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Five-Year Trajectory about Screening for Complication of Diabetic Kidney Disease and Cardiovascular Disease Mortality: Focusing on Regional Difference

Jina Han Gawon Kim Yeong Jun Ju Soon Young Lee

Department of Preventive Medicine and Public Health, Ajou University School of Medicine, Suwon, Republic of Korea

Keywords
Diabetes complication · Trends · Regional variation · Cardiovascular disease mortality · Community health survey

Abstract
Introduction: The overall screening rate for complication of diabetic kidney disease is improving; however, regional variations are increasing. It is necessary to identify regions vulnerable to change and understand their characteristics. ***Methods:*** Group-based trajectory analysis was used to derive patterns of change in screening rate for complication of diabetic kidney disease in 244 regions, utilizing data from the Korea Community Health Survey between 2015 and 2019. An analysis of variance test was used to examine the differences in regional characteristics and cardiovascular disease (CVD) within each change pattern. ***Results:*** The change patterns in screening rates for complication of diabetic kidney disease were classified into four groups: high and rapidly increasing (group 1, 15.2%), steady high (group 2, 8.2%), moderate and increasing (group 3, 52.9%), and low and slightly increasing (group 4, 23.8%). Group 4 had many rural areas and worse socioeconomic status, health care systems, health behaviors, and diabetes management. These regions exhibited higher CVD mortality rates. ***Conclusions:*** Regions where the screening rate for complication of diabetic kidney disease did not improve compared to other regions were vulnerable not only in socioeconomic status, health care system, and health behavior, but also in disease management. This suggests the need for local and environmental support, as well as aggressive health service interventions in relatively vulnerable areas.

Introduction

According to the International Diabetes Federation, in 2019, among adults aged 20–79 years worldwide, 463 million had diabetes, accounting for approximately 9.3% of the global adult population. The number of individuals with diabetes is expected to increase to approximately 700 million by 2045. Diabetes accounts for 11.3% of deaths worldwide, half of which include patients aged <60 years, making it the leading cause of premature death [1]. The prevalence of diabetes among adults aged ≥30 years in Korea is 15.9% for men and 11.8% for women, with one in

Jina Han and Gawon Kim contributed equally to this work.

karger@karger.com
www.karger.com/kbr

Correspondence to:
Soon Young Lee, solee@aumc.ac.kr

seven adults having diabetes and the population with diabetes and fasting glucose disorder reaching 14.4 million [2].

Patients with diabetes with complications such as stroke, myocardial infarction, peripheral vascular disease, complications of diabetes retinopathy, kidney disease, and neuropathy have reduced quality of life, increased disease burden, and premature death risk [3, 4]. Twenty to forty percent of patients with diabetes develop complication of diabetes kidney disease, which is the most common cause of end-stage renal disease [5]. End-stage renal disease in patients with diabetes increases cardiovascular disease risk. Albuminuria, a characteristic complication of diabetes kidney disease, is an indicator of CVD (cardiovascular disease) risk and an indicator of kidney disease occurrence [6, 7]. Therefore, annual kidney disease screening tests are recommended to manage diabetes effectively [8, 9].

Self-management of blood sugar is essential with diabetes. To overcome the problems associated with a treatment-oriented personal management system, a community-based chronic disease management model was proposed [10]. This led to a community-centered management system, which seeks to establish a diabetes management process within the community, introduces incentives to promote change, and provides services for continuous treatment and management. As chronic disease management is no longer an individual problem, communities have tried to manage it [11, 12].

The median screening rate for complication of diabetic kidney disease in 253 regions nationwide increased from 38.1% in 2015 to 50.9% in 2019 in Korea. However, the regional variation (%*p* = difference between maximum and minimum) increased from 68.2%p to 75.0%p during the same period [13]. While the overall screening rate for complication of diabetic kidney disease is improving, the regional variation is increasing.

To alleviate regional disparities, it is necessary to examine how the indicators are changing and whether the changes are meaningful, rather than simply monitoring and confirming the region's status [14]. Trajectory analysis is useful for visualizing various trends over a certain period and identifying clusters that follow similar patterns over time. Researchers have applied this approach to the causes and consequences of trajectories [15, 16]. Therefore, we aimed to identify patterns of change in screening rates for complication of diabetic kidney disease in each region, explore the characteristics of these patterns of change, and examine their influence on cardiovascular disease mortality.

Methods

Data Source

The study units for this ecological study were 244 regions. Regional data were collected from various sources from 2015 to 2019 (online suppl. Table S1; for all online suppl. material, see https://doi.org/10.1159/000538244). According to the classification of administrative districts in Korea, it is divided into 253 regions. However, some regions were integrated or divided during the study period, or the collection units of some data sources were not matched, leading to the integration or exclusion of value for those regions.

The main data source for this study was the KCHS (Korea Community Health Survey). In 2008, the KDCA (Korea Disease Control and Prevention Agency) initiated the first nationwide survey, the KCHS, to provide data that could be used to plan, implement, monitor, and evaluate community health promotion and disease prevention programs. This cross-sectional, community-based survey was conducted with 253 community health centers, 35 community universities, and 1,500 interviewers. Approximately 220,000 people complete the survey annually.

The survey population is defined as adults aged ≥19 years living within the jurisdiction of a community health center. According to the stratification of the survey population, the first stratum is Dong/Eup-Myeon (small administrative units), and the second stratum is housing units (apartments and houses). The sample design aims to produce accurate statistics using a small-scale sample survey with the help of stratification of the survey population.

The KCHS standardized questionnaire covers a variety of topics related to health behaviors and prevention and is administered by trained interviewers. Quality control of the KCHS was improved by the introduction of computer-assisted personal interviews in 2010. The KCHS data allowed for a direct comparison of the differences in health issues among provinces and regions. Furthermore, provinces can use these data for their own cost-effective health interventions to improve health promotion and disease prevention [17].

Measurements

Outcome Variable: CVD Mortality

CVD mortality rate was calculated using raw data from the Cause of Death Statistics from the National Statistical Office. CVD mortality was defined as the proportion of those who died from diabetes (E10–E14), hypertensive disease (I10–I13), ischemic heart disease (I20–I25), other heart diseases (I26–I51), or cerebrovascular disease (I60–I69) among the regional population. CVD mortality was standardized by sex and age. The outcome variable was the average standardized mortality per 100,000 population calculated for each year during the period of 2015–2019.

Interest Variable: Screening Rate for Complication of Diabetic Kidney Disease

The following question was asked: "In the last year, have you received a microurine test (microalbuminuria test) other than a stick urine test, to check whether a diabetes complication has occurred in the kidneys (complication of diabetes nephropathy)?" Screening rate for complication of diabetic kidney disease is

Table 1. Optimal trajectory model about trajectory of screening rate for complication of diabetic kidney disease in 2015–2019

	N (%)	Trajectory shape	Estimate	*p* value
Group 1	37 (15.2)	Linear	5.528[a]	0.003
Group 2	20 (8.2)	Intercept	51.188[b]	<0.001
Group 3	129 (52.9)	Quadratic	3.302[a]	<0.001
Group 4	58 (23.8)	Quadratic	1.547[a]	<0.001
Model fitting	BIC = −4,772.6/AIC = −4,749.9			

The optimal trajectory model was derived using group-based trajectory analysis, and the BIC and AIC values used as model fitting indices were presented. The number of regions corresponding to each group and the trajectory shape were shown. [a, b] The slope was estimated for the linear or quadratic model, and the intercept was estimated for the intercept model, separately.

defined as the proportion of people who responded "yes" to this question among those aged ≥30 years who were diagnosed with diabetes by a physician. This study used a standardized rate by sex and age.

Covariate: Regional Characteristics

Regional characteristics in 2015 included region type (metrocity, urban, rural), socioeconomic status factors (sex ratio, one-person household rate, and financial independence rate), health care system factors (health care budget rate, number of doctors, unmet need care rate, and rate of pre-hospital delay within the golden hours), health behavior factors (current smoking, binge drinking, smoking cessation attempt, alcohol abstinence, walking practice, health examination, and obesity rates), and morbidity and illness management factors (diagnosis of hypertension, diagnosis of diabetes, education of diabetes management, and treatment of diabetes rates).

Statistical Analyses

In the first analysis, the PROC TRAJ command was used for trajectory analysis in SAS. The PROC TRAJ is an SAS procedure for the GBTM (group-based trajectory modeling) of longitudinal data. This analysis to identify clusters following a similar progression of complication of diabetes kidney disease screening rate in from 2015 to 2019. This model applies nonparametric maximum likelihood estimation to identify the trajectory of behaviors during the study periods [18, 19]. The optimal fit model was based on the BIC (Bayesian information criterion), AIC (Akaike information criterion), average posterior probability of group members of each latent class for each participant (>0.7), and clinical plausibility. To obtain the best model with the number of distinct trajectories satisfying several assumptions, we estimated the appropriate trajectory model of screening rate for complication of diabetic kidney disease by increasing the number of clusters from three to five, assuming a flat/intercept, linear, and quadratic pattern variation in the complication of diabetes kidney disease screening rate during the study period. The BIC and AIC were used as fitness indices to determine the number of trajectories. Both indices simultaneously consider explanatory power and simplicity. Contrary to other statistical programs, the larger the value, the better the fit in the SAS procedure. Each participant was assigned to the group with the highest probability [20].

After obtaining the trajectories, χ^2 and analysis of variance tests were performed to examine regional characteristics. Furthermore, the effects of trajectories of screening rate for complication of diabetic kidney disease on CVD mortality were assessed using linear regression, adjusted for regional characteristics. Multicollinearity issues were not observed. The analyses were performed using SAS version 9.4 (Institute, Inc., Cary, NC, USA). All other statistical tests were two-sided, and statistical significance was set at $p < 0.05$.

Results

Identification of Trajectory of Screening Rate for Complication of Diabetic Kidney Disease

Table 1 presents the optimal model of the screening rate for complication of diabetic kidney disease. Changes in BIC and AIC for some trajectory fitting models are presented in online supplementary Figure S2. A four-group GBTM was considered optimal. The four groups are as follows: group 1, defined as a high and rapidly increasing trend (15.2%; complication of diabetes kidney disease screening rate increased from 46.0% to 66.4% during the study period); group 2, defined as a steady high trend (8.2%; complication of diabetes kidney disease screening rate maintained approximately 50% during the study period); group 3, defined as a moderate and increasing trend (52.9%; complication of diabetes kidney disease screening rate increased from 38.5% to 51.6% during the study period); and group 4, defined as a low and slightly increasing trend (23.8%; complication of diabetes kidney disease screening rate increased from 28.9% to 35.3% during the study period) (Fig. 1).

Regional Characteristics According to Trajectories of Screening Rate for Complication of Diabetic Kidney Disease

Table 2 compares the regional characteristics of different trajectory of screenomg rate for complication of diabetic kidney disease. Regions in group 4 were more rural and had a higher rate of one-person household rate (32.5%), rate of pre-hospital delay within golden hours (32.0%), current smoking rate (22.7%), binge drinking rate (19.6%), and obesity rate (26.6%) than did regions in group 1. These regions also had a lower financial independence rate (18.0%), health care budget rate (2.2%), smoking cessation attempt rate (30.5%), walking

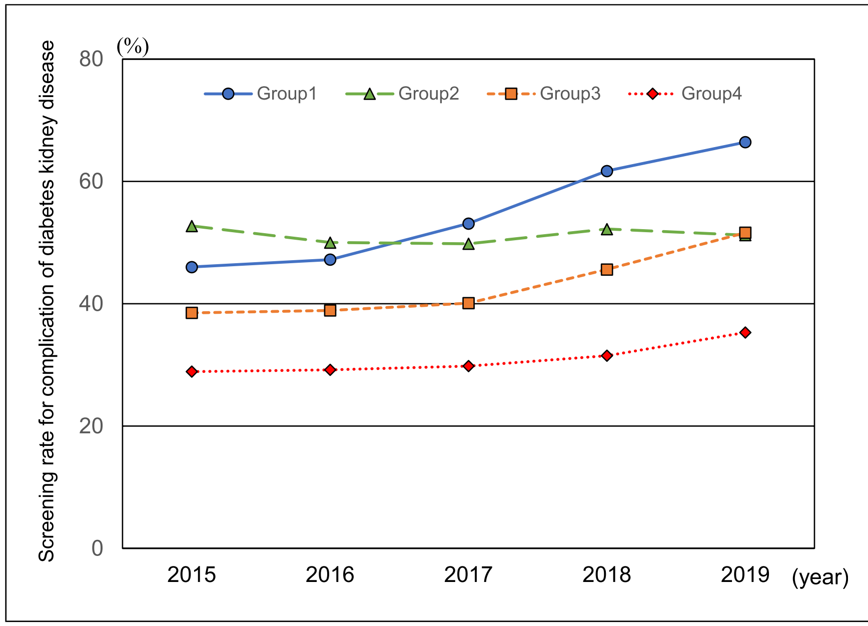

Fig. 1. Trajectory of screening rate for complication of diabetic kidney disease in 2015–2019. The data were analyzed by group-based trajectory analysis, and four groups were derived through a model fitting process to find the optimal solution: high and rapidly increasing trend (group 1), steady high trend (group 2), moderate and increasing trend (group 3), and low and slightly increasing trend (group 4).

practice rate (35.7%), and health examination rate (70.1%). There were no significant differences in hypertension and diabetes diagnoses. Regions in group 4 had lower rates of diabetes education management (22.6%) and higher rates of diabetes treatment (84.2%).

Different Trajectory of Screening Rate for Complication of Diabetic Kidney Disease and CVD Mortality

Figure 2 shows the standardized mortality rates of CVD with different trajectory of screening rate for complication of diabetic kidney disease. Mortality due to CVD was the highest in group 4 (84.3 per 100,000 persons) and the lowest in groups 1 and 2 (74.4 per 100,000 persons) ($p < 0.001$). Table 3 shows the linear regression model for trajectory of screening rate for complication of diabetic kidney disease on CVD mortality. CVD mortality rates were 4.251 and 6.003 in group 3 and group 4, respectively, and were higher than those in group 1 ($p = 0.060$ and $p = 0.004$, respectively).

Discussion

The study used the 2015–2019 KCHS to identify the change patterns of screening rates for complication of diabetic kidney disease in the region over 5 years and to understand the region's characteristics. The KCHS produces health statistics that are representative of the region and comparable across regions by standardizing the survey system and building networks within the community [21]. Using these regionally representative data, the optimal model was derived by statistically validating the pattern of change in screening rate for complication of diabetic kideney disease over the past 5 years. Changes in screening rates for complications of diabetic kidney disease in the 244 regions of Korea were classified into four patterns of change.

Groups 1 and 2, with high rates, increased more rapidly or remained at a high level, while group 4, with low rates, increased slightly, but the increase in the screening rate for the complication of diabetic kiney disease was very small compared with the other groups. The overall rate of screening for complication of diabetic kidney disease is improving due to the health care segment such as advances in diagnostic and treatment technologies [22], a nationwide chronic disease management system [23], and diversification of disease management information delivery channels such as health apps and social networking sites [24]. The study found that in group 4, however, which is vulnerable to change, it has not kept up with the rate of increase in other regions, resulting in worsening regional variation.

The regions in group 4 are mostly rural, have a high per capita ratio, and have very low levels of local financial independence, welfare budget, and access to health care compared to the other groups. The main findings of the present study are in accordance with those of previous studies that have reported disparities in diabetes management in rural areas or in districts with population decline [25–27]. This shows that access to the health care segment alone is not enough to reduce inequalities, but also a structure that is vulnerable to change.

Table 2. Community characteristics according to trajectory of screening rate for complication of diabetic kidney disease between 2015 and 2019

	Group 1 (37 regions)	Group 2 (20 regions)	Group 3 (129 regions)	Group 4 (58 regions)	*p* value
Region type					
Metrocity	26 (70.3)	10 (50.0)	49 (38.0)	7 (12.1)	<0.001
Urban	10 (27.0)	7 (35.0)	45 (34.9)	8 (13.8)	
Rural	1 (2.7)	8 (15.0)	35 (27.1)	43 (74.1)	
Socioeconomic status factors					
Sex ratio	99.6±4.0	99.9±3.9	101.2±5.1	100.2±6.9	0.337
One-person household	26.7±6.3	27.3±4.1	28.8±4.9	32.5±4.3	<0.001
Financial independence rate	39.8±13.9	32.8±16.1	27.1±13.4	18.0±9.8	<0.001
Health care system factors					
Budget of health care	3.1±0.9	2.7±0.7	2.4±0.7	2.2±0.7	<0.001
Number of doctor (per 1,000 persons)	2.6±1.6	2.9±2.1	2.5±2.1	2.3±2.8	0.816
Unmet need care	11.5±3.3	13.2±3.8	12.4±3.4	12.2±4.9	0.455
Pre-hospital delay within golden hours	0.2±1.0	8.9±16.3	12.5±22.8	32.0±27.4	<0.001
Health behaviors factors					
Current smoking	21.1±3.4	22.2±2.2	22.3±2.5	22.7±2.6	0.038
Binge drinking	17.7±3.0	18.7±2.7	19.4±3.3	19.6±4.2	0.045
Smoking cessation attempt	37.6±6.0	38.3±8.3	35.3±8.1	30.5±10.3	<0.001
Alcohol abstinence	14.6±3.9	14.1±4.0	14.0±4.2	13.6±4.5	0.721
Walking practice	49.2±8.5	42.0±13.7	40.0±11.1	35.7±11.4	<0.001
Health examination	76.0±2.9	74.6±5.1	74.9±3.9	70.1±6.4	<0.001
Obese	25.3±2.2	26.2±2.7	26.7±2.7	26.6±2.9	0.033
Morbidity and diabetes management factors					
Diagnosis of hypertension	19.6±2.0	15.6±2.3	19.3±2.2	19.3±2.7	0.834
Diagnosis of diabetes	7.8±1.2	7.8±1.2	7.9±1.2	7.7±1.2	0.676
Education of diabetes management	39.3±14.3	34.8±15.9	28.1±15.9	22.6±13.6	<0.001
Treatment of diabetes	81.6±6.8	81.9±4.7	85.6±5.6	84.2±5.9	0.001

Values are expressed as mean ± SD for continuous variables and percentage for categorical variables. *p* value was analyzed for continuous variables by ANOVA, for categorical variables by χ^2 test.

The World Health Organization proposes the concept of health equity as the absence of inequitable and avoidable differences in health between populations. Many of the behavioral, environmental, and social determinants of health that contribute to inequalities are modifiable but cannot be changed in the short term, so a step-by-step approach is needed [28, 29]. Continuous accumulation of scientific evidence, establishment of collaborative systems in various segments outside of health, setting of policy goals to address health disparities at the root, social consent, and sustained political attention are required [30–33].

It is also necessary to strengthen the autonomy and accountability of local health projects, as top-down approaches can lead to fragmented service delivery by providers in different units, making it difficult to achieve a targeted and integrated approach to chronic disease management, which requires linkages with other health services such as smoking cessation, sobriety, exercise, and nutrition. Localized approaches should be developed that reflect local demographic characteristics and socio-cultural contexts [34].

The results showed that in groups 3 and 4, which are vulnerable to changes in screening rates for complication of diabetic kidney disease, treatment rates were high, disease management education was low, and CVD mortality was high. To date, the treatment rate for diabetes has reached 90%, but the rate of diabetes management education or screening for diabetes complications has not caught up [13]. Diabetes management is still dominated by treatment-oriented approaches, such as prescribing medication in a health care setting.

Diabetes is not a clinical or individual problem, but a problem that must be solved together from a local public health perspective. It is a disease that requires not only

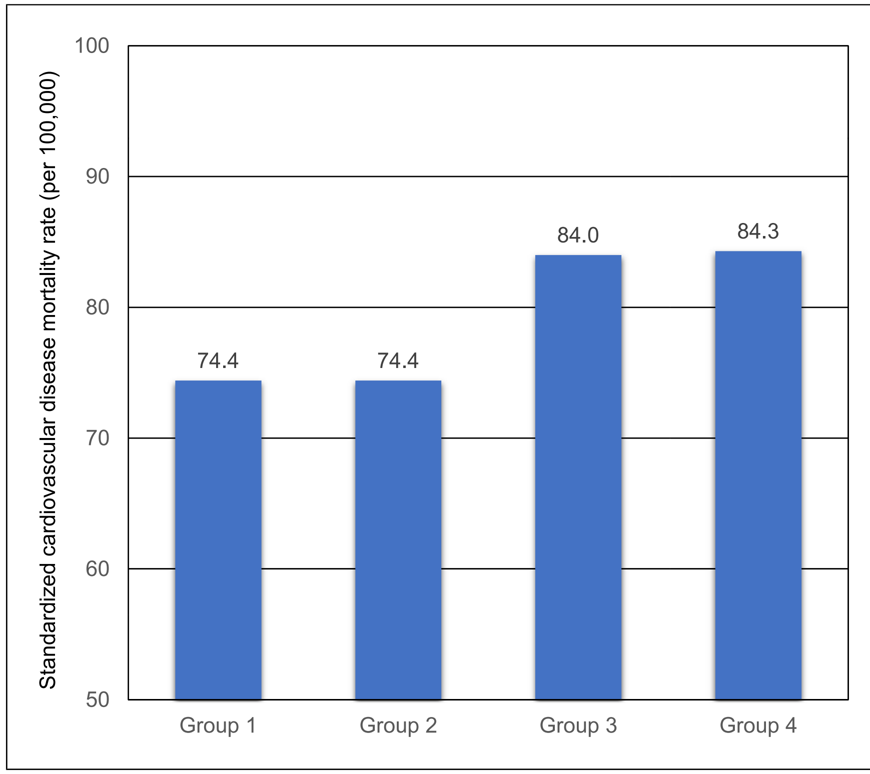

Fig. 2. Cardiovascular disease mortality by group of the screening rate for complication of diabetic kidney disease. Analysis of variance tests were used to examine differences in regional characteristics and cardiovascular disease in each group, and there were significant differences between the groups (F-value = 9.34, $p < 0.001$). Group 1, high and rapidly increasing trend; group 2, steady high trend; group 3, moderate and increasing trend; group 4, low and slightly increasing trend.

drug treatment but also self-management. Due to the aging of the population and the development of diagnostic and treatment technologies, the timing of diabetes diagnosis is accelerating, and the period to manage diabetes is lengthening, making it essential to develop more active self-management habits [35, 36]. The subject of disease management is the patient. The community has a role to play in reducing the burden of patients trying to manage their disease [30]. It is important to prevent situations where diabetes complications cannot be managed because of the patient's situation. It is necessary to combine personal and public responsibility [37, 38].

Socioeconomic status is a major barrier to self-management [39] and is a consistently strong predictor of the risk of complications and death [40]. Income level was related to the cost of screening for complications, education level was related to understanding of diabetes complications and self-management, and unsafe work environment was related to cancellation of visits to medical institutions for economic and time reasons. Lack of access to medical services is reported to reduce access to early screening and to have a negative impact on health outcomes related to blood glucose and diabetes. Economic and physical accessibility for the treatment or management of patients with diabetes in the community should be improved.

Disease management education plays a very important role in understanding the need for screening for complications of diabetic disease and increasing screening rates for complications of diabetic disease. Therefore, intensive support is needed to help patients acquire information and skills for self-management in the early stages of diagnosis. Therefore, to effectively promote the prevention and management of chronic diseases in communities, it is necessary to link public health centers with primary medical institutions [10, 11]. Thus, practical alternatives, such as active promotion, support, and strengthening of networks between primary medical institutions and public health centers, should be enforced.

Furthermore, screening for complication of diabetic kidney disease annually implies that patients with diabetes continuously monitor and manage their disease. Although complication of diabetic kidney disease directly affects death, mortality rate can be reduced by recognizing not only complication of diabetes kidney disease but also diabetes through regular monitoring and continuous management [8, 41]. CVD mortality rate was the lowest in groups 1 and 2 and highest in groups 3 and 4, suggesting that screening for complication of diabetic kidney disease directly or indirectly influences CVD mortality.

Table 3. Regression analyses of community characteristics and trajectory of screening rate for complication of diabetic kidney disease for age-standardized cardiovascular disease mortality

	Regression coefficients		
	parameter estimate	*t* value	*p* value
Region type			
Metrocity	Ref		
Urban	−3.571	−1.67	0.097
Rural	−6.638	−2.48	0.014
Socioeconomic status factors			
Sex ratio	0.347	2.05	0.041
One-person household	−0.042	−0.21	0.835
Financial independence rate	−0.180	−2.60	0.010
Health care system factors			
Budget of health care	0.855	0.80	0.423
Number of doctor (per 1,000 persons)	−0.189	−0.48	0.632
Unmet need care	−0.277	−1.22	0.226
Pre-hospital delay within golden hours	−0.082	−1.87	0.064
Health behaviors factors			
Current smoking	1.544	4.91	<0.001
Binge drinking	0.107	0.45	0.654
Smoking cessation attempt	0.032	0.33	0.739
Alcohol abstinence	−0.092	−0.43	0.671
Walking practice	−0.055	−0.72	0.473
Health examination	0.042	0.21	0.836
Morbidity and diabetes management factors			
Obese	0.396	1.09	0.278
Diagnosis of hypertension	−1.376	−3.42	0.001
Diagnosis of diabetes	0.765	1.08	0.282
Education of diabetes management	−0.144	−2.86	0.005
Treatment of diabetes	0.074	0.59	0.557
Trajectory of screening rate for complication of diabetes kidney disease			
Group 1	Ref		
Group 2	−2.632	−0.85	0.394
Group 3	4.251	1.82	0.060
Group 4	6.003	2.06	0.004

Parameter estimate and *t* value were calculated using multivariate linear regression analysis, entering all above variables with region type, socioeconomic status factors, health care system factors, health behaviors factors, mobility and diabetes management factors, and trajectory of screening rate for complication of diabetes kidney disease. Group 1, high and rapidly increasing trend; group 2, steady high trend; group 3, moderate and increasing trend; group 4, low and slightly increasing trend.

This study has several limitations. First, there is an ecological fallacy in studying regional units. Second, the indicators used were calculated from a community-based survey of residents. There is a concern that the research findings may be underestimated due to selection bias in the people who responded to the survey. Finally, there was ambiguity in defining which of the four groups in the screening rates for complication of diabetic kidney disease was better. By deriving the change patterns and characteristics of screening rate for complication of diabetic kidney disease, however, it is possible to present a basis for implementing policies and projects within the community to alleviate regional disparities. Furthermore, the change pattern observed in group 4, which was mainly discussed in this study, was clearly different from that of the other groups and could be defined as the group showing the worst change.

Conclusion

This study is significant as it takes a step further than previous studies on regional disparity and reveals regional differences in the patterns of change in indicators. In order to improve the overall health level of the population by improving the management and treatment rate of patients with diabetes, active identification of causes and efforts to solve problems by targeting areas with consistently poor levels are required to resolve problems in these areas.

Statement of Ethics

Ethical approval and consent were not required as this study was based on publicly available data. The Korea Community Health Survey (KCHS) data are openly published. Participants' data were fully anonymized prior to release. Our study was excluded from the review list pursuant to Article 2.2 of the Enforcement Rule of Bioethics and Safety Act in Korea since the data was exempted from the Institutional Review Board (IRB) review. All procedures performed in studies that involved human participants were in accordance with the ethical standards of the national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Conceptualization: Han J., Kim G., and Lee S.Y. Data curation: Han J. and Ju Y.J. Formal analysis, methodology, and writing – original draft: Han J. and Kim G. Project administration: Lee S.Y. Visualization: Kim G. and Ju Y.J. Writing – review and editing: Ju Y.J. and Lee S.Y.

Data Availability Statement

All data generated or analyzed during this study are included in this article. Further inquiries can be directed to the corresponding author.

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