Impact of the Primary Care-based Chronic Disease Management Program on Quality of Care and Health Outcomes among Patients with Type 2 Diabetes Mellitus

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Impact of the Primary Care-based Chronic Disease Management Program on Quality of Care and Health Outcomes among Patients with Type 2 Diabetes Mellitus

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ABSTRACT

Impact of the Primary Care-based Chronic Disease Management Program on Quality of Care and Health Outcomes among Patients with Type 2 Diabetes Mellitus

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Background: Pragmatic policy establishment for the early prediction, prevention, and management of high-risk groups for chronic diseases is essential for improving public health. Although the primary care-based chronic disease management program (PCDMP) has improved the behavior of patients with diabetes, there is insufficient evidence to determine whether this initiative has an impact on long-term health outcomes related to type 2 diabetes mellitus (T2DM). The purpose of this study was to examine the impact of PCDMP on the quality of care and health outcomes in patients with T2DM.

Methods: This study used the National Health Insurance Service National Sample Cohort data from 2002 to 2019, and newly diagnosed patients with T2DM, and without complication were selected for analysis. Patients participating in the PCDMP were set as the PCDMP group, while patients who did not participate in PCDMP were set as the control group. There were 3,222 patients in the PCDMP group and 6,444 in the matched control

group after 1:2 propensity score matching. The point of intervention was based on the PCDMP enrollment date, but since patients voluntarily enrolled in PCDMP, the time point of intervention was different for each subject. The matched control group, which did not participate in PCDMP, was given the same intervention time point as the PCDMP group. The main dependent variables were continuity of care (COC) and completion of examinations as quality of care indicators, and onset of diabetes complications, complication-related hospitalizations and mortality as health outcome indicators. A Difference in differences (DID) model was used to examine any changes in quality of care indicators among the PCDMP group in before and after intervention periods, relative to changes in quality of care indicators of the control group. The interaction terms of the PCDMP and the control group before and after policy implementation were evaluated. The generalized estimation equation model was applied for statistical analysis. In addition, the health outcome indicators were analyzed using the Cox proportional hazards model.

Results: In the PCDMP group, the proportion of good COC increased by 15% compared to the control group (exp(β)=1.15, 95% confidence interval (CI)=1.06-1.24, p=0.0009). The differential change in the PCDMP group after the intervention point was 8% higher than that of the control group for the completion of all examinations, including the HbA1c test, lipid profile test, and fundoscopic examination. However, this difference was not statistically significant (exp(β)=1.08, 95% CI=0.98-1.18, p=0.1029). Even for each test, differential changes were slightly higher in the exposed group, but only the HbA1c test was significant (HbA1c test, exp(β)=1.10, 95% CI=1.03-1.18, p= 0.0038; lipid profile test, exp(β)=1.05, 95% CI=0.98-1.11, p=0.1765; fundoscopic examination, exp(β)=1.02, 95% CI=0.95-1.11, p=0.5548). There was no difference in the hazard ratio (HR) of newly developed diabetes complications between the PCDMP and control groups (HR:1.00, 95%

CI=0.94-1.06). For cardiovascular complications, the PCDMP group had significantly lower risk of complications by 9% than the control group (HR:0.91, 95% CI=0.84-0.99). In contrast, in microvascular complications, the PCDMP group had 7% higher risk than the control group, but the difference was not statistically significant (HR:1.07, 95% CI=0.99-1.16). Diabetic foot disease also had 30% lower risk in the PCDMP group than in the control group (HR: 0.71; 95% CI=0.57-0.88). The risk of hospitalization for diabetic complications was significantly lower in the PCDMP group than in the control group. Both cardiovascular and microvascular complication hospitalization were lower in risk by more than 30% (diabetes-related hospitalization, HR: 0.66, 95% CI=0.57-0.76; cardiovascular complication hospitalization, HR: 0.71, 95% CI=0.61-0.84; microvascular complication hospitalization for, HR: 0.52, 95% CI=0.40-0.68). Additionally, the PCDMP group had 0.51 times lower mortality compared with the control group (HR: 0.51, 95% CI=0.40-0.64).

Conclusions: PCDMP can significantly improve the health outcomes of patients with T2DM by increasing the continuity of care and preventing complications. This study is meaningful in that it comprehensively evaluated the effectiveness of the PCDMP in Korea, which strengthened the role of primary care, from a long-term perspective. It is necessary to develop healthcare policies to reform and establish a chronic disease management system based on primary care settings.

Keywords: primary care, chronic disease management, quality of care, health outcome, type 2 diabetes mellitus

I. Introduction

1. Background

Diabetes mellitus is a serious health problem that has a significant impact on the lives and well-being of individuals and society. The global prevalence of diabetes has nearly doubled since 1980.[1] In 2021, it was estimated that 10.5% (536.6 million) of adults aged 20 to 79 years have diabetes worldwide. This number continues to grow rapidly and is predicted to rise to 12.2% (783.2 million) by 2045.[2] As of 2020, the prevalence of diabetes in Korea over the age of 30 is 16.7%, and it is estimated to be 30.1% in adults over the age of 65.[3]

Over 90% of diabetes mellitus cases have type 2 diabetes mellitus (T2DM).[4] Along with genetic factors, various factors affect the development of T2DM, including population aging, economic development, overweight and obesity, sedentary lifestyle, and unhealthy diets.[3-5] In general, Asian countries are considered to be a major region of the T2DM epidemic, and the Asian population tends to develop diabetes at a younger age than the white population.[4,5] This faster onset of T2DM in the Asian population has a greater impact on morbidity and mortality associated with T2DM and its complications.[5]

T2DM and its negative health consequences have a high social burden of disease.[6] Diabetes is the 10th leading cause of death among adults, and it has been reported that four million people died from diabetes globally in 2017.[7] T2DM and its complications are also the leading cause of death in Korea, accounting for the 6th leading cause of death[6]. Korea

has a higher age-standardized mortality rate for diabetes than other Organization for Economic Cooperation and Development (OECD) countries.[6]

T2DM seriously threatens public health as it leads to hospitalization or serious complications if it is not continuously managed in an outpatient setting.[8] In particular, diabetes is a disease in which the quality of life decreases and medical costs increase due to complications rather than the disease itself.[9] Complications from T2DM include cardiovascular disease, stroke, peripheral vascular disease, neuropathy, nephropathy, retinopathy, and diabetic foot.[10] Complications can be either episodic or progressive. Episodic complications (e.g., foot ulcers) are treatable and may recur multiple times. Progressive complications (e.g., nephropathy) cause further damage to organs and greater loss of functionality over time.[10]

The establishment of practical policies for the early prediction, prevention, and management of patients with T2DM is essential for the promotion of public health. In addition, it is important for patients to check and manage their condition on their own. Primary care can play a gatekeeper role in effectively managing the health conditions of patients with chronic diseases including T2DM. The Institute of Medicine states (IOM) states that primary care is the provision of integrated, accessible healthcare services by clinicians, developing a sustained partnership with patients.[11] Due to these features of continuous and comprehensive primary care, it is suitable for chronic disease management that requires long-term supervision and observation.[12]

Countries with primary care systems can achieve better health outcomes at lower costs.[13] Accordingly, several countries are promoting various policies and programs to ease the burden of chronic diseases by strengthening the foundation for primary care. Australia, England, and the Netherlands have the objective of driving patient enrollment in general practice to enhance the quality and accessibility of primary care.[14] Based on the Patient-

Centered Medical Home (PCMH) in the United States and Chronic Disease Prevention and Management (CDPM) framework in Canada; an integrated approach including patients, public health professionals, and the community is being pursued.[15,16] Korea has also introduced and implemented a chronic disease management system to manage chronic disease patients such as those with T2DM and hypertension in primary care and the local community.[17]

The Korean government has been promoting various forms of primary care-based chronic disease management programs (PCDMP) since 2007.[18] The purpose of which is to establish a continuous and comprehensive management system for diabetes and hypertension, improve control rates through treatment, and delay or prevent complications, as well as support the self-management of patients with chronic diseases and to connects local clinics and community health care resources.[17,19]

In most cases, PCDMP in Korea has been a pilot project limited to some regions or is implemented after receiving separate applications for participation from patients and clinics.[18] Among them, PCDMP, which was introduced in 2012, targets all clinics across the country and enrolls only those patients who express an intent to receive continuous management at one clinic without a separate application process. Patients enrolled in this program receive a reduction in copayment from 30% to 20%, and services such as notification services, health professional counseling, and booklet provision can be provided through health support services. In addition, incentives are provided to clinics to manage patients consistently and appropriately with diabetes and hypertension. Hence, this study aimed to examine the effectiveness of managing patients with T2DM in primary care settings, focusing on the PCDMP, which has the widest range of subject targets.[18]

Several studies have already shown that PCDMP is helpful for better health behaviors and health outcomes in patients with chronic diseases, including those with

T2DM.[17,20-22] However, previous studies have focused on evaluating the effectiveness of the PCDMP in hypertension patients, who account for the majority of PCDMP participants, and most of them have confirmed short-term effects. In addition, the effectiveness of the PCDMP was mainly evaluated on process indicators such as continuity of care and medication adherence, but the evaluation of health outcome indicators such as risk of complications, hospitalization, and mortality is insufficient.[23]

For effective chronic disease management, it is necessary to check the effects of the projects that have been underway and supplement the deficiencies of the policy by accumulating evidence. Therefore, evaluating the long-term impact of T2DM management in primary care settings can provide an important basis for health authorities to establish PCDMP for patients with T2DM in the future.

2. Study objectives

This study aims to examine the impact of PCDMP on the quality of care and health outcomes of patients with T2DM. Additionally, this study aims to provide a basis for establishing policies on chronic disease management in the primary care environment by examining the effectiveness of the PCDMP.

Details of the study objectives are as follows:

(1) To investigate whether there is a difference in continuity of care between patients who participated in the PCDMP and those who did not.

(2) To investigate whether there is a difference in whether patients with T2DM receive regular examinations for diabetes management according to their PCDMP participation.

(3) To investigate the effect of PCDMP participation in patients with T2DM on the risk of developing diabetes complications, cause-specific hospitalization, and all-cause mortality.

II. Literature Review

1. Conceptual framework for chronic disease management

A representative and widely-used chronic disease management model is the Chronic Care Model (CCM). The CCM was developed by the MacColl Institute for Healthcare Innovation led by Wagner et al. in the United States in the mid-1990s.[24] This model presents a framework for the implementation of chronic care provided within the primary care setting.[25,26] The CCM is a pillar of current patient-centered healthcare service.[27]

The main purpose of this model is to reorganize the healthcare system interactions with patients, medical providers, and communities, focusing on preventing disease exacerbation and complications, rather than the current focus on acute disease and treatment services. This model presents six key elements of effective chronic disease management: community resources, health systems, self-management support, delivery system design, decision support, and clinical information systems (Figure 1).[24,25]

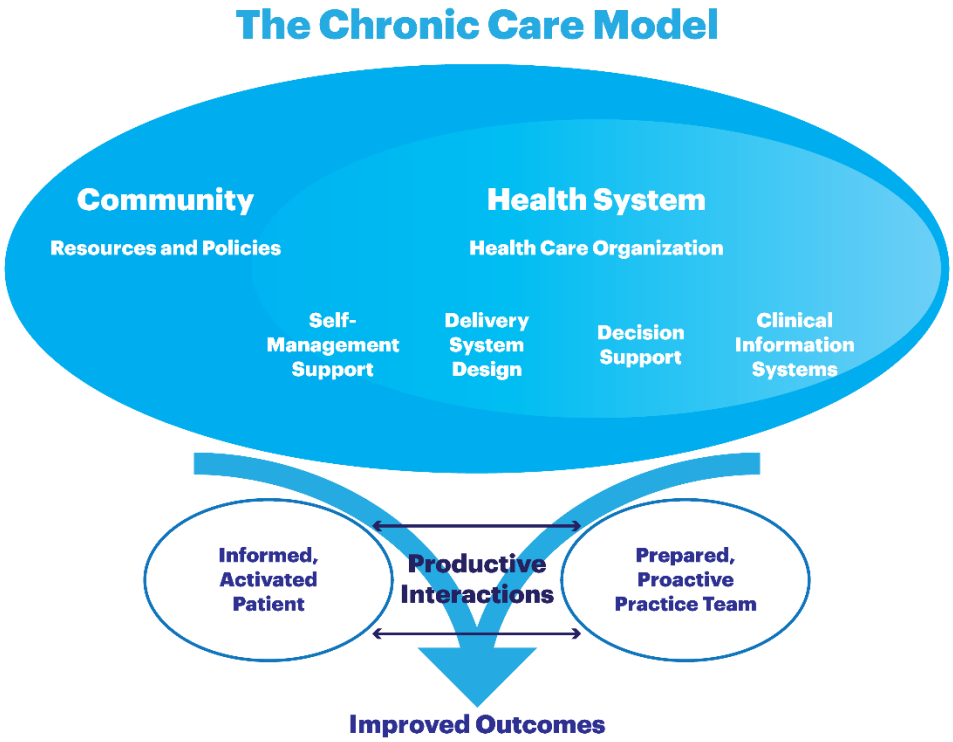


Figure 1. The Chronic Care Model

Source: EH Wagner. Chronic disease management: what will it take to improve care for chronic illness?. Effective Clinical Practice 1998;1(1):2-4

Several countries have pursued strategies to improve the quality of chronic disease care in primary care settings based on the CCM. It was confirmed that the model was more effective in improving health outcomes when several elements were applied in combination.[27,28] The application of the CCM has been shown to be effective in improving health outcomes and reducing healthcare costs.[26,29]

A study on patients with congestive heart failure demonstrated that a nurse-directed program of patient education was associated with a greater than 50% reduction in readmission rates. It was also effective in improving quality of life and reducing overall medical costs.[30,31] [30,31] For diabetic patients, annual screenings, including hemoglobin A1c (HbA1c) tests, lipid tests, microalbumin assessments, and eye exams all increased significantly.[26,32] The risk of blindness, end-stage renal disease, and coronary artery disease was reduced, and quality-adjusted life-years increased, resulting in social cost effectiveness.[32] The CCM resulted in fewer hospitalizations and emergency department visits for three chronic diseases: congestive heart failure, asthma, and diabetes.[26] In particular, in the case of diabetes, not only short-term cost savings due to improved diabetic glycemic control but also long-term cost savings through the prevention of complications, were confirmed.[33,34]

As the demand for chronic disease management has increased, the World Health Organization (WHO) introduced the Innovative Care for Chronic Conditions (ICCC) Framework as an expanded version of the CCM.[35] This framework is a model for integrated management of non-communicable diseases and focuses on the policy environment that encompasses patients, their families, healthcare teams, and communities. Policy environments include legislation, leadership, policy integration, partnerships, financing, and allocation of human resources.

The ICCC addresses how policymakers can take effective and innovative actions to achieve positive outcomes in chronic disease conditions. The triad at the center of the ICCC Framework consists of the patient and family, community partners, and the healthcare team (Figure 2).

When each component functions integrally, the patient actively participates in care with the support of community and healthcare teams. Cooperation and communication between each component are important for the proper functioning of the patient, community partners, and healthcare team. ICCC is fundamentally based on the micro- (patient and family), meso- (healthcare team and community), and macro- (policy) levels.[35,36]

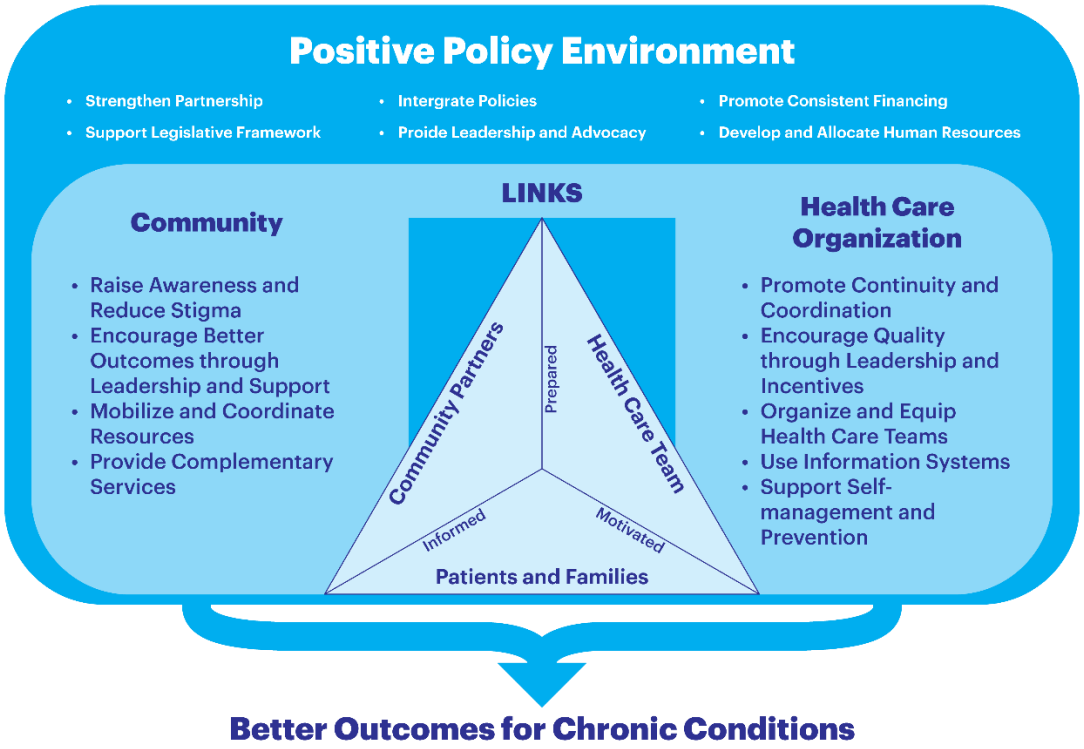


Figure 2. The Innovative Care for Chronic Conditions Framework

Source: World Health Organization. Innovation care for chronic conditions: building blocks for actions: global report. World Health Organization, 2002

2. Primary care-based chronic disease management program in Korea

Korea has been promoting projects related to chronic diseases based on the CCM or ICCC. It aims to produce positive health outcomes by forming and continuously maintaining a mutual relationship between the 'informed, activated patient' and the 'prepared, proactive practice team'.[37] The PCDMP in Korea emerged to improve health by preventing the occurrence of cardiovascular and cerebrovascular diseases, which is the primary cause of death. Diabetes and hypertension are representative causes of cardiovascular and cerebrovascular diseases, and the PCDMP was introduced to manage these diseases at the national level.[38] As a chronic disease management program centered on primary care, the 'community-based hypertension and diabetes registry program', the 'primary care(clinic)-based disease management program', the 'community-based primary care pilot project', the 'chronic disease management charges pilot project', and the 'primary care-based chronic disease management integrated pilot project' have been promoted (Table 1).[37,39]

1) The community-based hypertension and diabetes registry program

The first PCDMP in Korea was a community-based hypertension and diabetes registry program initiated in 2007. The purpose of this project is to reduce the medical expense burden by improving the continuity of care and health behaviors to reduce complications of hypertension and diabetes.[40] Starting with Daegu Metropolitan City as a pilot area in 2007, 31 local governments are participating in the program as of 2021.[39] The project targets hypertensive/diabetic patients aged 30 or older residing in the project area. The participating institutions are primary medical institutions, pharmacies, and public

health centers that treat hypertension/diabetic patients.[41] This program promotes continuous treatment by subsidizing the medical institution's registration fee and supporting medical and pharmaceutical expenses for the patient. The education center, operated by the public health center, manages patients enrolled in medical institutions. The center guides patients on the dates of monthly medical visits and provides education to help them manage their own blood sugar levels.[40]

2) The primary care (clinic)-based disease management program

This program, which was implemented in April 2012, aims to increase the continuity of care for hypertension and diabetes patients centering on neighborhood clinics to provide primary care.[42] This project is available at all clinical-level medical institutions, allowing patients to participate voluntarily. Patients with hypertension and diabetes can participate if they express their intention to receive continuous treatment in a single clinic. If the patient continues to manage the disease at a specific clinic, the copayment of outpatient examination fees is reduced from 30% to 20%, and the National Health Insurance Service provides health support services to patients (SMS notification service, blood pressure and blood glucose meter rental, health consultation, education service, etc.). The participants in the project were patients with essential hypertension (I10) and non-insulin-dependent diabetes (E11), which are disease codes based on the International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10).[42,43] In addition, incentives are provided to clinics that properly manage patients through quality assessment of healthcare services.

3) The community-based primary care pilot project

This pilot project was implemented in March 2014 to reestablish a healthcare delivery system. It was promoted to overcome the lack of active participation of the medical community, which is one of the limitations of existing projects. The project was designed according to WHO's ICCC model. Primary care physicians were assigned a leading role, and National Health Insurance Finance provided incentives for doctors' educational counseling. The doctor established a care plan for the patient, provided direct education and consultation, and was compensated with a fee-for-service.[22]

4) Chronic disease management charges pilot project

The project, which began in 2016, was a pilot project that introduced a non-face-to-face management method and focused on strengthening the self-management of patients with chronic diseases. This differs from other projects in that medical insurance fees are applied to non-face-to-face management. The doctor establishes a care plan according to the patient's health condition and manages chronic diseases integrally through continuous observation and consultation with patients in a non-face-to-face manner. This was carried out by limiting the number of registered patients per medical institution.[22] Patients send their self-measured blood pressure and blood sugar levels to the doctor every week through a mobile application, and the doctor provides telephone consultations if necessary.[44]

5) Primary care-based chronic disease management integrated pilot project

Recently, in order to promote project efficiency, an integrated model linking the strengths of each project has been developed as a pilot project.[45] In 2019, the ‘primary care-based chronic disease management integrated pilot project’ was introduced to integrate the

‘community-based primary care pilot project’ started in 2014 and the ‘chronic disease management charges pilot project’ started in 2016.[45]

This pilot project is being implemented to strengthen patient-centered medical systems based on primary care. The project supports the self-management of patients with chronic diseases and lays the foundation for comprehensive chronic disease management through connections with local clinics and community healthcare resources. The maximum number of registered patients per clinic was 300.

The medical institutions participating in the project established an annual care plan for each patient. Individual patient management, drug therapy, and lifestyle improvement goals were established. After establishing an annual plan, medical staff provide education and counseling to patients. Additionally, patient monitoring and counseling were conducted using text messages, phone calls, and mobile applications. Depending on the patient management status, the care plan is periodically checked, modified, and supplemented. The patients participating in the project were provided with a customized check-up voucher.[19,45]

As such, several projects were implemented with the purpose of preventing disease worsening in patients with diabetes and hypertension by increasing the continuous treatment rate and improving lifestyle. However, each project's model and participating organizations were not uniform and implementation was fragmented and duplicative. Thus, to confirm the long-term effect of PCDMP, this study aims to examine its effectiveness, focusing on the clinic-based PCDMP in 2012, which has a long implementation period and the widest range of participants. As this project was conducted in a way in which patients voluntarily participated in all clinical-level medical institutions, it can be regarded as a nationwide project rather than applying only to a specific region.

Table 1. Comparison of chronic disease management programs and systems in Korea

	Community-based hypertension and diabetes registry program	**Primary care(clinic)-based chronic disease management program**	**Community-based primary care pilot project**	**Chronic disease management charges pilot project**	**Primary care-based chronic disease management integrated pilot project**
Implementation period (year.month)	2007.9 ~	2012.4 ~	2014.10 ~ 2018.12	2016.9 ~ 2018.12	2019.1 ~
Participating institution	Clinics and pharmacies that have applied for participation	The whole of clinics	Clinics that have applied for participation	Clinics that have applied for participation	Clinics that have applied for participation
Target population	(required) Hypertensive/diabetic patients aged 65 or older (recommend) Hypertensive/diabetic patients aged 30 or older	Hypertensive/diabetic patients	Hypertensive/diabetic patients attending participating clinics	Hypertensive/diabetic patients attending participating clinics	Hypertensive/diabetic patients attending participating clinics
Program details	• Medical institution: patient registration management • Registered Education Center: Education consultation, recall/remind service • Public Health Center: Reimbursement of medical expenses and pharmaceutical expenses	• Patients: designation of local clinics and doctors for continuous treatment and management • Medical institution: management and consultation on patient disease • National Health Insurance Service: provision of health support service	• Medical institution: patient registration and planning, educational consultation (on a yearly basis) • Health Companion Center: education and counseling for lifestyle improvement	• Medical institution: patient registration and planning, continuous observation (non-face-to-face), telephone consultation and check/evaluation (monthly) • Patient: self-management through mobile application (*e.g.*, entering blood sugar levels)	• Medical institution: patient registration and care plan establishment (on a yearly basis), check and evaluation • Care coordinator: patient management (monitoring, consultation, service coordination, education, etc.)

Clinic benefits	• (age 65+) Registration fee KRW 1,000/year per person • (age 30-64) Registration fee of KRW 5,000/year per person	KRW 200,000 per year (30 registered patients) ~ maximum KRW 6.2 million per year (1,000 registered patients)*	Maximum annual reimbursement of about KRW 140,000 per patient	Monthly average of KRW 29,000 per patient	Maximum annual reimbursement of about KRW 340,000 per patient
Patient benefits	(age 65+) KRW 3,500/month	• Reduction of copayment by 10% (30% → 20%) • Providing health support services (*e.g.*, counseling, education)	None	None	Customized check-up voucher for patients aged over 40 years or older

KRW: Korean Won.

*As a result of the Quality Assurance program by the Health Insurance Review & Assessment Service.

Source: Lee YJ, Han JO, Seo SI, Shin SY. The Status of Chronic Disease Management Project in Korea: Focusing on Gyeonggi-do. Issue Briefing: Gyeonggi public health policy institute; 2019.

3. Donabedian model

The evaluation of the healthcare system was conducted using indicators that measure its adequacy in terms of structure, process, and outcome. Accordingly, this study selected Avedis Donabedian's model as the research model. In 1966, he proposed a conceptual model for evaluating the quality of care.[46] Based on this model, we reviewed whether the primary care chronic disease management program for diabetic patients affected the patient's quality of care and health outcomes. The framework of this model is shown in Figure 3.[46]

The structure represents factors that have an important influence on maintaining the quality of service and primarily refers to the human, material, and financial resources required to provide services. The process refers to all activities required to deliver care and reflects how the system works to achieve desired outcomes. Therefore, a process that does not affect the results is meaningless. The outcomes concern the impact on the patient and whether the ultimate goal has been achieved. The outcome indicators are the final products of the service, mainly referring to changes in health status. Examples include reduced mortality, length of stay, adverse incidents, emergency hospitalizations, and patient experience.[47]

When measuring only outcomes, one cannot be sure the changes actually occurred in practice and therefore cannot link the improvements to outcomes.[48] If measuring just process, one cannot be sure if the outcomes have changed and the aims achieved and therefore there is the risk that the process improved but the outcomes did not. Hence, it is important to implement both the process and outcome measures.

The PCDMP aims to manage the patient's health condition at an appropriate level through quality control of process indicators such as continuity of care, adherence to medication and examination schedules, to improve outcome indicators such as the risk of complications, hospitalization, and death. However, most indicators of the national quality assessment program for diabetes-related medical services are process indicators, such as continuity of care, prescription and examination adherence. As a result, the evaluation of outcome indicators is relatively insufficient.[23] Therefore, this study attempted to comprehensively examine the effects of PCDMP participation by type 2 diabetes patients on the quality of the treatment process and health outcomes.

Figure 3. The Donabedian model for quality of care

Source: Donabedian A. Evaluating the quality of medical care. The Milbank memorial fund quarterly 1966;44:166-206

III. Material and Methods

1. Framework of the study design

This study aimed to investigate whether the PCDMP improves the quality of care and health outcomes in patients with T2DM. Continuity of care and examination completion were investigated as quality of care indicators, and the onset of new complications, cause-specific hospitalization, and all-cause mortality were examined as health outcome indicators (Figure 4).

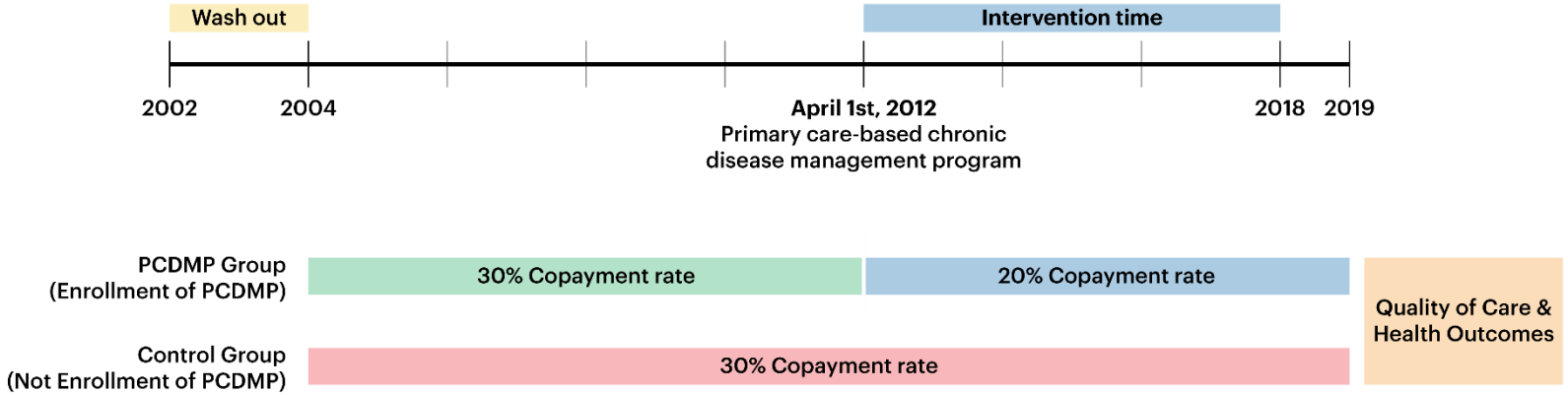


Figure 4. Study design

2. Data and study population

The data in this study were obtained from the National Health Insurance Service National Sample Cohort (NHIS-NSC) for the years 2002 to 2019. The NHIS-NSC data include a sample of 2.2% of 48,222,537 Korean individuals in 2006 using stratified random sampling by age, sex, and health insurance premium, and observed from 2002 to 2019. These data were constructed to provide representative information regarding Korean citizens' utilization of health insurance and health examinations for policymakers and public health research.[49] The NHIS-NSC records patients' claim data in four categories: insurance eligibility; medical institutions' data; health examination data; and medical treatments, which include diagnosis codes, medications, and treatments.

Patients with newly developed type 2 diabetes were selected to participate in this study. The ICD-10 codes 'E11' and 'E11.9' were used to select patients without diabetic complications. This cohort included 162,023 participants with T2DM from an entire cohort of 1,134,108 individuals. Of these, patients diagnosed with T2DM between January 1, 2002, and December 31, 2003, were excluded to include only patients with new-onset T2DM. To select patients with newly developed T2DM, those without a record of prescription diabetes medications or insulin before the diagnosis of T2DM were excluded. In addition, to define the criteria for diabetic patients as patients with a record of prescription diabetes medications along with ICD-10 codes, patients who had never been prescribed diabetes medications were excluded.

Medicaid patients who were not eligible for the PCDMP were excluded. Patients with diabetes-related complications before the onset of diabetes were excluded from the study. Patients with no history of visiting a primary medical institution were excluded. To

measure the effectiveness of the program, those who were followed up for less than one year before and after PCDMP were excluded, as were those under 19 years of age and missing covariate values.

As a result, a cohort of 23,475 patients with T2DM remained, of which 3,639 participated in the PCDMP and 19,836 did not. Those who participated in the program are classified into PCDMP group. Propensity score matching was performed in 1:2 ratios using age, sex, income, region, medical insurance, disability, Charlson comorbidity index (CCI), hypertension, and year of T2DM diagnosis. Among the matching variables, age group, sex, and year of T2DM diagnosis were exactly matched. A total of 9,666 individuals were included in this study after propensity score matching, and the PCDMP and control groups were 3,222 and 6,222, respectively (Figure 5). Since the PCDMP is a policy project in which patients voluntarily request enrollment, the enrollment date for the PCDMP is different for each patient. Therefore, the matched control group was assigned the PCDMP enrollment date for the PCDMP group.

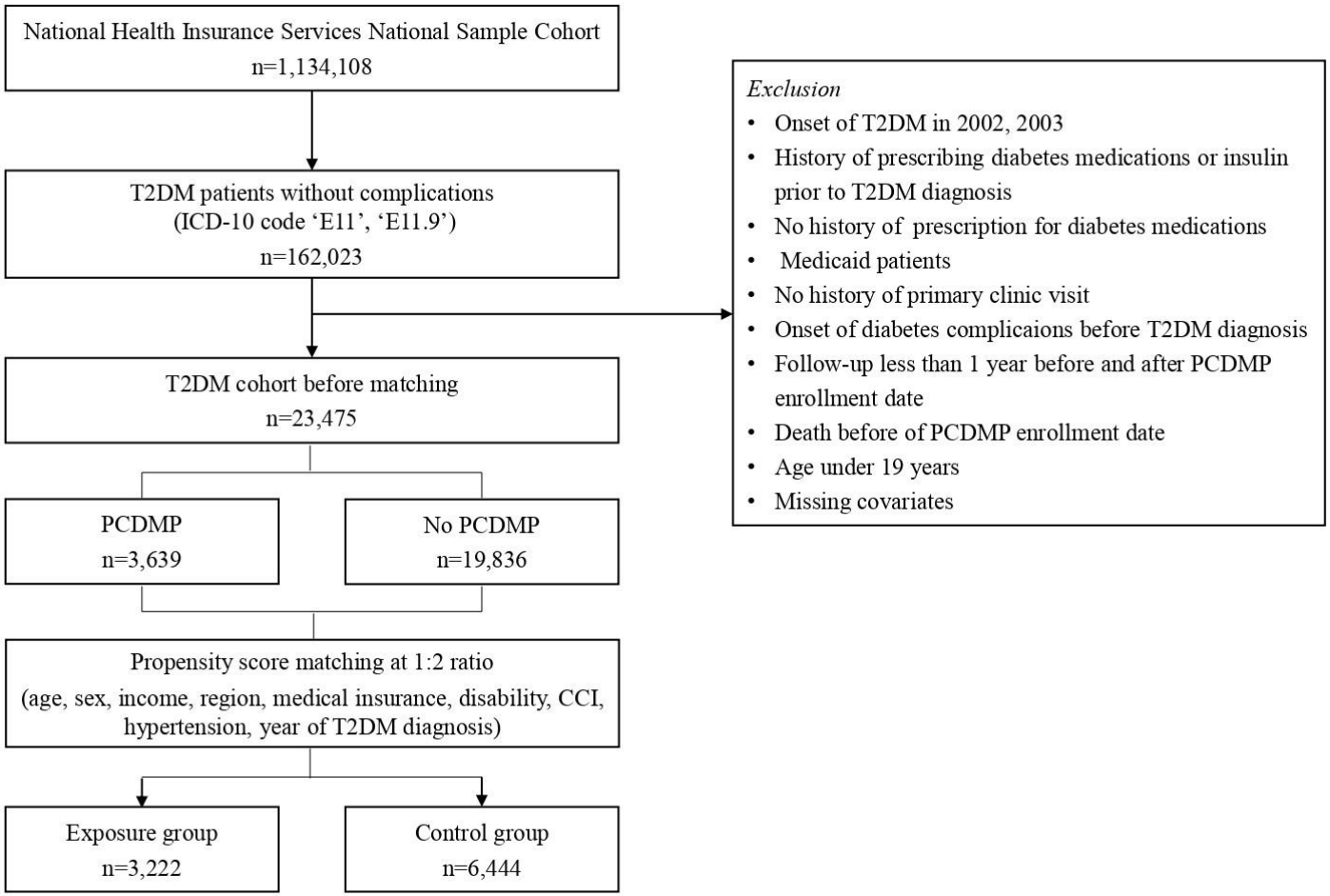


Figure 5. Flow chart of the study population

3. Variables

1) Dependent variables

The dependent variables of this study were divided into quality of care and health outcome indicators for patients with T2DM. The quality of care indicators were continuity of care and completion of examinations. Health outcome indicators included the onset of diabetes complications, cause-specific hospitalization regarding diabetes complications, and all-cause mortality.

(A) Quality of care indicator

The primary dependent variables regarding quality of care were used to measure continuity of care, and we used the COC index proposed by Bice et al.[50] The COC index is the most representative index among several methods of measuring COC, combining aspects of both visit concentration and visit distribution. Considering the characteristics of South Korea, there is no primary care physician (gatekeeper), and patients can freely choose which medical institution they want to visit.[51] The formula for the COC index is as follows:

$$\text{COCI} = \frac{\sum_{j=1}^{M} {n_j}^2 - N}{N(N-1)}$$

where N is total number of outpatient visits, n_j is number of visits to provider j, and M is the number of providers. The COC index ranges from 0 to 1, with higher values

indicating better continuity. A COC score of 1 indicates that all outpatient visits are focused on the same provider, whereas a score of 0 means that each outpatient visit is distributed to different providers. The COC index was calculated only for participants who had four or more T2DM-related outpatient visits. Because it is relatively easy to obtain COC scores of 0 or 1 using three or fewer visits, the COC cannot be evaluated well. In this study, the COC cut-off point was set at 0.75. A value of 0.75 or more was defined as good continuity of care.[52] For performing sensitivity analysis, COC was calculated using usual provider of continuity (UPC) index.[53]

Completion of the examination was evaluated based on whether HbA1c, lipid profile, and fundoscopy tests were performed at least once per year. The procedure code of the diabetes quality assurance program by the Health Insurance Review and Assessment Service (HIRA) was used (Table 2).[54] The analysis included only the examinations taken during the outpatient visit. The completion of examinations was defined as complete when all three tests were performed. In addition, the completion of each inspection was investigated.

Table 2. Diabetes-related examinations and procedure codes

Examination	Procedure code
HbA1c	C3825
	(2018.1.1~) D3061, D3062, D3063, D3064, D3065
Lipid profile	C2443, C2411, C2430
	(2018.1.1~) D2263, D2265, D2266, D2611, D2616, D2617, D2613, D2618, D2619, D2614
Fundoscopy	E6660, E6670, E6681
	(2018.1.1~) E6660, E6670, E6674, E6681, E6682

† Change procedure code collectively after 2018.1.1

Source: HIRA. The results of diabetes quality assessment 2020(10th).

(B) Health outcome indicator

The secondary dependent variables regarding health outcomes were the onset of complications, cause-specific hospitalization for diabetic complications, and all-cause mortality. Diabetic complications were divided into three categories: cardiovascular complications, microvascular complications, and diabetic foot. Cardiovascular complications include ischemic heart disease, myocardial infarction, heart failure, stroke, and peripheral circulatory disease. Microvascular complications include diabetic neuropathy, retinopathy, and nephropathy. Finally, ulcers, gangrene, and amputations were used for diabetic foot; however, there were no diabetic patients with amputations in this study. The diagnosis code for complications was confirmed using the related disease codes in the ICD-10 (Table 3). Diabetes complications were in accordance with the criteria for diabetes and complications in Korea of the Korean Diabetes Association[55-58]. Diabetes-related hospitalization was defined based on the first diabetes-related hospitalization after enrollment in the PCDMP.

Table 3. Classification of diabetes-related complication and ICD-10 codes of diagnoses

Classification	ICD-10 codes
Cardiovascular Complications	
Ischemic heart disease	I20.x, I23.x, I24.x, I25.x
Myocardial infarction	I21.x, I22.x,
Heart failure	I50.x
Stroke	I60.x, I61.x, I62.x, I63.x
Peripheral circulatory disease	I70.x, I71.x, E11.5, E12.5, E13.5, E14.5, I73.8, I73.9, I77.1, I79.0, I79.2
Microvascular Complications	
Diabetic Neuropathy	E11.4, E12.4, E13.4, E14.4, G59.0, G63.2, G99.0
Diabetic Retinopathy	H36.0, E11.3, E12.3, E13.3, E14.3
Diabetic Nephropathy	N08.3, E11.2, E12.2, E13.2, E14.2
Diabetic foot	E11.7, E12.7, E13.7, E14.7, L97.x, R02.x, Z89.4, Z89.5, Z89.7, Z89.8, Z89.9

†ICD-10, 10th edition of the International Classification of Diseases

2) Interesting variable

The interesting variable of this study was enrollment in the PCDMP. Patients who were enrolled in the PCDMP from April 1, 2012, to December 31, 2018, were defined by claims code "AA250".[43] Patients participating in the PCDMP were set as the PCDMP group and defined "PCDMP" variable as "1". Patients who did not participate in PCDMP were designated as the control group and defined "PCDMP" variable as "0".

The intervention variable was based on the PCDMP enrollment date. Since the patients voluntarily enrolled in the PCDMP, the time point of intervention was different for each subject. In the case of the matched control group selected by matching each individual in the PCDMP group, the intervention time point of the PCDMP and control groups were the same. Thus, the before period of PCDMP enrollment indicated the "Intervention" variable as "0" and after period of PCDMP enrollment indicated the "Intervention" variable as "1".

3) Independent variables

The independent variables of this study were age (19–39, 40–49, 50–59, 60–69, and ≥70 years), sex (male or female), income level (low, middle, and high), region (metropolitan, city, and other), insurance type (self-employed insured, employee insured), disability (yes or no), CCI (0, 1, 2, 3, or over), hypertension (yes or no), and year of T2DM diagnosis (Table 4). The CCI was calculated using Quan's method.[59]

Table 4. Description of covariates for the analysis

Variables		Description
Socioeconomic factors	Age	19-39, 40-49, 50-59, 60-69, ≥70
	Sex	Male, female
	Region	Metropolitan, city, other
	Income	Low, middle, high
Health-related factors	Type of medical insurance	Self-employed insured, Employee insured
	Disability	Yes, no
	Charlson Comorbidity Index	0, 1, 2, ≥3
	Hypertension	Yes, no
	Year of diabetes diagnosis	2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018

4. Statistical methods

Chi-square tests were used to examine the distribution of the general characteristics and the distributions of the study populations according to all outcomes. General characteristics were reported as frequencies and percentages.

To investigate the impact of PCDMP on the quality of care in patients with T2DM patients, a difference-in-differences (DID) method of analysis was used to examine any changes in continuity of care and completion of examinations among the PCDMP group in the pre-intervention and post-intervention periods relative to changes in the control group.

The following equation for the DID analysis using a generalized estimating equation (GEE)[60,61] was used to evaluate the impact of PCDMP.

$$\mathbf{g}(\boldsymbol{E}(\boldsymbol{Y_{it}})) = \boldsymbol{\beta_0} + \boldsymbol{\beta_1}(\boldsymbol{Time_{it}}) + \boldsymbol{\beta_2}(\boldsymbol{PCDMP_{it}}) + \boldsymbol{\beta_3}(\boldsymbol{Intervention_{it}}) + \boldsymbol{\beta_4}(\boldsymbol{PCDMP_{it}} \times \boldsymbol{Intervention_{it}}) + \boldsymbol{\gamma'Z_i}$$

g: *link function*

E: *Expectation*

Y: dependent variables

i: individual (*i*=1, 2, …, n)

t: time period

Time: time variable before and after the PCDMP enrollment date (continuous variable in units of one year (365 days))

PCDMP*:* dummy variable that assigns 1 if the PCDMP group (individuals who participated in the PCDMP, PCDMP=1: PCDMP group, PCDMP=0: control group)

$\boldsymbol{Intervention}$: dummy variable that is assigned 1 if time is after enrollment in the PCDMP (intervention=1: after enrollment in the PCDMP, intervention=0: before enrollment in the PCDMP)

$\boldsymbol{Z_i}$: covariates (sex, age, income, region, medical insurance type, disability, CCI, hypertension, year of T2DM diagnosis)

The differences between the pre-and post-intervention dependent variables for quality of care were compared using the DID model with the above formula. Based on the time of intervention, the continuity of care of patients with T2DM and whether the examination was regularly received were investigated every year before and after the intervention (Figure 6). The GENMOD procedure with logit link, binomial distribution, and Autoregressive (1) Correlation Matrix Type was used to analyze dichotomous variables.

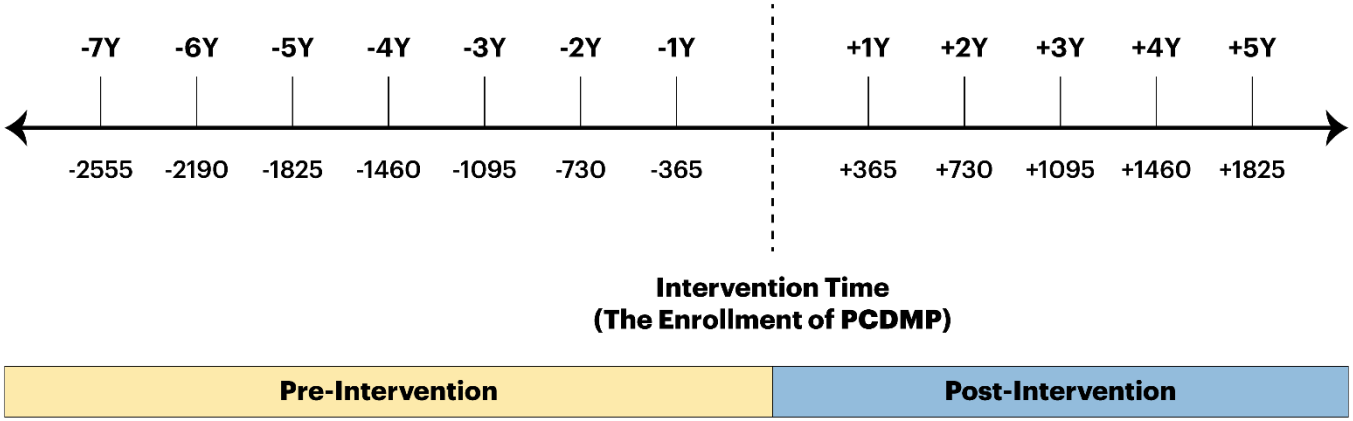


Figure 6. Measuring period of the before and after intervention

To calculate the association between participation in the PCDMP and dependent variables for health outcomes (the risks of complications, hospitalizations, and mortality), the Cox proportional hazards regression model was employed to calculate the adjusted hazard ratios (HR) and 95% confidence intervals (CIs). The Cox proportional hazard model has achieved widespread use in the analysis of time-to event (e.g., time to incidence of complication) data.[62] The Cox proportional hazard model specifies that $\boldsymbol{\lambda}(\mathbf{t}|\mathbf{Z}) = \boldsymbol{\lambda_0}(\boldsymbol{t})\boldsymbol{e}^{\boldsymbol{\beta' Z}}$, where β is a set of unknown regression parameters, Z is a vector of covariates of interest, and $\boldsymbol{\lambda_0}(\boldsymbol{t})$ is a baseline hazard function. In this study, time zero (index time) was set to the date of PCDMP enrollment for each patient. Survivor time was defined by the number of days from time zero to the date of the event, date of death, or December 31, 2019, whichever came first. The cumulative incidence of PCDMP group and control group was evaluated using the Kaplan–Meier method and stratified log-rank test. The incidence rate (IR, the number of events per 1,000 person-years) and the 95% CI was calculated using a generalized estimating equation with a Poisson distribution.

Differences were considered statistically significant at $p<0.05$. All statistical analyses were performed using the SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA) and R Studio (version 4.2.1; R studio Inc., Boston, MA, USA).

5. Ethics statement

This study was reviewed and approved by the International Review Board of Yonsei University's Health System (IRB number: 4-2022-0825) and adhered to the tenets of the Declaration of Helsinki. The need for informed consent was waived since the NHIS-NSC do not contain any personally identifiable information.

IV. Results

1. General characteristics of the study population

Table 5 shows the general characteristics and distribution of the study population before and after propensity score matching. Before matching, the PCDMP group included 3,639 (15.5%) individuals, whereas the control group included 19,836 (84.5%) individuals. After 1:2 propensity score matching, there were 3,222 (33.3%) patients in the PCDMP group and 6,444 (66.7%) in the matched control group. The balance of covariate distribution between the PCDMP and control groups was presented as the standardized mean difference (SMD). In general, if the SMD value is less than 0.1, the covariate distribution is considered balanced.[63,64] The changes in the SMD after propensity score matching are reported in Appendix 1.

To conduct the DID analysis on quality of care indicators, the dependent variables were measured at one-year intervals before and after the intervention for each participant; the number of participants for each time point are shown in Table 6. The larger the time interval from the intervention, the smaller the number of participants included.

Table 5. General characteristics of study population before and after propensity score matching

Variables	Before matching					After matching				
	PCDMP		Control		SMD	PCDMP		Control		SMD
	N	%	N	%		N	%	N	%	
Age					0.299					0.003
19-39	421	11.6	2,375	12.0		386	12.0	772	12.0	
40-49	1,176	32.3	4,724	23.8		1,063	33.0	2,126	33.0	
50-59	1,380	37.9	5,763	29.1		1,212	37.6	2,424	37.6	
60-69	510	14.0	4,317	21.8		448	13.9	896	13.9	
≥ 70	152	4.2	2,657	13.4		113	3.5	226	3.5	
Sex					0.031					<.0001
Male	2,187	60.1	11,622	58.6		1,901	59.0	3,802	59.0	
Female	1,452	39.9	8,214	41.4		1,321	41.0	2,642	41.0	
Income					0.012					0.013
High	1,401	38.5	7,774	39.2		1,255	39.0	2,535	39.3	
Middle	1,704	46.8	8,843	44.6		1,502	46.6	2,897	45.0	
Low	534	14.7	3,219	16.2		465	14.4	1,012	15.7	
Region					0.016					0.017
Metropolitan	1,536	42.2	8,351	42.1		1,348	41.8	2,783	43.2	
City	988	27.2	5,161	26.0		878	27.3	1,676	26.0	
Other	1,115	30.6	6,324	31.9		996	30.9	1,985	30.8	
Medical insurance					0.038					0.020
Self-employed insured	1,545	42.5	8,052	40.6		1,396	43.3	2,857	44.3	
Employee insured	2,094	57.5	11,784	59.4		1,826	56.7	3,587	55.7	
Disability					0.070					0.001
No	3,471	95.4	18,608	93.8		3,077	95.5	6,156	95.5	
Yes	168	4.6	1,228	6.2		145	4.5	288	4.5	
CCI					0.032					0.021
0	1,907	52.4	10,286	51.9		1,685	52.3	3,422	53.1	
1	1,165	32.0	6,156	31.0		1,018	31.6	2,021	31.4	
2	409	11.2	2,404	12.1		379	11.8	743	11.5	
≥ 3	158	4.3	990	5.0		140	4.3	258	4.0	
Hypertension					0.039					0.044

No	2,515	69.1	14,060	70.9		2,276	70.6	4,680	72.6	
Yes	1,124	30.9	5,776	29.1		946	29.4	1,764	27.4	
Year of diagnosis					0.522					<.0001
2004	520	14.3	2,260	11.4		461	14.3	922	14.3	
2005	535	14.7	2,185	11.0		484	15.0	968	15.0	
2006	425	11.7	1,716	8.7		388	12.0	776	12.0	
2007	358	9.8	1,488	7.5		317	9.8	634	9.8	
2008	353	9.7	1,289	6.5		320	9.9	640	9.9	
2009	375	10.3	1,213	6.1		350	10.9	700	10.9	
2010	327	9.0	1,168	5.9		302	9.4	604	9.4	
2011	259	7.1	1,118	5.6		185	5.7	370	5.7	
2012	142	3.9	1,070	5.4		119	3.7	238	3.7	
2013	123	3.4	1,060	5.3		111	3.4	222	3.4	
2014	84	2.3	1,048	5.3		80	2.5	160	2.5	
2015	79	2.2	1,050	5.3		68	2.1	136	2.1	
2016	45	1.2	1,114	5.6		34	1.1	68	1.1	
2017	14	0.4	1,111	5.6		3	0.1	6	0.1	
2018	0	0.0	946	4.8		-		-		
Total	3,639	100.0	19,836	100.0		3,222	100.0	6,444	100.0	

PCDMP, primary care-based chronic disease management program; SMD, standardized mean difference; CCI, Charlson comorbidity index

Table 6. Distribution of study population by time based on before and after intervention

Variables	Total		PCDMP		Control	
	N	%	N	%	N	%
Time before and after intervention						
-7 year	4,444	4.7	1,490	33.5	2,954	66.5
-6 year	5,515	5.8	1,845	33.5	3,670	66.5
-5 year	6,497	6.9	2,183	33.6	4,314	66.4
-4 year	7,575	8.0	2,545	33.6	5,030	66.4
-3 year	8,637	9.2	2,918	33.8	5,719	66.2
-2 year	9,427	10.0	3,171	33.6	6,256	66.4
-1 year	9,483	10.1	3,221	34.0	6,262	66.0
+1 year	9,484	10.1	3,222	34.0	6,262	66.0
+2 year	9,440	10.0	3,215	34.1	6,225	65.9
+3 year	8,773	9.3	3,008	34.3	5,765	65.7
+4 year	7,939	8.4	2,712	34.2	5,227	65.8
+5 year	7,079	7.5	2,422	34.2	4,657	65.8
Total	94,293	100.0	31,952	33.9	62,341	66.1

PCDMP, primary care-based chronic disease management program.

2. Quality of Care

1) Continuity of care

The changes in the distribution of good COC before and after intervention in the PCDMP and control groups are presented in Table 7. Figure 7 shows the change in the proportion of good COC of the exposure and control groups by time point. The COC variable met a parallel trend assumption in the PCDMP and control groups before intervention period (Appendix 2). The difference between the two groups before intervention was not statistically significant (p=0.6886).

The results of the DID analysis of COC before and after the intervention are shown in Table 8. This result presents the differential change of COC in the PCDMP group and control group. The proportion of good COC was observed to be associated with a significant (15%) increase after the intervention in the PCDMP group relative to the control group (exp(β)=1.15, 95% CI=1.06-1.24, p=0.0009).

In addition, as shown in Appendix 3-5, the results of the COC using the UPC index as part of the sensitivity analysis were similar. The results of the pre-intervention parallel trend test for the UPC index are also presented in Appendix 2; there was no statistically significant difference (p=0.4843).

Table 7. Continuity of care by before and after intervention

Variables	Continuity of care (measured by COCI)*												
	Before intervention							After intervention					
	Total		Good		Bad			Total		Good		Bad		
	N	%	N	%	N	%	*p*-value	N	%	N	%	N	%	*p*-value
Participation of PCDMP							<.0001							<.0001
Yes	16,247	34.3	2,870	17.7	13,377	82.3		14,311	35.0	2,559	17.9	11,752	82.1	
No	31,113	65.7	4,921	15.8	26,192	84.2		26,538	65.0	3,937	14.8	22,601	85.2	
Age							<.0001							<.0001
19-39	5,532	11.7	945	17.1	4,587	82.9		4,527	11.1	839	18.5	3,688	81.5	
40-49	15,750	33.3	2,939	18.7	12,811	81.3		13,354	32.7	2,506	18.8	10,848	81.2	
50-59	17,704	37.4	2,924	16.5	14,780	83.5		15,804	38.7	2,287	14.5	13,517	85.5	
60-69	6,720	14.2	789	11.7	5,931	88.3		5,822	14.3	693	11.9	5,129	88.1	
≥ 70	1,654	3.5	194	11.7	1,460	88.3		1,342	3.3	171	12.7	1,171	87.3	
Sex							<.0001							<.0001
Male	27,013	57.0	5,407	20.0	21,606	80.0		23,433	57.4	4,587	19.6	18,846	80.4	
Female	20,347	43.0	2,384	11.7	17,963	88.3		17,416	42.6	1,909	11.0	15,507	89.0	
Income							<.0001							0.0001
High	18,593	39.3	2,750	14.8	15,843	85.2		16,132	39.5	2,418	15.0	13,714	85.0	
Middle	21,616	45.6	3,787	17.5	17,829	82.5		18,486	45.3	3,082	16.7	15,404	83.3	
Low	7,151	15.1	1,254	17.5	5,897	82.5		6,231	15.3	996	16.0	5,235	84.0	
Region							0.0029							0.0068
Metropolitan	19,956	42.1	3,403	17.1	16,553	82.9		17,386	42.6	2,876	16.5	14,510	83.5	
City	12,527	26.5	2,055	16.4	10,472	83.6		10,812	26.5	1,692	15.6	9,120	84.4	
Other	14,877	31.4	2,333	15.7	12,544	84.3		12,651	31.0	1,928	15.2	10,723	84.8	
Medical insurance							0.0011							0.1067
Self-employed insured	21,407	45.2	3,653	17.1	17,754	82.9		18,134	44.4	2,943	16.2	15,191	83.8	
Employee insured	25,953	54.8	4,138	15.9	21,815	84.1		22,715	55.6	3,553	15.6	19,162	84.4	
Disability							0.0125							0.1649
No	45,292	95.6	7,492	16.5	37,800	83.5		38,985	95.4	6,221	16.0	32,764	84.0	
Yes	2,068	4.4	299	14.5	1,769	85.5		1,864	4.6	275	14.8	1,589	85.2	

CCI							<.0001						<.0001
0	24,551	51.8	5,138	20.9	19,413	79.1		21,167	51.8	4,284	20.2	16,883	79.8	
1	14,997	31.7	1,950	13.0	13,047	87.0		13,007	31.8	1,642	12.6	11,365	87.4	
2	5,752	12.1	543	9.4	5,209	90.6		4,903	12.0	433	8.8	4,470	91.2	
≥ 3	2,061	4.4	161	7.8	1,900	92.2		1,772	4.3	137	7.7	1,635	92.3	
Hypertension							0.0001						<.0001
No	33,509	70.8	5,654	16.9	27,855	83.1		25,634	62.8	1,681	6.6	23,953	93.4	
Yes	13,851	29.2	2,137	15.4	11,714	84.6		15,215	37.2	4,815	31.6	10,400	68.4	
Year of diagnosis							<.0001						<.0001
2004	8,888	18.8	1,354	15.2	7,534	84.8		6,170	15.1	830	13.5	5,340	86.5	
2005	9,204	19.4	1,477	16.0	7,727	84.0		6,318	15.5	985	15.6	5,333	84.4	
2006	7,001	14.8	1,245	17.8	5,756	82.2		5,236	12.8	841	16.1	4,395	83.9	
2007	5,170	10.9	897	17.4	4,273	82.6		4,187	10.2	659	15.7	3,528	84.3	
2008	4,541	9.6	742	16.3	3,799	83.7		4,260	10.4	657	15.4	3,603	84.6	
2009	4,198	8.9	638	15.2	3,560	84.8		4,531	11.1	731	16.1	3,800	83.9	
2010	2,925	6.2	529	18.1	2,396	81.9		3,996	9.8	756	18.9	3,240	81.1	
2011	1,823	3.8	308	16.9	1,515	83.1		2,265	5.5	392	17.3	1,873	82.7	
2012	1,279	2.7	196	15.3	1,083	84.7		1,334	3.3	227	17.0	1,107	83.0	
2013	963	2.0	149	15.5	814	84.5		1,166	2.9	184	15.8	982	84.2	
2014	656	1.4	134	20.4	522	79.6		713	1.7	123	17.3	590	82.7	
2015	498	1.1	84	16.9	414	83.1		464	1.1	69	14.9	395	85.1	
2016	198	0.4	36	18.2	162	81.8		192	0.5	39	20.3	153	79.7	
2017	16	0.0	2	12.5	14	87.5		17	0.0	3	17.6	14	82.4	
Total	**47,360**	**100.0**	**7,791**	**16.5**	**39,569**	**83.5**		**40,849**	**100.0**	**6,496**	**15.9**	**34,353**	**84.1**	

PCDMP, primary care-based chronic disease management program; COCI, continuity of care index; CCI, Charlson comorbidity index
*The continuity of care index was calculated only with outpatient treatment more than four times a year.

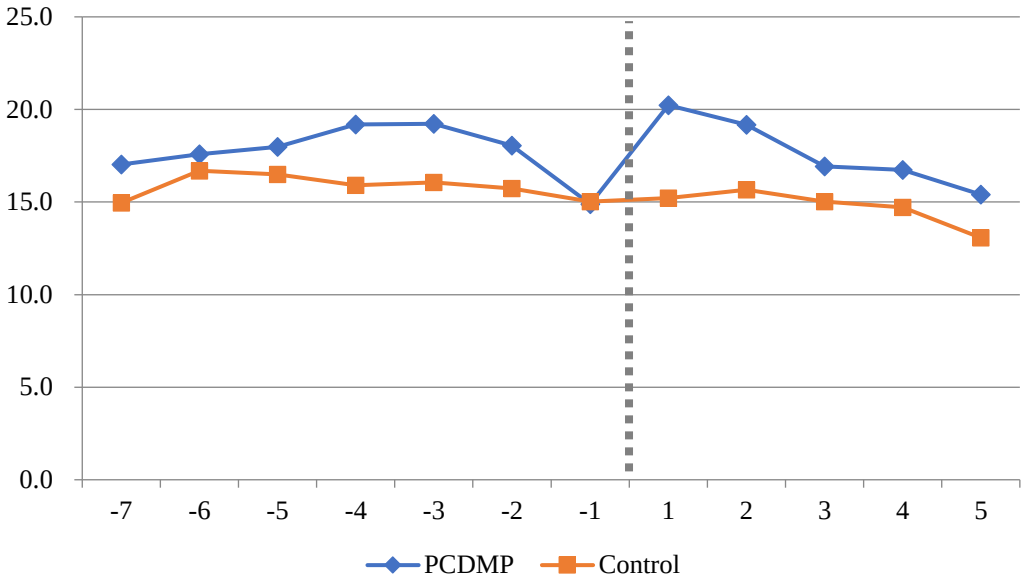


Figure 7. Trends in the proportion of good COC according to participation in PCDMP (%, year, measured by COCI)

Table 8. Differential change of continuity of care according to participation in PCDMP

Variables	Continuity of care*		
	exp(β)	95% CI	*p*-value
Time	0.96	(0.95 - 0.97)	<.0001
Pre-intervention	ref.		
Post-intervention	1.09	(1.02 - 1.17)	0.0151
Control group	ref.		
PCDMP group	1.11	(1.03 - 1.20)	0.0053
Intervention*PCDMP	1.15	(1.06 - 1.24)	0.0009
Age			
19-39	ref.		
40-49	1.13	(1.02 - 1.25)	0.0235
50-59	0.99	(0.89 - 1.10)	0.8095
60-69	0.79	(0.69 - 0.90)	0.0006
≥ 70	0.93	(0.74 - 1.17)	0.5361
Sex			
Male	ref.		
Female	0.56	(0.53 - 0.61)	<.0001
Income			
High	ref.		
Middle	1.19	(1.11 - 1.28)	<.0001
Low	1.22	(1.11 - 1.35)	<.0001
Region			
Metropolitan	ref.		
City	0.93	(0.86 - 1.01)	0.0827
Other	0.91	(0.84 - 0.98)	0.0125
Medical insurance			
Self-employed insured	ref.		
Employee insured	0.94	(0.88 - 1.00)	0.0540
Disability			
No	ref.		
Yes	0.89	(0.75 - 1.04)	0.1519
CCI			
0	ref.		
1	0.60	(0.56 - 0.64)	<.0001
2	0.42	(0.37 - 0.47)	<.0001
≥ 3	0.36	(0.30 - 0.44)	<.0001

Hypertension			
No	ref.		
Yes	1.09	(1.01 - 1.17)	0.0327
Year of diagnosis			
2004	ref.		
2005	1.14	(1.01 - 1.28)	0.0334
2006	1.24	(1.10 - 2.71)	0.0004
2007	1.19	(1.04 - 1.35)	0.0104
2008	1.19	(1.04 - 1.35)	0.0101
2009	1.16	(1.02 - 1.32)	0.0220
2010	1.51	(1.31 - 1.73)	<.0001
2011	1.34	(1.15 - 1.57)	0.0003
2012	1.36	(1.13 - 1.64)	0.0011
2013	1.22	(1.01 - 1.49)	0.0430
2014	1.53	(1.24 - 1.90)	<.0001
2015	1.09	(0.86 - 1.39)	0.4528
2016	1.53	(1.09 - 2.13)	0.0132
2017	0.82	(0.32 - 2.11)	0.6801

PCDMP, primary care-based chronic disease management program; CI, confidence interval; CCI, Charlson comorbidity index.
*The continuity of care index was calculated only with outpatient visit more than four times a year.

2) Completion of examinations

Table 9 shows the changes in completion of all tests before and after the intervention by the PCDMP and control groups. In both the PCDMP and control groups, the rate of completion for all tests increased from 7.9% to 11.5% and 9.0% to 12.3%, respectively. Looking at each test individually, the completion rate of the test after intervention increased in the HbA1c test and fundoscopic examination, excluding the lipid profile test (Appendix 6-8).

Figures 8 and 9 show the trend of the completion of all tests and each test for the PCDMP and control groups before and after intervention. Appendix 2 presents the parallel trend test results according to the dependent variables before intervention. Except for the HbA1c test, all dependent variables met the parallel trend assumption before the intervention period (p=0.1843 for all tests, p<0.001 for HbA1c test, p=0.8891 for lipid profile test, and p=0.9400 for fundoscopic examination).

The results of the DID analysis of all examination completions before and after the intervention are presented in Table 10. The differential changes in receiving all three diabetes-related tests were approximately 8% higher in the PCDMP group than in the control group, but the difference was not statistically significant (exp(β)=1.08, 95% CI=0.98-1.18, p=0.1029).

The differential changes in each test for the PCDMP group after the intervention point were 10% in the HbA1C test, 5% in the lipid profile test, and 2% in the fundoscopic examination. However, only the HbA1C test was statistically significant (HbA1C test, exp(β)=1.10, 95% CI=1.03-1.18, p= 0.0038; lipid profile test, exp(β)=1.05, 95% CI=0.98-1.11, p=0.1765; fundoscopic examination, exp(β)=1.02, 95% CI=0.95-1.11, p=0.5548, Table 11).

Table 9. Completion of all examinations by before and after intervention

Variables	Completion of all examinations*													
	Before intervention							After intervention						
	Total		Good		Bad			Total		Good		Bad		
	N	%	N	%	N	%	*p*-value	N	%	N	%	N	%	*p*-value
Participation of PCDMP							<.0001							0.0260
Yes	17,373	33.7	1,373	7.9	16,000	92.1		14,579	34.1	1,683	11.5	12,896	88.5	
No	34,205	66.3	3,078	9.0	31,127	91.0		28,136	65.9	3,456	12.3	24,680	87.7	
Age							<.0001							<.0001
19-39	6,404	12.4	535	8.4	5,869	91.6		4,944	11.6	504	10.2	4,440	89.8	
40-49	17,566	34.1	1,335	7.6	16,231	92.4		14,094	33.0	1,500	10.6	12,594	89.4	
50-59	18,937	36.7	1,693	8.9	17,244	91.1		16,326	38.2	2,201	13.5	14,125	86.5	
60-69	6,971	13.5	744	10.7	6,227	89.3		5,969	14.0	825	13.8	5,144	86.2	
≥ 70	1,700	3.3	144	8.5	1,556	91.5		1,382	3.2	109	7.9	1,273	92.1	
Sex							<.0001							<.0001
Male	30,131	58.4	2,294	7.6	27,837	92.4		24,829	58.1	2,518	10.1	22,311	89.9	
Female	21,447	41.6	2,157	10.1	19,290	89.9		17,886	41.9	2,621	14.7	15,265	85.3	
Income							<.0001							0.0922
High	20,239	39.2	1,967	9.7	18,272	90.3		16,851	39.4	2,098	12.5	14,753	87.5	
Middle	23,540	45.6	1,916	8.1	21,624	91.9		19,354	45.3	2,267	11.7	17,087	88.3	
Low	7,799	15.1	568	7.3	7,231	92.7		6,510	15.2	774	11.9	5,736	88.1	
Region							<.0001							<.0001
Metropolitan	21,855	42.4	2,191	10.0	19,664	90.0		18,238	42.7	2,349	12.9	15,889	87.1	
City	13,640	26.4	1,049	7.7	12,591	92.3		11,293	26.4	1,315	11.6	9,978	88.4	
Other	16,083	31.2	1,211	7.5	14,872	92.5		13,184	30.9	1,475	11.2	11,709	88.8	
Medical insurance							0.6150							0.5075
Self-employed insured	23,327	45.2	2,029	8.7	21,298	91.3		18,969	44.4	2,260	11.9	16,709	88.1	
Employee insured	28,305	54.9	2,422	8.6	25,883	91.4		23,746	55.6	2,879	12.1	20,867	87.9	
Disability							0.6410							0.1615
No	49,365	95.7	4,254	8.6	45,111	91.4		40,783	95.5	4,887	12.0	35,896	88.0	
Yes	2,213	4.3	197	8.9	2,016	91.1		1,932	4.5	252	13.0	1,680	87.0	
CCI							<.0001							<.0001

0	27,250	52.8	2,241	8.2	25,009	91.8		22,397	52.4	2,415	10.8	19,982	89.2	
1	16,162	31.3	1,391	8.6	14,771	91.4		13,488	31.6	1,704	12.6	11,784	87.4	
2	6,033	11.7	557	9.2	5,476	90.8		5,028	11.8	714	14.2	4,314	85.8	
≥ 3	2,133	4.1	262	12.3	1,871	87.7		1,802	4.2	306	17.0	1,496	83.0	
Hypertension							0.5122							0.0023
No	37,212	72.1	3,230	8.7	33,982	91.3		30,371	71.1	3,561	11.7	26,810	88.3	
Yes	14,366	27.9	1,221	8.5	13,145	91.5		12,344	28.9	1,578	12.8	10,766	87.2	
Year of cohort entry							<.0001							<.0001
2004	9,408	18.2	905	9.6	8,503	90.4		6,362	14.9	1,005	15.8	5,357	84.2	
2005	9,873	19.1	781	7.9	9,092	92.1		6,583	15.4	849	12.9	5,734	87.1	
2006	7,610	14.8	650	8.5	6,960	91.5		5,400	12.6	751	13.9	4,649	86.1	
2007	5,624	10.9	421	7.5	5,203	92.5		4,360	10.2	560	12.8	3,800	87.2	
2008	4,976	9.6	458	9.2	4,518	90.8		4,435	10.4	534	12.0	3,901	88.0	
2009	4,673	9.1	399	8.5	4,274	91.5		4,772	11.2	591	12.4	4,181	87.6	
2010	3,254	6.3	261	8.0	2,993	92.0		4,192	9.8	397	9.5	3,795	90.5	
2011	2,040	4.0	185	9.1	1,855	90.9		2,400	5.6	228	9.5	2,172	90.5	
2012	1,418	2.7	155	10.9	1,263	89.1		1,411	3.3	100	7.1	1,311	92.9	
2013	1,118	2.2	98	8.8	1,020	91.2		1,264	3.0	74	5.9	1,190	94.1	
2014	744	1.4	60	8.1	684	91.9		774	1.8	40	5.2	734	94.8	
2015	585	1.1	55	9.4	530	90.6		527	1.2	8	1.5	519	98.5	
2016	237	0.5	23	9.7	214	90.3		217	0.5	2	0.9	215	99.1	
2017	18	0.0	0	0.0	18	100.0		18	0.0	0	0.0	18	100.0	
Total	**51,578**	**100.0**	**4,451**	**8.6**	**47,127**	**91.4**		**42,715**	**100.0**	**5,139**	**12.0**	**37,576**	**88.0**	

PCDMP, Primary care-based chronic disease management program; CCI, Charlson comorbidity index.

*All examinations include HbA1c test, lipid profile test, and fundoscopic examination. The analysis included only the examinations taken at the outpatient visit.

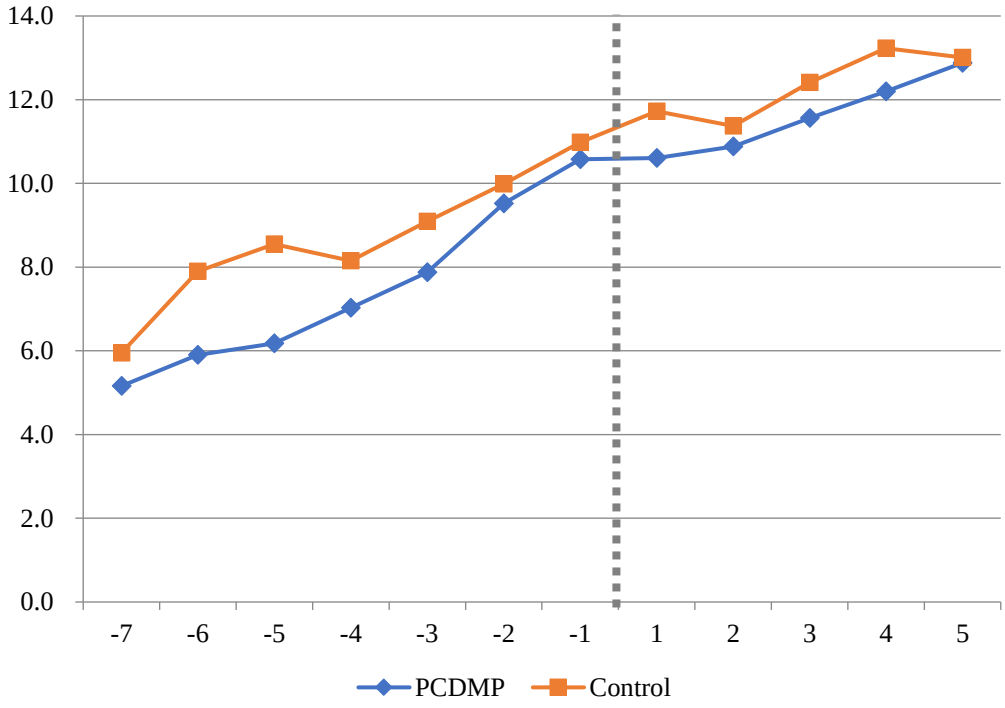
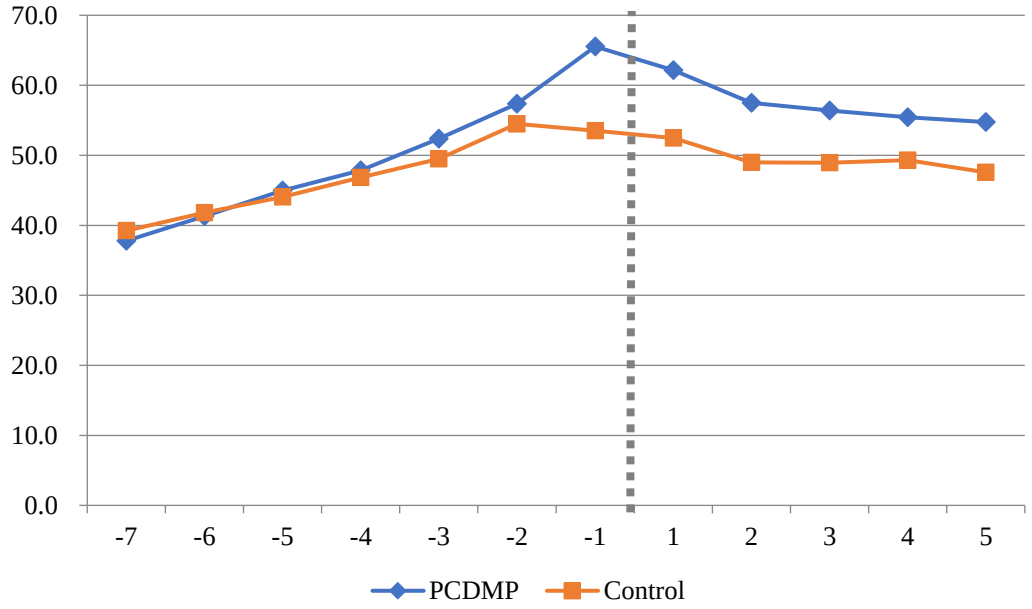


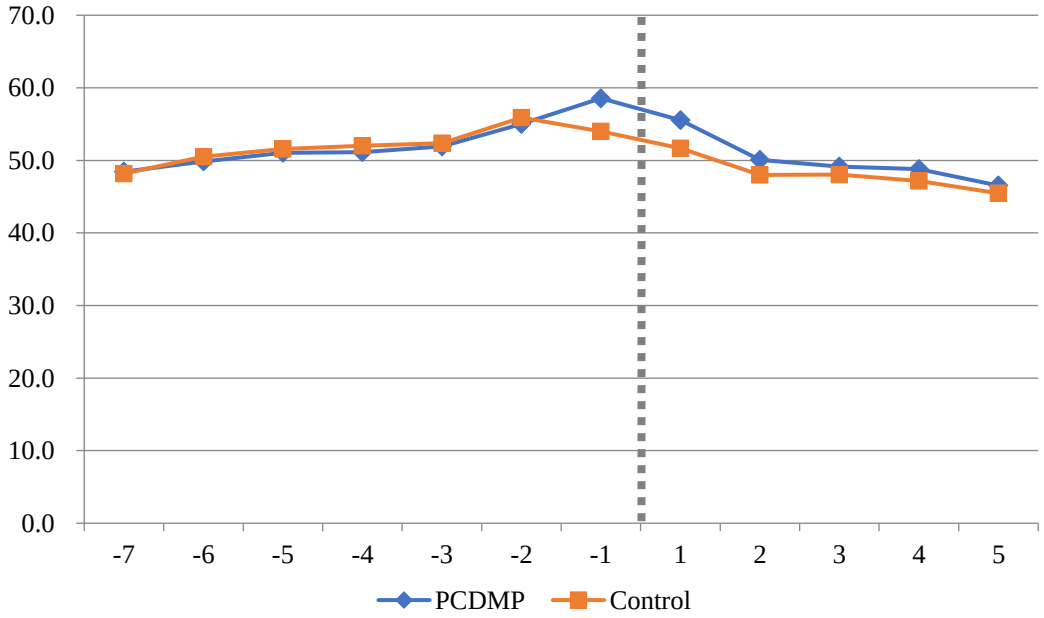
Figure 8. Trends in completion of all examinations according to participation in PCDMP

(%, year)

(A) Trends in proportion of HbA1c test (%, year)



(B) Trends in proportion of lipid profile test (%, year)



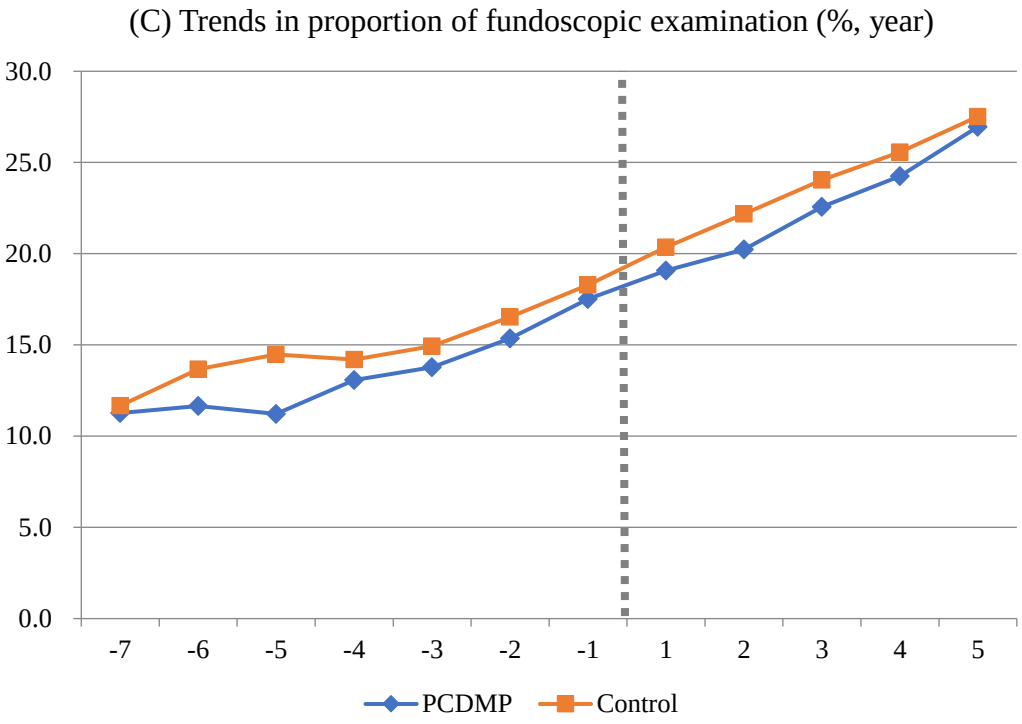


Figure 9. Trends in completion of each examination according to participation in PCDMP (%, year)

Table 10. Differential change in completion of all examinations according to participation in PCDMP

Variables	Completion of all examinations*		
	exp(β)	95% CI	*p*-value
Time	1.09	(1.08 - 1.11)	<.0001
Pre-intervention	ref.		
Post-intervention	0.90	(0.83 - 0.98)	0.0198
Control group	ref.		
PCDMP group	0.87	(0.81 - 0.93)	<.0001
Intervention*PCDMP	1.08	(0.98 - 1.18)	0.1029
Age			
19-39	ref.		
40-49	0.95	(0.88 - 1.02)	0.1574
50-59	1.17	(1.08 - 1.26)	<.0001
60-69	1.24	(1.14 - 1.36)	<.0001
≥ 70	0.78	(0.67 - 0.90)	0.0010
Sex			
Male	ref.		
Female	1.41	(1.35 - 1.47)	<.0001
Income			
High	ref.		
Middle	0.87	(0.83 - 0.91)	<.0001
Low	0.81	(0.76 - 0.86)	<.0001
Region			
Metropolitan	ref.		
City	0.82	(0.78 - 0.87)	<.0001
Other	0.79	(0.75 - 0.83)	<.0001
Medical insurance			
Self-employed insured	ref.		
Employee insured	1.04	(1.00 - 1.09)	0.0490
Disability			
No	ref.		
Yes	1.11	(1.00 - 1.23)	0.0440
CCI			
0	ref.		
1	1.09	(1.03 - 1.14)	0.0010
2	1.18	(1.11 - 1.27)	<.0001
≥ 3	1.54	(1.40 - 1.69)	<.0001

Hypertension			
No	ref.		
Yes	0.93	(0.88 - 0.97)	0.0029
Year of diagnosis			
2004	ref.		
2005	0.80	(0.74 - 0.86)	<.0001
2006	0.86	(0.80 - 0.92)	<.0001
2007	0.76	(0.70 - 0.83)	<.0001
2008	0.80	(0.73 - 0.86)	<.0001
2009	0.77	(0.71 - 0.84)	<.0001
2010	0.61	(0.55 - 0.67)	<.0001
2011	0.66	(0.59 - 0.73)	<.0001
2012	0.63	(0.55 - 0.72)	<.0001
2013	0.50	(0.42 - 0.59)	<.0001
2014	0.46	(0.37 - 0.57)	<.0001
2015	0.41	(0.32 - 0.54)	<.0001
2016	0.39	(0.26 - 0.59)	<.0001
2017	-	-	-

PCDMP, primary care-based chronic disease management program; CI, confidence interval; CCI, Charlson comorbidity index

*All examinations include HbA1c test, lipid profile test, and fundoscopic examination. The analysis included only the examinations taken at the outpatient visit.

Table 11. Differential change in completion of each diabetes-related examination according to participation in PCDMP

Variables	HbA1C test			Lipid profile test			Fundoscopic examination		
	exp(β)	95% CI	*p*-value	exp(β)	95% CI	*p*-value	exp(β)	95% CI	*p*-value
Time	1.03	(1.02 - 1.04)	<.0001	0.99	(0.98 - 1.00)	0.0173	1.10	(1.09 - 1.12)	<.0001
Pre-intervention	ref.			ref.			ref.		
Post-intervention	0.83	(0.79 - 0.87)	<.0001	0.85	(0.80 - 0.89)	<.0001	1.04	(0.97 - 1.10)	0.2609
Control group	ref.			ref.			ref.		
PCDMP group	1.18	(1.12 - 1.25)	<.0001	1.02	(0.97 - 1.08)	0.4167	0.90	(0.83 - 0.98)	0.0109
Intervention*PCDMP	1.10	(1.03 - 1.18)	0.0038	1.05	(0.98 - 1.11)	0.1765	1.02	(0.95 - 1.11)	0.5548
Age									
19-39	ref.			ref.			ref.		
40-49	1.05	(0.97 - 1.13)	0.2536	1.12	(1.04 - 1.21)	0.0035	0.99	(0.89 - 1.10)	0.8480
50-59	1.10	(1.02 - 1.19)	0.0140	1.26	(1.17 - 1.36)	<.0001	1.31	(1.17 - 1.46)	<.0001
60-69	0.86	(0.78 - 0.94)	0.0014	1.08	(0.99 - 1.19)	0.0868	1.63	(1.44 - 1.85)	<.0001
≥ 70	0.50	(0.42 - 0.58)	<.0001	0.77	(0.67 - 0.88)	0.0002	1.41	(1.17 - 1.71)	0.0004
Sex									
Male	ref.			ref.			ref.		
Female	1.00	(0.96 - 1.05)	0.8656	1.10	(1.06 - 1.16)	<.0001	1.40	(1.32 - 1.49)	<.0001
Income									
High	ref.			ref.			ref.		
Middle	0.91	(0.86 - 0.95)	0.0002	0.91	(0.87 - 0.95)	0.0001	0.91	(0.86 - 0.98)	0.0070
Low	0.87	(0.81 - 0.94)	0.0002	0.86	(0.80 - 0.92)	<.0001	0.84	(0.77 - 0.92)	0.0003
Region									
Metropolitan	ref.			ref.			ref.		
City	0.85	(0.81 - 0.90)	<.0001	0.81	(0.77 - 0.86)	<.0001	0.96	(0.89 - 1.03)	0.2280
Other	0.76	(0.72 - 0.80)	<.0001	0.80	(0.76 - 0.85)	<.0001	0.88	(0.82 - 0.94)	0.0003
Medical insurance									
Self-employed insured	ref.			ref.			ref.		
Employee insured	1.06	(1.01 - 1.11)	0.0264	1.02	(0.98 - 1.07)	0.3914	1.06	(1.00 - 1.13)	0.0578

Disability												
No	ref.				ref.				ref.			
Yes	0.89	(0.79	-	0.99)	0.0367	0.95	(0.85	-	1.05)	0.3083	1.20	(1.03	-	1.39)	0.0182
CCI												
0	ref.				ref.				ref.			
1	0.99	(0.94	-	1.05)	0.8285	1.16	(1.11	-	1.22)	<.0001	1.06	(0.99	-	1.14)	0.0800
2	1.02	(0.95	-	1.10)	0.6102	1.35	(1.26	-	1.45)	<.0001	1.18	(1.08	-	1.30)	0.0004
≥ 3	1.15	(1.02	-	1.30)	0.0230	1.57	(1.40	-	1.76)	<.0001	1.43	(1.24	-	1.64)	<.0001
Hypertension												
No	ref.				ref.				ref.			
Yes	0.99	(0.94	-	1.05)	0.7832	1.18	(1.12	-	1.24)	<.0001	0.92	(0.86	-	0.99)	0.0272
Year of diagnosis												
2004	ref.				ref.				ref.			
2005	0.88	(0.80	-	0.95)	0.0022	0.92	(0.85	-	1.00)	0.0464	0.81	(0.72	-	0.90)	<.0001
2006	1.06	(0.96	-	1.16)	0.2370	1.09	(1.00	-	1.18)	0.4475	0.81	(0.73	-	0.91)	0.0003
2007	1.11	(1.01	-	1.23)	0.0307	1.04	(0.95	-	1.13)	0.1039	0.73	(0.64	-	0.83)	<.0001
2008	1.18	(1.07	-	1.30)	0.0008	1.08	(0.98	-	1.18)	0.2604	0.71	(0.62	-	0.80)	<.0001
2009	1.22	(1.11	-	1.35)	<.0001	1.05	(0.96	-	1.15)	0.8591	0.72	(0.64	-	0.80)	<.0001
2010	1.22	(1.11	-	1.35)	<.0001	1.01	(0.92	-	1.11)	0.0677	0.55	(0.49	-	0.63)	<.0001
2011	1.15	(1.03	-	1.28)	0.0131	0.91	(0.82	-	1.01)	0.0002	0.66	(0.57	-	0.76)	<.0001
2012	1.07	(0.96	-	1.21)	0.2169	0.81	(0.72	-	0.91)	<.0001	0.71	(0.60	-	0.85)	0.0001
2013	0.92	(0.82	-	1.03)	0.1377	0.68	(0.61	-	0.76)	<.0001	0.66	(0.56	-	0.79)	<.0001
2014	0.89	(0.78	-	1.00)	0.0561	0.55	(0.48	-	0.63)	<.0001	0.58	(0.47	-	0.72)	<.0001
2015	0.73	(0.63	-	0.84)	<.0001	0.54	(0.46	-	0.62)	<.0001	0.65	(0.52	-	0.81)	0.0001
2016	0.74	(0.61	-	0.90)	0.0024	0.53	(0.43	-	1.54)	<.0001	0.58	(0.39	-	0.86)	0.0071
2017	0.39	(0.23	-	0.64)	0.0002	0.24	(0.12	-	0.49)	<.0001	0.74	(0.24	-	2.29)	0.6071

HbA1c, hemoglobin A1c; PCDMP, primary care-based chronic disease management program; CI, confidence interval; CCI, Charlson comorbidity index
The analysis included only the examinations taken at the outpatient visit.

3. Health outcome

1) Diabetes complication

Table 12 shows the general characteristics of the study population according to the onset of diabetes complication. The overall rate of diabetic complications was similar regardless of participation in PCDMP. The incidence of cardiovascular complications was slightly lower and the incidence of microvascular complications was slightly higher in the PCDMP group (Appendix 9-10).

Figure 10 shows the cumulative incidence for the composite of all diabetes complications, cardiovascular complications, and microvascular complications. The cumulative incidence of cardiovascular complication in the PCDMP group had lower than it had been in control group. There was not statistically significant difference between the PCDMP and control group.

Table 13 (more details in Appendix 11-13) shows the number of events and results of the Cox proportional hazard regression for the onset of complications. According to the Cox proportional hazard regression analysis, there was no difference in the risk of onset of diabetic complications between the PCDMP and control groups (HR: 1.00, 95% CI=0.94-1.06). However, depending on the type of complication, the risk of cardiovascular complications was significantly lower in the PCDMP group than that in the control group by almost 9% (HR:0.91, 95% CI=0.84-0.99). In contrast, in the case of microvascular complications, the PCDMP group had a 7% higher risk than the control group, but the difference was not statistically significant (HR:1.07, 95% CI=0.99-1.16). According to the subgroup results analyzed for each complication, the risk of heart failure and stroke was significantly reduced in the PCDMP group. (HR:0.59, 95% CI=0.45-0.78 for heart failure;

HR:0.68, 95% CI=0.56-0.83 for stroke). In contrast, in the case of microvascular complications, the risk of diabetic retinopathy increased more in the PCDMP group than in the control group (HR:1.15, 95% CI=1.03-1.27). In the case of diabetic foot disease, the PCDMP group had a 30% lower risk than the control group (HR: 0.71, 95% CI=0.57-0.88).

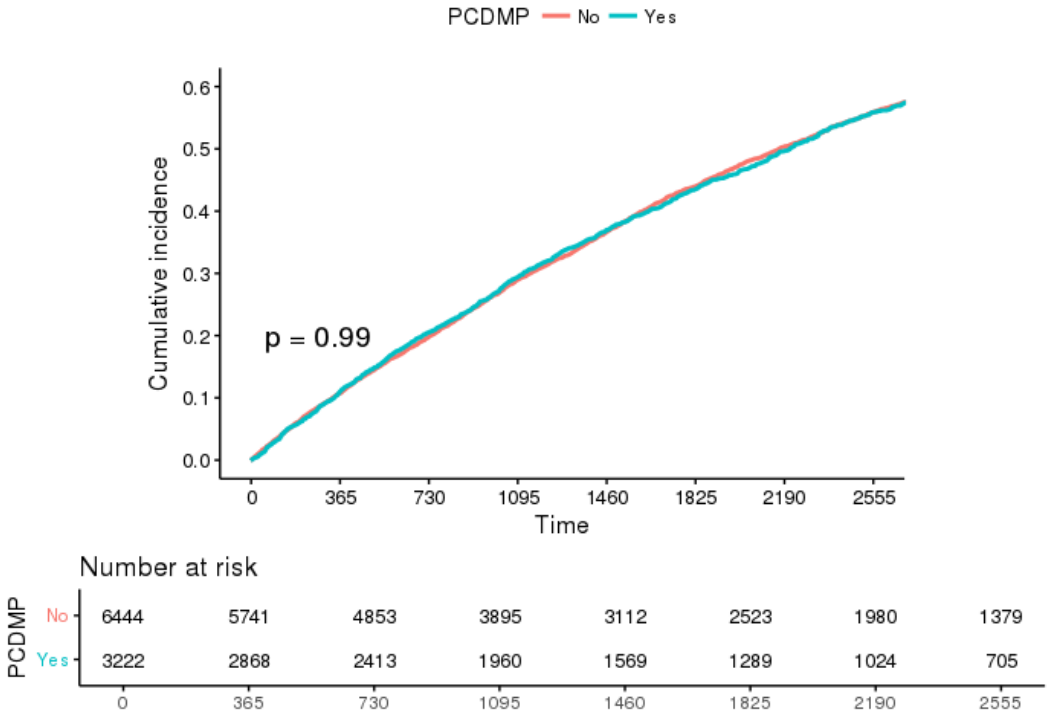
Table 12. General characteristics of study population with onset of diabetes complication

Variables	Composite of diabetes complication						
	Total		Yes		No		
	N	%	N	%	N	%	*p*-value
Participation of PCDMP							0.7406
Yes	3,222	33.3	1,553	48.2	1,669	51.8	
No	6,444	66.7	3,083	47.8	3,361	52.2	
Age							<.0001
19-39	1,158	12.0	454	39.2	704	60.8	
40-49	3,189	33.0	1,433	44.9	1,756	55.1	
50-59	3,636	37.6	1,855	51.0	1,781	49.0	
60-69	1,344	13.9	714	53.1	630	46.9	
≥ 70	339	3.5	180	53.1	159	46.9	
Sex							0.0414
Male	5,703	59.0	2,686	47.1	3,017	52.9	
Female	3,963	41.0	1,950	49.2	2,013	50.8	
Income							0.5865
High	3,790	39.2	1,793	47.3	1,997	52.7	
Middle	4,399	45.5	2,129	48.4	2,270	51.6	
Low	1,477	15.3	714	48.3	763	51.7	
Region							0.0149
Metropolitan	4,131	42.7	1,921	46.5	2,210	53.5	
City	2,554	26.4	1,225	48.0	1,329	52.0	
Other	2,981	30.8	1,490	50.0	1,491	50.0	
Medical insurance							0.0292
Self-employed insured	4,253	44.0	2,093	49.2	2,160	50.8	
Employee insured	5,413	56.0	2,543	47.0	2,870	53.0	
Disability							0.3587
No	9,233	95.5	4,419	47.9	4,814	52.1	
Yes	433	4.5	217	50.1	216	49.9	
CCI							0.0272
0	5,107	52.8	2,401	47.0	2,706	53.0	
1	3,039	31.4	1,465	48.2	1,574	51.8	
2	1,122	11.6	554	49.4	568	50.6	
≥ 3	398	4.1	216	54.3	182	45.7	

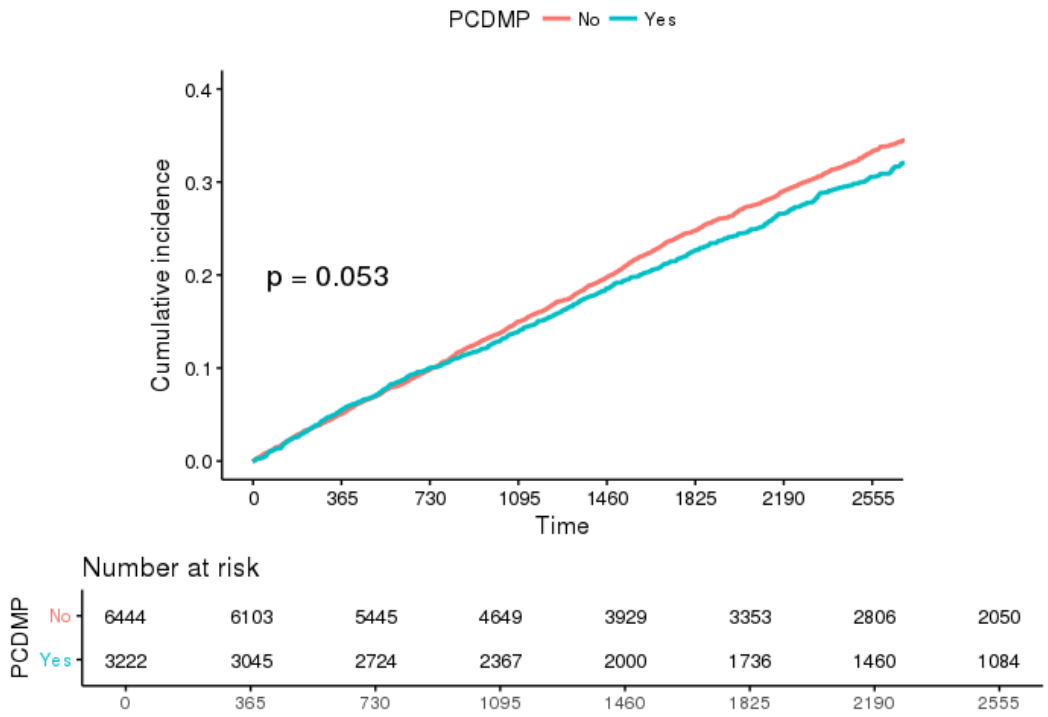
Hypertension							<.0001
No	6,956	72.0	3,230	46.4	3,726	53.6	
Yes	2,710	28.0	1,406	51.9	1,304	48.1	
Year of diagnosis							<.0001
2004	1,383	14.3	750	54.2	633	45.8	
2005	1,452	15.0	750	51.7	702	48.3	
2006	1,164	12.0	618	53.1	546	46.9	
2007	951	9.8	477	50.2	474	49.8	
2008	960	9.9	473	49.3	487	50.7	
2009	1,050	10.9	531	50.6	519	49.4	
2010	906	9.4	438	48.3	468	51.7	
2011	555	5.7	225	40.5	330	59.5	
2012	357	3.7	135	37.8	222	62.2	
2013	333	3.4	111	33.3	222	66.7	
2014	240	2.5	67	27.9	173	72.1	
2015	204	2.1	46	22.5	158	77.5	
2016	102	1.1	14	13.7	88	86.3	
2017	9	0.1	1	11.1	8	88.9	
Total	**9,666**	**100.0**	**4,636**	**48.0**	**5,030**	**52.0**	

PCDMP, primary care-based chronic disease management program; CCI, Charlson comorbidity index.

Diabetic Complication



Cardiovascular Complication



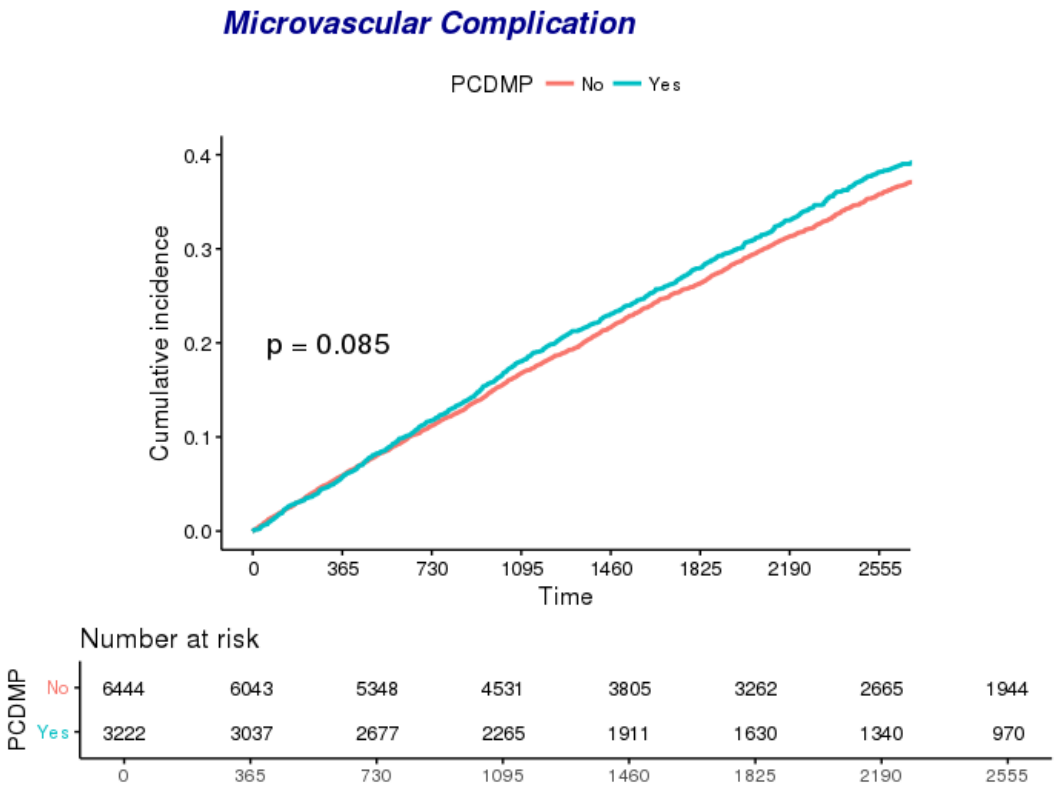


Figure 10. Cumulative incidence for onset of complications

Table 13. Result of Cox proportional hazards model for diabetes complication

Variables	PCDMP group (n=3,222)			Control group (n=6,444)			Hazard Ratio (95% CI)†
	Events	Person years	Incidence rate (95% CI)*	Events	Person years	Incidence rate (95% CI)*	
Primary outcome							
Composite of diabetes complications	1,553	134,434	115.5 (109.9 - 121.4)	3,083	26,699	115.5 (111.5 - 119.6)	1.00 (0.94 - 1.06)
Secondary outcome							
Composite of cardiovascular complications	839	16,063	52.2 (48.8 - 55.9)	1,789	31,614	56.6 (54.0 - 59.3)	0.91 (0.84 - 0.99)
Composite of microvascular complications	1,028	15,456	66.5 (62.6 - 70.7)	1,922	30,880	62.2 (59.5 - 65.1)	1.07 (0.99 - 1.16)
Individual clinical endpoint							
Cardiovascular complications							
Ischemic heart disease	260	17,946	14.5 (12.8 - 16.4)	570	35,319	16.1 (14.9 - 17.5)	0.89 (0.77 - 1.03)
Myocardial Infarction	40	18,665	2.1 (1.6 - 2.9)	84	36,755	2.3 (1.8 - 2.8)	0.93 (0.64 - 1.35)
Heart failure	65	18,604	3.5 (2.7 - 4.5)	209	36,409	5.7 (5.0 - 6.6)	0.59 (0.45 - 0.78)
Stroke	128	18,417	7.0 (5.8 - 8.3)	361	36,146	10.0 (9.0 - 11.0	0.68 (0.56 - 0.83)
Peripheral circulatory disease‡	547	17,084	32.0 (29.4 - 34.8)	1,107	33,789	32.8 (30.9 - 34.8)	0.97 (0.88 - 1.08)
Microvascular complications							
Neuropathy	414	17,571	23.6 (21.4 - 25.9)	837	34,580	24.2 (22.6 - 25.9)	0.97 (0.86 - 1.09)
Retinopathy	557	17,013	32.7 (30.1 - 35.6)	978	34,020	28.7 (27.0 - 30.6)	1.15 (1.03 - 1.27)
Nephropathy	258	17,962	14.4 (12.7 - 16.2)	550	35,296	15.6 (14.3 - 17.0)	0.93 (0.80 - 1.08)
Diabetic Foot	116	18,443	6.3 (5.2 - 7.5)	319	36,069	8.8 (7.9 - 9.9)	0.71 (0.57 - 0.88)

PCDMP, primary care-based chronic disease management program; CI: confidence interval.

*Per 1,000 person years.

†HR adjusted for all covariates in this study.

‡Peripheral circulatory disease included peripheral vessel disease, atherosclerosis and aortic disease.

2) Cause-specific hospitalization

Table 14 shows the general characteristics of the study population according to diabetes complication-related hospitalization. Diabetes complication-related hospitalization was 8.2% in the PCDMP participating group, lower than 11.8% in the non-participating group. Both hospitalizations for cardiovascular complication and hospitalizations for microvascular complication were lower in patients participating in PCDMP than in the control group (Appendix 14-15).

The cumulative incidence for diabetes complication-related hospitalization, cardiovascular complication-related hospitalization, and microvascular complication-related hospitalization, respectively is shown in Figure 11. The cumulative incidence of cause-specific hospitalizations was lower in the PCDMP group than in the control group and was statistically significant.

Table 15 (more details in Appendix 16-18) shows the number of events and results of the Cox proportional hazard regression for diabetes complication-related hospitalization. In cause-specific hospitalization according to the complication classification, the exposure group had a significantly lower hospitalization incidence and HR than the control group. Total complication-related hospitalizations were approximately 34% lower in the PCDMP group participating in the PCDMP, which was statistically significant (HR: 0.66, 95% CI=0.57-0.76). Depending on the complication classification, hospitalizations related to cardiovascular complications were about 30% and hospitalizations related to microvascular complications were about 50%, showing a lower possibility in the PCDMP group than in the control group (HR:0.71, 95% CI=0.61-0.84 for cardiovascular complication related hospitalization; HR:0.52, 95% CI=0.40-0.68 for microvascular complication related hospitalization). As a result of the subgroup analysis of hospitalization due to each

complication, the PCDMP group had a lower risk than the control group in all complication-related hospitalizations, except for myocardial infarction. In the case of myocardial infarction, it should be considered that the statistical power may be low because the number of events is very small.

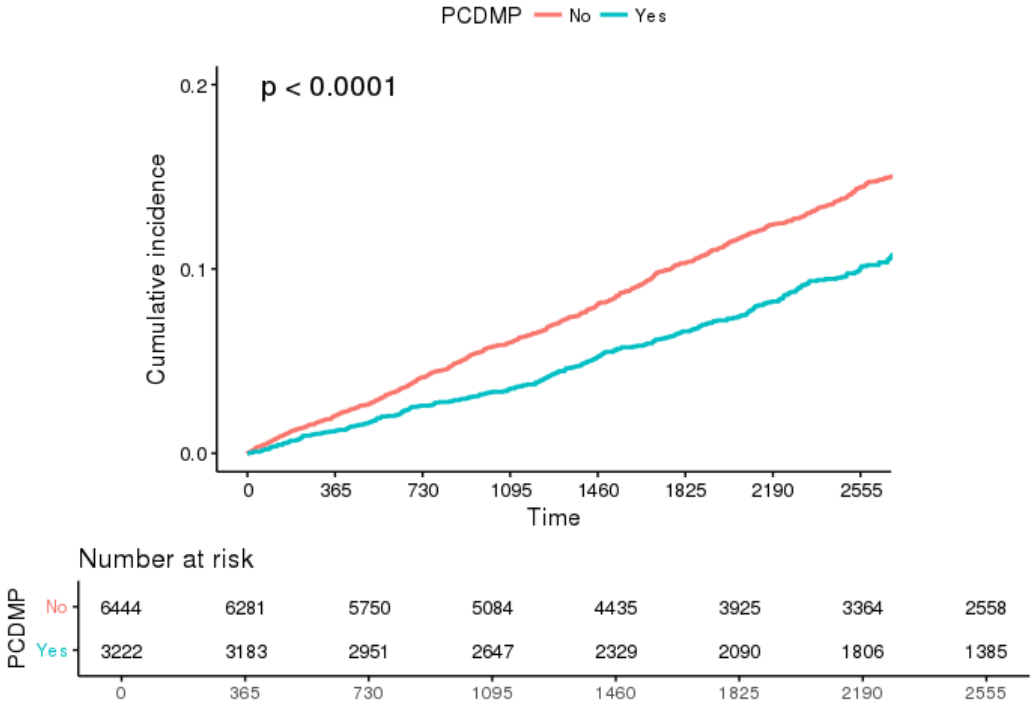
Table 14. General characteristics of study population hospitalized for diabetes complication

Variables	Hospitalization for diabetes complication						
	Total		Yes		No		
	N	%	N	%	N	%	*p*-value
Participation of PCDMP							<.0001
Yes	3,222	33.3	264	8.2	2,958	91.8	
No	6,444	66.7	761	11.8	5,683	88.2	
Age							<.0001
19-39	1,158	12.0	100	8.6	1,058	91.4	
40-49	3,189	33.0	276	8.7	2,913	91.3	
50-59	3,636	37.6	413	11.4	3,223	88.6	
60-69	1,344	13.9	171	12.7	1,173	87.3	
≥ 70	339	3.5	65	19.2	274	80.8	
Sex							0.0003
Male	5,703	59.0	658	11.5	5,045	88.5	
Female	3,963	41.0	367	9.3	3,596	90.7	
Income							0.0148
Low	1,477	15.3	167	11.3	1,310	88.7	
Middle	4,399	45.5	499	11.3	3,900	88.7	
High	3,790	39.2	359	9.5	3,431	90.5	
Region							0.0032
Metropolitan	4,131	42.7	391	9.5	3,740	90.5	
City	2,554	26.4	278	10.9	2,276	89.1	
Other	2,981	30.8	356	11.9	2,625	88.1	
Medical insurance							0.0078
Self-employed insured	4,253	44.0	491	11.5	3,762	88.5	
Employee insured	5,413	56.0	534	9.9	4,879	90.1	
Disability							0.9893
No	9,233	95.5	979	10.6	8,254	89.4	
Yes	433	4.5	46	10.6	387	89.4	
CCI							0.1212
0	5,107	52.8	572	11.2	4,535	88.8	
1	3,039	31.4	289	9.5	2,750	90.5	
2	1,122	11.6	121	10.8	1,001	89.2	
≥ 3	398	4.1	43	10.8	355	89.2	

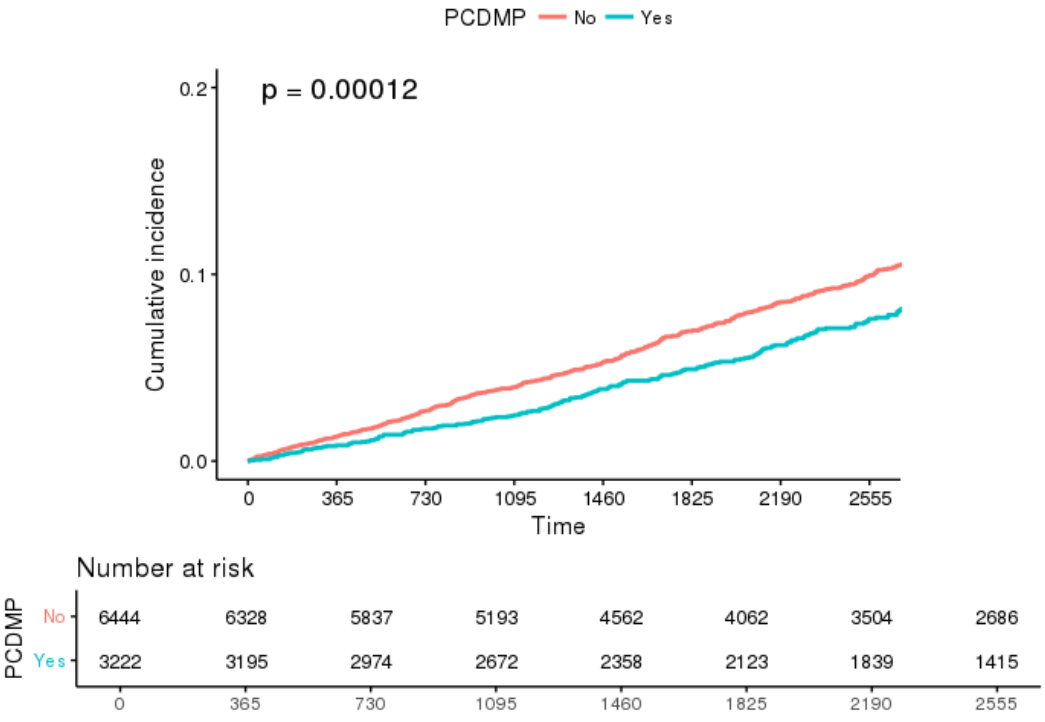
Hypertension							<.0001
No	6,956	72.0	679	9.8	6,277	90.2	
Yes	2,710	28.0	346	12.8	2,364	87.2	
Year of cohort entry							<.0001
2004	1,383	14.3	209	15.1	1,174	84.9	
2005	1,452	15.0	194	13.4	1,258	86.6	
2006	1,164	12.0	147	12.6	1,017	87.4	
2007	951	9.8	115	12.1	836	87.9	
2008	960	9.9	93	9.7	867	90.3	
2009	1,050	10.9	112	10.7	938	89.3	
2010	906	9.4	73	8.1	833	91.9	
2011	555	5.7	41	7.4	514	92.6	
2012	357	3.7	19	5.3	338	94.7	
2013	333	3.4	10	3.0	323	97.0	
2014	240	2.5	4	1.7	236	98.3	
2015	204	2.1	6	2.9	198	97.1	
2016	102	1.1	2	2.0	100	98.0	
2017	9	0.1	0	0.0	9	100.0	
Total	9,666	**100.0**	**1,025**	**10.6**	**8,641**	**100.0**	

PCDMP, primary care-based chronic disease management program; CCI: Charlson comorbidity index.

Hospitalization for diabetes complication



Hospitalization for cardiovascular complication



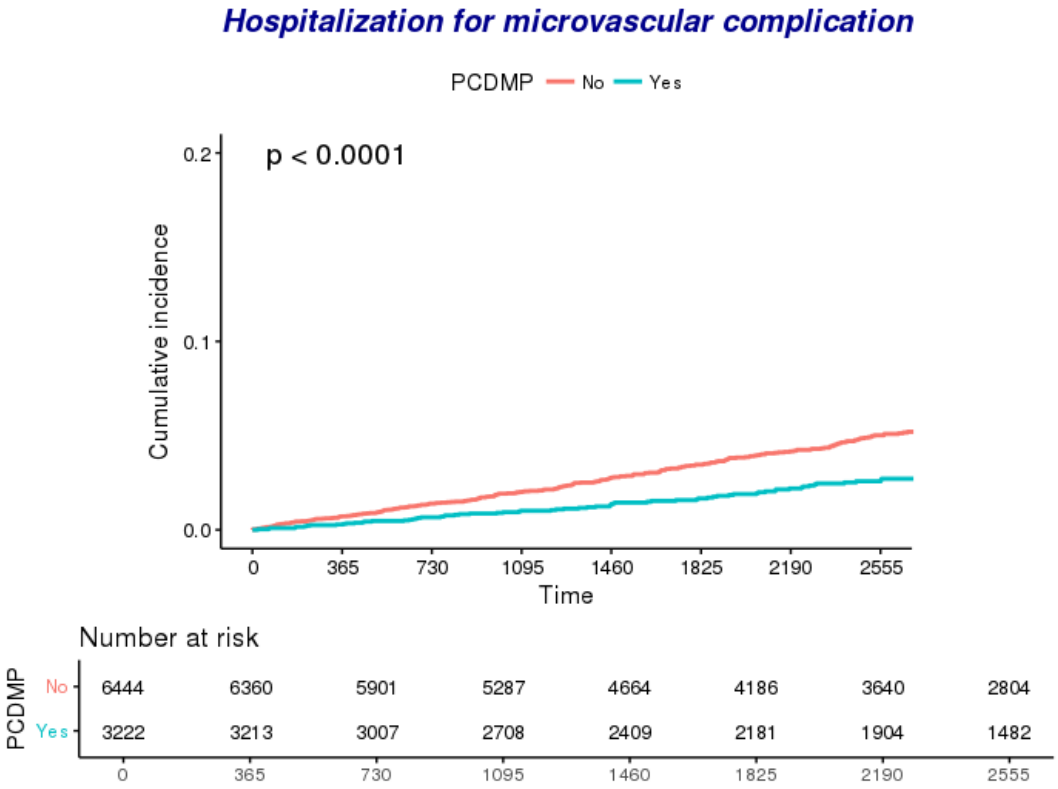


Figure 11. Cumulative incidence for cause-specific hospitalization

Table 15. Result of Cox proportional hazards model for diabetes-related hospitalization

Variables	PCDMP group (n=3,222)			Control group (n=6,444)			Hazard Ratio (95% CI)†
	Events	Person years	Incidence rate (95% CI)*	Events	Person years	Incidence rate (95% CI)*	
Primary outcome							
Composite of diabetes complications	264	18,057	14.6 (13.0 - 16.5)	761	34,726	21.9 (20.4 - 23.5)	0.66 (0.57 - 0.76)
Secondary outcome							
Composite of cardiovascular complications	197	18,242	10.8 (9.4 - 12.4)	527	35,498	14.8 (13.6 - 16.2)	0.71 (0.61 - 0.84)
Composite of microvascular complications	68	18,573	3.7 (2.9 - 4.6)	257	36,187	7.1 (6.3 - 8.0)	0.52 (0.40 - 0.68)
Individual clinical endpoint							
Cardiovascular complications							
Ischemic heart disease	106	18,477	5.7 (4.7 - 6.9)	257	36,176	7.1 (6.3 - 8.0)	0.79 (0.63 - 0.99)
Myocardial Infarction	29	18,696	1.6 (1.1 - 2.2)	57	36,810	1.5 (1.2 - 2.0)	1.01 (0.64 - 1.57)
Heart failure	18	18,746	1.0 (0.6 - 1.5)	59	36,843	1.6 (1.2 - 2.0)	0.58 (0.34 - 0.98)
Stroke	63	18,591	3.4 (2.6 - 4.3)	211	36,462	5.8 (5.0 - 6.6)	0.57 (0.43 - 0.76)
Peripheral circulatory disease‡	9	18,730	0.5 (0.3 - 0.9)	31	36,871	0.8 (0.6 - 1.2)	0.58 (0.27 - 1.21)
Microvascular complications							
Neuropathy	38	18,671	2.0 (1.5 - 2.8)	145	36,505	4.0 (3.4 - 4.7)	0.51 (0.36 - 0.73)
Retinopathy	23	18,696	1.2 (0.8 - 1.9)	75	36,723	2.0 (1.6 - 2.6)	0.62 (0.39 - 0.99)
Nephropathy	14	18,713	0.7 (0.4 - 1.3)	63	36,822	1.7 (1.3 - 2.2)	0.45 (0.25 - 0.80)
Diabetic Foot	16	18,710	0.9 (0.5 - 1.4)	61	36,787	1.7 (1.3 - 2.1)	0.52 (0.30 - 0.91)

PCDMP, primary care-based chronic disease management program; CI: confidence interval.

*Per 1,000 person years.

†HR adjusted for all covariates in this study.

‡Peripheral circulatory disease included peripheral vessel disease, atherosclerosis and aortic disease.

3) All-cause mortality

As a result of analyzing the risk of mortality in the PCDMP group who participated in the PCDMP and control group who did not participate in the PCDMP, it was confirmed that 425 deaths occurred in total; 92 (2.9%) of 3,222 died in the PCDMP group, and 343 (5.3%) of 6,444 died in the control group (Table 16). The result of cumulative incidence is shown in Figure 12. The cumulative incidence of mortality in the PCDMP group was statistically significantly lower than in the control group.

Table 17 shows the results of the Cox proportional hazards model, which examined the risk of mortality after adjusting for all covariates. Mortality in the PCDMP group was 0.51 times lower than that in the control group (HR:0.51, 95% CI=0.40-0.64).

Table 16. General characteristics of study population with all-cause mortality

Variables	All-cause mortality						
	Total		Yes		No		
	N	%	N	%	N	%	*p*-value
Participation of PCDMP							<.0001
Yes	3,222	33.3	92	2.9	3,130	97.1	
No	6,444	66.7	343	5.3	6,101	94.7	
Age							<.0001
19-39	1,158	12.0	26	2.2	1,132	97.8	
40-49	3,189	33.0	69	2.2	3,120	97.8	
50-59	3,636	37.6	151	4.2	3,485	95.8	
60-69	1,344	13.9	112	8.3	1,232	91.7	
≥ 70	339	3.5	77	22.7	262	77.3	
Sex							0.0003
Male	5,703	59.0	293	5.1	5,410	94.9	
Female	3,963	41.0	142	3.6	3,821	96.4	
Income							0.0800
High	3,790	39.2	149	3.9	3,641	96.1	
Middle	4,399	45.5	210	4.8	4,189	95.2	
Low	1,477	15.3	76	5.1	1,401	94.9	
Region							0.0149
Metropolitan	4,131	42.7	1,921	46.5	2,210	53.5	
City	2,554	26.4	1,225	48.0	1,329	52.0	
Other	2,981	30.8	1,490	50.0	1,491	50.0	
Medical insurance							0.0660
Self-employed insured	4,253	44.0	210	4.9	4,043	95.1	
Employee insured	5,413	56.0	225	4.2	5,188	95.8	
Disability							0.0063
No	9,233	95.5	404	4.4	8,829	95.6	
Yes	433	4.5	31	7.2	402	92.8	
CCI							0.0215
0	5,107	52.8	214	4.2	4,893	95.8	
1	3,039	31.4	130	4.3	2,909	95.7	
2	1,122	11.6	65	5.8	1,057	94.2	
≥ 3	398	4.1	26	6.5	372	93.5	

Hypertension							<.0001
No	6,956	72.0	273	3.9	6,683	96.1	
Yes	2,710	28.0	162	6.0	2,548	94.0	
Year of diagnosis							<.0001
2004	1,383	14.3	93	6.7	1,290	93.3	
2005	1,452	15.0	79	5.4	1,373	94.6	
2006	1,164	12.0	62	5.3	1,102	94.7	
2007	951	9.8	51	5.4	900	94.6	
2008	960	9.9	37	3.9	923	96.1	
2009	1,050	10.9	38	3.6	1,012	96.4	
2010	906	9.4	29	3.2	877	96.8	
2011	555	5.7	21	3.8	534	96.2	
2012	357	3.7	9	2.5	348	97.5	
2013	333	3.4	10	3.0	323	97.0	
2014	240	2.5	2	0.8	238	99.2	
2015	204	2.1	3	1.5	201	98.5	
2016	102	1.1	1	1.0	101	99.0	
2017	9	0.1	0	0.0	9	100.0	
Total	**9,666**	**100.0**	**435**	**4.5**	**9,231**	**95.5**	

PCDMP, primary care-based chronic disease management program; CCI, Charlson comorbidity index.

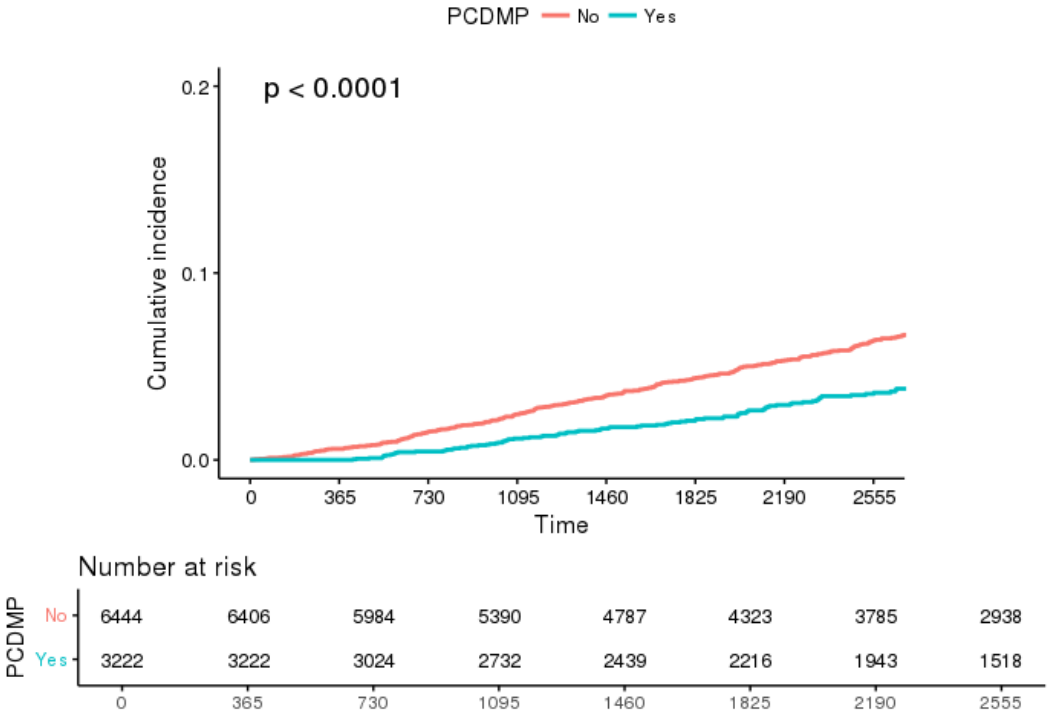


Figure 12. Cumulative incidence for all-cause mortality

Table 17. Results of Cox proportional hazard model for all-cause mortality

Variables	All-cause mortality	
	HR	95% CI
Participation of PCDMP		
Yes	0.51	(0.40 - 0.64)
No	1.00	
Age		
19-39	1.00	
40-49	1.01	(0.64 - 1.59)
50-59	2.16	(1.42 - 3.29)
60-69	5.37	(3.46 - 8.35)
≥ 70	21.23	(13.17 - 34.23)
Sex		
Male	1.00	
Female	0.43	(0.35 - 0.53)
Income		
High	1.00	
Middle	1.40	(1.14 - 1.73)
Low	1.60	(1.21 - 2.11)
Region		
Metropolitan	1.00	
City	1.18	(0.93 - 1.50)
Other	1.32	(1.06 - 1.65)
Medical insurance		
Self-employed insured	1.00	
Employee insured	0.75	(0.62 - 0.90)
Disability		
No	1.00	
Yes	1.34	(0.93 - 1.94)
CCI		
0	1.00	
1	0.95	(0.76 - 1.19)
2	1.21	(0.91 - 1.61)
≥ 3	1.48	(0.98 - 2.23)

Hypertension		
No	1.00	
Yes	1.19	(0.96 - 1.48)
Year of diagnosis		
2004	1.00	
2005	0.78	(0.58 - 1.05)
2006	0.75	(0.54 - 1.03)
2007	0.68	(0.48 - 0.97)
2008	0.51	(0.35 - 0.75)
2009	0.48	(0.33 - 0.70)
2010	0.34	(0.22 - 0.52)
2011	0.57	(0.36 - 0.93)
2012	0.49	(0.24 - 0.97)
2013	0.66	(0.34 - 1.27)
2014	0.22	(0.05 - 0.89)
2015	0.59	(0.18 - 1.88)
2016	0.64	(0.09 - 4.65)
2017	-	

PCDMP, primary care-based chronic disease management program; HR, hazard ratio; CI, confidence interval; CCI, Charlson comorbidity index.

V. Discussion

1. Discussion of the study method

This study was conducted to evaluate the effect of PCDMP among patients with T2DM. Two different statistical methodologies were applied to measure the effect of PCDMP on quality of care and health outcome. Quality of care is the degree to which healthcare service for T2DM patients increase the likelihood of desired health outcome. Continuity of care and completion of regular health examination were the main aspects of quality of care which were identified through DID analysis. Accordingly, the benefits of participation in PCDMP were observed in T2DM patients with better continuity of care and better likelihood of receiving regular health checks. The risk for onset of diabetic complications, hospitalization, and mortality were examined through Cox proportional hazard model, all of which were the indicators of health outcome. Those who participated in PCDMP had lower risk for adverse health outcome in compared to their counterparts.

The strength of this study is that it comprehensively analyzed the effect of PCDMP and the extent of its achievement using the data derived from the real world evidence. The data has been accumulated from 2002 to 2019 with the national representative sample. The majority of findings suggested in the previous literature were drawn from the data with limited observation[17,19,21,43,44], and thus, the results of this study could enable insights for the long-term effect of the PCDMP.

NHIS-NSC database is the national big data in healthcare which includes massive volumes of health information of insured population from 2002 to 2019. The study subjects

were those who were newly diagnosed with T2DM without complications following 2004. The PCDMP group was classified according to their participation status following 2012 which was the year of initiation. To minimize the confounding in the study, the control group were selected through propensity score match method. Variables such as gender, age, and year of diabetes diagnosis were exactly matched to the PCDMP group, and income level, region, medical insurance type, disability, CCI, and hypertension were similarly matched according to adjacent propensity scores of the PCDMP group. Propensity score matching is a statistical technique for sampling close to random selection by matching subjects with similar attributes.[65,66]

The PCDMP group and the control group were constituted as quasi-experimental conditions, and the DID method of analysis was used to estimate the change and difference in the quality of care between the PCDMP group and the control group after the implementation of the PCDMP. The DID analysis is a method for evaluating the effect of policy or program in force at a particular point in time. This method is to compares the difference in outcomes before and after intervention for group affected by the intervention with the same difference for the group not affected.[67] The difference in the difference is considered the effect of the policy. Furthermore, the Cox proportional hazard regression was used to analyze the association between PCDMP participation and the risk of health outcomes including complication, hospitalization, and mortality. This can provide information on how changes in quality of care by PCDMP relate to health outcomes.

However, this study has several limitations that should be considered when interpreting the results. First, NHIS-NSC data are administrative data, so they do not include information on health behaviors such as smoking, drinking, physical activity, and diet, or records accumulated from laboratories. Thus, this study could not consider health

behavior-related covariates that could affect quality of care and health outcomes. Second, the accuracy of administrative data has been discussed since the primary purpose of NHIS-NSC data is health insurance claims.[68] For this reason, ICD-10 codes may not always represent patient's real disease status. However, when selecting subjects, patients without a history of diabetes-related medication prescription and patients without a history of primary care visits were excluded in order to overcome the limitations of claim data. Third, as claims data is generated to reimburse healthcare services eligible for coverage, there is no information about non-covered healthcare services under the system. Uninsured patients with diabetes are also not included. However, since Korea is a national health insurance system, the proportion of uninsured people will be very small. Fourth, the severity of T2DM could not be controlled. However, efforts were made to minimize the difference in the effect of diabetes severity by adding the presence of hypertension as a covariate and accurately matching the incidence year of T2DM between the PCDMP group and control group. Fifth, because the analysis of process indicators has a long follow-up period, it is possible that other factors may have influenced it compared to that investigated for a short period of observation. The influence of residual confounding in these findings should be considered. However, since T2DM is a chronic disease that requires long-term management, it can be helpful in providing the basis for reorganization and formulation of chronic disease management programs in the future. In addition, follow-up studies using other research methods other than DID or survival analysis need to be conducted. As an example, intention to treat (ITT) analysis can also be considered to better reflect real-world situations. ITT can give a pragmatic estimate of the benefit of a change in policy.[69]

Despite these limitations, the present study was able to demonstrate that participating PCDMP associated with better quality of care and health outcomes among patients with T2DM. The study used nationally representative population-based data

tracked for over 10 years. Therefore, these results can provide the evidence needed to develop appropriate programs for managing chronic diseases in primary care settings.

2. Discussion of the results

The purpose of this study was to investigate the impact of PCDMP on quality of care and health outcomes among patients with T2DM. The results of the study showed significant findings that PCDMP can be associated with better COC, improved completion of examinations, and lower risk of negative health outcomes among patients with T2DM.

In this study, the COC of patients with T2DM who participated in PCDMP was approximately 15% higher than that of patients who did not participate. This result is similar to the results of a previous study that PCDMP improves COC and medication adherence in diabetic patients.[43,70]

In addition, patients who participated in PCDMP had a higher rate of regular screening than those who did not. The rate of taking all examinations, including HbA1c test, lipid profile test, and fundoscopic examination, was 8% higher. For each test, HbA1c test was the highest at 10%, lipid profile test at 5%, and fundoscopic examination at 2%. According to a preceding study that conducted a meta-analysis, as a result of disease and case management interventions for diabetic patients, HbA1c tests increased by an average of 15.6%, lipid tests by an average of 24%, and fundus tests by 9%.[71]

As such, this study can provide additional empirical evidence to the literature suggesting that PCDMP is potentially associated with improved quality of care among patients with T2DM. Additionally, participating in PCDMP was positively associated with reduced events of diabetic complication, hospitalization, and mortality. This finding aligns with previous studies that presented PCDMP diabetic patients with high COC had a lower risk of complications.[72-74] This suggests that PCDMP can induce patients to improve their health behaviors leading to better health outcomes. In terms of cost-effectiveness of

PCDMP, the participating population presumed to have better health outcome with reduced healthcare expenses[75]. Therefore, PCDMP could be a cost-effective strategy for the management of T2DM. In contrast, there was a study that diabetes education and compulsory tests in the local healthcare centers, which are the part of PCDMP, do not have significant effect on maintaining healthy blood sugar level of diabetic patients.[76]

In particular, the risk of cardiovascular complications significantly decreased in the patients who participated in PCDMP. The basis of PCDMP implementation is to reduce the burden of cardiovascular events among T2DM patients, and the result in this study implies that the PCDMP may have achieved its goal to a certain extent. Meanwhile, there was an increase in the risk of developing retinopathy complications in the PCDMP group. This can be interpreted as the effective of PCDMP with an increased rate of fundoscopic examination which corresponds to the early detection of the disease. This tendency is similar to the increase in the early detection of thyroid cancer in magnitude with increased with the increase in ultrasound examination.[77] Due to the nature of the diabetes, it is important to prevent adverse complications through active management starting from the early stage.[78] Therefore, improving the rate of regular examinations can be an effective regime in the management of diabetes and early detection of diabetic complications.

Although various PCDMPs have been implemented to date, this study only evaluated the programs conducted at the clinic level of healthcare. However, since the clinic level PCDMP is the only voluntary participatory project implemented nationwide and the project was implemented for a relatively long period, the long-term effects of the PCDMP could be identified with generalizability. Even with the low incentives for participation in PCDMP[18], its effect on the management of chronic patients on the basis of primary care was observed. Therefore, better effect could be visible with improved incentives for patients and healthcare institutions participating in PCDMP.

3. Policy implication

Several studies have shown the association of PCDMP participation with improved quality of care and health outcomes in diabetic patients. Efforts are ongoing at the national level to effectively manage chronic diseases based on primary care. Recently, the government has begun developing policies and developing an integrated program at the national level that complements the weakness and maximizes the strength of the existing pilot programs.

In order to strengthen chronic care management in primary medical care, a virtuous cycle is important, in which experiences in various programs that have been conducted are monitored and achievements are accumulated in aid of policy development.[22] That is, objective evaluation indices and systems should be designed as programs are carried forward, and program quality should be improved through the disclosure of evaluation results and feedback.

Involvement of patients, medical institutions, and the community is important for long-term implementation of the ongoing PCDMP and evaluation of its effectiveness. In order to effectively manage chronic diseases by improving primary care functions, it is necessary to strengthen inducement so that patients and medical institutions can continue to participate. In addition to external factors, patients need intrinsic motivation to manage their health.[79] Patient empowerment is an important factor in behavioral change in diabetes management.[80] Developing a range of educational interventions for patient empowerment also would be an effective approach in advancing the PCDMP. Through this, PCDMP should be developed and promoted to enhance the efficiency of the medical delivery system

and patient satisfaction and to contribute to the prevention of complications through continuous treatment.

VI. Conclusion

This study is meaningful in that it comprehensively evaluated the effectiveness of the PCDMP in Korea, which strengthened the role of primary care, from a long-term perspective. Reinforcing the role of primary care for diabetes can significantly improve the health outcomes of patients with diabetes by increasing the continuity of care and preventing complications. The present results provide critical information for supporting primary care reinforcement, which is gaining global importance. Furthermore, this information may be valuable for the reform and establishment of chronic disease management systems.

Abbreviations

CCI — Charlson Comorbidity Index

CCM — Chronic Care Model

CI — Confidence Interval

COC — Continuity of Care

COCI — Continuity of Care Index

DID — Difference-in-differences

HbA1c — Hemoglobin A1c

HIRA — Health Insurance Review and Assessment Service

HR — Hazard Ratio

ICCC — Innovative Care for Chronic Conditions

ICD-10 — International Statistical Classification of Diseases and Related Health Problems, 10th revision

NHIS-NSC — National Health Insurance Service National Sample Cohort

PCDMP — Primary care-based Chronic Disease Management Program

SMD — Standardized Mean Difference

T2DM — Type 2 Diabetes Mellitus

UPC — Usual Provider Continuity

WHO — World Health Organization

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Appendix

Appendix 1. Standardized mean differences before and after propensity score matching

Appendix 2. Results of parallel trend test assessing the validity of DID model

Appendix 3. Continuity of care measured by UPC before and after intervention

Appendix 4. Differential changes of continuity of care measured by UPC according to participation in PCDMP

Appendix 5. Trends in the proportion of good COC according to participation in PCDMP (%, year)

Appendix 6. Completion of HbA1c test by before and after intervention

Appendix 7. Completion of lipid profile test by before and after intervention

Appendix 8. Completion of fundoscopic examination by before and after intervention

Appendix 9. General characteristics of the study population with onset of cardiovascular complication according to participation in PCDMP

Appendix 10. General characteristics of the study population with onset of microvascular complication according to participation in PCDMP

Appendix 11. Results of Cox proportional hazard model for onset of diabetes complication

Appendix 12. Results of Cox proportional hazard model for onset of cardiovascular complication

Appendix 13. Results of Cox proportional hazard model for onset of microvascular complication

Appendix 14. General characteristics of the study population hospitalized for cardiovascular complication according to participation in PCDMP

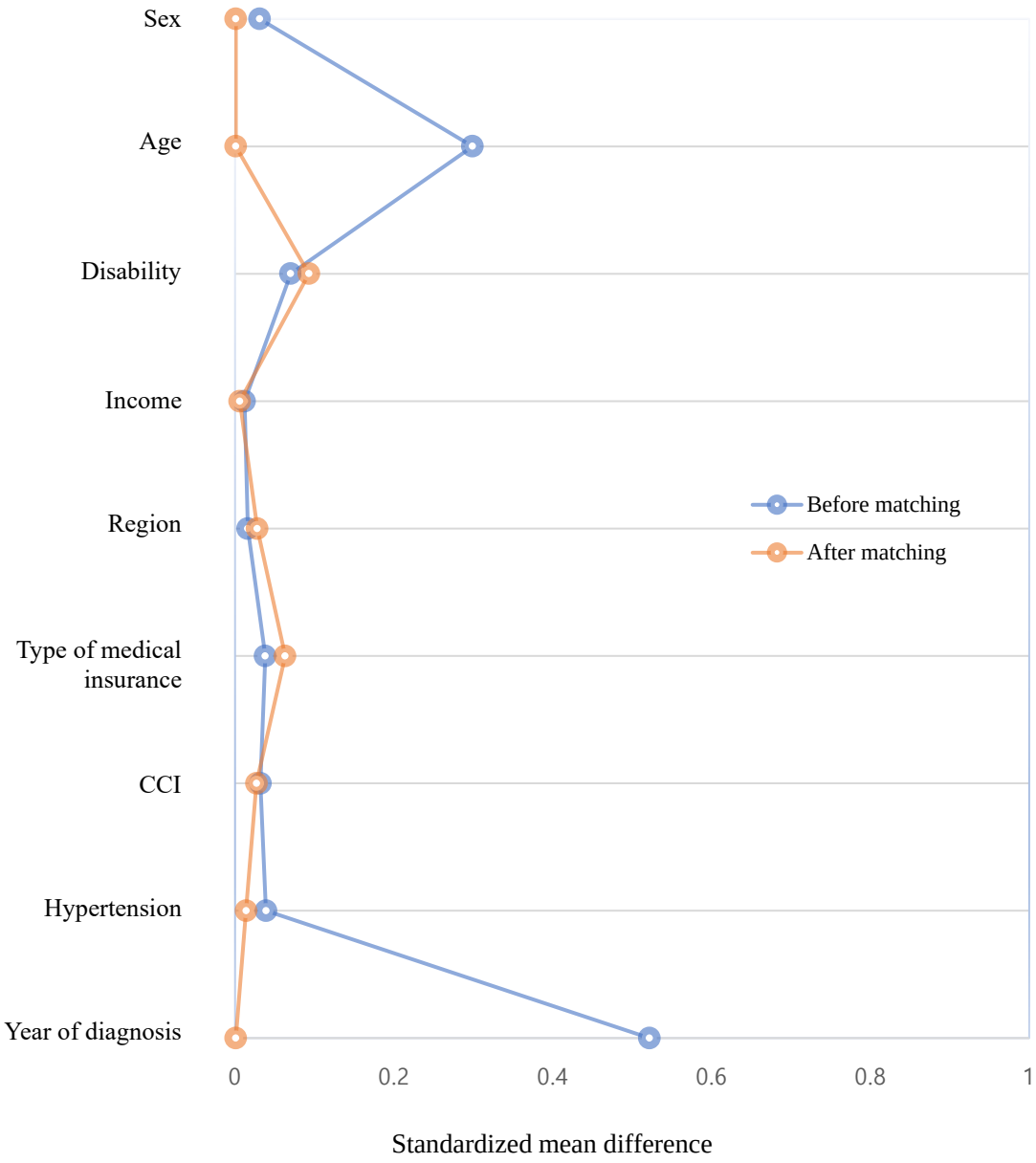
Appendix 15. General characteristics of the study population hospitalized for microvascular complication according to participation in PCDMP

Appendix 16. Results of Cox proportional hazard model for diabetes-related hospitalization

Appendix 17. Results of Cox proportional hazard model for cardiovascular complication hospitalization

Appendix 18. Results of Cox proportional hazard model for microvascular complication hospitalization

Appendix 1. Standardized mean difference after propensity score matching



Appendix 2. Results of parallel trend test assessing the validity of DID model

Variables	PCDMP*Time (Interaction effect)		
	β	**SE**	***p*-value**
Continuity of care (COCI)	-0.0046	0.0115	0.6886
Continuity of care (UPC)	-0.0071	0.0101	0.4843
Completion of all tests	0.0185	0.014	0.1843
HbA1C test	0.0581	0.0084	<.0001
Lipid profile test	0.0014	0.0097	0.8891
Fundoscopic examination	0.0011	0.00141	0.9400

DID, difference-in-difference; PCDMP, primary care-based chronic disease management program; COCI, continuity of care index; UPC, usual provider continuity; HbA1c, hemoglobin A1c.

All covariates are included in the regression.

Appendix 3. Continuity of care measured by UPC before and after intervention

Variables	Continuity of care (measured by UPC)*												
	Before intervention							After intervention					
	Total		Good		Bad			Total		Good		Bad		
	N	%	N	%	N	%	*p*-value	N	%	N	%	N	%	*p*-value
Participation of PCDMP							<.0001							<.0001
Yes	16,247	34.3	5,162	31.8	11,085	68.2		14,311	35.0	4,471	31.2	9,840	68.8	
No	31,113	65.7	8,917	28.7	22,196	71.3		26,538	65.0	7,150	26.9	19,388	73.1	
Age							<.0001							<.0001
19-39	5,532	11.7	1,734	31.3	3,798	68.7		4,527	11.1	1,519	33.6	3,008	66.4	
40-49	15,750	33.3	5,235	33.2	10,515	66.8		13,354	32.7	4,424	33.1	8,930	66.9	
50-59	17,704	37.4	5,223	29.5	12,481	70.5		15,804	38.7	4,089	25.9	11,715	74.1	
60-69	6,720	14.2	1,513	22.5	5,207	77.5		5,822	14.3	1,265	21.7	4,557	78.3	
≥ 70	1,654	3.5	374	22.6	1,280	77.4		1,342	3.3	324	24.1	1,018	75.9	
Sex							<.0001							<.0001
Male	27,013	57.0	9,471	35.1	17,542	64.9		23,433	57.4	7,969	34.0	15,464	66.0	
Female	20,347	43.0	4,608	22.6	15,739	77.4		17,416	42.6	3,652	21.0	13,764	79.0	
Income							<.0001							0.0004
Low	10,111	21.3	5,150	50.9	4,961	49.1		16,132	39.5	4,444	27.5	11,688	72.5	
Middle	21,616	45.6	6,739	31.2	14,877	68.8		18,486	45.3	5,437	29.4	13,049	70.6	
High	18,593	39.3	5,150	27.7	13,443	72.3		6,231	15.3	1,740	27.9	4,491	72.1	
Region							0.0002							0.0211
Metropolitan	19,956	42.1	6,116	30.6	13,840	69.4		17,386	42.6	5,067	29.1	12,319	70.9	
City	12,527	26.5	3,703	29.6	8,824	70.4		10,812	26.5	3,045	28.2	7,767	71.8	
Other	14,877	31.4	4,260	28.6	10,617	71.4		12,651	31.0	3,509	27.7	9,142	72.3	
Medical insurance							0.0136							0.0080
Self-employed insured	21,407	45.2	6,486	30.3	14,921	69.7		18,134	44.4	5,279	29.1	12,855	70.9	
Employee insured	25,953	54.8	7,593	29.3	18,360	70.7		22,715	55.6	6,342	27.9	16,373	72.1	
Disability							0.0094							0.1516
No	45,292	95.6	13,517	29.8	31,775	70.2		38,985	95.4	11,118	28.5	27,867	71.5	
Yes	2,068	4.4	562	27.2	1,506	72.8		1,864	4.6	503	27.0	1,361	73.0	

CCI							<.0001							<.0001
0	24,551	51.8	8,831	36.0	15,720	64.0		21,167	51.8	7,258	34.3	13,909	65.7	
1	14,997	31.7	3,770	25.1	11,227	74.9		13,007	31.8	3,152	24.2	9,855	75.8	
2	5,751	12.1	1,115	19.4	4,636	80.6		4,903	12.0	904	18.4	3,999	81.6	
≥ 3	2,061	4.4	363	17.6	1,698	82.4		1,772	4.3	307	17.3	1,465	82.7	
Hypertension							<.0001							<.0001
No	33,509	70.8	10,207	30.5	23,302	69.5		28,768	70.4	8,629	30.0	20,139	70.0	
Yes	13,851	29.2	3,872	28.0	9,979	72.0		12,081	29.6	2,992	24.8	9,089	75.2	
Year of cohort entry							0.0002							<.0001
2004	8,888	18.8	2,504	28.2	6,384	71.8		6,170	15.1	1,537	24.9	4,633	75.1	
2005	9,204	19.4	2,687	29.2	6,517	70.8		6,318	15.5	1,767	28.0	4,551	72.0	
2006	7,001	14.8	2,193	31.3	4,808	68.7		5,236	12.8	1,476	28.2	3,760	71.8	
2007	5,170	10.9	1,601	31.0	3,569	69.0		4,187	10.2	1,177	28.1	3,010	71.9	
2008	4,541	9.6	1,348	29.7	3,193	70.3		4,260	10.4	1,232	28.9	3,028	71.1	
2009	4,198	8.9	1,222	29.1	2,976	70.9		4,531	11.1	1,291	28.5	3,240	71.5	
2010	2,925	6.2	896	30.6	2,029	69.4		3,996	9.8	1,293	32.4	2,703	67.6	
2011	1,823	3.8	539	29.6	1,284	70.4		2,265	5.5	687	30.3	1,578	69.7	
2012	1,279	2.7	352	27.5	927	72.5		1,334	3.3	381	28.6	953	71.4	
2013	963	2.0	283	29.4	680	70.6		1,166	2.9	336	28.8	830	71.2	
2014	656	1.4	217	33.1	439	66.9		713	1.7	221	31.0	492	69.0	
2015	498	1.1	157	31.5	341	68.5		464	1.1	149	32.1	315	67.9	
2016	198	0.4	75	37.9	123	62.1		192	0.5	69	35.9	123	64.1	
2017	16	0.0	5	31.3	11	68.8		17	0.0	5	29.4	12	70.6	
Total	**47,360**	**100.0**	**14,079**	**29.7**	**33,281**	**70.3**		**40,849**	**100.0**	**11,621**	**28.4**	**29,228**	**71.6**	

PCDMP, primary care-based chronic disease management program; UPC, usual provider continuity; CCI, Charlson comorbidity index
*The continuity of care index was calculated only with outpatient treatment more than four times a year.

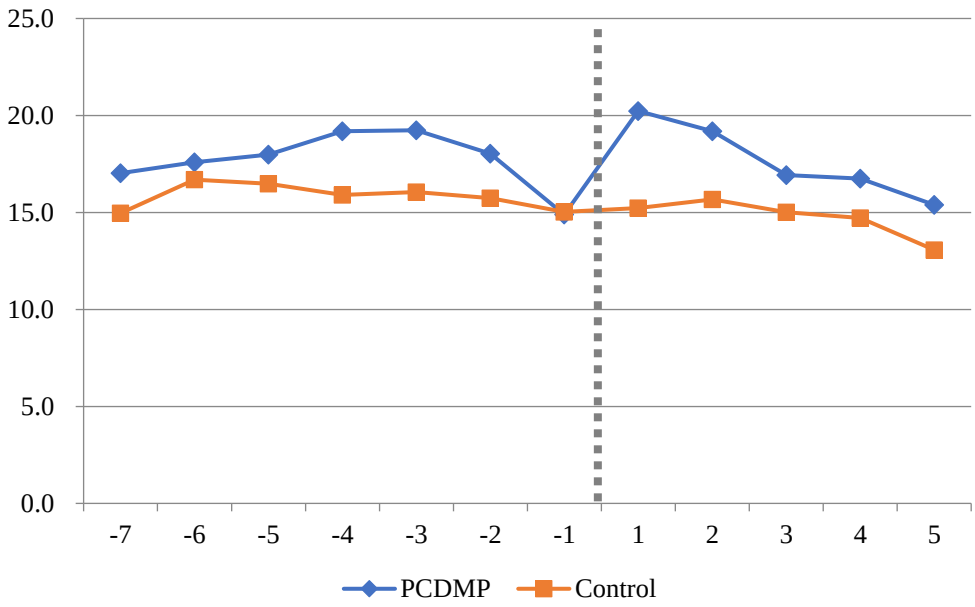
Appendix 4. Differential changes of continuity of care measured by UPC according to participation in PCDMP

Variables	Continuity of care*		
	exp(β)	95% CI	*p*-value
Time	0.96	(0.95 - 0.97)	<.0001
Pre-intervention	ref.		
Post-intervention	1.09	(1.02 - 1.17)	0.0151
Control group	ref.		
PCDMP group	1.11	(1.03 - 1.20)	0.0053
Intervention*PCDMP	1.15	(1.06 - 1.24)	0.0009
Age			
19-39	ref.		
40-49	1.13	(1.02 - 1.25)	0.0235
50-59	0.99	(0.89 - 1.10)	0.8095
60-69	0.79	(0.69 - 0.90)	0.0006
≥ 70	0.93	(0.74 - 1.17)	0.5361
Sex			
Male	ref.		
Female	0.56	(0.53 - 0.61)	<.0001
Income			
High	ref.		
Middle	1.19	(1.11 - 1.28)	<.0001
Low	1.22	(1.11 - 1.35)	<.0001
Region			
Metropolitan	ref.		
City	0.93	(0.86 - 1.01)	0.0827
Other	0.91	(0.84 - 0.98)	0.0125
Medical insurance			
Self-employed insured	ref.		
Employee insured	0.94	(0.88 - 1.00)	0.0540
Disability			
No	ref.		
Yes	0.89	(0.75 - 1.04)	0.1519
CCI			
0	ref.		
1	0.60	(0.56 - 0.64)	<.0001
2	0.42	(0.37 - 0.47)	<.0001
≥ 3	0.36	(0.30 - 0.44)	<.0001

Hypertension					
No	ref.				
Yes	1.09	(1.01	-	1.17)	0.0327
Year of diagnosis					
2004	ref.				
2005	1.14	(1.01	-	1.28)	0.0334
2006	1.24	(1.10	-	2.71)	0.0004
2007	1.19	(1.04	-	1.35)	0.0104
2008	1.19	(1.04	-	1.35)	0.0101
2009	1.16	(1.02	-	1.32)	0.0220
2010	1.51	(1.31	-	1.73)	<.0001
2011	1.34	(1.15	-	1.57)	0.0003
2012	1.36	(1.13	-	1.64)	0.0011
2013	1.22	(1.01	-	1.49)	0.0430
2014	1.53	(1.24	-	1.90)	<.0001
2015	1.09	(0.86	-	1.39)	0.4528
2016	1.53	(1.09	-	2.13)	0.0132
2017	0.82	(0.32	-	2.11)	0.6801

PCDMP, primary care-based chronic disease management program; UPC, usual provider continuity; CI, confidence interval; CCI, Charlson comorbidity index
*The continuity of care index was calculated only with outpatient treatment more than four times a year.

Appendix 5. Trends in the proportion of good COC according to participation in PCDMP (%, year, measured by UPC)



Appendix 6. Completion of HbA1c test by before and after intervention

Variables	HbA1c test												
	Before intervention							After intervention					
	Total		Good		Bad			Total		Good		Bad		
	N	%	N	%	N	%	*p*-value	N	%	N	%	N	%	*p*-value
Participation of PCDMP							<.0001							<.0001
Yes	17,373	33.7	8,984	51.7	8,389	48.3		14,579	34.1	8,378	57.5	6,201	42.5	
No	34,205	66.3	16,543	48.4	17,662	51.6		28,136	65.9	13,950	49.6	14,186	50.4	
Age							<.0001							<.0001
19-39	6,404	12.4	3,235	50.5	3,169	49.5		4,944	11.6	2,447	49.5	2,497	50.5	
40-49	17,566	34.1	8,824	50.2	8,742	49.8		14,094	33.0	7,556	53.6	6,538	46.4	
50-59	18,937	36.7	9,655	51.0	9,282	49.0		16,326	38.2	9,014	55.2	7,312	44.8	
60-69	6,971	13.5	3,212	46.1	3,759	53.9		5,969	14.0	2,886	48.3	3,083	51.7	
≥ 70	1,700	3.3	601	35.4	1,099	64.6		1,382	3.2	425	30.8	957	69.2	
Sex							<.0001							0.2339
Male	30,131	58.4	15,255	50.6	14,876	49.4		24,829	58.1	12,918	52.0	11,911	48.0	
Female	21,447	41.6	10,272	47.9	11,175	52.1		17,886	41.9	9,410	52.6	8,476	47.4	
Income							<.0001							<.0001
High	20,239	39.2	10,365	51.2	9,874	48.8		16,851	39.4	9,034	53.6	7,817	46.4	
Middle	23,540	45.6	11,450	48.6	12,090	51.4		19,354	45.3	10,019	51.8	9,335	48.2	
Low	7,799	15.1	3,712	47.6	4,087	52.4		6,510	15.2	3,275	50.3	3,235	49.7	
Region							<.0001							<.0001
Metropolitan	21,855	42.4	11,682	53.5	10,173	46.5		18,238	42.7	9,947	54.5	8,291	45.5	
City	13,640	26.4	6,600	48.4	7,040	51.6		11,293	26.4	5,893	52.2	5,400	47.8	
Other	16,083	31.2	7,245	45.0	8,838	55.0		13,184	30.9	6,488	49.2	6,696	50.8	
Medical insurance							<.0001							0.0020
Self-employed insured	23,327	45.2	11,244	48.2	12,083	51.8		18,969	44.4	10,074	53.1	8,895	46.9	
Employee insured	28,251	54.8	14,283	50.6	13,968	49.4		23,746	55.6	12,254	51.6	11,492	48.4	
Disability							0.2035							<.0001
No	49,365	95.7	24,461	49.6	24,904	50.4		40,783	95.5	21,429	52.5	19,354	47.5	
Yes	2,213	4.3	1,066	48.2	1,147	51.8		1,932	4.5	899	46.5	1,033	53.5	

CCI							0.0170						0.0052
0	27,250	52.8	13,616	50.0	13,634	50.0		22,397	52.4	11,588	51.7	10,809	48.3	
1	16,162	31.3	7,888	48.8	8,274	51.2		13,488	31.6	7,060	52.3	6,428	47.7	
2	6,033	11.7	2,930	48.6	3,103	51.4		5,028	11.8	2,677	53.2	2,351	46.8	
≥ 3	2,133	4.1	1,093	51.2	1,040	48.8		1,802	4.2	1,003	55.7	799	44.3	
Hypertension							<.0001						0.4735
No	37,212	72.1	18,754	50.4	18,458	49.6		30,371	71.1	15,842	52.2	14,529	47.8	
Yes	14,366	27.9	6,773	47.1	7,593	52.9		12,344	28.9	6,486	52.5	5,858	47.5	
Year of diagnosis							<.0001						<.0001
2004	9,408	18.2	4,255	45.2	5,153	54.8		6,362	14.9	3,609	56.7	2,753	43.3	
2005	9,873	19.1	4,052	41.0	5,821	59.0		6,583	15.4	3,533	53.7	3,050	46.3	
2006	7,610	14.8	3,581	47.1	4,029	52.9		5,400	12.6	3,059	56.6	2,341	43.4	
2007	5,624	10.9	2,720	48.4	2,904	51.6		4,360	10.2	2,485	57.0	1,875	43.0	
2008	4,976	9.6	2,586	52.0	2,390	48.0		4,435	10.4	2,481	55.9	1,954	44.1	
2009	4,673	9.1	2,531	54.2	2,142	45.8		4,772	11.2	2,675	56.1	2,097	43.9	
2010	3,254	6.3	1,840	56.5	1,414	43.5		4,192	9.8	2,191	52.3	2,001	47.7	
2011	2,040	4.0	1,233	60.4	807	39.6		2,400	5.6	1,103	46.0	1,297	54.0	
2012	1,418	2.7	949	66.9	469	33.1		1,411	3.3	509	36.1	902	63.9	
2013	1,118	2.2	750	67.1	368	32.9		1,264	3.0	381	30.1	883	69.9	
2014	744	1.4	497	66.8	247	33.2		774	1.8	203	26.2	571	73.8	
2015	585	1.1	385	65.8	200	34.2		527	1.2	66	12.5	461	87.5	
2016	237	0.5	141	59.5	96	40.5		217	0.5	33	15.2	184	84.8	
2017	18	0.0	7	38.9	11	61.1		18	0.0	0	0.0	18	100.0	
Total	**51,578**	**100.0**	**25,527**	**49.5**	**26,051**	**50.5**		**42,715**	**100.0**	**22,328**	**52.3**	**20,387**	**47.7**	

HbA1c, hemoglobin A1c; PCDMP, primary care-based chronic disease management program; CCI, Charlson comorbidity index
The analysis included only the examinations taken at the outpatient visit.

Appendix 7. Completion of lipid profile test by before and after intervention

Variables	Lipid profile test												
	Before intervention							After intervention					
	Total		Good		Bad			Total		Good		Bad		
	N	%	N	%	N	%	*p*-value	N	%	N	%	N	%	*p*-value
Participation of PCDMP							0.4195							<.0001
Yes	17,373	33.7	9,202	53.0	8,171	47.0		14,579	34.1	7,329	50.3	7,250	49.7	
No	34,205	66.3	17,989	52.6	16,216	47.4		28,136	65.9	13,576	48.3	14,560	51.7	
Age							<.0001							<.0001
19-39	6,404	12.4	3,098	48.4	3,306	51.6		4,944	11.6	2,126	43.0	2,818	57.0	
40-49	17,566	34.1	9,012	51.3	8,554	48.7		14,094	33.0	6,821	48.4	7,273	51.6	
50-59	18,937	36.7	10,517	55.5	8,420	44.5		16,326	38.2	8,460	51.8	7,866	48.2	
60-69	6,971	13.5	3,760	53.9	3,211	46.1		5,969	14.0	2,948	49.4	3,021	50.6	
≥ 70	1,700	3.3	804	47.3	896	52.7		1,382	3.2	550	39.8	832	60.2	
Sex							<.0001							<.0001
Male	30,131	58.4	15,487	51.4	14,644	48.6		24,829	58.1	11,811	47.6	13,018	52.4	
Female	21,447	41.6	11,704	54.6	9,743	45.4		17,886	41.9	9,094	50.8	8,792	49.2	
Income							<.0001							<.0001
High	20,239	39.2	11,097	54.8	9,142	45.2		16,851	39.4	8,463	50.2	8,388	49.8	
Middle	23,540	45.6	12,163	51.7	11,377	48.3		19,354	45.3	9,365	48.4	9,989	51.6	
Low	7,799	15.1	3,931	50.4	3,868	49.6		6,510	15.2	3,077	47.3	3,433	52.7	
Region							<.0001							<.0001
Metropolitan	21,855	42.4	12,270	56.1	9,585	43.9		18,238	42.7	9,392	51.5	8,846	48.5	
City	13,640	26.4	6,854	50.2	6,786	49.8		11,293	26.4	5,311	47.0	5,982	53.0	
Other	16,083	31.2	8,067	50.2	8,016	49.8		13,184	30.9	6,202	47.0	6,982	53.0	
Medical insurance							0.0179							0.0034
Self-employed insured	23,327	45.2	12,164	52.1	11,163	47.9		18,969	44.4	9,434	49.7	9,535	50.3	
Employee insured	28,251	54.8	15,027	53.2	13,224	46.8		23,746	55.6	11,471	48.3	12,275	51.7	
Disability							0.2700							0.0023
No	49,365	95.7	25,999	52.7	23,366	47.3		40,783	95.5	20,025	49.1	20,758	50.9	
Yes	2,213	4.3	1,192	53.9	1,021	46.1		1,932	4.5	880	45.5	1,052	54.5	

CCI						<.0001							<.0001
0	27,250	52.8	13,485	49.5	13,765	50.5		22,397	52.4	10,393	46.4	12,004	53.6	
1	16,162	31.3	8,760	54.2	7,402	45.8		13,488	31.6	6,808	50.5	6,680	49.5	
2	6,033	11.7	3,575	59.3	2,458	40.7		5,028	11.8	2,702	53.7	2,326	46.3	
≥ 3	2,133	4.1	1,371	64.3	762	35.7		1,802	4.2	1,002	55.6	800	44.4	
Hypertension						<.0001							<.0001
No	37,212	72.1	19,068	51.2	18,144	48.8		30,371	71.1	14,373	47.3	15,998	52.7	
Yes	14,366	27.9	8,123	56.5	6,243	43.5		12,344	28.9	6,532	52.9	5,812	47.1	
Year of diagnosis						<.0001							<.0001
2004	9,408	18.2	4,727	50.2	4,681	49.8		6,362	14.9	3,400	53.4	2,962	46.6	
2005	9,873	19.1	4,766	48.3	5,107	51.7		6,583	15.4	3,422	52.0	3,161	48.0	
2006	7,610	14.8	4,108	54.0	3,502	46.0		5,400	12.6	2,951	54.6	2,449	45.4	
2007	5,624	10.9	2,972	52.8	2,652	47.2		4,360	10.2	2,272	52.1	2,088	47.9	
2008	4,976	9.6	2,727	54.8	2,249	45.2		4,435	10.4	2,317	52.2	2,118	47.8	
2009	4,673	9.1	2,552	54.6	2,121	45.4		4,772	11.2	2,451	51.4	2,321	48.6	
2010	3,254	6.3	1,806	55.5	1,448	44.5		4,192	9.8	2,000	47.7	2,192	52.3	
2011	2,040	4.0	1,140	55.9	900	44.1		2,400	5.6	1,054	43.9	1,346	56.1	
2012	1,418	2.7	866	61.1	552	38.9		1,411	3.3	470	33.3	941	66.7	
2013	1,118	2.2	671	60.0	447	40.0		1,264	3.0	330	26.1	934	73.9	
2014	744	1.4	398	53.5	346	46.5		774	1.8	151	19.5	623	80.5	
2015	585	1.1	328	56.1	257	43.9		527	1.2	59	11.2	468	88.8	
2016	237	0.5	124	52.3	113	47.7		217	0.5	28	12.9	189	87.1	
2017	18	0.0	6	33.3	12	66.7		18	0.0	0	0.0	18	100.0	
Total	**51,578**	**100.0**	**27,191**	**52.7**	**24,387**	**47.3**		**42,715**	**100.0**	**20,905**	**48.9**	**21,810**	**51.1**	

PCDMP, primary care-based chronic disease management program; CCI, Charlson comorbidity index
The analysis included only the examinations taken at the outpatient visit.

Appendix 8. Completion of fundoscopic examination by before and after intervention

Variables	Fundoscopic examination												
	Before intervention							After intervention					
	Total		Good		Bad			Total		Good		Bad		
	N	%	N	%	N	%	*p*-value	N	%	N	%	N	%	*p*-value
Participation of PCDMP							<.0001							0.0018
Yes	17,373	33.7	2,414	13.9	14,959	86.1		14,579	34.1	3,256	22.3	11,323	77.7	
No	34,205	66.3	5,220	15.3	28,985	84.7		28,136	65.9	6,662	23.7	21,474	76.3	
Age							<.0001							<.0001
19-39	6,404	12.4	781	12.2	5,623	87.8		4,944	11.6	958	19.4	3,986	80.6	
40-49	17,566	34.1	2,132	12.1	15,434	87.9		14,094	33.0	2,787	19.8	11,307	80.2	
50-59	18,937	36.7	2,864	15.1	16,073	84.9		16,326	38.2	4,173	25.6	12,153	74.4	
60-69	6,971	13.5	1,480	21.2	5,491	78.8		5,969	14.0	1,676	28.1	4,293	71.9	
≥ 70	1,700	3.3	377	22.2	1,323	77.8		1,382	3.2	324	23.4	1,058	76.6	
Sex							<.0001							<.0001
Male	30,131	58.4	3,924	13.0	26,207	87.0		24,829	58.1	4,890	19.7	19,939	80.3	
Female	21,447	41.6	3,710	17.3	17,737	82.7		17,886	41.9	5,028	28.1	12,858	71.9	
Income							<.0001							0.2140
High	20,239	39.2	3,264	16.1	16,975	83.9		16,851	39.4	3,987	23.7	12,864	76.3	
Middle	23,540	45.6	3,346	14.2	20,194	85.8		19,354	45.3	4,432	22.9	14,922	77.1	
Low	7,799	15.1	1,024	13.1	6,775	86.9		6,510	15.2	1,499	23.0	5,011	77.0	
Region							<.0001							0.0167
Metropolitan	21,855	42.4	3,464	15.8	18,391	84.2		18,238	42.7	4,291	23.5	13,947	76.5	
City	13,640	26.4	1,959	14.4	11,681	85.6		11,293	26.4	2,680	23.7	8,613	76.3	
Other	16,083	31.2	2,211	13.7	13,872	86.3		13,184	30.9	2,947	22.4	10,237	77.6	
Medical insurance							0.4311							0.0026
Self-employed insured	23,327	45.2	3,421	14.7	19,906	85.3		18,969	44.4	4,274	22.5	14,695	77.5	
Employee insured	28,251	54.8	4,213	14.9	24,038	85.1		23,746	55.6	5,644	23.8	18,102	76.2	
Disability							0.0037							0.0004
No	49,365	95.7	7,259	14.7	42,106	85.3		40,783	95.5	9,405	23.1	31,378	76.9	
Yes	2,213	4.3	375	16.9	1,838	83.1		1,932	4.5	513	26.6	1,419	73.4	

CCI							<.0001							<.0001
0	27,250	52.8	3,763	13.8	23,487	86.2		22,397	52.4	4,827	21.6	17,570	78.4	
1	16,162	31.3	2,450	15.2	13,712	84.8		13,488	31.6	3,179	23.6	10,309	76.4	
2	6,033	11.7	990	16.4	5,043	83.6		5,028	11.8	1,362	27.1	3,666	72.9	
≥ 3	2,133	4.1	431	20.2	1,702	79.8		1,802	4.2	550	30.5	1,252	69.5	
Hypertension							0.0003							<.0001
No	37,212	72.1	5,377	14.4	31,835	85.6		30,371	71.1	6,885	22.7	23,486	77.3	
Yes	14,366	27.9	2,257	15.7	12,109	84.3		12,344	28.9	3,033	24.6	9,311	75.4	
Year of diagnosis							<.0001							<.0001
2004	9,408	18.2	1,601	17.0	7,807	83.0		6,362	14.9	1,838	28.9	4,524	71.1	
2005	9,873	19.1	1,435	14.5	8,438	85.5		6,583	15.4	1,582	24.0	5,001	76.0	
2006	7,610	14.8	1,125	14.8	6,485	85.2		5,400	12.6	1,317	24.4	4,083	75.6	
2007	5,624	10.9	759	13.5	4,865	86.5		4,360	10.2	990	22.7	3,370	77.3	
2008	4,976	9.6	725	14.6	4,251	85.4		4,435	10.4	951	21.4	3,484	78.6	
2009	4,673	9.1	667	14.3	4,006	85.7		4,772	11.2	1,075	22.5	3,697	77.5	
2010	3,254	6.3	401	12.3	2,853	87.7		4,192	9.8	783	18.7	3,409	81.3	
2011	2,040	4.0	289	14.2	1,751	85.8		2,400	5.6	508	21.2	1,892	78.8	
2012	1,418	2.7	239	16.9	1,179	83.1		1,411	3.3	320	22.7	1,091	77.3	
2013	1,118	2.2	149	13.3	969	86.7		1,264	3.0	284	22.5	980	77.5	
2014	744	1.4	103	13.8	641	86.2		774	1.8	146	18.9	628	81.1	
2015	585	1.1	97	16.6	488	83.4		527	1.2	90	17.1	437	82.9	
2016	237	0.5	41	17.3	196	82.7		217	0.5	30	13.8	187	86.2	
2017	18	0.0	3	16.7	15	83.3		18	0.0	4	22.2	14	77.8	
Total	**51,578**	**100.0**	**7,634**	**14.8**	**43,944**	**85.2**		**42,715**	**100.0**	**9,918**	**23.2**	**32,797**	**76.8**	

PCDMP, primary care-based chronic disease management program; CCI, Charlson comorbidity index
The analysis included only the examinations taken at the outpatient visit.

Appendix 9. General characteristics of study population with onset of cardiovascular complication according to participation in PCDMP

Variables	Composite of cardiovascular complication						
	Total		Yes		No		
	N	%	N	%	N	%	*p*-value
Participation of PCDMP							0.0728
Yes	3,222	33.3	839	26.0	2,383	74.0	
No	6,444	66.7	1,789	27.8	4,655	72.2	
Age							<.0001
19-39	1,158	12.0	199	17.2	959	82.8	
40-49	3,189	33.0	720	22.6	2,469	77.4	
50-59	3,636	37.6	1,087	29.9	2,549	70.1	
60-69	1,344	13.9	483	35.9	861	64.1	
≥ 70	339	3.5	139	41.0	200	59.0	
Sex							0.0271
Male	5,703	59.0	1,503	26.4	4,200	73.6	
Female	3,963	41.0	1,125	28.4	2,838	71.6	
Income							0.6881
High	3,790	39.2	1,012	26.7	2,778	73.3	
Middle	4,399	45.5	1,209	27.5	3,190	72.5	
Low	1,477	15.3	407	27.6	1,070	72.4	
Region							0.0061
Metropolitan	4,131	42.7	1,068	25.9	3,063	74.1	
City	2,554	26.4	688	26.9	1,866	73.1	
Other	2,981	30.8	872	29.3	2,109	70.7	
Medical insurance							0.1575
Self-employed insured	4,253	44.0	1,187	27.9	3,066	72.1	
Employee insured	5,413	56.0	1,441	26.6	3,972	73.4	
Disability							0.7174
No	9,233	95.5	2,507	27.2	6,726	72.8	
Yes	433	4.5	121	27.9	312	72.1	
CCI							<.0001
0	5,107	52.8	1,301	25.5	3,806	74.5	
1	3,039	31.4	848	27.9	2,191	72.1	
2	1,122	11.6	344	30.7	778	69.3	
≥ 3	398	4.1	135	33.9	263	66.1	

Hypertension							<.0001
No	6,956	72.0	1,713	24.6	5,243	75.4	
Yes	2,710	28.0	915	33.8	1,795	66.2	
Year of diagnosis							<.0001
2004	1,383	14.3	436	31.5	947	68.5	
2005	1,452	15.0	437	30.1	1,015	69.9	
2006	1,164	12.0	349	30.0	815	70.0	
2007	951	9.8	285	30.0	666	70.0	
2008	960	9.9	274	28.5	686	71.5	
2009	1,050	10.9	293	27.9	757	72.1	
2010	906	9.4	250	27.6	656	72.4	
2011	555	5.7	120	21.6	435	78.4	
2012	357	3.7	69	19.3	288	80.7	
2013	333	3.4	61	18.3	272	81.7	
2014	240	2.5	32	13.3	208	86.7	
2015	204	2.1	14	6.9	190	93.1	
2016	102	1.1	8	7.8	94	92.2	
2017	9	0.1	0	0.0	9	100.0	
Total	**9,666**	**100.0**	**2,628**	**27.2**	**7,038**	**72.8**	

PCDMP, primary care-based chronic disease management program; CCI, Charlson comorbidity index.

Appendix 10. General characteristics of study population with onset of microvascular complication according to participation in PCDMP

Variables	Composite of microvascular complication						
	Total		Yes		No		
	N	%	N	%	N	%	*p*-value
Participation of PCDMP							0.0364
Yes	3,222	33.3	1,028	31.9	2,194	68.1	
No	6,444	66.7	1,922	29.8	4,522	70.2	
Age							0.0060
19-39	1,158	12.0	341	29.4	817	70.6	
40-49	3,189	33.0	969	30.4	2,220	69.6	
50-59	3,636	37.6	1,163	32.0	2,473	68.0	
60-69	1,344	13.9	400	29.8	944	70.2	
≥ 70	339	3.5	77	22.7	262	77.3	
Sex							0.9827
Male	5,703	59.0	1,741	30.5	3,962	69.5	
Female	3,963	41.0	1,209	30.5	2,754	69.5	
Income							0.1285
High	3,790	39.2	1,112	29.3	2,678	70.7	
Middle	4,399	45.5	1,374	31.2	3,025	68.8	
Low	1,477	15.3	464	31.4	1,013	68.6	
Region							0.4910
Metropolitan	4,131	42.7	1,251	30.3	2,880	69.7	
City	2,554	26.4	765	30.0	1,789	70.0	
Other	2,981	30.8	934	31.3	2,047	68.7	
Medical insurance							0.0750
Self-employed insured	4,253	44.0	1,338	31.5	2,915	68.5	
Employee insured	5,413	56.0	1,612	29.8	3,801	70.2	
Disability							0.6809
No	9,233	95.5	2,814	30.5	6,419	69.5	
Yes	433	4.5	136	31.4	297	68.6	
CCI							0.7703
0	5,107	52.8	1,579	30.9	3,528	69.1	
1	3,039	31.4	906	29.8	2,133	70.2	
2	1,122	11.6	342	30.5	780	69.5	
≥ 3	398	4.1	123	30.9	275	69.1	

Hypertension							0.0547
No	6,956	72.0	2,162	31.1	4,794	68.9	
Yes	2,710	28.0	788	29.1	1,922	70.9	
Year of diagnosis							<.0001
2004	1,383	14.3	484	35.0	899	65.0	
2005	1,452	15.0	467	32.2	985	67.8	
2006	1,164	12.0	405	34.8	759	65.2	
2007	951	9.8	294	30.9	657	69.1	
2008	960	9.9	284	29.6	676	70.4	
2009	1,050	10.9	357	34.0	693	66.0	
2010	906	9.4	277	30.6	629	69.4	
2011	555	5.7	145	26.1	410	73.9	
2012	357	3.7	87	24.4	270	75.6	
2013	333	3.4	66	19.8	267	80.2	
2014	240	2.5	42	17.5	198	82.5	
2015	204	2.1	33	16.2	171	83.8	
2016	102	1.1	8	7.8	94	92.2	
2017	9	0.1	1	11.1	8	88.9	
Total	**9,666**	**100.0**	**2,950**	**30.5**	**6,716**	**69.5**	

PCDMP, primary care-based chronic disease management program; CCI, Charlson comorbidity index.

Appendix 11. Results of Cox proportional hazard model for onset of diabetes complication

Variables	Composite of diabetes complication	
	HR	95% CI
Participation of PCDMP		
Yes	1.00	(0.94 - 1.06)
No	1.00	
Age		
19-39	1.00	
40-49	1.18	(1.06 1.31)
50-59	1.37	(1.24 - 1.53)
60-69	1.49	(1.31 - 1.68)
≥ 70	1.54	(1.28 - 1.85)
Sex		
Male	1.00	
Female	1.00	(0.94 - 1.06)
Income		
High	1.00	
Middle	1.07	(1.00 - 1.14)
Low	1.05	(0.97 - 1.15)
Region		
Metropolitan	1.00	
City	1.03	(0.96 - 1.10)
Other	1.10	(1.03 - 1.18)
Medical insurance		
Self-employed insured	1.00	
Employee insured	0.97	(0.92 - 1.03)
Disability		
No	1.00	
Yes	1.02	(0.89 - 1.17)
CCI		
0	1.00	
1	1.02	(0.96 - 1.09)
2	1.03	(0.94 - 1.13)
≥ 3	1.15	(1.00 - 1.32)

Hypertension		
No	1.00	
Yes	0.99	(0.93 - 1.06)
Year of diagnosis		
2004	1.00	
2005	0.92	(0.83 - 1.02)
2006	0.94	(1.84 - 1.04)
2007	0.86	(0.77 - 0.97)
2008	0.85	(0.76 - 0.96)
2009	0.92	(0.82 - 1.03)
2010	0.80	(0.72 - 0.91)
2011	0.79	(0.68 - 0.92)
2012	1.01	(0.84 - 1.21)
2013	0.91	(0.74 - 1.11)
2014	0.92	(0.71 - 1.18)
2015	0.95	(0.71 - 1.28)
2016	0.69	(0.41 - 1.17)
2017	0.61	(0.09 - 4.31)

PCDMP, primary care-based chronic disease management program; HR, hazard ratio; CI, confidence interval; CCI, Charlson comorbidity index.

Appendix 12. Results of Cox proportional hazard model for onset of cardiovascular complication

Variables	Composite of cardiovascular complication	
	HR	95% CI
Participation of PCDMP		
Yes	0.92	(0.84 - 0.99)
No	1.00	
Age		
19-39	1.00	
40-49	1.32	(1.13 - 1.55)
50-59	1.79	(1.53 - 2.08)
60-69	2.23	(1.88 - 2.64)
≥ 70	2.77	(2.21 - 3.48)
Sex		
Male	1.00	
Female	0.93	(0.86 - 1.01)
Income		
High	1.00	
Middle	1.08	(1.00 - 1.18)
Low	1.08	(0.96 - 1.21)
Region		
Metropolitan	1.00	
City	1.05	(0.95 - 1.16)
Other	1.14	(1.04 - 1.25)
Medical insurance		
Self-employed insured		
Employee insured	0.96	(0.89 - 1.04)
Disability		
No	1.00	
Yes	0.92	(0.76 - 1.10)
CCI		
0	1.00	
1	1.06	(0.98 - 1.17)
2	1.12	(0.99 - 1.26)
≥ 3	1.23	(1.03 - 1.48)

Hypertension		
No	1.00	
Yes	1.15	(1.05 - 1.25)
Year of diagnosis		
2004	1.00	
2005	0.90	(0.79 - 1.03)
2006	0.87	(0.76 - 1.00)
2007	0.88	(0.76 - 1.02)
2008	0.82	(0.70 - 0.95)
2009	0.84	(0.72 - 0.97)
2010	0.75	(0.65 - 0.88)
2011	0.71	(0.58 - 0.87)
2012	0.84	(0.65 - 1.09)
2013	0.90	(0.69 - 1.18)
2014	0.80	(0.56 - 1.14)
2015	0.53	(0.31 - 0.91)
2016	0.76	(0.38 - 1.54)
2017	-	

PCDMP, primary care-based chronic disease management program; HR, hazard ratio; CI, confidence interval; CCI, Charlson comorbidity index.

Appendix 13. Results of Cox proportional hazard model for onset of microvascular complication

Variables	Composite of microvascular complication	
	HR	95% CI
Participation of PCDMP		
Yes	1.07	(0.99 - 1.16)
No	1.00	
Age		
19-39	1.00	
40-49	1.03	(0.91 - 1.16)
50-59	1.08	(0.96 - 1.22)
60-69	1.06	(0.91 - 1.24)
≥ 70	0.86	(0.67 - 1.12)
Sex		
Male	1.00	
Female	1.00	(0.92 - 1.08)
Income		
High	1.00	
Middle	1.09	(1.01 - 1.19)
Low	1.10	(0.99 - 1.23)
Region		
Metropolitan	1.00	
City	0.98	(0.89 - 1.07)
Other	1.04	(0.96 - 1.14)
Medical insurance		
Self-employed insured	1.00	
Employee insured	0.97	(0.90 - 1.05)
Disability		
No	1.00	
Yes	1.05	(0.89 - 1.25)
CCI		
0	1.00	
1	0.98	(0.90 - 1.06)
2	1.00	(0.89 - 1.12)
≥ 3	1.00	(0.83 - 1.21)

Hypertension		
No	1.00	
Yes	0.86	(0.79 - 0.94)
Year of diagnosis		
2004	1.00	
2005	0.91	(0.80 1.04)
2006	0.97	(0.85 - 1.11)
2007	0.85	(0.74 - 0.99)
2008	0.82	(0.71 - 0.95)
2009	1.00	(0.87 - 1.15)
2010	0.86	(0.74 - 1.00)
2011	0.87	(0.72 - 1.05)
2012	1.12	(0.89 - 1.41)
2013	0.93	(0.72 - 1.21)
2014	1.02	(0.75 - 1.04)
2015	1.26	(0.88 - 1.80)
2016	0.74	(0.37 - 1.50)
2017	1.45	(0.20 - 10.32)

PCDMP, primary care-based chronic disease management program; HR, hazard ratio; CI, confidence interval; CCI, Charlson comorbidity index.

Appendix 14. General characteristics of study population hospitalized for cardiovascular complication according to participation in PCDMP

Variables	Cardiovascular complication hospitalization						
	Total		Yes		No		
	N	%	N	%	N	%	*p*-value
Participation of PCDMP							0.0003
Yes	3,222	33.3	197	6.1	3,025	93.9	
No	6,444	66.7	527	8.2	5,917	66.2	
Age							<.0001
19-39	1,158	12.0	44	3.8	1,114	12.5	
40-49	3,189	33.0	173	5.4	3,016	33.7	
50-59	3,636	37.6	307	8.4	3,329	37.2	
60-69	1,344	13.9	142	10.6	1,202	13.4	
≥ 70	339	3.5	58	17.1	281	3.1	
Sex							<.0001
Male	5,703	59.0	483	8.5	5,220	58.4	
Female	3,963	41.0	241	6.1	3,722	41.6	
Income							0.2773
Low	1,477	15.3	113	7.7	1,364	15.3	
Middle	4,399	45.5	347	7.9	4,052	45.3	
High	3,790	39.2	264	7.0	3,526	39.4	
Region							0.2128
Metropolitan	4,131	42.7	287	6.9	3,844	43.0	
City	2,554	26.4	200	7.8	2,354	26.3	
Other	2,981	30.8	237	8.0	2,744	30.7	
Medical insurance							0.2954
Self-employed insured	4,253	44.0	332	7.8	3,921	43.8	
Employee insured	5,413	56.0	392	7.2	5,021	56.2	
Disability							0.9156
No	9,233	95.5	691	7.5	8,542	95.5	
Yes	433	4.5	33	7.6	400	4.5	
CCI							0.4860
0	5,107	52.8	394	7.7	4,713	52.7	
1	3,039	31.4	212	7.0	2,827	31.6	
2	1,122	11.6	91	8.1	1,031	11.5	
≥ 3	398	4.1	27	6.8	371	4.1	

Hypertension							<.0001
No	6,956	72.0	449	6.5	6,507	72.8	
Yes	2,710	28.0	275	10.1	2,435	27.2	
Year of diagnosis							<.0001
2004	1,383	14.3	147	10.6	1,236	13.8	
2005	1,452	15.0	151	10.4	1,301	14.5	
2006	1,164	12.0	104	8.9	1,060	11.9	
2007	951	9.8	80	8.4	871	9.7	
2008	960	9.9	66	6.9	894	10.0	
2009	1,050	10.9	76	7.2	974	10.9	
2010	906	9.4	47	5.2	859	9.6	
2011	555	5.7	30	5.4	525	5.9	
2012	357	3.7	13	3.6	344	3.8	
2013	333	3.4	5	1.5	328	3.7	
2014	240	2.5	2	0.8	238	2.7	
2015	204	2.1	2	1.0	202	2.3	
2016	102	1.1	1	1.0	101	1.1	
2017	9	0.1	0	0.0	9	0.1	
Total	**9,666**	**100.0**	**724**	**7.5**	**8,942**	**100.0**	

PCDMP, primary care-based chronic disease management program; CCI, Charlson comorbidity index.

Appendix 15. General characteristics of study population hospitalized for microvascular complication according to participation in PCDMP

Variables	Microvascular complication hospitalization						
	Total		Yes		No		
	N	%	N	%	N	%	*p*-value
Participation of PCDMP							<.0001
Yes	3,222	33.3	68	2.1	3,154	97.9	
No	6,444	66.7	257	4.0	6,187	96.0	
Age							0.0015
19-39	1,158	12.0	60	5.2	1,098	94.8	
40-49	3,189	33.0	105	3.3	3,084	96.7	
50-59	3,636	37.6	121	3.3	3,515	96.7	
60-69	1,344	13.9	31	2.3	1,313	97.7	
≥ 70	339	3.5	8	2.4	331	97.6	
Sex							0.7965
Male	5,703	59.0	194	3.4	5,509	96.6	
Female	3,963	41.0	131	3.3	3,832	96.7	
Income							0.0534
Low	1,477	15.3	58	3.9	1,419	96.1	
Middle	4,399	45.5	160	3.6	4,239	96.4	
High	3,790	39.2	107	2.8	3,683	97.2	
Region							0.0055
Metropolitan	4,131	42.7	118	2.9	4,013	97.1	
City	2,554	26.4	81	3.2	2,473	96.8	
Other	2,981	30.8	126	4.2	2,855	95.8	
Medical insurance							0.0006
Self-employed insured	4,253	44.0	173	4.1	4,080	95.9	
Employee insured	5,413	56.0	152	2.8	5,261	97.2	
Disability							0.6707
No	9,233	95.5	312	3.4	8,921	96.6	
Yes	433	4.5	13	3.0	420	97.0	
CCI							0.0077
0	5,107	52.8	195	3.8	4,912	96.2	
1	3,039	31.4	82	2.7	2,957	97.3	
2	1,122	11.6	29	2.6	1,093	97.4	
≥ 3	398	4.1	19	4.8	379	95.2	

Hypertension							0.1625
No	6,956	72.0	245	3.5	6,711	96.5	
Yes	2,710	28.0	80	3.0	2,630	97.0	
Year of diagnosis							<.0001
2004	1,383	14.3	70	5.1	1,313	94.9	
2005	1,452	15.0	60	4.1	1,392	95.9	
2006	1,164	12.0	45	3.9	1,119	96.1	
2007	951	9.8	36	3.8	915	96.2	
2008	960	9.9	29	3.0	931	97.0	
2009	1,050	10.9	35	3.3	1,015	96.7	
2010	906	9.4	25	2.8	881	97.2	
2011	555	5.7	11	2.0	544	98.0	
2012	357	3.7	4	1.1	353	98.9	
2013	333	3.4	3	0.9	330	99.1	
2014	240	2.5	2	0.8	238	99.2	
2015	204	2.1	4	2.0	200	98.0	
2016	102	1.1	1	1.0	101	99.0	
2017	9	0.1	0	0.0	9	100.0	
Total	**9,666**	**100.0**	**325**	**3.4**	**9,341**	**96.6**	

PCDMP, primary care-based chronic disease management program; CCI, Charlson comorbidity index.

Appendix 16. Results of Cox proportional hazard model for diabetes-related hospitalization

Variables	Diabetes-related hospitalization	
	HR	95% CI
Participation of PCDMP		
Yes	0.66	(0.57 - 0.76)
No	1.00	
Age		
19-39	1.00	
40-49	1.01	(0.80 1.27)
50-59	1.42	(1.14 - 1.78)
60-69	1.78	(1.37 - 2.30)
≥ 70	3.38	(2.42 - 4.72)
Sex		
Male	1.00	
Female	0.67	(0.58 - 0.76)
Income		
High	1.00	
Middle	1.29	(1.13 - 1.48)
Low	1.31	(1.09 - 1.58)
Region		
Metropolitan	1.00	
City	1.19	(1.02 - 1.39)
Other	1.28	(1.11 - 1.48)
Medical insurance		
Self-employed insured	1.00	
Employee insured	0.87	(0.77 - 0.99)
Disability		
No	1.00	
Yes	0.92	(0.68 - 1.24)
CCI		
0	1.00	
1	0.84	(0.73 - 0.97)
2	0.93	(0.76 - 1.13)
≥ 3	0.92	(0.67 - 1.26)

Hypertension		
No	1.00	
Yes	1.14	(0.99 - 1.31)
Year of diagnosis		
2004	1.00	
2005	0.85	(0.70 1.04)
2006	0.77	(0.62 - 0.95)
2007	0.74	(0.59 - 0.93)
2008	0.59	(0.46 - 0.76)
2009	0.67	(0.53 - 0.85)
2010	0.46	(0.35 - 0.61)
2011	0.52	(0.37 - 0.72)
2012	0.51	(0.32 - 0.82)
2013	0.32	(0.17 - 0.60)
2014	0.22	(0.08 - 0.58)
2015	0.51	(0.22 - 1.14)
2016	0.45	(0.11 - 1.81)
2017	-	

PCDMP, primary care-based chronic disease management program; HR, hazard ratio; CI, confidence interval; CCI, Charlson comorbidity index.

Appendix 17. Results of Cox proportional hazard model for cardiovascular complication hospitalization

Variables	Cardiovascular complication hospitalization	
	HR	95% CI
Participation of PCDMP		
Yes	0.71	(0.61 - 0.84)
No	1.00	
Age		
19-39	1.00	
40-49	1.46	(1.05 - 2.04)
50-59	2.49	(1.81 - 3.44)
60-69	3.50	(2.47 - 4.97)
≥ 70	7.42	(4.90 - 11.25)
Sex		
Male	1.00	
Female	0.54	(0.46 - 0.64)
Income		
High	1.00	
Middle	1.25	(1.07 - 1.47)
Low	1.22	(0.98 - 1.53)
Region		
Metropolitan	1.00	
City	1.17	(0.97 - 1.40)
Other	1.14	(0.96 - 1.36)
Medical insurance		
Self-employed insured	1.00	
Employee insured	0.94	(0.81 - 1.09)
Disability		
No	1.00	
Yes	0.90	(0.63 - 1.28)
CCI		
0	1.00	
1	0.87	(0.73 - 1.03)
2	0.96	(0.76 - 1.22)
≥ 3	0.79	(0.54 - 1.18)

Hypertension		
No	1.00	
Yes	1.24	(1.05 - 1.46)
Year of diagnosis		
2004	1.00	
2005	0.94	(0.75 - 1.18)
2006	0.75	(0.58 - 0.96)
2007	0.69	(0.53 - 0.91)
2008	0.57	(0.43 - 0.76)
2009	0.62	(0.47 - 0.82)
2010	0.39	(0.28 - 0.54)
2011	0.50	(0.34 - 0.74)
2012	0.47	(0.27 - 0.84)
2013	0.22	(0.09 - 0.53)
2014	0.15	(0.04 - 0.63)
2015	0.23	(0.06 - 0.92)
2016	0.32	(0.04 - 2.27)
2017	-	

PCDMP, primary care-based chronic disease management program; HR, hazard ratio; CI, confidence interval; CCI, Charlson comorbidity index.

Appendix 18. Results of Cox proportional hazard model for microvascular complications hospitalization

Variables	Microvascular complication hospitalization	
	HR	95% CI
Participation of PCDMP		
Yes	0.52	(0.40 - 0.68)
No	1.00	
Age		
19-39	1.00	
40-49	0.61	(0.44 - 0.84)
50-59	0.65	(0.47 - 0.89)
60-69	0.50	(0.32 - 0.80)
≥ 70	0.61	(0.28 - 1.31)
Sex		
Male	1.00	
Female	1.00	(0.79 - 1.25)
Income		
High	1.00	
Middle	1.26	(0.99 - 1.62)
Low	1.44	(1.04 - 2.00)
Region		
Metropolitan	1.00	
City	1.12	(0.85 - 1.49)
Other	1.50	(1.16 - 1.93)
Medical insurance		
Self-employed insured	1.00	
Employee insured	0.73	(0.58 - 0.91)
Disability		
No	1.00	
Yes	0.92	(0.53 - 1.61)
CCI		
0	1.00	
1	0.77	(0.59 - 1.00)
2	0.74	(0.50 - 1.09)
≥ 3	1.37	(0.85 - 2.21)

Hypertension		
No	1.00	
Yes	0.93	(0.71 - 1.22)
Year of diagnosis		
2004	1.00	
2005	0.82	(0.58 1.15)
2006	0.77	(0.53 - 0.11)
2007	0.77	(0.52 - 0.16)
2008	0.63	(0.41 - 0.98)
2009	0.71	(0.47 - 1.07)
2010	0.59	(0.37 - 0.93)
2011	0.51	(0.27 - 0.97)
2012	0.41	(0.15 1.13)
2013	0.34	(0.11 1.08)
2014	0.39	(0.10 - 1.60)
2015	1.27	(0.46 - 3.51)
2016	0.78	(0.11 - 5.65)
2017	-	

PCDMP, primary care-based chronic disease management program; HR, hazard ratio; CI, confidence interval; CCI, Charlson comorbidity index.

Korean Abstract (국문요약)

일차의료 기반 만성질환관리제가 제 2 형 당뇨병 환자의 진료의 질과 건강결과에 미치는 영향

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서론: 만성질환 발병률이 날로 증가함에 따라 당뇨병 환자 등 만성질환 고위험군의 조기예측·예방·관리를 위한 실질적인 정책수립은 국민건강증진을 위해 필수적이다. 만성질환관리에서 일차의료의 역할이 강조되면서 만성질환자의 건강증진 및 합병증 예방을 목적으로 일차의료 기반 만성질환관리제가 도입되었다. 이 제도는 당뇨병 환자의 건강행태 및 건강결과 개선에 효과가 있다고 보고되고 있지만 대부분 단기적인 평가이므로 장기적인 관점에서 평가될 필요가 있다. 이 연구는 일차의료 환경에서 만성질환관리의 효과성을 확인하기 위하여 2012 년 4 월부터 시행된 일차의료 기반 만성질환관리제가 당뇨병 환자의 진료의 질과 건강결과에 미치는 영향을 종합적으로 살펴보고자 하였다.

연구방법: 이 연구는 국민건강보험공단 표본 코호트 2002 년부터 2019 년까지의 자료를 사용하였으며, 합병증이 없는 제 2 형 당뇨병 신규환자를 선정하여 분석하였다. 일차의료 기반 만성질환관리제에 참여한 환자를 실험군으로, 참여하지 않은 환자를 대조군으로 설정하였다. 성향점수 매칭법(Propensity score matching)을 사용하여 실험군과 대조군을 1:2 비율로 매칭하였다. 일차의료 기반 만성질환관리제에 등록 시점이 환자마다 다르기

때문에 실험군의 등록 날짜를 매칭된 대조군에 동일하게 적용하였다. 주요 종속변수는 진료의 질 지표인 진료지속성과 검사 수행률과 건강결과 지표인 당뇨합병증 발생, 당뇨합병증 관련 입원, 사망률이었다. 진료의 질 지표에 대해서는 이중차이분석(difference-in-difference) 방법을 사용하여 분석하였으며, 제도 참여 전후 실험군과 비교군의 교호작용항을 확인하였다. 건강결과 지표에 대해서는 콕스 비례위험 회귀분석(Cox proportional hazard model)을 사용하여 분석하였다.

연구결과: 일차의료 기반 만성질환관리제에 참여한 실험군은 진료지속성이 상대적으로 유의하게 증가하였다(exp(β)=1.15, 95% CI: 1.06-1.24, p-value=0.0009). 당화혈색소검사, 지질검사, 안저검사를 모두 받은 정기검진 수행률도 비교군에 비해 증가한 것으로 확인됐으나, 통계적으로 유의하지는 않았다(exp(β)=1.08, 95% CI: 0.98-1.18, p-value=0.1029). 하위그룹 분석을 통해 세 가지 검사 각각의 차이를 분석한 결과 세 검사 모두 실험군이 대조군에 비해 검사 수행률이 약간 증가하였으나 당화혈색소검사를 제외하고 유의하지 않았다(당화혈색소검사, exp(β)=1.10, 95% CI: 1.03-1.18, p-value=0.0038 지질검사, exp(β)=1.05, 95% CI: 0.98-1.11, p-value=0.1765; 안저검사, exp(β)=1.02, 95% CI: 0.95-1.11, p-value=0.0.5548). 전체 당뇨합병증 발생의 경우 실험군과 비교군이 유의한 차이를 보이지 않았으나, 실험군에서 심혈관계 합병증 발생 위험이 크게 감소하였다(HR: 0.91, 95% CI: 0.84-1.06). 반면 미세혈관계 합병증의 발생 위험은 비교군 대비 실험군이 더 높았으나 통계적으로 유의하지 않았다(HR: 1.07, 95% CI: 0.99-1.16). 특히 당뇨합병증으로 인한 입원은 실험군이 비교군에 비해 30% 이상 낮았다(전체 당뇨합병증 입원, HR: 0.66, 95% CI: 0.57-0.76, 심혈관계 합병증 입원, HR: 0.71, 95% CI: 0.61-0.84, 미세혈관계 합병증 입원, HR: 0.52, 95% CI: 0.40-0.68). 사망 위험도 실험군이 대조군에 비해 0.51 배 더 낮았다(HR: 0.51, 95% CI: 0.40-0.64).

결론: 일차의료 기반 만성질환관리제도는 제 2 형 당뇨환자의 진료의 질과 건강결과를 개선시키는 데 긍정적인 영향을 미쳤다. 특히 진료지속성을 높이고 심혈관계 합병증 발생 위험과 합병증으로 인한 입원을 크게 감소시켜 만성질환관리제도의 도입 목적에 따른 효과가 있음을 확인할 수 있었다. 이 연구는 일차의료 기반 만성질환관리제의 효과를 장기적 관점에서 종합적으로 평가했다는 점에서 의의가 있다. 분절적으로 시행되고 있는

일차의료 기반 만성질환관리제를 개편하고 확립해 나가는 과정에서 이 연구가 정책적 근거를 제시할 수 있기를 기대한다.

핵심어: 일차의료, 만성질환관리제, 진료의 질, 건강결과, 제 2 형 당뇨병