A study of glycemic control among community-dwelling patients with diabetes and its association with common complications based on latent class analysis -postprint

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Abstract

Background Community-based health management for patients with diabetes still faces many challenges, and it remains difficult to effectively improve glycemic control rates. Exploring factors influencing blood glucose control, in order to delay or reverse the occurrence and progression of diabetic complications, is of great significance. Objective To explore the specific latent class characteristics and influencing factors of blood glucose control among community-dwelling patients with diabetes, as well as its association with common complications, so as to provide a scientific basis for the management of community-based diabetic patients. Methods From March 2023 to April 2024, a questionnaire survey was conducted among 417 patients with diabetes from Qintong Town in Jiangyan District of Taizhou City, Jishi Town of Jingjiang City, and Chenbao Town of Xinghua City, to collect data on demographic characteristics, health education, disease conditions, and health management. Latent class analysis was used to classify patients according to their blood glucose control status. Multivariate logistic regression analysis was then employed to investigate the prevalence of complications and the influencing factors among diabetic patients in different blood glucose control classes. Results According to the latent class analysis, 417 patients with diabetes were divided into three classes: Class 1: elderly-low health literacy group, 181 cases (43.41%); Class 2: middle-aged-moderate health literacy group, 158 cases (37.89%); Class 3: younger-high health literacy group, 78 cases (18.71%). There were statistically significant differences among the three groups in the prevalence of hypertension, stroke, and neuropathy (all $P<0.05$); the proportions of comorbid hypertension, stroke, and neuropathy in the elderly-low health literacy group and the middle-aged-moderate health literacy group were all higher than those in the younger-

high health literacy group (all P<0.01). Multivariate logistic regression analysis showed that, compared with the younger-high health literacy group, having an education level of junior high school or above (OR=0.256, 95%CI=0.129-0.510, P<0.001; OR=0.355, 95%CI=0.181-0.696, P=0.003) and having more than three measures for blood glucose control (OR=0.272, 95%CI=0.148-0.499, P<0.001; OR=0.542, 95%CI=0.298-0.986, P=0.045) were protective factors for glycemic control in the elderly-low health literacy group and the middle-aged-moderate health literacy group. Being unmarried/divorced/widowed in the middle-aged-moderate health literacy group (OR=3.303, 95%CI=1.208-9.035, P=0.020) was a risk factor affecting blood glucose control in patients with diabetes. Conclusion Community-dwelling patients with diabetes in Taizhou present distinct latent classes of blood glucose control. The distributions of comorbid hypertension, stroke, and neuropathy differ across latent classes. Influencing factors include glycated hemoglobin, age, BMI, disease duration, health literacy, educational level, marital status, and measures for blood glucose control. Targeted, category-specific interventions should be implemented according to the characteristics of different patient classes.

Full Text

A Study of Glycemic Control and Its Association with Common Complications in Community-Dwelling Diabetic Patients Based on Latent Class Analysis

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Abstract

Background: Community-based health management of diabetic patients continues to face numerous challenges, with glycemic control rates remaining difficult to improve effectively. Investigating factors that influence glycemic control is crucial for delaying or reversing the development of diabetic complications.

Objective: To explore the specific categorical characteristics of glycemic control, influencing factors, and their associations with common complications among community-dwelling diabetic patients, thereby providing a scientific basis for community diabetes management.

Methods: From March 2023 to April 2024, questionnaire surveys were administered to 417 diabetic patients across three county-level regions in Taizhou City—Qintong Town in Jiangyan District, Jishi Town in Jingjiang City, and Chenbao Town in Xinghua City—to collect data on demographic characteristics, health education, disease status, and health management. Latent class analysis was

employed to categorize patients' glycemic control status, while multivariate logistic regression analysis was used to examine the prevalence of complications and associated factors across different glycemic control categories.

Results: Based on latent class analysis, the 417 diabetic patients were classified into three distinct groups: Class 1, the older-age/low-health-literacy group (n=181, 43.41%); Class 2, the middle-age/moderate-health-literacy group (n=158, 37.89%); and Class 3, the younger-age/high-health-literacy group (n=78, 18.71%). Significant differences were observed among the three groups in the prevalence of hypertension, stroke, and neuropathic complications (P<0.05). Both the older-age/low-health-literacy and middle-age/moderate-health-literacy groups exhibited significantly higher rates of comorbid hypertension, stroke, and neuropathy compared to the younger-age/high-health-literacy group (all P<0.01). Multivariate logistic regression analysis revealed that, relative to the younger-age/high-health-literacy group, having a junior high school education or above (OR=0.256, 95%CI=0.129-0.510, P<0.001; OR=0.355, 95%CI=0.181-0.696, P=0.003) and implementing more than three blood glucose control measures (OR=0.272, 95%CI=0.148-0.499, P<0.001; OR=0.542, 95%CI=0.298-0.986, P=0.045) were protective factors for glycemic control in the older-age/low-health-literacy and middle-age/moderate-health-literacy groups, respectively. Conversely, being unmarried/divorced/widowed (OR=3.303, 95%CI=1.208-9.035, P=0.020) was identified as a risk factor for glycemic control in the middle-age/moderate-health-literacy group.

Conclusion: Glycemic control among community-dwelling diabetic patients in Taizhou exhibits distinct categorical characteristics, with varying distributions of hypertension, stroke, and neuropathic complications across different latent classes. Key influencing factors include HbA1c levels, age, BMI, disease duration, health literacy, education level, marital status, and glycemic control measures. Targeted, category-specific interventions should be implemented based on the characteristic profiles of each patient group.

Keywords: Diabetes mellitus; Glycemic control; Latent class analysis

Introduction

Diabetes is estimated to be the eighth leading cause of death and disability worldwide. Substantial evidence indicates that diabetes prevalence continues to increase globally, with projections suggesting that over 1.31 billion people will be affected by 2050, representing a major public health challenge. Early identification and management of diabetic patients during the initial disease stages are critical for preventing and controlling complications, thereby reducing disability and premature mortality rates. In 2009, China incorporated diabetes patient health management into its National Essential Public Health Services Program, which has gradually improved control rates and helped curb the rapid

rise in cardiovascular mortality among urban and rural residents. However, these rates remain lower than those in Western countries, and community-based diabetes prevention and management continue to face significant challenges.

Chronic hyperglycemia-induced vascular complications constitute the primary cause of mortality and morbidity in diabetic patients, making effective glycemic control essential for delaying or reversing chronic complications and improving quality of life. Glycemic control status varies among patients due to numerous factors including age, BMI, lifestyle, family history, complications, and disease duration. Previous research has predominantly focused on examining the impact of single factors on glycemic control, with limited investigation of comprehensive categorical analyses involving multiple factors. This study employs latent class analysis (LCA), a statistical method that classifies populations based on individual response patterns across multiple observed indicators, to categorize glycemic control status among community-dwelling diabetic patients in three county-level cities of Taizhou. The aim is to comprehensively understand community diabetes management status and explore specific categorical characteristics, influencing factors, and relationships with complications to provide scientific evidence for community-based diabetes management.

Methods

Study Subjects

From March 2023 to April 2024, we enrolled 417 diabetic patients from three villages each in Qintong Town (Jiangyan District), Jishi Town (Jingjiang City), and Chenbao Town (Xinghua City) in Taizhou. Inclusion criteria were: (1) permanent residents in the survey areas (Chinese citizens who had lived in the county/district for $ $6 months during the past 12 months); and (2) type 2 diabetes patients registered in the health records of primary healthcare institutions. Exclusion criteria included: (1) individuals with mobility difficulties or communication barriers; (2) residents living in functional areas (defined as closed or semi-closed areas serving specific non-residential purposes such as education, production, medical care, or military functions, where residents' identity, occupation, or lifestyle patterns are highly uniform and directly dependent on the core function, such as community elderly care centers or nursing homes), or those registered in the community but not residing there; and (3) patients with severe mental disorders, heart failure, or cancer. All participants provided informed consent.

Sample size calculation: Based on a reported glycemic control rate of 33.1% among diabetic patients, with a 5% margin of error, the required sample size was calculated using the formula $n = \frac{Z^2 \times p \times (1-p)}{E^2}$, where n represents sample size, p is the expected population rate, Z is the standard normal distribution value, and E is the margin of error. This yielded a required sample size of approximately 340 participants; this study ultimately enrolled 417 subjects.

Methods

Questionnaire Survey A customized questionnaire was developed based on literature review, expert consultation, and the actual management conditions of diabetic patients in Taizhou communities. The survey collected data on demographic characteristics, health education, disease status, and health management. Demographic variables included gender, age, education level, marital status, occupation, annual household income, and family history of diabetes. Health education comprised 13 knowledge test questions (all related to common diabetes control knowledge). Disease status included presence of complications, complication types and severity, and diabetes detection method (medical consultation, physical examination, follow-up, screening, or other). Health management data included usual healthcare facility, referral status, glycemic control measures, medication/insulin adherence, blood glucose monitoring compliance, active monitoring of blood glucose at different times, and history of hypoglycemia.

Venous blood samples were collected from all 417 participants, and HbA1c levels were measured using chromatography.

Glycemic Control Standards According to the *National Guideline for Primary Diabetes Prevention and Management (2022)*, which establishes an HbA1c control target of <7% for type 2 diabetes in China, laboratory HbA1c values <7% were defined as good recent glycemic control, while HbA1c $ $7% indicated poor recent glycemic control.

Health Literacy Definition Health literacy categories were defined based on participants' responses to 13 health knowledge questions. The test had a total score of 13 points, with 1 point awarded for each correct answer and 0 for incorrect answers. A total score <8 was classified as good health literacy, while $ $8 indicated poor health literacy.

Latent Class Analysis Variable Selection and Grouping Eight manifest variables were selected for latent class analysis: HbA1c, age, BMI, health literacy, disease duration, family history, presence of complications, and history of hypoglycemia. After dichotomizing these variables (0,1), Mplus 8.3 software was used to perform latent class analysis on the 417 diabetic patients. The optimal number of latent classes was selected based on model fit parameters, and each class was characterized by examining the conditional probabilities of manifest variables.

Quality Control The field survey questionnaire was designed based on literature review, expert recommendations, and actual community diabetes management conditions in Taizhou. All field survey staff, blood collection personnel, and laboratory technicians underwent standardized training. Local health department support was secured to ensure resident cooperation. Quality control

officers were assigned to each survey site. Collected questionnaires underwent quality control checks, with double data entry and verification for completeness and logical consistency. Non-compliant questionnaires were re-administered.

Statistical Analysis Questionnaire data were entered using Epidata 3.1 and analyzed using SPSS 22.0. Categorical data were expressed as relative frequencies, with between-group comparisons performed using chi-square tests. Latent class analysis was conducted using Mplus 8.3. Multivariate logistic regression analysis was employed to explore factors influencing glycemic control categories. The significance level was set at α=0.05, adjusted to α=0.01 for pairwise comparisons among the three groups.

Results

Demographic Characteristics

A total of 417 diabetic patients were surveyed, including 151 males (36.21%) and 266 females (63.79%). The mean age was (69.31$±$9.41) years. Education levels were distributed as follows: bachelor' s degree or above, 1 case (0.24%); junior college, 4 cases (0.96%); high school/technical secondary school, 13 cases (3.12%); junior high school, 71 cases (17.03%); and primary school or below, 328 cases (78.66%). Regarding marital status, 331 (79.38%) were married, 7 (1.68%) unmarried, 3 (0.72%) divorced, and 76 (18.23%) widowed. Occupations included farmer (238 cases, 57.07%), homemaker (53 cases, 12.71%), self-employed (8 cases, 1.92%), worker (69 cases, 16.55%), teacher (1 case, 0.24%), medical staff (2 cases, 0.48%), enterprise/institution employee (13 cases, 3.12%), and other (33 cases, 7.91%). Annual household income was <20,000 yuan for 161 cases (41.39%), 20,000–40,000 yuan for 111 cases (28.53%), 40,000–60,000 yuan for 47 cases (12.08%), 60,000–100,000 yuan for 30 cases (7.71%), and >100,000 yuan for 41 cases (10.29%).

Diabetic Complications

Among the 417 diabetic patients, 358 (85.85%) had complications, including 286 (68.59%) with hypertension, 60 (14.39%) with coronary heart disease, 106 (25.42%) with hyperlipidemia, 61 (14.63%) with stroke, 17 (4.08%) with diabetic nephropathy, 25 (6.00%) with diabetic foot, 82 (19.66%) with retinopathy, 89 (21.34%) with neuropathy, and 12 (2.88%) with other complications. The number of concurrent complication types ranged from 0 to 7, with distributions as follows: 0 complications, 59 cases (14.15%); 1 complication, 137 cases (32.85%); 2 complications, 124 cases (29.74%); 3 complications, 53 cases (12.71%); 4 complications, 32 cases (7.67%); 5 complications, 9 cases (2.16%); 6 complications, 2 cases (0.48%); and 7 complications, 1 case (0.24%).

Latent Class Analysis Results

Model Fitting Eight manifest variables (HbA1c, age, BMI, health literacy, disease duration, family history, presence of complications, and history of hypoglycemia) were selected for model fitting. All variables were dichotomized, and four models were fitted by sequentially increasing the number of latent classes from 1. Variable assignments are shown in Table 1 , and model fit parameters are presented in Table 2 . The latent class model fitting results indicated that as the number of latent classes increased, the Akaike Information Criterion (AIC) and likelihood ratio chi-square statistic (G2) decreased. When the model was fitted with three latent classes, the sample-size-adjusted Bayesian Information Criterion (BIC) was minimized (3,989.02) and entropy was maximized (0.979). Additionally, both the Lo-Mendell-Rubin (LMR) test and Bootstrap Likelihood Ratio Test (BLRT) yielded P values <0.05. Therefore, the three-class model was selected as the optimal model.

Conditional Probabilities and Class Probabilities The three-class model yielded conditional probabilities and class probabilities for the eight manifest variables (Table 3). In Class 1, 181 patients (100%) were aged $ $65 years, 54 (29.8%) had poor health literacy (score $ $8), and 105 (58.0%) had disease duration $ $10 years. Compared to Classes 2 and 3, this class exhibited characteristics of older age, low health literacy, and longer disease duration, and was thus defined as the older-age/low-health-literacy group. In Class 2, 130 patients (82.3%) were aged $ $65 years, 59 (37.2%) had poor health literacy, and 102 (64.2%) had disease duration <10 years. Compared to Classes 1 and 3, this class showed moderately older age, moderate health literacy, and shorter disease duration, and was defined as the middle-age/moderate-health-literacy group. In Class 3, all 78 patients (100%) were aged <65 years, and 50 (63.6%) had poor health literacy. Compared to the other classes, this group exhibited younger age and higher health literacy, and was defined as the younger-age/high-health-literacy group. Based on model fitting results, the 417 diabetic patients were distributed across the three classes as follows: 181 cases (43.41%) in the older-age/low-health-literacy group, 158 cases (37.89%) in the middle-age/moderate-health-literacy group, and 78 cases (18.71%) in the younger-age/high-health-literacy group, with the older-age/low-health-literacy group representing the largest proportion.

Complication Distribution Across the Three Glycemic Control Classes

Significant differences were observed among the three groups in the prevalence of hypertension, stroke, and neuropathy (all P<0.05). Both the older-age/low-health-literacy and middle-age/moderate-health-literacy groups had significantly higher rates of comorbid hypertension, stroke, and neuropathy compared to the younger-age/high-health-literacy group (all P<0.01), as shown in Table 4 .

Univariate Analysis of the Three Glycemic Control Classes

Significant differences were found among the three groups in education level, marital status, occupation, annual household income, and number of glycemic control measures (P<0.05), as presented in Table 5 . Chi-square trend test analysis revealed a positive weak correlation between the three classes and the number of glycemic control measures (r=0.208, P<0.001).

Multivariate Logistic Regression Analysis of Factors Influencing Glycemic Control Categories

Using different glycemic control categories as the dependent variable and the younger-age/high-health-literacy group as the reference, variables showing statistical significance in univariate analysis were entered into a multivariate logistic regression model. Results showed that, compared to the younger-age/high-health-literacy group, having a junior high school education or above (OR=0.256, 95%CI=0.129-0.510, P<0.001; OR=0.355, 95%CI=0.181-0.696, P=0.003) and implementing more than three blood glucose control measures (OR=0.272, 95%CI=0.148-0.499, P<0.001; OR=0.542, 95%CI=0.298-0.986, P=0.045) were protective factors for glycemic control in the older-age/low-health-literacy and middle-age/moderate-health-literacy groups, respectively. In the middle-age/moderate-health-literacy group, being unmarried/divorced/widowed (OR=3.303, 95%CI=1.208-9.035, P=0.020) was a risk factor for glycemic control, as shown in Table 6 .

Discussion

This study identified three distinct subgroups of community-dwelling diabetic patients along the age-health literacy continuum using latent class analysis. The older-age/low-health-literacy and middle-age/moderate-health-literacy subgroups represent key target populations for comprehensive diabetes management, as their glycemic control is influenced by a combination of education level, self-management behaviors, and marital status. The results indicate that 85.85% of diabetic patients in Taizhou had complications, with 68.59% having hypertension—higher than the 75.5% complication prevalence and 34.2% hypertension comorbidity rate reported in national surveys. This discrepancy may be attributed to the higher mean age $(69.31\pm9.41 years)$ and longer disease duration $(10.10\pm7.12 years)$ in our sample compared to national data $(58.3\pm1$ years), as advanced age and prolonged disease duration are established risk factors for diabetic complications.

Our latent class analysis of 417 patients based on eight glycemic control factors revealed three subgroups: older-age/low-health-literacy, middle-age/moderate-health-literacy, and younger-age/high-health-literacy. Notably, 61.9% (258/417) of patients had HbA1c $ $7%, indicating poor recent glycemic control, which substantially exceeds the 33.1% reported in national surveillance data and suggests suboptimal overall glycemic control in our study population. Examination

of conditional probabilities revealed that HbA1c, age, BMI, health literacy, and disease duration showed distinct distributions across the three latent classes, whereas family history and hypoglycemia history had relatively uniform distributions, indicating weaker associations with the identified classes. While previous studies have demonstrated significant associations between poor glycemic control and family history, and between hypoglycemia (an acute adverse reaction in diabetic patients) and multiple adverse outcomes, our study showed low associations with these factors, possibly due to the relatively low prevalence of family history (20.67%) and hypoglycemia history (27.60%) in our sample.

Analysis of complication distribution across classes showed that the older-age/low-health-literacy and middle-age/moderate-health-literacy groups had higher proportions of hypertension, stroke, and neuropathy compared to the younger-age/high-health-literacy group, indicating that elevated HbA1c, older age, overweight status, longer disease duration, and low health literacy are important factors influencing complication development, particularly for cardiovascular and neurological diseases. HbA1c is the most widely used indicator for glycemic regulation, with internationally recognized control targets primarily set at 7% and 6.5%. Poor HbA1c control (>7%) combined with random blood glucose >7 mmol/L has been strongly associated with high complication burden. High health literacy serves as a protective factor for HbA1c, likely exerting its effects through influencing lifestyle behaviors such as physical activity. Age, BMI, and disease duration affect complication risk by influencing glycemic control.

Chi-square trend analysis demonstrated a positive weak correlation between the three latent classes and number of glycemic control measures, suggesting that younger patients with higher health literacy implemented more control measures. Multivariate logistic regression revealed that lower education level, insufficient glycemic control measures ($ $3), and unfavorable marital status (unmarried/divorced/widowed) were more prevalent in the older-age/low-health-literacy and middle-age/moderate-health-literacy groups, identifying these as risk factors for poor glycemic control. The impact of education on glycemic control has been well-documented, while marital status may influence control through differences in family function or support.

This study has several limitations. First, complication data were self-reported, and the low education level of participants (78.66% with primary school education or below) may have resulted in incomplete responses and potential recall bias. Second, although our variable categorizations were based on relevant literature, some degree of inaccuracy in classification definitions may have affected result reliability. Nevertheless, our findings reflect the glycemic control status of community-dwelling diabetic patients in Taizhou and provide a scientific basis for community diabetes management and complication control.

In conclusion, this study identified three subgroups of community diabetic patients with distinct profiles along the age-health literacy dimension. The older-age/low-health-literacy and middle-age/moderate-health-literacy subgroups rep-

resent priority populations for integrated diabetes management, with glycemic control influenced by education, self-management behaviors, and marital status. Community-level interventions should be tailored to subgroup characteristics, focusing on weight management guidance, health education to improve literacy, and promotion of comprehensive glycemic control measures. This study provides valuable scientific reference for implementing precision, stratified management of diabetic patients in community settings.

Author Contributions: LI Menglin was responsible for study design, data analysis, and manuscript writing. DING Fang, QIAN Yu, PU Dong, DU Qianqian, and GUAN Tianhang participated in study implementation and data collection. HE Yilin conceived the study design and revised the manuscript.

Conflict of Interest: The authors declare no conflicts of interest.

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Note: Figure translations are in progress. See original paper for figures.