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Organisational and individual characteristics associated with glycaemic control among patients with type 2 diabetes: cross-sectional study in China

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ABSTRACT

Objective There is a high prevalence of poor glycaemic control among patients with type 2 diabetes (T2DM) in China. This study aimed to explore both organisational and individual characteristics associated with glycaemic control among patients with T2DM.

Design Cross-sectional survey.

Setting Shandong Province, China.

Participants The participants were 2166 patients with T2DM and 337 healthcare providers from 36 urban communities and 36 rural villages in Shandong Province.

Primary and secondary outcome measures Multistage stratified sampling procedures were used to measure demand-side individual demographic, clinical and self-management characteristics, and supply-side organisational characteristics, and the status of glycaemic control. Multilevel logistic regression analysis was performed to assess key determinants of glycaemic control.

Results Only 42.8% of the patients with T2DM achieved good glycaemic control. Age, income, hypertension and self-efficacy were significantly positive predictors of optimal glycaemic control, while duration of diabetes, antidiabetic drugs and monitoring of blood glucose were significantly negative predictors of that. Private VCs (OR=0.48, 95% CI 0.29 to 0.82, p<0.01) and lack of healthcare providers (OR=0.69, 95% CI 0.53 to 0.89, p<0.01; OR=0.71, 95% CI 0.52 to 0.98, p<0.05) were significantly negative predictors of optimal glycaemic control, while diabetes knowledge level of healthcare providers (OR=1.36, 95% CI 1.02 to 1.83, p<0.05; OR=1.45, 95% CI 1.00 to 2.10, p<0.05) and kinds of antidiabetic drugs (OR=1.37, 95% CI 0.97 to 1.93, p<0.1; OR=1.46, 95% CI 1.07 to 2.00, p<0.05) were significantly positive predictors of that.

Conclusions Glycaemic control was suboptimal among patients with T2DM in China. The determinants of failing to achieve good glycaemic control included both organisational and individual characteristics. Potential interventions that target patients, providers and the healthcare organisations should be taken to improve the glycaemic control and health outcome among patients with T2DM.

Strengths and limitations of this study

- ► This study is novel by simultaneously exploring patient-level, provider-level and health system-level factors associated with glycaemic control among patients with T2DM, which could provide interesting findings for policy makers and practitioners.
- ► The large sample size from a multicentre study enabled us to achieve sufficient statistical power in the model, thereby achieving reliable results.
- ► The retrospective approach to collect data using self-designed questionnaires might have led to recall and self-reporting bias.
- ► A cross-sectional study at baseline would limit the interpretation of causal inference between influencing factors and glycaemic control.

INTRODUCTION

Diabetes mellitus is a chronic metabolic disease with an increasing prevalence in developing countries and particularly in China.[1 2] In 2017, the International Diabetes Federation (IDF) reported that 425 million people had diabetes (9.2% prevalence) worldwide, and China had about 104 million patients with diabetes (11.2% prevalence).[3] Diabetes has a tremendous impact on health spending and quality of life for those suffering from the disease. Diabetes and its comorbidities have placed a heavy burden on the Chinese healthcare system and the whole society. It was reported that 800 000 Chinese persons died of diabetes in 2015.[4] About US$110 billion (12% of total heath expenditure) is spent on the management and treatment of diabetes and its complications each year in China.[3] Thus, diabetes has become one of the most serious public health issues in China.

Diabetes involves numerous long-term complications that markedly impair the quality of life, lead to premature deaths and contribute to healthcare costs.[5 6] Nevertheless, successful prevention and management of diabetes can substantially reduce

the harm of diabetes. Several studies have demonstrated that good glycaemic control can avoid or delay diabetes complications.[5 7] The IDF has suggested that the target of glycaemic control should be glycosylated hemoglobin (HbA1c)<7% or fasting plasma glucose (FPG)<7.0 mmol/L.[1] However, previous studies have shown that glycaemic control was poor among Chinese patients with diabetes, and only 26%–40% of patients with diabetes achieved the target.[6 7] Thus, it is very important to understand factors influencing glycaemic control to prevent and delay diabetes complications.

Optimal glycaemic control calls for not only rapid initiation of medication therapy[1] but also proactive management that patients with diabetes often find difficult in everyday life.[8] Although diabetes management and treatment guidelines have been designed, many patients are still not achieving glycaemic goals.[9] Thus, improving the management regimen may require evaluation of barriers such as income, health literacy, distress, self-efficacy and self-care behaviours.[10] Previous studies have examined demographic, clinical, treatment, psychological and behavioural factors influencing glycaemic control among patients with diabetes.[7 9] It has been shown that positive health outcomes among patients with diabetes are associated with good adherence to treatment and management.[8] There is evidence that the characteristics of patients with diabetes and their communities may determine the risk of complications.[11 12]

Diabetes management and treatment mostly occur in outpatient settings and in primary care institutions in both developed and developing countries.[13] Barriers to optimal glycaemic control are complex and multifactorial, involving factors at levels of individual, community and health system. Patients with diabetes have the ability to affect their health outcomes through self-management, treatment adherence and health promotion.[14] Primary care providers (PCPs) are known to provide healthcare for the majority of patients with diabetes,[11] and the patients receive most of healthcare for glycaemic control from primary care institutions.[15] Therefore, the PCPs and healthcare organisations are essential determinants of diabetes care and outcomes.[16] In light of this, the Chinese government implemented National Essential Public Health Services Program (EPHSP) to manage and control diabetes. The EPHSP requires the PCPs to provide follow-up services for patients with type 2 diabetes mellitus (T2DM). Up to 2017, there were about 24 million patients with T2DM registered in the management system.[17] Thus, supply-side characteristics in healthcare for diabetes could play an important role in T2MD management and glycaemic control in China.

Numerous studies have explored the factors influencing glycaemic control among patients with T2DM. Nevertheless, the majority of the studies have focused on the factors of glycaemic control at the individual level.[18–20] Several studies have evaluated the effects of implementing a programme on glycaemic control and its influencing factors.[6] A few studies have analysed the association between glycaemic control and the characteristics of healthcare institutions and healthcare providers.[9 21 22] Little is known about how system-level organisational characteristics associate with glycaemic control.[15] Reliable evidences on the factors on both demand side and supply side are required to provide further insight for policy makers to evaluate T2DM management strategies and outcomes. Therefore, this study aimed to explore both organisational and individual characteristics influencing glycaemic control among patients with T2DM in China.

METHODS

Study design and setting

This is a cross-sectional study conducted in Shandong from August to September 2017. Shandong is a major province in east China with a vast area and large population, named ‘small China’ because of the same geographical and economical distribution as China. A multistage stratified randomised sampling method was used in this study. First, four prefectures (Qingdao, Weifang, Jinan and Heze) were selected based on their geographical location and economic development status within the province. Second, three urban districts and three rural towns were randomly selected from each prefecture. Third, three communities from each district and three villages from each town were randomly selected. In total, 36 urban community health stations (CHSs) and 36 rural village clinics (VCs) were selected.

Participants

This study selected patients with T2DM and healthcare providers in the sampling CHSs and VCs as participants. The inclusion criteria of patients with T2DM were (1) diagnosis of T2DM by the clinician, (2) being registered in the management system of national EPHSP, (3) age of 35–<80 years and (4) willingness to participate. The exclusion criteria of patients with T2DM were (1) age of <35 or ≥80 years, (2) severe physical or mental illness, (3) lack of ability to normally communicate and (4) unwillingness to participate. In each CHS or VC, we randomly selected 35 eligible patients with T2DM according to their names in the management system and invited all diabetes care providers available at the workplace on the investigation day to participate in the survey. Finally, 2166 patients with T2DM (a response rate of 86%) and 337 healthcare providers (102 physicians, 115 public health workers and 120 village doctors) completed the survey. All participants were volunteers and provided written informed consent for participation in the survey before data were collected.

Data collection

The trained researchers and investigators successively visited the selected CHSs and VCs. Participants were interviewed face-to-face by investigators using self-designed questionnaires, and the relevant information was obtained by recall. Furthermore, blood pressure was measured at the non-dominant arm for three times consecutively

with a 1 min interval between measurements using an automated device (OMRON Model HEM-8611) and standardised procedure by local healthcare providers. A blood sample (12 mL) was drawn after 12 hours overnight fast via venipuncture using vacuum blood collection tubes containing anticoagulant sodium fluoride. Whole blood was centrifuged and the serum was tested for glucose. Glucose was measured with a Hitachi 7600 analyser using a glucose oxidase phenol 4-aminoantipyrine peroxidase kit in a third-party laboratory (King Med Diagnostics Co).

Variables and measurement

The dependent variable was glycaemic control. Good glycaemic control was defined as FPG<7.0 mmol/L, while poor glycaemic control was defined as FPG≥7.0 mmol/L.[23–25] Independent variables included demand-side individual characteristics (sociodemographic, clinical and self-management characteristics) and supply-side organisational characteristics (organisational model of diabetes management, level of providers' diabetes knowledge, kinds of antidiabetics drugs and number of patients per manager).

Sociodemographic characteristic variables included residence (urban or rural), sex (male or female), age (35–49, 50–64 and 65–79 years), marital status (unmarried or married), education (illiterate, primary school, junior school or ≥senior school) and annual household income per capita (¥0–¥4999, ¥5000–¥19 999 or ≥¥20 000 CNY). Clinical characteristics variables included duration of diabetes (0–4, 5–9 or ≥10 years), diabetic complication (no or yes), hypertension (no or yes), antidiabetic treatment (non-drugs, oral drug and insulin treatment) and body mass index (<25 or ≥25 kg/m^2).

Self-management characteristic variables included physical exercise, dietary plan, blood glucose monitoring, diabetes knowledge and perceived self-efficacy. In accordance with recommendations from the China Guideline for Type 2 Diabetes,[26] regular physical exercise was identified if the goal of 150 min per week of moderate intensity physical activity was achieved, and healthy dietary plan would be identified if the intake of total caloric, high-fat and high-sugar foods was controlled together in daily life, and blood glucose monitoring was classified by frequency into two groups (≥1 time per month and <1 time per month). Diabetes knowledge was measured by self-developed questionnaire with 16 items. Total scores ranged from 0 to 16, with a larger score indicating a higher knowledge level. Self-efficacy was measured using the Chinese version of the Diabetes Empowerment Scale-Short Form, with eight items rated on a 5-point Likert scale.[27] Total scores ranged from 8 to 40, with a higher score indicating a higher self-efficacy level.

The organisational model of diabetes management was classified into four models according to the type of health institution managing patients with T2DM, including community or township health centre, community or township health center-owned and community or township health center-managed health station or village clinic, community or village committee-owned and community or village committee-managed health station or village clinic (CHS/CVC), and private-owned and private-managed health station or village clinic (PHS/PVC). The level of providers' diabetes knowledge was measured using the questionnaires with 24 items developed by researchers according to the China Guideline for Type 2 Diabetes, and divided into three groups based on the total scores (<14, 14–16 and ≥16). The kind of antidiabetics drugs was assessed by the generic name of drugs available at the clinics and categorised into three groups (1–2, 3 and 4–5). The number of patients per manager was assessed by the total number of patients with T2DM divided by the total number of healthcare providers in each clinic and was classified into three groups (0–30, 31–60 and ≥61).

Statistical analysis

We used descriptive analyses to examine individual and organisational characteristics. The frequency and percentage were calculated and presented for categorical variables. χ^2 tests were used to test the variations of proportion between poor and good glycaemic control groups. Multilevel analyses were used to simultaneously identify the individual characteristics and organisational characteristics associated with glycaemic control.[28 29] Multilevel logistic regression analyses were performed with the data of 2166 participants (level 1) nested in the data of 72 communities or villages (level 2) and glycaemic control as the dependent variable. Models 1, 2, 3 and 4 were two-level logistic regressions to take into account the organisational model of diabetes management, level of providers' diabetes knowledge, kinds of antidiabetic drugs and number of patients per manager, respectively. We present ORs and 95% CIs. All statistical analyses were conducted using STATA V.15.0. The significance level for statistics was set at p<0.1, p<0.05 and p<0.01.

Patient and public involvement

There are no patients or public directly involved in the design, planning, conception and conduct of this study. This is a cross-sectional survey study with patients or public involved as participants.

RESULTS

Individual demographic characteristics and glycaemic control status

Demographic characteristic were listed for overall sample and by the status of glycaemic control (table 1). Among 2166 patients with T2DM, only 42.8% achieved good glycaemic control. The majority of the patients was elderly (94.4%), married (86.1%) and had low educational attainment (89.4%). Nearly 40% of respondents had low household income. Compared with participants in the group with good glycaemic control, those in the group with poor glycaemic control were more likely in

Table 1 Demographic characteristics by glycaemic control status of patiens with type 2 diabetes mellitus (n, %)

		Total	FPG≥7.0 mmol/L	FPG<7.0 mmol/L	χ^2	P value
Gender	Male	749 (34.6)	433 (34.9)	316 (34.1)	0.15	0.701
	Female	1417 (65.4)	807 (65.1)	467 (65.9)		
Age (years)	35–49	121 (5.6)	84 (6.8)	37 (4.0)	15.72	**<0.001**
	50–64	965 (44.6)	577 (46.5)	388 (41.9)		
	65–79	1080 (49.9)	579 (46.7)	501 (54.1)		
Marital status	Unmarried	301 (13.9)	172 (13.9)	129 (13.9)	0.01	0.968
	Married	1865 (86.1)	1068 (86.1)	797 (86.1)		
Educational level	Illiterate	711 (32.8)	398 (32.1)	313 (33.8)	2.16	0.541
	Primary school	716 (33.1)	403 (32.5)	313 (33.8)		
	Junior school	509 (23.5)	303 (24.4)	206 (22.3)		
	≥Senior school	230 (10.6)	136 (11.0)	94 (10.2)		
Household income per capita (¥)	0–4999	852 (39.3)	482 (38.9)	370 (40.0)	2.14	0.342
	5000–19 999	1049 (48.4)	615 (49.6)	434 (46.9)		
	≥20 000	265 (12.2)	143 (11.5)	122 (13.2)		
Residence area	Rural	1070 (49.4)	615 (49.6)	455 (49.1)	0.05	0.832
	Urban	1096 (50.6)	625 (50.4)	471 (50.9)		

FPG, fasting plasma glucose.

the age group of 50–64 years and less likely in the age group of 65–79 years (χ^2=15.86, p<0.001).

Individual clinical characteristics and glycaemic control status

Clinical characteristics were presented for the overall sample and by the status of glycaemic control (table 2). Among 2166 patients with T2DM, 38.5% of the participants reported their duration of diabetes being 0–4 years; 35.7% of the participants reported having diabetic complication; 49.1% of the participants reported having hypertension; and 57.3% of the participants were overweight or obese. More than 70% of the participants took only oral antidiabetic drugs, while nearly 14% of the participants did not use antidiabetic drugs. Compared with the good control group, the poor control group had a longer duration of diabetes (χ^2=70.45, p<0.001), was more likely to have diabetic complication (χ^2=10.93, p=0.001) and hypertension (χ^2=10.40, p=0.001) and was more likely to use oral antidiabetic drugs or insulin (χ^2=150.27, p<0.001).

Individual self-management characteristics and glycaemic control status

Self-management characteristics were listed for the overall sample and by the status of glycaemic control (table 3).

Table 2 Clinical characteristics by glycaemic control status of patients with type 2 diabetes mellitus (n, %)

		Total	FPG≥7.0 mmol/L	FPG<7.0 mmol/L	χ^2	P value
Duration of diabetes (years)	0–4	833 (38.5)	392 (31.6)	441 (47.6)	70.45	**<0.001**
	5–9	680 (31.4)	400 (32.3)	280 (30.2)		
	≥10	653 (30.2)	448 (36.1)	205 (22.1)		
Diabetic complication	No	1393 (64.3)	761 (61.4)	632 (68.3)	10.93	**0.001**
	Yes	773 (35.7)	479 (38.6)	294 (31.8)		
Hypertension	No	1102 (50.9)	668 (53.9)	434 (46.9)	10.40	**0.001**
	Yes	1064 (49.1)	572 (46.1)	492 (53.1)		
Antidiabetic treatment	No drugs	300 (13.9)	80 (6.5)	220 (23.8)	150.27	**<0.001**
	OADs only	1545 (71.3)	927 (74.8)	618 (66.7)		
	Insulin	321 (14.8)	233 (18.8)	88 (9.5)		
BMI	<25 kg/m^2	925 (42.7)	542 (43.7)	383 (41.4)	1.12	0.274
	≥25 kg/m^2	1241 (57.3)	698 (56.3)	543 (58.6)		

BMI, body mass index; FPG, fasting plasma glucose; OADs, oral antidiabetic drug.

Table 3 Self-management characteristics by glycaemic control status of patients with type 2 diabetes mellitus (n, %)

		Total	FPG≥7.0 mmol/L	FPG<7.0 mmol/L	χ^2	P value
Regular physical exercise	No	1889 (87.2)	1085 (87.5)	804 (86.8)	0.22	0.642
	Yes	277 (12.8)	155 (12.5)	122 (13.2)		
Healthy dietary plan	No	553 (25.5)	325 (26.2)	228 (24.6)	0.70	0.402
	Yes	1613 (74.5)	915 (73.8)	698 (75.4)		
Blood glucose monitoring	<1 time/month	1755 (81.0)	955 (77.0)	800 (86.4)	30.32	**<0.001**
	≥1 time/month	411 (19.0)	285 (23.0)	126 (13.6)		
Diabetes knowledge	Low (<12)	1291 (59.6)	699 (56.4)	592 (63.9)	12.58	**<0.001**
	High (≥12)	875 (40.4)	541 (43.6)	334 (36.1)		
Diabetes self-efficacy	Low (<33)	931 (43.0)	560 (45.2)	371 (40.1)	5.62	**0.018**
	High (≥33)	1235 (57.0)	680 (54.8)	555 (59.9)		

FPG, fasting plasma glucose.

Only 12.8% of the participants reported that they had regular physical exercise, while 74.5% of the participants reported being on healthy dietary plans. Only 19.0% of the participants performed blood glucose monitoring for at least one time per month. About 40.4% of the participants had a high level of diabetes knowledge, while 43.0% had a low level of diabetes self-efficacy. Compared with the good control group, the poor control group had significantly more frequent blood glucose monitoring (χ^2=30.32, p<0.001), higher level of diabetes knowledge (χ^2=12.58, p<0.001) and lower level of diabetes self-efficacy (χ^2=5.62, p=0.018).

Supply-side organisational characteristics and glycaemic control status

Supply-side characteristics were presented for the overall sample and by the status of glycaemic control (table 4). About 48.4% of the participants received diabetes care from CHS/CVC, while 16.3% of the participants received diabetes care from PHS/PVC. Only 21.1% of the participants received diabetes care from healthcare providers with high diabetes knowledge. About 41.3% of the participants were managed by the health institutions with four to five antidiabetic drugs. Nearly 20% of the participants were managed by healthcare providers managing more than 60 patients with diabetes each. Compared with the good control group, the poor control group was more likely to be managed by PHS/PVC (χ^2=34.57, p<0.001), healthcare providers with low diabetes knowledge (χ^2=9.20, p=0.010), health institutions with less antidiabetic drugs (χ^2=11.97, p=0.003) and healthcare providers managing more patients with diabetes (χ^2=8.50, p=0.014).

Determinants of glycaemic control by multilevel logistic regression

For each organisational characteristic, a multilevel logistic regression analysis was performed controlling for individual characteristics (table 5). Patients with diabetes

Table 4 Supply-side characteristics by glycaemic control status of patients with type 2 diabetes mellitus (n, %)

		Total	FPG≥7.0 mmol/L	FPG<7.0 mmol/L	χ^2	P value
Organisational model of diabetes management	CHC/THC	274 (12.7)	150 (12.1)	124 (13.4)	34.57	**<0.001**
	HHS/HVC	490 (22.6)	236 (19.0)	254 (27.4)		
	CHS/CVC	1049 (48.4)	614 (49.5)	435 (47.0)		
	PHS/PVC	353 (16.3)	240 (19.4)	113 (12.2)		
Diabetes knowledge of providers	Low	488 (22.5)	308 (24.8)	180 (19.4)	9.20	**0.010**
	Middle	1222 (56.4)	684 (55.2)	538 (58.1)		
	High	456 (21.1)	248 (20.0)	208 (22.5)		
Kinds of antidiabetics drugs	1–2	547 (25.3)	343 (27.7)	204 (22.0)	11.97	**0.003**
	3	725 (33.5)	419 (33.8)	306 (33.1)		
	4–5	894 (41.3)	478 (38.6)	416 (44.9)		
Number of patients per manager	0–30	956 (44.1)	514 (41.5)	442 (47.7)	8.50	**0.014**
	31–60	793 (36.6)	477 (38.5)	316 (34.1)		
	≥61	417 (19.3)	249 (20.1)	168 (18.1)		

CHC/THC, community or township health centre; CHS/CVC, community or village committee-owned and community or village committee-managed health station or village clinic; FPG, fasting plasma glucose; HHS/HVC, community or township health center-owned and community or township health center-managed health station or village clinic; PHS/PVC, private-owned and private-managed health station or village clinic.

Table 5 Multilevel logistic regression models to identify factors associated with glycaemic control (OR, 95% CI)

Variable	Category	Model 1	Model 2	Model 3	Model 4
Gender (ref=male)	Female	1.09 (0.88 to 1.34)	1.08 (0.87 to 1.34)	1.08 (0.87 to 1.33)	1.10 (0.89 to 1.37)
Age (ref=35–49 years)	50–64	1.89 (1.20 to 2.97)***	1.93 (1.22 to 3.03)***	1.89 (1.20 to 2.99)***	1.95 (1.24 to 3.07)***
	65–79	2.46 (1.55 to 3.90)***	2.53 (1.59 to 4.03)***	2.46 (1.55 to 3.93)***	2.50 (1.57 to 3.98)***
Marital status (ref=unmarried)	Married	1.13 (0.86 to 1.48)	1.18 (0.90 to 1.56)	1.17 (0.89 to 1.54)	1.18 (0.90 to 1.55)
Educational level (ref=illiteracy)	Primary school	1.09 (0.86 to 1.38)	1.05 (0.83 to 1.34)	1.04 (0.81 to 1.32)	1.08 (0.85 to 1.38)
	Junior school	1.02 (0.77 to 1.37)	1.01 (0.75 to 1.35)	0.99 (0.74 to 1.33)	1.01 (0.76 to 1.36)
	≥Senior school	1.01 (0.69 to 1.47)	1.02 (0.70 to 1.49)	1.01 (0.69 to 1.47)	1.03 (0.70 to 1.50)
Household income per capita (ref=0–4999)	5000–19999	1.02 (0.83 to 1.25)	1.04 (0.84 to 1.28)	1.03 (0.84 to 1.27)	1.05 (0.85 to 1.29)
	≥20 000	1.37 (0.99 to 1.88)*	1.42 (1.03 to 1.97)**	1.40 (1.01 to 1.93)**	1.43 (1.04 to 1.98)**
Residence (ref=urban area)	Rural area	1.01 (0.72 to 1.43)	1.03 (0.79 to 1.33)	1.08 (0.82 to 1.41)	0.98 (0.77 to 1.24)
Duration of diabetes (ref=0–4)	5–9	0.72 (0.58 to 0.90)***	0.72 (0.57 to 0.90)***	0.72 (0.57 to 0.89)***	0.72 (0.58 to 0.90)***
	≥10	0.54 (0.42 to 0.70)***	0.54 (0.42 to 0.70)***	0.54 (0.42 to 0.69)***	0.54 (0.42 to 0.69)***
Diabetic complication (ref=no)	Yes	0.90 (0.73 to 1.10)	0.89 (0.73 to 1.09)	0.89 (0.73 to 1.09)	0.90 (0.73 to 1.10)
Diagnosed hypertension (ref=no)	Yes	1.33 (1.10 to 1.61)***	1.34 (1.11 to 1.62)***	1.34 (1.11 to 1.62)***	1.34 (1.11 to 1.62)***
Antidiabetics treatment (ref=no drugs)	OADs	0.27 (0.20 to 0.36)***	0.29 (0.21 to 0.38)***	0.29 (0.22 to 0.39)***	0.28 (0.21 to 0.37)***
	Insulin	0.21 (0.14 to 0.31)***	0.21 (0.14 to 0.32)***	0.22 (0.15 to 0.33)***	0.21 (0.14 to 0.31)***
BMI (ref=≤25 kg/m^2)	≥25 kg/m^2	0.99 (0.83 to 1.20)	0.99 (0.82 to 1.20)	0.99 (0.83 to 1.21)	0.99 (0.82 to 1.20)
Physical exercise (ref=no regular)	Regular	1.07 (0.81 to 1.42)	1.07 (0.81 to 1.42)	1.06 (0.80,1.40)	1.06 (0.80 to 1.41)
Dietary plan (ref=not on a plan)	On a plan	1.14 (0.92 to 1.42)	1.15 (0.93 to 1.44)	1.16 (0.93 to 1.45)	1.14 (0.92 to 1.42)
Blood glucose monitoring (ref=≤1 time/month)	≥1 time/month	0.68 (0.53 to 0.88)***	0.67 (0.52 to 0.87)***	0.67 (0.52 to 0.86)***	0.67 (0.52 to 0.87)***
Diabetes knowledge (ref=low)	High	0.91 (0.74 to 1.13)	0.92 (0.74 to 1.14)	0.91 (0.73 to 1.13)	0.90 (0.73 to 1.12)
Diabetes self-efficacy (ref=low)	High	1.32 (1.09 to 1.59)***	1.33 (1.10 to 1.62)***	1.32 (1.09 to 1.61)***	1.32 (1.09 to 1.61)***
Organisational model of diabetes management (ref=CHC/THC)	HHS/HVC	1.22 (0.74 to 1.99)			
	CHS/CVC	0.82 (0.59 to 1.15)			
	PHC/PVC	0.48 (0.29 to 0.82)***			
Diabetes knowledge of providers (ref=low)	Middle		1.36 (1.02 to 1.83)**		
	High		1.45 (1.00 to 2.10)**		
Kinds of antidiabetics drugs (ref=1–2)	3			1.37 (0.97 to 1.93)*	
	4–5			1.46 (1.07 to 2.00)**	
Number of patients per manager (ref=0–30)	31–60				0.69 (0.53 to 0.89)***
	≥61				0.71 (0.52 to 0.98)**
Constant		1.08 (0.52 to 2.25)	0.62 (0.29 to 1.30)	0.62 (0.29 to 1.31)	1.02 (0.50 to 2.09)
Mixed-effects Wald χ^2		215.63	194.28	194.78	197.95
P value		0.000	0.000	0.000	0.000
Var (_cons)		0.03 (0.01 to 0.23)	0.10 (0.04 to 0.24)	0.10 (0.04 to 0.24)	0.09 (0.03 to 0.23)
Random-effects Wald χ^2		1.31	9.38	9.41	8.08
P value		0.126	0.001	0.001	0.002

*P<0.1, **P<0.05, ***P<0.01.
BMI, body mass index; CHC/THC, community or township health centre; CHS/CVC, community or village committee-owned and community or village committee-managed health station or village clinic; HHS/HVC, community or township health center-owned and community or township health center-managed health station or village clinic; OADs, oral antidiabetic drug; PHS/PVC, private-owned and private-managed health station or village clinic; ref, reference.

who were older and had higher household income, hypertension, and higher self-efficacy were significantly more likely to have good glycaemic control than the others. Patients with diabetes with longer duration of diabetes, antidiabetic drug treatment and frequent blood glucose monitoring were significantly more likely to have poor glycaemic control than others. Patients with diabetes managed by PHS/PVC were significantly more

likely to have poor glycaemic control (OR=0.48, p<0.01). Patients with diabetes managed by healthcare providers with higher-level diabetes knowledge were more likely to have good glycaemic control (OR=1.36, p<0.05; OR=1.45, p<0.05). Patients with diabetes managed by the health institutions with more kinds of antidiabetic drugs were significantly more likely to have good glycaemic control (OR=1.37, p<0.1; OR=1.46, p<0.05). Patients with diabetes managed by healthcare providers managing more patients were significantly more likely to have poor glycaemic control (OR=0.69, p<0.01; OR=0.71, p<0.05).

DISCUSSION

This study assessed the status of glycaemic control and explored both individual and organisational characteristics influencing the status of glycaemic control among patients with T2DM managed in community health institutions in China. The results suggested that the majority of patients with T2DM could not achieve good glycaemic control. There is an urgent need to determine the barriers to achieving good glycaemic control. Glycaemic control was significantly associated with not only patient factors but also organisational characteristics. The findings implied that more efforts should be made to promote glycaemic control from the perspective of public health.[30] Variations in individual and organisational characteristics raised important implications for the tailored ways of improving glycaemic control.[31] Attempts to reach glycaemic control targets required joint efforts from both patients with diabetes and care providers. This study showed that despite the implementation of standard diabetes management,[9] there is a need for approaches for patients to reach good glycaemic control targets.

Only 42.8% of patients with T2DM in this study achieved the glycaemic control target of FPG less than 7.0 mmol/L. According to several studies in China, the proportion of patients with good glycaemic control increased from 26.8% in 2006 to 40.3% in 2016.[1 7] It indicated that more and more patients with T2DM achieved good glycaemic control since the national EPHSP launched in 2009. Nonetheless, this study showed that the prevalence of poor glycaemic control was still very high among patients with T2DM in China. This finding was similar to the prevalence of poor glycaemic control (59%) in Malaysia.[30] Comparatively, the prevalence of patients with diabetes with good glycaemic control in the Gulf area countries ranged from 21% to 41%.[13 32] Furthermore, higher prevalence of patients with diabetes with poor glycaemic control was reported in African countries such as Uganda (79%), Botswana (82%), Nigeria (62%) and Congo (68%), but the prevalence of good glycaemic control was estimated to be 52.5% in USA and 49.1% in Korea.[33] The variations in glycaemic control among Western, Asian and African countries may be attributed to different reasons, including diabetes services and operational programmes, medical staff and healthcare system, and individual characteristics and preference.[33 34] It indicated that glycaemic control among patients with diabetes is a serious challenge worldwide.

Findings from this study indicated that there are significant differences in individual characteristics among patients with diabetes between good and poor glycaemic control groups. Consistent with previous studies, older patients with diabetes tended to achieve better glycaemic control than younger ones.[13 35] The reason may be that older patients are more concerned about their disease worsening,[30] while younger patients are less concerned about their diet.[13] Given the progressive feature of diabetes, it is not surprising that poor glycaemic control is significantly associated with longer duration of diabetes[35]; thus, tight glycaemic control should begin when diabetes is initially diagnosed.[30] Similar with other studies, patients treated with insulin were found to have poorer glycaemic control, because they might have more complications that required aggressive treatment for glycaemic control.[32 33] Patients with diabetes might have multiple reasons for poor glycaemic control.[36] Early interventions to prevent complications should be implemented to the specific group. Variations in glycaemic control related to individual characteristics suggested that tailored interventions might be needed for patients in different subgroups.[31] It is vital to take particular measures for specific patients rather than a one-size-fits-all model.[30]

Furthermore, the results suggested that organisational characteristics, including the PCC/PVC managing model, lower diabetes knowledge of healthcare providers, fewer kinds of antidiabetic drugs in the community health institutions and fewer healthcare providers managing patients with diabetes, were significantly associated with poor glycaemic control. The main explanation may be that these health system-level characteristics in the practice setting are essential determinants of the quality of diabetes care, which consequently influences the treatment compliance, management behaviour and health outcomes. Similarly, previous studies have demonstrated that glycaemic control was affected by the practice level, quality of care and effective interaction with healthcare providers.[31 37] Poor glycaemic control among patients with diabetes may be attributable to a number of factors, including disease progression, side effects of therapy and therapeutic inertia on the part of clinicians.[36] One study has shown that a greater proportion of the difference in health outcome was explained by physician level effects rather than individual demographic factors.[11] Healthcare interventions have been found to be a promising strategy for improving diabetes outcomes.[16 38] Patients with diabetes require high-quality care to ensure good glycaemic control and health outcomes.[23] Therefore, we should emphasise a well-structured healthcare system to guide effective personalised care in diabetes clinical practice.[6] Moreover, the optimal diabetes management model requires the involvement of a coordinated team of qualified healthcare providers.[10]

There are a few limitations to acknowledge in this study. First, although we evaluated a broad set of patient factors

associated with glycaemic control, it is not possible to assess all possible factors, such as disease features, personality and health beliefs.[34] However, we established the model based on a comprehensive literature review to include as many variables as possible. Second, the data collected are cross-sectional at baseline, so the present analysis cannot identify the causal relationship between individual and organisational characteristics and glycaemic control. Further research should investigate the causality with longitudinal data. Third, the participants were patients with T2DM managed in communities by EPHSP, which may overestimate the proportion of patients with optimal glycaemic control. Future studies of patients with T2DM who are not registered on the list of EPHSP are needed to provide more evidence. Fourth, the sample was selected from one province, which might compromise the representativeness of the sample, so the extrapolation of findings and conclusions at the national level could be challenged. Finally, glycaemic control was assessed using FPG. Although there are two evidence-based approaches (FPG and HbA1c) for diagnosing and treating diabetes mellitus in the clinical medicine, it is feasible and convenient to use only FPG for assessing glycaemia in the diabetes management. Despite these limitations, this study is novel by simultaneously exploring patient-level, provider-level and system-level factors associated with glycaemic control, which could provide interesting findings for policy makers and practitioners.

CONCLUSIONS

Glycaemic control was suboptimal among patients with T2DM in China. Poor glycaemic control was partly determined by individual characteristics at the patient level, and partly by organisational characteristics and the way of delivering care in each practice setting. Thus, potential interventions targeting patients, providers and the healthcare organisations should be developed to improve the glycaemic control and health outcome among patients with diabetes. Accordingly, optimal glycaemic control should be individualised by considering treatment goals, comorbidities, patients' characteristics and adherence. Furthermore, improving care delivery models, training providers' knowledge, increasing antidiabetic drugs and recruiting qualified providers are essential to developing a more supportive environment for diabetes management.

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