# A Predictive Model of Prediabetics' Awareness of Diabetes Education and its Effects in the Republic of Korea: A Pilot Study Using a System Dynamics Method[**]

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**Abstract**

*This study was conducted to evaluate the preventive effect of self-management related to the awareness of prediabetes on the progression from prediabetes to diabetes and to analyze the ripple effect of prevention according to an increase in the patient's awareness of the diagnosis. To analyze the effects of awareness and self-care for people with prediabetes, an SFD was built based on the causal relation of each of the variables. As a result of raising the rate of awareness of prediabetes and participation in diabetes prevention education, the incidence of diabetes was declined. Such model-based insights may help organizations within the country, which have policies targeting prediabetes, to identify more effective public health strategies and also to interact more effectively with one another on diabetes projects.*

**Keyword**: Prediabetes Awareness, Diabetes Prevention Education, Self-Care, System Dynamics, Simulation Modeling

## 1. Introduction

Prediabetes is a medical condition in which one's blood glucose levels are higher than the normal range, but not high enough for a diagnosis of diabetes (Centers for Disease Control Prevention [CDC], 2014). Prediabetes has recently received attention due to the high risk for development of diabetes (Eldin, Emara, and Shoker, 2008). The probability of the progression to diabetes is 5 to 15 times greater in individuals with prediabetes than in those with normal glucose levels (Heianza et al., 2011; Rasmussen et al., 2008). In other words, for both prediabetes and diabetes, it is vitally important to increase awareness of the possibility of diabetic complications to prevent their incidence and eventually to improve the quality of

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life for a group of people at high risk.

In South Korea, ongoing projects have focused only on people with diabetes. South Korea's national projects on diabetes care are currently conducted for two different purposes. The "Chronic Disease Management System" under the National Health Insurance Service takes advantage of clinics and projects that manage diabetes and hypertension to register them as public health centers supervised by the Korea Centers for Disease Control and Prevention, which is involved with patients in intensive care. Despite these national efforts, rates of diabetes awareness and control have remained unchanged for the last five years, but the prevalence of diabetes is growing (Korean Diabetes Association [KDA], 2013) . Thus, the need to expand the target to the management of people with prediabetes has been raised (Chun, 2011). Awareness of prediabetes is defined as the patient being aware of their prediabetes or of having been diagnosed with the condition by a doctor. Efforts must be made to promote awareness of prediabetes, (Li et al., 2013) yet due to a lack of research on prediabetes in South Korea, even the term "awareness of prediabetes" is unfamiliar.

In contrast, from 1989, the CDC in the United States has supported the nationwide implementation of the Diabetes Prevention Program and the National Diabetes Education Program to change lifestyles at the community level by encouraging modest weight loss, good dietary habits, regular physical activity, and the ability to react for those at high risk for developing type 2 diabetes. Prevention and management of diabetes through these programs have already begun. In addition, by performing a national survey and research on the awareness of prediabetes, the U.S. has a system in place for the early-stage screening and management of those with prediabetes (Eldin *et al.*, 2008).

It is essential to examine or estimate the level of awareness to help in the planning of diabetes prevention. In South Korea, the data on public awareness of prediabetes is inadequate because few Korean publications address the condition. For this reason, considering the various causal variables, we should develop a model using system dynamics that can observe dynamic changes and then try to estimate them through simulation. In this study, we aimed to estimate the awareness of prediabetes and to develop and evaluate a model predicting the effect of education on people with prediabetes (Li et al., 2013).

## 2. Literature Review

### 2.1. Progression from prediabetes to diabetes

The population-based South Korea National Health and Nutrition Examination Survey (KHANES) suggested that 19.3% of South Korea adults over 30 years of age had prediabetes in 2011 based on fasting plasma glucose or hemoglobin A1c levels, but not including oral glucose tolerance test results. According to the CDC (2014), 86 million American adults—more than 1 in 3—have prediabetes. Bullard et al. reported an increase in the prevalence of prediabetes from 27.4% in 1999-2002 to 34.1% in 2007-2010, using National Health and Nutrition Examination Survey data.

If people with prediabetes do not seek treatment for or self-manage their condition, approximately 5–10% of them will progress to diabetes annually although the transition rate varies according to population characteristics and the criteria of prediabetes (Forouhi et al., 2007). In recent major studies, estimates of progression to diabetes have been similar: the

annualized incidence was 11% in the Diabetes Prevention Program Outcomes Study. According to an American Diabetes Association expert panel, up to 70% of patients with prediabetes will eventually progress to diabetes. In a Chinese diabetes prevention study, the 20-year cumulative incidence of diabetes was even higher (>90%) among controls with impaired glucose tolerance (Li et al., 2008).

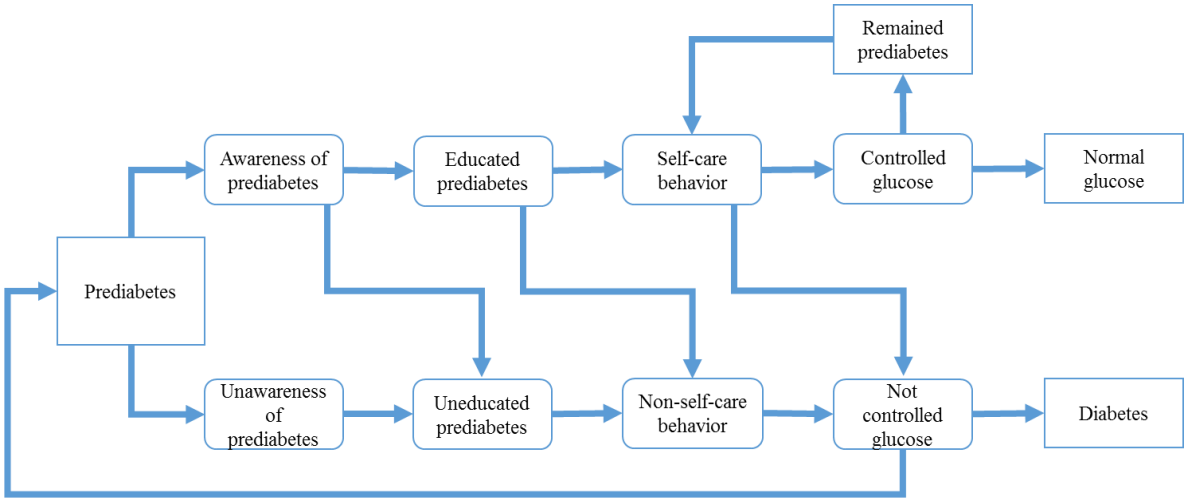
## 2.2. Awareness of prediabetes

Identifying people with prediabetes and instructing them about their increased risk for diabetes are the first steps in supporting them in making healthy lifestyle changes. Unlike people with diabetes, however, it is difficult for those with prediabetes to even be aware that they have the condition, given its uncommon manifestation. For this reason, only about 7% of people with prediabetes were aware that they had prediabetes during the 2005–2006 period (Geiss et al., 2010). To examine recent changes in the awareness of prediabetes among adults aged ≥20 years, the CDC reported that approximately 11% of those with prediabetes were aware of their condition. In the U.S., people with prediabetes, including those with regular access to health care, might benefit from efforts aimed at making them aware that they are at increased risk for developing type 2 diabetes and that they can reduce that risk with self-management. Consequently, these efforts are necessary to raise awareness.

## 2.3. Education on self-care among those with prediabetes

The Diabetes Prevention Program has shown that people with prediabetes can often prevent or delay diabetes if they lose a modest amount of weight by cutting fat and caloric intake and increasing their physical activity. Losing just 5 to 7% of body weight prevents or delays diabetes by nearly 60% (Knowler et al., 2002). Likewise, these lifestyle changes can contribute to the partial prevention of prediabetes. These people need education on the prevention of diabetes or prediabetes to recognize the importance of self-care. Many nurses perform a variety of educational tasks that encourage those with prediabetes to learn about diabetes and change their habits or behavior appropriately.

**Figure 1. Flow diagram of prediabetes**



## 3. Methods

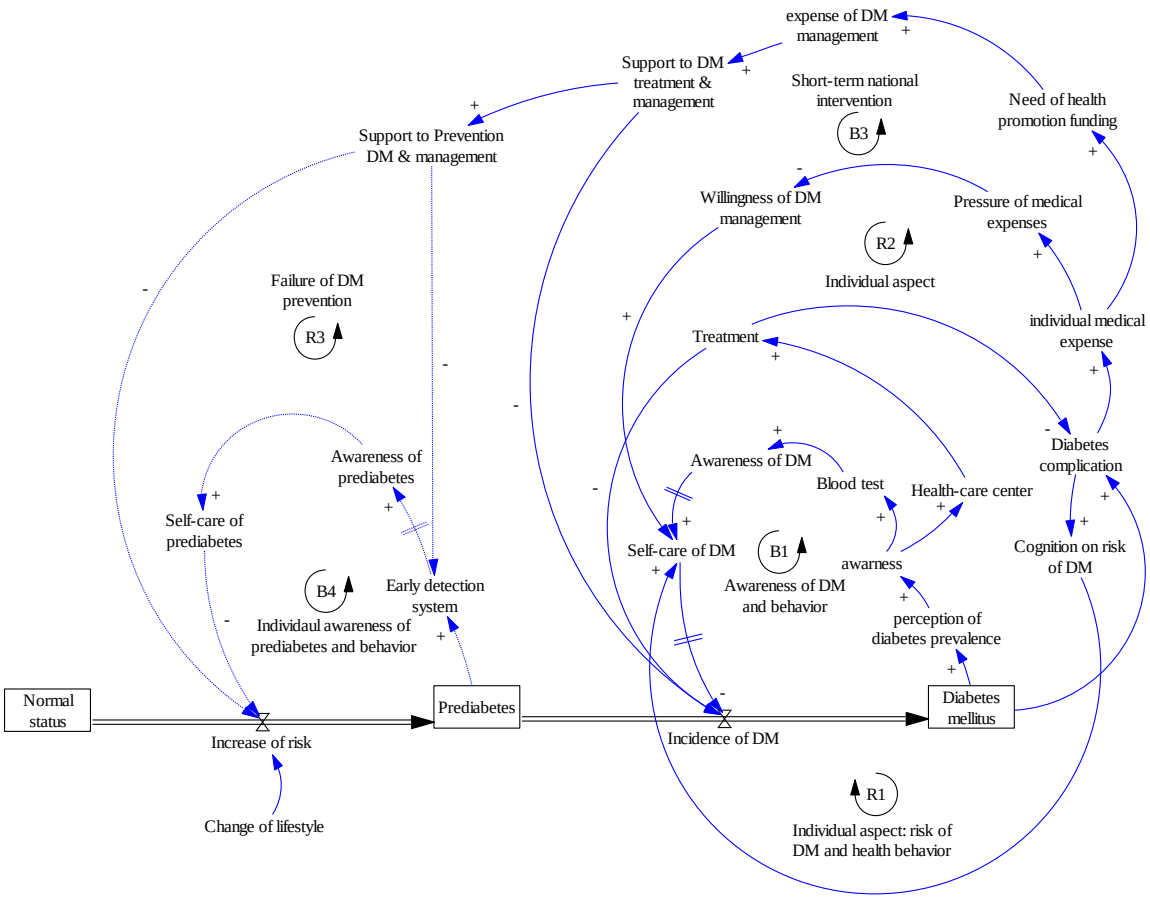
### 3.1. Objective of the model

The goals of this model were to evaluate the preventive effect of self-management related to the awareness of prediabetes on the progression from prediabetes to diabetes and to analyze the ripple effect of prevention according to an increase in the patient's awareness of the diagnosis. Figure 1. is a flow diagram of prediabetes.

### 3.2. Dynamic Hypothesis

We have also developed a dynamic hypothesis, represented in a causal loop diagram (CLD) shown below in Figure 2, which demonstrates our hypothesized understanding of the ripple effect of increasing Prediabetics' Awareness we discuss in this study. And the causal loop diagram shows three balancing loops and three reinforcing loops.

**Figure 2 Awareness of Prediabetes Causal Loop Diagram**



### 3.3. Designing the stock and flow diagram (SFD)

This study identified and confirmed the association between the awareness of prediabetes and various factors using an SFD. We used KHANES data from 2013 to quantify the model and the effects of the simulated intervention. The model was built using Powersim Studio 10.0.

**Table 1. Description of main variable**

| Variable | Description |
|---|---|
| Diabetes (D) | A condition in which too much sugar, or glucose, remains in the blood because the body doesn't properly convert it to energy. |
| Prediabetes (PD) | A condition in which one's blood sugar level is higher than normal, but not yet high enough to be classified as type 2 diabetes. |
| Normal glucose state (NG) | A condition in which remaining one's blood sugar level within the normal range. |
| Awareness of prediabetes (APD) | Being aware about oneself's prediabetic condition. |
| Unawareness of prediabetes (UAPD) | Not being aware about oneself's prediabetic condition. |
| Educated APD | Persons' (APD) participation in diabetes prevention education including self-care. |
| self-care behavior (SCB) | The engagement in self-care or self-management for diabetes prevention. |
| Non-self-care behavior (NSCB) | No engagement in self-care or self-management for diabetes. |
| D with SCB | Progression from PD to D despite of engagement in self-care. |
| D because of NSCB | Progression from PD to D because of no engagement in self-care. |

## 4. Results

### 4.1. The stock and flow diagram

To estimate the effects of self-care for people with prediabetes, an SFD was built based on the causal relation of each of the variables. Figure 2. depicts a stock and flow structure related to the awareness and self-care of those with prediabetes.

Patients with prediabetes were classified as individuals who either did or did not perform blood glucose testing according to their economic status and accessibility to medical services under the supposition that people who tested their blood glucose levels were aware that they had prediabetes. In this study, we assumed that all patients who checked their glucose levels were aware of their diagnosis of prediabetes. Those who were aware of their prediabetes typically received diabetes self-care education, and they transferred it into action or self-care

activities involving dietary change, weight loss, and regular physical activity. The model showed that among the participants in self-care, 4.8 cases per 100 person-years would progress to diabetes, and annually, X% of the participants in self-care were able to achieve normal glucose regulation, with the rest of the participants remaining in a prediabetic state. However, some of the individuals who did not take care of their prediabetes developed diabetes, and the remainder with prediabetes flowed into the stock of "people with prediabetes" on the SFD.

## 4.2. Simulation of the scenarios

### 4.2.1. Scenario 1: Implementing policies to increase the awareness of prediabetes

We ran the above-developed model using this scenario with respect to a change in new-onset diabetes in the prediabetic population. The intervention of raising the rate of awareness of prediabetes by 10% was input into the model. As a result of this intervention, more people with prediabetes are effectively managed. Consequently, the portion of people with diabetes onset decreased from the baseline level of 82.6% to 77.8% in 40 time steps. Consequently, a reduction in the onset of prediabetes could then lead to a reduction in its prevalence.

### 4.2.2. Scenario 2: Implementing diabetes prevention education policies

This scenario was designed to explore how the intervention of increasing the rates of participation in diabetes prevention education targeting people with prediabetes would affect or reduce the incidence of diabetes. As a result of this intervention, the rate of activation of self-care behavior increases. Also, self-care behavior allows greater recovery from prediabetes back to a normal glycemic level, and the prevalence of prediabetes thus declines. Consequently, the portion of people with new-onset diabetes was declined.

**Figure 3. The structure of the model**

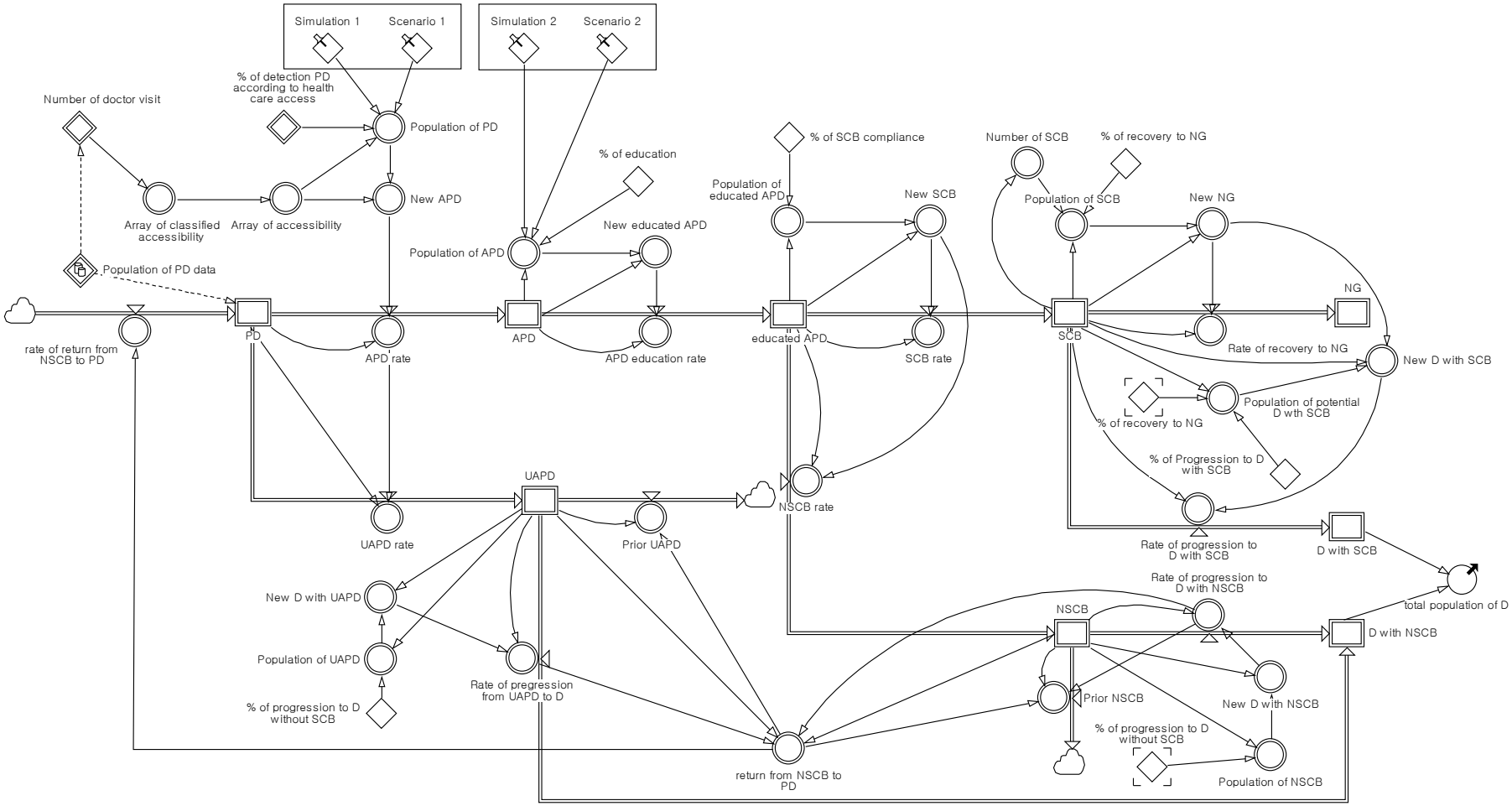


**Figure 4. The result of simulation1: Raising rate of awareness by 10%**

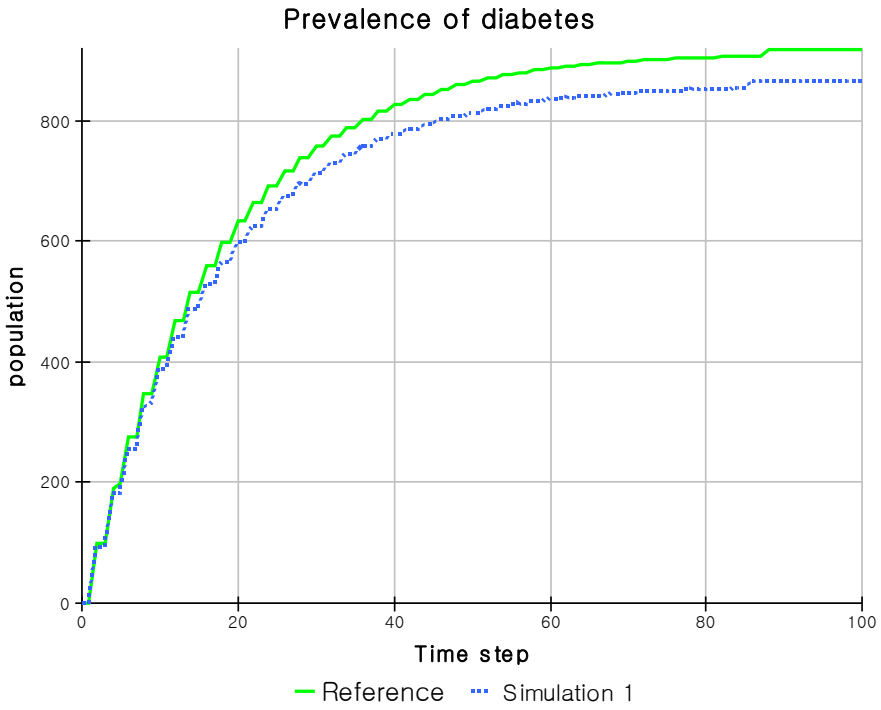
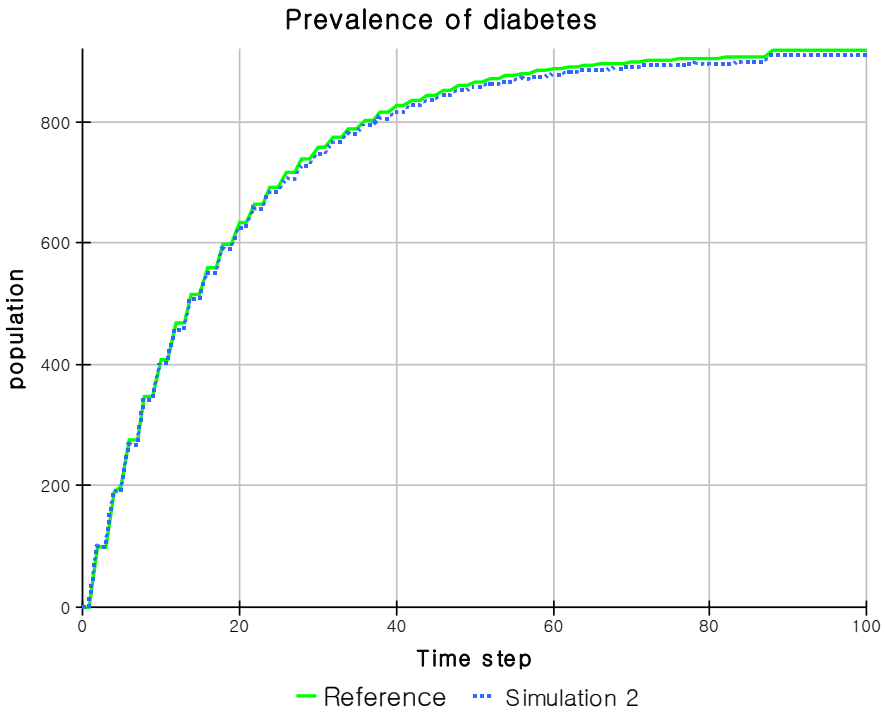



**Figure 5. The result of simulation2: Raising rate of education participation**



## 5. Conclusion

There are two contributions made by this paper. First, it is estimated that a policy of raising the awareness of prediabetes would reduce the incidence of diabetes by 5.8% in 40 time steps, suggesting that early identification of prediabetes may provide at-risk individuals with the chance to make long-term lifestyle changes that could prevent future progression to diabetes. Thus, further studies and examinations are needed to detect and support people with prediabetes. Second, with an intervention policy on diabetes prevention education that targets people with prediabetes, the model estimated that those with prediabetes could avoid developing diabetes. This result indicates that diabetes education is a critical element of care for all at-risk people. Thus, there is a need to increase the efforts of community-based health care providers as educators.

This study is significant because the model enabled the estimation of rates of awareness of prediabetes using empirical data in South Korea and captured the uncertainty of change in the process from prediabetes to diabetes. The analyses presented indicate the dynamic estimation of the effects of self-care on diabetes prevention that one may draw from simulation experiments. Such model-based insights may help organizations within the country, which have policies targeting prediabetes, to identify more effective public health strategies and also to interact more effectively with one another on diabetes projects.

Because this was a pilot study, the model is limited in that it cannot be used to actually establish policies. Further research should be undertaken in future studies to expand the model by adding various settings, such as physiological, environmental, individual, and socioeconomic factors, to assess the effects of simulator training when this training is embedded in ordinary teaching and to allow the model to be run for longer times and with more repetitions.

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