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ORIGINAL

Latent class analysis suggests four classes of persons with type 2 diabetes mellitus based on complications and comorbidities in Tianjin, China: a cross-sectional analysis

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Abstract. The aim of this study was to explore a new classification way in persons with type 2 diabetes mellitus based on complications and comorbidities using Latent Class Analysis, moreover, finding out the factors associated with different latent classes and making specific suggestions. In this study, 5,500 patients with type 2 diabetes mellitus from ten hospitals in Tianjin, China were selected, and the response rate was 96.2%. Latent Class Analysis was used to cluster patients. After compared the baseline characteristics, multinomial logistic regression was applied. Patients with type 2 diabetes mellitus were classified into four classes. In the univariate analysis, all variables were significant ($p<0.05$). According to multinomial logistic regression, we found longer duration of type 2 diabetes mellitus, family history of diabetes, older age, obesity and central obesity, female menopause, living in a suburb, having a higher 2hPG at diagnosis, smoking and drinking were associated with the prevalence of complications and comorbidities. In conclusion, LCA was shown to be an effective method for grouping patients with T2DM, which presented a nuanced approach to data reduction. Further research using LCA may be especially useful to investigate causal relationships between complications and the significant factors identified in our study.

Key words: Type 2 diabetes mellitus, Complication, Comorbidity, Latent Class Analysis

DIABETES MELLITUS (DM) is a serious, chronic disease. World leaders have treated it as a significant public health problem and one of four priority non-communicable diseases owing to the steady increase in the past few decades [1]. In particular, the prevalence of diabetes among Chinese adults has reached 11.6%, accounting for 113.9 million adults, which was revealed in a national study in China [2]. Thus, DM is not only a worldwide health issue but also a serious challenge to the national health of China.

Type 2 diabetes mellitus (T2DM) is the main type of diabetes and has been widely studied [3-5]. A previous study demonstrated that patients with T2DM exhibit complications and comorbidities in many parts of the body if the illness is not properly controlled, which then leads to blindness, end-stage renal failure, amputations and other diseases, increasing the overall risk of dying prematurely [6]. Additionally, the treatment of T2DM is costly, of these costs, only 50% is due to the diabetes treatment itself, and the others stem from the treatment of complications [7]. Numerous studies have explored the risk factors of T2DM by dividing patients

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Abbreviation: DM, Diabetes mellitus; T2DM,Type 2 diabetes mellitus; BMI, Body mass index; LCA, Latent Class Analysis; SDOSI, Special disease outpatient service insurance; FPG, Fasting blood glucose; 2hPG, 2h postprandial blood glucose; HbA1c, Hemoglobin A1c protein; WC, Waist circumference; DPN, Diabetic peripheral neuropathy; DR, Diabetic retinopathy; HTN, Hypertension; CVD, cardiovascular diseases; MS, Metabolic syndrome; BIC, Bayesian Information Criterion; LRT, Likelihood Ration Test; CI, Confidence interval.

into several groups based upon different standards, such as physical activity [8], glycemic control [9], age at diagnosis [10], and body mass index (BMI) [11]. However, few studies have attempted to group patients with T2DM by complications and comorbidities. In consideration of the huge burden of complications, it is important to discover the association between the characteristics of patients and the prevalence of complications and comorbidities.

Latent Class Analysis (LCA) is a statistical procedure for modeling a latent variable with several local dependent classes to explain the relationship among response to sets of observed categorical variables. In contrast with the variable-centered approach (*i.e.*, the focus is on relationships among variables, such as exploratory factor analysis), LCA is a person-centered approach (*i.e.*, the interest is finding heterogeneous groups of individuals) [12]. Using LCA to group patients with T2DM may provide a practical alternative to previous classification criteria.

In conclusion, an exploratory Latent Class Analysis of patients with T2DM is presented herein. Our goals were to (1) illustrate the effectiveness of LCA in diabetic research; (2) classify patients with T2DM into latent classes based upon the prevalence of complications and comorbidities; and (3) find the factors associated with different latent classes and making specific suggestions.

Materials and Methods

Subjects

A cross-sectional study was conducted by a structured questionnaire. The study setting was outpatient clinics of ten hospitals in Tianjin. The sample consisted of patients with T2DM who sought care in outpatient clinics according to a multi-stage simple random sampling. In the first stage, 10 municipal districts covering urban areas and suburb were randomly selected from 15 municipal districts. Next, one medical-insurance-appointed hospital was randomly selected from each district. In the last stage, patients who sought care from November 23, 2015, to January 13, 2016, were selected, and the target quantity was 5,500 patients. The inclusion criteria were persons (1) who had T2DM and were covered by special disease outpatient service insurance (SDOSI), (2) who were mentally competent and able to communicate verbally, and (3) who were able to provide informed consent. The exclusion criteria were (1) type 1 diabetes mellitus and (2) diabetes secondary to other diseases. Ultimately, 5,500 patients were selected, and 197 patients failed to complete the entire questionnaire. The response rate was 96.2% and the final sample size was 5292 patients.

According to Municipal Human Resources and Social Security Bureau, a patient's reimbursement ratio of expenses for medicine would be improved when covered by SDOSI, but the patient's qualifications will be identified only after testing of the fasting plasma glucose (FPG), 2 h postprandial plasma glucose (2hPG) of the glucose tolerance test and hemoglobin A1c protein (HbA1c) by the appointed hospitals before the enrollment. In this study, we only included patients who were covered by SDOSI because they were properly diagnosed previously and because all had accurate glycemic records at Municipal Human Resources and in the Social Security Bureau.

Measurements

A structured questionnaire including four parts was used. The first part addressed demographic factors. It contained questions about age, residence, gender, family history (diabetes), BMI (the weight in kilograms divided by square of the height in meters; normal: BMI<25, overweight: 25≤BMI<30, obesity: BMI≥30) [13] and central obesity (male waistline≥90cm, female waistline≥85cm) [14]. The second part addressed diabetes severity, including the duration of T2DM (years), FPG at diagnosis, 2hPG at diagnosis and HbA1c at diagnosis. The third part addressed behavioral factors, including smoking and drinking. The last part addressed the prevalence of complications and comorbidities. Complications included cardiovascular diseases (CVD), cerebrovascular diseases, diabetic lower limb vascular disease, diabetic nephropathy, diabetic peripheral neuropathy (DPN), diabetic retinopathy (DR) and diabetic foot disease while comorbidities included hypertension (HTN), dyslipidemia, and metabolic syndrome (MS) [14].

Procedures for data collection

Before the interview, physicians briefly explained the purpose of this study to the patients who met the inclusion criteria. Those who were willing to participate in the interview were asked to sign a consent form. The FPG, 2hPG, and HbA1c at diagnosis were extracted from the Tianjin Social Insurance Bureau, and the prevalence of complications and comorbidities diagnosed by secondary or tertiary hospitals were obtained from the medical records. The questionnaire was completed by physicians. The present study was a questionnaire survey without the collection of blood samples and laboratory examinations; in addition, the physicians only inquired regarding the health status and recorded it objectively. Therefore, this study did not require ethics approval.

Statistical analysis

Latent Class Analysis

LCA was applied to ten complications and comorbidities of T2DM. The analytical procedure of LCA consisted of four parts. The first part was probabilistic parameterization, which included latent class probabilities (*i.e.*, the probability that individuals selected randomly from the sample belonged to each latent class; the sum was 1) and conditional probabilities (*i.e.*, the probability that an individual would provide a certain response to a specific item of an observed variable given that she or he has been classified in a specific latent class; the sum of each observed variable was 1). The second part was a parametric estimation using maximum likelihood. The third part was model selection, and the last part was latent class cluster analysis, which means that, for each individual, the posterior probability of belonging to each class was calculated using Bayes' theorem and assigned to an exclusive latent class based upon the maximum probability. Individuals within the same latent class were homogeneous for certain criteria, whereas those in different latent classes were dissimilar from each other [12].

Selecting a model was the central element in LCA. Testing from a one-class model to an increasing number of classes, the number of latent classes was determined iteratively. Due to lack of a gold standard, integrated criteria were used to confirm the optimal number of classes, including clinical relevance, interpretability and the following statistical tests of model fit: Bayesian Information Criterion (BIC) (a lower value represents a better fit); entropy (an index measuring the overall accuracy of classification; a higher value represents a better fit); log-likelihood (a higher value means a better fit); and boot-strapped likelihood ratio tests (BLRT) (a small probability value (*e.g.*, $p < 0.05$) indicates that the K_n-class model provides a significantly better fit to the observed data than the K_{n-1}-class model) [15]. In the present study, the goal of LCA was to find the best fitting set of classes to describe underlying profiles among the prevalence of complications and comorbidities.

Descriptive and Univariate Analysis

After the LCA analysis, the patients were classified into four groups. Descriptive data were expressed as the mean ± standard deviation (SD) or as the median (interquartile range) for continuous variables and were expressed as proportions for categorical variables. Continuous variables were compared among subgroups using an analysis of variance test for normal distributions or the Kruskal-Wallis test for non-normal distributions. Categorical variables were compared using the chi-square test or Kruskal-Wallis test for ordinal variables.

Multinomial logistic regression

The multivariable analysis of variables associating with latent classes was a multinomial logistic regression, using latent class 4 as the reference category. The variables for the multivariable analysis were selected according to the significant univariate analysis. FPG was divided into three categories, normal (<6.1 mmol/L), impaired fasting glucose (IFG) (6.1~7.0 mmol/L) and diabetes (≥7.0 mmol/L) [16]. 2hPG less than 7.8 mmol/L was considered normal, 7.8~11.1 mmol/L and greater to or equal to 11.1 mmol/L was defined as impaired glucose tolerance (IGT) and diabetes, respectively [16]. HbA1c≥6.5% was defined as diabetes [17]. The duration of diabetes in years was categorized as ≤8 years and >8 years based upon the median. Residence was divided into urban arears and suburb. In particular, menopause is an important physiological event, especially for females. It may influence the risk of diabetes because of the biological and psychosocial changes. In previous research, the median age of menopause among women with diabetes was 48.5 years old [18]. In consideration that the diagnosis of male menopause is complicated and is not related to aging [19], we divided age into two parts based upon 48.5 years old [18] to analyze the effect of menopause (Table 1).

To investigate how menopause influence the prevalence of complications and comorbidities, females were divided based on the age of 48.5 years and compared with male. Adjusted ORs were calculated after adjusting for residence, duration of T2DM, family history, BMI, central obesity, 2hPG at diagnosis, HbA1c at diagnosis, FPG at diagnosis, drinking and smoking. Statistical significance was set at $p \leq 0.05$, with a 95% confidence interval (CI).

Mplus version 7 was used to perform the LCA. All statistical comparisons among classes and multinomial logistic regression were performed with SAS version 9.4 (SAS institute Inc., Cary, NC).

Results

Latent Class Analysis

A four-class model was selected after considering the latent class model from one to six classes. The four-class model had a higher log-likelihood value and a lower BIC than did models with three or fewer classes, a statistically significant boot-strapped LRT (p<0.05) over the three-class model, and the highest entropy statistic (0.749) (Table 2). Moreover, the six-class model was much more difficult to interpret clinically and was not as meaningful as the four-class model. Considering of above, we determined that the four-class model had the best overall fit.

The latent class probabilities of the four classes were 6.1%, 25.7%, 14.3% and 53.9% separately. Except for the lowest probability of diabetic foot disease in all latent classes, patients with T2DM in the first class (n=323, 6.1%) were termed the "complications & comorbidities group" due to a high conditional probability of suffering from all complications and comorbidities. Patients with T2DM in the second class (n=1,360, 25.7%), termed the "high risk of complications group", were distinguished by the high conditional probability of DPN, DR and diabetic lower limb vascular disease. The third class, denoted the "high risk of comorbidities and CVD group" (n=757, 14.3%) was characterized by a relatively high conditional probability of hypertension, dyslipidemia, MS and CVD. The last class, called the "diabetes without complications & comorbidities group" (n=2,852, 53.9%), was characterized by the lower conditional probability of having all complications and comorbidities compared with the former classes (Fig. 1).

Table 1 Variable codes of multinomial logistic regression

Factors	Variable	Code
Gender	X1	Male = 0, Female = 1
Residence	X2	Urban areas=1, Suburb=2;
Age	X2	≤48.5 years = 0, >48.5 years = 1;
BMI	X3	Normal = 1, Overweight = 2 , Obesity = 3;
Central obesity	X4	No = 0 , Yes = 1;
Duration of T2DM	X5	≤8 years = 0, >8 years =1;
FPG at diagnosis	X6	Normal = 1, IFG= 2 , Diabetes = 3;
2hPG at diagnosis	X7	Normal =1, IGT= 2 , Diabetes = 3;
HbA1C at diagnosis	X8	Normal = 0, Diabetes = 1;
Family history	X9	No = 0 , Yes = 1;
Current smoker	X13	No = 0 , Yes = 1;
Current drinker	X14	No = 0 , Yes = 1;

Characteristics of latent class membership

Table 3 shows the study population characteristics and results of the univariate analysis. The final study contained 5292 patients (49.2% were female, and 50.8% were male) with T2DM, and the median age was 63 years (IQR= 14).

Demographic factors

The "diabetes without complications & comorbidities group" (class 4) was the youngest (median, 62 years; IQR, 12) and had the lowest proportion of family history (35.3% *vs*. 53.2%), female (48.0% *vs*. 58.6%), general obesity (8.3% *vs*. 18.3%) and central obesity (54.7% *vs*. 76.9%), whereas the "complications & comorbidities group" (class 1) had the largest percentage. The majority of class 1 lived in the suburb (54.6%), whereas more than 50% of the patients in the "high risk of complications group" (class 2), "high risk of comorbidities and CVD group" (class 3) and class 4 lived in the urban areas. In comparison with class 2, class 3 was older (median, 65 years; IQR, 12), had a

Table 2 Model fit statistics for latent classes of patients with Type 2 diabetes

Classes Number	Log-likelihood	BIC	Entropy	Boot strapped LRT p-value (k-1 *vs*. k)
2	-19343.05	38866.15	0.74	0.000
3	-19061.84	38398.04	0.74	0.000
4	-18795.15	37958.97	0.75	0.000
5	-18701.36	37865.71	0.73	0.000
6	-18639.50	37836.31	0.73	0.000

Abbreviations: BIC, Bayseian Information Criterion; LRT, Likelihood Ration Test.

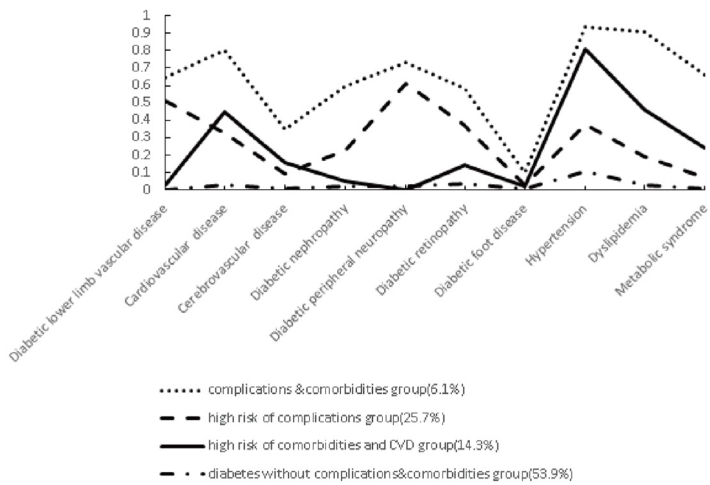

Fig. 1 Predicted Probabilities of Complications and Comorbidities by Latent Class Analysis

"Probabilities of class membership identified through Latent Class Analysis. Number of classes determined based on BIC, entropy and boot-strapped LRT."

Table 3 Baseline Characteristics of patients with Type 2 diabetes by Latent Class Analysis

Characteristics	Overall	Class 1	Class 2	Class 3	Class 4	*p* value
N (%)	5292(100)	323(6.1)	1360(25.7)	757(14.3)	2852(53.9)	
Demographic factors						
Age (years)	63(14)	65(10)	64 (13)	65(12)	62(14)	0.000[b]
Residence						
Urban areas	54.5	45.4	53.2	55.6	55.7	0.006[a]
Suburb	20.1	54.6	46.8	44.4	44.3	
Gender(Female)	49.2	53.6	49.1	53.1	48.0	0.000[a]
Family history	39	53.2	44.6	39.5	35.3	0.000[a]
BMI						
Healthy	45.8	33.6	49.2	35.0	47.9	
Overweight	44.4	48.1	41.3	51.2	43.8	0.000[b]
Obesity	9.8	18.3	9.5	13.8	8.3	
Central obesity	59	76.9	62.7	64.1	54.7	0.000[a]
Diabetes severity						
Duration of T2DM(years)	8(8)	12(12)	10(9)	9(10)	7(7)	0.000[b]
FPG at diagnosis (mmol/L)	9.1(3)	9.3(4)	9.4(3)	9.1(3.5)	9.0(3)	0.000[b]
2hPG at diagnosis (mmol/L)	14(6)	15(5.7)	15(6)	14(5.3)	13.5(5.7)	0.000[b]
HbA1c at diagnosis						
(%)	9.0(2.0)	9.0(2.0)	9.0(2.0)	8.9(2.0)	9.0(2.1)	0.000[b]
(mmol/mol)	75(22)	75(22)	75(22)	74(22)	75(23)	0.000[b]
Behavioral factors						
Current smoker	15.4	13.2	20.6	15.6	13.4	0.000[a]
Current drinker	9.2	9.8	9.5	12.5	8.3	0.008[a]

Data are median (IQR) and % except for appointed. [a] Chi-square test; [b] Kruskal-Wallis test. Abbreviations: BMI, Body Mass Index; FPG, Fasting Plasma Glucose; 2hPG, 2h Postprandial Plasma Glucose; HbA1c, Hemoglobin A1c Protein. Class 1, complications & comorbidities group; Class 2, high risk of complications group; Class 3, high risk of comorbidities and CVD group; Class4, diabetes without complications & comorbidities. % are column percent, and the overall row percent may be not 100% owing to the missing data.

higher proportion of general obesity (13.8% *vs*. 9.5%) and central obesity (64.1% *vs*. 62.7%) and had a lower percentage of family history (39.5% *vs*. 44.6%). The differences were statistically significant.

Diabetes severity

The median duration of T2DM was 8 years, and there was a decreasing duration of disease from class 1 to class 4. The FPG and 2hPG at diagnosis were higher in classes 1-3 compared with class 4, and the HbA1c levels were higher in classes 1-2 and class 4. All of the differences were statistically significant.

Behavioral factors

A larger percentage of current smokers were in class 2 and class 3 (20.6% and 15.6%, respectively), whereas the percentage of current drinkers in class 3 (12.5%) was the highest.

Multinomial logistic regression

Table 4 summarizes the results of the multinomial logistic regression. Our multivariable analysis demonstrated that patients who were older than 48.5 years, who had central obesity, who had a higher 2hPG at diagnosis and whose duration of T2DM was over 8 years had significantly higher odds of being in classes 1-3 *versus* class 4. Patients with a family history had significantly higher odds of being in classes 1-2, and those who resided in a suburb had significantly higher odds of being in class 1 (OR 1.48, 95%CI 1.16-1.89). Moreover, patients with higher BMIs had significantly higher odds of being in class 1 (OR 1.43, 95%CI 1.19-1.73) and class 3 (OR 1.45, 95%CI 1.27-1.65). Current smokers had significantly higher odds of being in class 2 (OR 1.81, 95%CI 1.49-2.21), whereas current drinkers had significantly higher odds of being in class 3 (OR 1.67, 95% CI 1.23-2.25).

Table 5 reveals the details of how menopause influenced the prevalence of complications and comorbidities. Compared with males, females≤48.5 years of age had lower adjusted odds of being in class 2 (OR 0.59, 95% CI 0.37-1.95) and class 3 (OR 0.46, 95% CI 0.23-0.91). Females older than 48.5 years had higher adjusted odds of being in class 3 (OR 1.40, 95% CI 1.17-1.68).

Table 4 Factors associated with class membership identified using multinomial logistic regression

	Class 1 *vs*. Class 4		Class 2 *vs*. Class 4		Class 3 *vs*. Class 4	
	OR	95%CI	OR	95%CI	OR	95%CI
Age	1.94*	1.12-3.36	1.83*	1.39-2.41	2.05*	1.43-2.94
Gender	1.12	0.87-1.46	1.19	0.94-1.25	1.29*	1.07-1.55
Duration of T2DM	2.35*	1.82-3.08	2.09*	1.82-2.40	1.48*	1.25-1.75
Family history	1.96*	1.53-2.50	1.42*	1.23-1.64	1.13	0.95-1.34
Central obesity	2.21*	1.65-2.98	1.39*	1.20-1.60	1.22*	1.01-1.46
BMI	1.43*	1.19-1.73	1.01	0.82-1.03	1.45*	1.27-1.65
Residence	1.48*	1.16-1.89	1.09	0.95-1.24	0.98	0.83-1.17
2hPG at diagnosis	2.49*	1.72-3.59	1.61*	1.37-1.89	1.42*	1.17-1.74
Current smoker	0.96	0.64-1.43	1.81*	1.49-2.21	1.14	0.87-1.48
Current drinker	1.25	0.79-1.98	0.89	0.68-1.15	1.67*	1.23-2.25

Abbreviations: CI, Confidence Interval; OR, Odds Ratio; T2DM, Type 2 diabetes mellitus. Class 1, complications & comorbidities group; Class 2, high risk of complications group; Class 3, high risk of comorbidities and CVD group; Class 4, diabetes without complications & comorbidities group. *$p<0.05$

Table 5 Association between gender divided by 48.5 years and class membership

	Class1 *vs*. Class4		Class2 *vs*. Class4		Class3 *vs*. Class4	
	OR[a]	95%CI	OR[a]	95%CI	OR[a]	95%CI
Male	Ref		Ref		Ref	
Female≤48.5 years	0.80	0.36-1.77	0.59*	0.37-0.95	0.46*	0.23-0.91
Female>48.5 years	1.18	0.91-1.54	1.15	0.99-1.33	1.40*	1.17-1.68

[a] OR was adjusted for residence, duration of T2DM, family history, BMI, central obesity, 2hPG at diagnosis, HbA1c at diagnosis, FPG at diagnosis, drinking and smoking. * $p<0.05$

Discussion

From diabetes to its complications and comorbidities, patients have to suffer more pain and financial burdens. Using LCA, we identified four distinct classes of patients with T2DM, creating a new classification method. Across classes, we found notable differences in demographics, diabetes severity, and behavioral factors.

Most of the patients belonged to the "diabetes without complications & comorbidities group," and only fewer than 10% of the patients had both complications and comorbidities, which meant that T2DM was well controlled in Tianjin. HTN, obesity and dyslipidemia were risk factors for CVD [20]; although CVD and cerebrovascular disease were macro-vascular complications, they were included in class 3 along with comorbidities.

The present study showed that a longer duration of T2DM and older age were associated with a higher prevalence of all complications and comorbidities, which is consistent with previous studies [21, 22]. In addition, patients with a family history were significantly correlated with diabetes and its complications (*e.g.*, diabetic lower limb vascular disease and diabetic peripheral neuropathy), in agreement with other studies [23, 24].

We found that female patients were associated with an increasing prevalence of HTN, dyslipidemia and CVD compared with males, which agreed with former studies [25-28]. Table 5 shows that premenopausal women (females≤48.5 years of age) were less likely to suffer from complications and comorbidities compared with males. Conversely, postmenopausal women (females>48.5 years of age) were associated with higher risks of comorbidities and CVD compared with premenopausal women and males. Inconsistent with other research [29,30], female patients in our study were associated with higher odds of comorbidities, and the CVD in Table 4 was mainly due to menopause and increasing age, whereas in young subjects, comorbidities and complications were more common in men. Our findings indicated that more medical resources are necessary to shift the care for midlife women, especially for postmenopausal women.

Lifestyle factors are known to play important roles in the progression of T2DM [31]. Current smokers in our study were correlated with a higher prevalence of complications, which was consistent with previous studies [32, 33]. Moreover, current drinkers were more likely to have comorbidities and CVD—a finding that is probably debatable. Blomster provided evidence that patients with T2DM who drink alcohol moderately have a lower risk of CVD and microvascular complications compared with those who do not drink at all [34]. Temperate drinking appears to be a protective factor against diabetes. In view of the above, patients should be encouraged to quit smoking and to drink moderately to prevent complications and comorbidities, respectively.

Overweight (46.9%) and obesity (21.3%) were prevalent among persons with T2DM. A previous study in Sweden had shown that patients with T2DM who were overweight and obese had higher frequencies of HTN, CVD and dyslipidemia [35], which was again verified in our study. Patients with higher BMIs were more likely to suffer from comorbidities and CVD.

BMI as an index of general obesity and waist circumference (WC) as an index of central obesity have been proven in epidemiological studies [36-38]. There is evidence that both general obesity and central obesity are significantly associated with T2DM [39-41]. In this study, central obesity was associated with a higher risk of all complications and comorbidities. Furthermore, the ORs of central obesity were higher than those of BMI, which was coincident with the IDEA results, which showed that central obesity had a graded relationship with DM at all levels of BMI [39]. Considering both BMI and central obesity, our findings indicated that patients should strengthen their consciousness of weight control and, especially, physique management.

Patients in suburbs had a higher risk of suffering from complications and comorbidities than did patients in the urban areas, showing that the proportions of those who managed their glucose well were higher in economically developed than in underdeveloped regions. This difference was in line with the national study in China [2]. However, only the OR of class 1 was significant, which indicated that residence would exert an influence when the glucose control was extremely poor; for most of the patients, residence had no influence.

For newly detected diabetes, 46.6% had FPG<7.0 mmol/L but 2hPG≥11.1 mmol/L; 2hPG is more meaningful in patients in China [14]. In our research, the higher 2hPG at diagnosis associating with a higher prevalence of all complications and comorbidities also proved the importance of 2hPG. Therefore, physicians should focus on complications and comorbidities with more caution if patients have a higher 2hPG at diagnosis.

The main strength of our study was the patient diversity. Our dataset included patients from secondary hospitals to accredited 3A hospitals (*i.e.*, the elite hospitals) covering the urban areas and suburbs in Tianjin, China. The range of patients was wide, including men and women from 17 to 95 years of age. We believe that our results are typical and applicable to other patients in Tianjin, China. Furthermore, the initial records were extracted from the Municipal Human Resources and Social Security Bureau; therefore, they were accurate and credible without recall bias.

The present study also had several limitations. First, complications and comorbidities were obtained from medical records instead of screening. Owing to the financial disadvantages or any other reasons, some patients might not have sought treatment and thus been missed. The prevalence in Tianjin was likely to have been underestimated in this study. Second, discussions were mainly focused on four latent groups, and consequently, the associations between the specific disease and factors were unidentified. However, this limitation was also the strength of the LCA, which could identify the overall tendency of treatment in the clinic. Third, menopause was simply divided by age; therefore, the classification was imprecise and lacked information regarding male menopause. A study with a rigorous definition of menopause is necessary to explore the association between menopause and T2DM. Finally, but most importantly, the cross-sectional design only describes the exposure and outcomes at a given time point, and a causal relationship cannot be established; therefore, a longitudinal study is needed to assess the relationship found in our study. However, few studies have attempted to classify T2DM patients based on complications and comorbidities. Thus, we suggest that the results of this study are very important and have clinical implications for T2DM management.

In conclusion, this LCA study suggests four subgroups of patients with T2DM characterized by the prevalence of complications and comorbidities. Longer duration of T2DM, family history of diabetes, older age, obesity and central obesity, female menopause, living in a suburb, having a higher 2hPG at diagnosis, and smoking and drinking were associated with the prevalence of complications and comorbidities. Although LCA was shown to be an effective method for grouping patients with T2DM, the generalizability of the characteristics associated with different latent classes remains to be determined. However, LCA presents a nuanced approach to data reduction. Further research using LCA may be especially useful to investigate causal relationships between complications and the significant factors identified in our study; subsequently, physicians might control T2DM specifically based on distinctive characteristics.

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Disclosure

None of the authors have any potential conflicts of interest associated with this research.

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