and novel payment structures." [31] Further efforts to understand the role that technology will play in delivering online lifestyle counseling may offer additional solutions for the future to address the obesity and diabetes epidemics.[32]

Previous studies have laid the foundation for translating diabetes prevention into care delivery. However, our study builds upon these results by demonstrating broad support by organizational leadership and providers for enrolling patients in the program, while revealing promising effectiveness of the intervention amidst modest fidelity to the program as originally intended. Distinct patient characteristics such as female sex, older versus younger age, metformin, and categorized as overweight all had an increased likelihood of association with participation. A potentially unique finding from this study suggested that patients diagnosed with depression were more likely to participate as compared with those without the diagnosis. This may be attributed to high functioning, multidisciplinary teams which were able to identify patients with mental health disease and due to additional opportunities for contact with their care providers, were invited to

participate in the program.

Another unique finding suggested that there was broad adoption by providers and leadership across the system; however, there was distinct variability in the implementation or fidelity to the program across regions. Some regions supported implementation of the Prediabetes 101 class while others were more apt to refer patients to intensive lifestyle interventions, suggesting that providers or patients may inherently gravitate towards counseling that best fits individual needs. Among all regions, when a clinical champion was identified, we observed greater adoption and referral to all pathways within the IH DPP program. All findings warrant further validation and longitudinal study.

Limitations

Patients were not randomly assigned to participate in the intervention and therefore, motivation to participate or increased readiness to change behavior may explain associations in participation or the weight loss differences observed. This evaluation was performed within a short period of time after enrollment and further longitudinal study is needed to determine the sustainability of its impact over a prolonged period of time. While the methodology used in this study attempted to account for variation in reach and adoption of the program across the IH clinics where the patients received care, it might not account for all variation in practice which could affect the observed results.

Study groups found within this study were carefully selected based on the definitions found within the literature; however, there is always a possibility that data could have been miscoded creating selection bias within this evaluation. Female patients

who consider their obstetrician or gynecologist as the provider who delivers their care primarily were not studied in this analysis and may warrant further study. Patients with prevalent T2DM diagnosis were excluded, yet there remains a possibility that their diagnosis was not identified due to the definition criteria or care that occurred outside of the IH system.

Findings from this study may not be generalizable to populations outside of IH because of differences in patient characteristics, local implementation, and resources allocated to this program. Information was not available on weight loss activities outside of the IH DPP program which potentially could differ between participants and nonparticipants. Social determinants of health such as where the patient was born, their current living conditions, and education and income level have also been associated with health outcomes, but were not available for study. Finally, we were limited in our ability to assess all dimensions of the RE-AIM framework, including direct measures of implementation and maintenance of the program.

Conclusions

DPP-based lifestyle interventions deployed within IH's delivery system demonstrated moderate effectiveness in the short-term, yet the proportion of patients who were eligible to enroll was low. Broad adoption across regions by providers and leadership revealed organizational buy-in, while demonstrating that much of the clinical effect was seen when patients participated in an intervention that was far less resource intensive as compared to the landmark studies by the National Diabetes Prevention Program. As demonstrated by the large population and low reach of participation that was identified within this study, leveraging technology may be a key strategy to reach

more of our affected populations and scale these established interventions for those at risk for disease.

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CHAPTER 5

CONCLUSION

The prevalence and costs associated with type II diabetes (T2DM) not only challenge the financial integrity of our healthcare system, but present a clinical epidemic that has made preventing this disease a public health priority. The ability to recognize those who are at-risk for T2DM, by identifying patients with prediabetes (preDM), represents an opportunity to reduce both the incidence and cost of disease over time. Several published studies have established the utility of screening protocols and the effectiveness of basic healthy lifestyle interventions within a preDM population, yet very few healthcare delivery systems target these patients with such an intervention. Compared to the amount of research demonstrating the efficacy of such interventions, relatively few studies have assessed the external validity of implementing a Diabetes Prevention Program (DPP) and the impact in the short term. This body of research indicated that:

1. Confirmed and unconfirmed preDM is strongly associated with the development of T2DM as compared to patients with only risk factors for disease. Furthermore, increasing age in addition to preDM increases a person's chance of developing T2DM, confirming the recent screening recommendations from the American Diabetes Association.

2. Adaptation of DPP-based lifestyle interventions deployed within primary care clinics demonstrated a significant improvement in achieving a 5% weight loss and reduced the incidence of T2DM among participants when compared to nonenrollees.
3. Intermountain Healthcare's DPP demonstrated significant effectiveness in the short-term, yet the proportion of patients who enrolled was low. Additionally, broad adoption by providers and operational leadership revealed organizational buy-in, while demonstrating much of the clinical effect was seen when patients participated in an intervention that was far less resource intensive as compared to landmark studies by the National Diabetes Prevention Program.

The results of this dissertation suggest that diabetes prevention using known lifestyle interventions delivered within primary care practices is feasible and an effective intervention to use in patients with confirmed preDM. Future directions for study include: further longitudinal evaluation to determine the sustained impact of the DPP program; extending invitation to other eligible populations (such as patients with unconfirmed preDM) to participate in the DPP intervention; leveraging technology to reach more of the affected population and scale evidence-based interventions; and including other stakeholders (i.e., patients, families, and insurers) within the implementation process to garner further refinement of the program.