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ORIGINAL RESEARCH

Blood Glucose Monitoring and Its Determinants in Diabetic Patients: A Cross-Sectional Study in Shandong, China

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ABSTRACT

Introduction: The aim of this study was to explore the status of blood glucose monitoring and its determinants in diabetic patients in Shandong Province, China.

Methods: This was a cross-sectional survey conducted from 31 August to 12 October 12, in Shandong Province. A multi-stage stratified cluster sampling method was used to select participants. A total of 2183 diabetic patients were included in the analysis. Frequencies and proportions were used to describe the data, and multiple binary logistic regressions were performed to determine factors associated with blood glucose monitoring.

Results: Of the participants, 51.4% tested their blood glucose level more than once a month. The multivariate logistic regression model showed that seven variables were significantly associated with the frequency of blood glucose monitoring: education level, residence, household income, self-reported health, physical examination, anti-diabetic drug or insulin injection, and comorbidity.

Conclusions: The level of blood glucose monitoring among diabetic patients in Shandong Province is low. Based on these results we recommend that the cost of blood glucose monitoring by professionals in laboratories be reimbursed or at least reduced and that diabetic patients be encouraged to undergo regular physical examinations.

Keywords: Diabetes; Frequency; Influencing factors; Monitoring of blood glucose

Abdul Marouf Raoufi and Xue Tang contributed equally to this study and are joint co-first authors of this paper.

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INTRODUCTION

Diabetes is one of the most important public health problems of the 21st century [1]. The prevalence of diabetes has increased due to changes of lifestyle and an increased life expectancy [2, 3]. According to the International Diabetes Federation, 8.8% of adults aged 20–79 years were estimated to have diabetes in

2017, and the number of people with diabetes in that year reached 425 million people worldwide. The number of people with diabetes increases to 451 million if the age range is expanded to 18–99 years. Should these trends continue, by 2045, 693 million people aged 18–99 years, or 629 million people aged 20–79 years, will have diabetes [4]. As in many other countries, the prevalence of diabetes is rising rapidly in China [5]. According to the World Health Organization (WHO) diabetes country profiles for 2016, the number of deaths in China due to diabetes in that year was 224,700; in the age range 30–69 years 37,000 of these were male and 56,000 were female, and in the age range 69–70 years 49,300 were male and 82,400 were female [6].

Blood glucose monitoring can timely reflect the influence of diet, exercise, stress, and drugs on the blood glucose level of patients with diabetes, providing the necessary data for evidenced-based clinical decision-making by healthcare professionals [7]. Several studies have shown that blood glucose monitoring is an effective tool for managing diabetes [8], with regular monitoring of blood glucose levels associated with reduced blood glucose level and an improved quality of life [9–12]. The frequency of blood glucose monitoring negatively correlates with levels of blood glucose [13–17]. Nevertheless, the implementation of blood glucose monitoring is far from satisfactory worldwide [18]. Studies carried out in the USA and Australia found that age, socioeconomic status, and duration of diabetes were associated with compliance with blood glucose monitoring [14, 19, 20]. The authors of two studies carried out in China found that factors affecting the frequency of blood glucose monitoring included diabetes, diet control, exercise therapy, and glycosylated hemoglobin (HbA1c) [7, 17]. The authors of these studies also found that age, fasting blood sugar, 2 h postprandial blood sugar, diabetes education, insulin therapy, and hypoglycemia can also affect the frequency of blood glucose monitoring [7, 17].

Although there are many health benefits associated with blood glucose monitoring, many diabetics do not test their blood glucose regularly [21]. A patient's blood glucose monitoring compliance is an important factor in determining the performance of blood glucose monitoring, thus it is particularly important to identify a patient's compliance with blood glucose monitoring and the factors that affect it [22]. In China, many patients, especially in rural areas, do not practice self-monitoring of blood glucose (SMBG). Thus, blood glucose levels are monitored by professionals working in laboratories, and the results are of great significance to healthcare professionals who then have trustworthy values on which to base decisions regarding the management of their patient's diabetes. To date, however, most previous studies have focused on SMBG, and few studies have explored blood glucose monitoring by professionals in diabetes patients, especially in China [23–26]. To remedy this situation, the aim of this study was to explore blood glucose monitoring in diabetes patients in China by professionals working in laboratories. To this end, we first explored the prevalence of blood glucose monitoring in diabetes patients by professionals in China, and then we identified the factors associated with blood glucose monitoring.

METHODS

Subjects

This study was conducted in Shandong Province, China. Shandong is the second most populated province in China (nearly 100 million in 2016). In 2008, the prevalence of diabetes mellitus in people living in Sandong Province who were aged $\geq$ 20 years was 9.9%, which was significantly higher than the average level in the whole country. For our study, we used a multi-stage stratified cluster sampling method to select participants, as described in detail in a previous study [27]. A total of 2481 diabetes patients registered in the NCDs management system in the sampling communities or villages were recruited to the survey, and 2183 diabetic patients for whom a complete dataset were available were included in the analysis, with a response rate of 87.99%. The inclusion criteria were: (1) diagnosis of diabetes based on WHO criteria for > 1 year [28, 29]; (2) age of ≥ 18 years; and (3) ability to understand the questions on the questionnaire.

A cross-sectional study was conducted from August to October 2016. All subjects were interviewed face-to-face using a structured questionnaire by trained Master students from Shandong University School of Public Health. To ensure quality, all of the completed questionnaires were carefully checked by quality supervisors after the interview each day. The questionnaire included: (1) the patient's basic information, such as gender, age, marital status, education, employment status, family size, residence, exercise, household income; (2) patient's health status, including self-reported health, body mass index (BMI), diabetes and its comorbidity, and duration of diagnosis; and (3) health management and health service use, including blood glucose monitoring by professionals, insulin injection, and outpatient and inpatient services.

Variables and Measures

Dependent Variable

The dependent variable was the frequency of blood glucose monitoring of participants, and the question was "How often did you monitor your blood glucose by professionals after being diagnosed with diabetes?" The answers were classified into five categories: 1—more than once a month, 2—once every 1–6 months, 3—once every 7–12 months, 4—less than once a year, 5—never. We combined five categories into two categories, namely, monthly and below and more than monthly, in order to conduct binary logistic regression, according to the Guideline for Blood Glucose Monitoring in China [7]. In the present study, "monitoring by professionals" refers to blood glucose being measured during visits to a healthcare professional.

Independent Variable

Independent variables included socio-demographic characteristics, such as gender (male vs. female), age (≤ 60, 61–70, > 70 years), marital status (single or married, with single encompassing the not-married, divorced, and widowed states, respectively), education level (illiterate, primary school, junior school, high school and higher), employment status (unemployed vs. employed), family size (≤ 3 vs. > 3), residence (rural vs. urban), exercise (no vs. yes), and household income (Q1, Q2, Q3, and Q4 quintiles, whereby quintile 1(Q1) was the lowest income and quintile 4 (Q4) was the highest income. Also included as independent variables were self-reported health (good, normal, poor), physical examination (no vs. yes, whereby physical examination means regular physical examination [excluding check-ups for the treatment of diseases]), BMI (< 18.5, 18.5–23.99, 24–27.99, ≥ 28 kg/m^2), duration of diagnosis (≤ 5, 6–10, > 10 years), anti-diabetic drug or insulin therapy in the past 2 weeks (no vs. yes), diabetes-related education (no vs. yes), outpatient service in the past 2 weeks (no vs. yes), inpatient service in the past year (no vs. yes), and comorbidity (no vs. yes). In this study, comorbidity means the presence of any other disease(s) or condition(s) (diabetic nephropathy, diabetic eye complications, diabetic foot, diabetic cardiovascular complications, diabetic cerebrovascular disease, and diabetic neuropathy). The measurement details and the code for each variable are presented in Electronic Supplementary Material (ESM) 1.

Statistical Analysis

Data was entered into a computer using the Statistical Package for Social Sciences (SPSS) software version 24.0 (IBM Corp., Armonk, NY, USA). Data was described using frequencies and proportions wherever appropriate. Univariate logistic regression analysis was used to analyze the effect of each potential factor on a patient's blood glucose monitoring compliance. Multiple binary logistic regressions were performed to determine variables for which a P value of < 0.05 in univariate logistic regression were associated with blood glucose monitoring adherence. A P value of < 0.05 was considered to be statistically significant. Survey procedures were used to analyze survey data by taking into account the sample design.

Compliance with Ethics Guidelines

The study protocol for this study involving human participants was approved by the Ethical Committee of Shandong University School of Public Health and was in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The investigation was conducted after the informed consent of all participants was obtained.

RESULTS

Patients' Characteristics

A total of 2183 patients with DM (1461 females, 722 males) were enrolled in this study. Their age ranged from 21 to 106 years, and the majority (85.0%) were married. With respect to education level, 7.2% of the participants had high school and above,, 18.3% had junior school education, 30.7% had primary school education, and 43.7% had no formal education. Half of the participants (50.0%) were unemployed, and the majority (86.3%) had a family size of ≤ 3 people. By far the majority (88.2%) lived in rural areas, with only 11.8% living in urban areas. Only 22.5% of the participants thought they had a good health condition, although 62.1% of all participants reported exercising regularly. The majority (88.4%) of the participants had had the physical examination. The BMI ranged between 18.5 and 23.99 kg/m^2 for 31.4% of participants, and 66.0% of participants were overweight. Overall, 29.7% of patients had diabetes for > 10 years, and 91.3% of participants had used anti-diabetic drug or injected insulin in the past 2 weeks. The percentages of anti-diabetic drug or insulin injection are given in ESM 2. Only 14.0% of participants had no diabetes-related education, 17.4% had diabetes complications, 2.7% of used outpatient service, and 7.7% used inpatient service (Table 1).

Table 1 Basic information on 2183 participants with diabetes mellitus in Shandong, China, 2016

Characteristics	*N*	Weight (%)
Gender (*n*)		
Male	722	33.1
Female	1461	66.9
Age (years)		
≤ 60	554	28.3
61–70	1002	45.5
> 70	627	26.2
Marital status		
Single[a]	327	15.0
Married	1856	85.0
Education		
Illiterate	826	43.7
Primary school	732	30.7
Junior school	449	18.3
High school and above	176	7.2
Employment status		
Unemployed	1195	50.0
Employed	988	50.0
Family size		
≤ 3	1900	86.3
> 3	283	13.7
Residence		
Rural	1692	88.2
Urban	491	11.8
Exercise		
No	808	37.9
Yes	1375	62.1
Household income[b]		
Q1	546	28.8
Q2	549	25.7
Q3	543	25.2
Q4	545	20.3

Table 1 continued

Characteristics	*N*	Weight (%)
Self-reported health		
Good	521	22.5
Normal	913	42.4
Poor	749	35.2
Physical examination		
No	274	11.6
Yes	1909	88.4
Body mass index (kg/m^2)		
< 18.5	53	2.6
18.5–23.99	672	31.4
24–27.99	954	43.6
≥ 28	504	22.4
Duration of diagnosis (years)		
≤ 5	773	38.3
6–10	680	32.0
> 10	730	29.7
Type of diabetes		
I	238	11.3
II	1948	88.7
Anti-diabetic drug or insulin injections		
No	174	8.7
Yes	2009	91.3
Diabetes-related education		
No	317	14.0
Yes	1866	86.0
Comorbidity		
No	1796	82.6
Yes	387	17.4
Outpatient service		
No	2121	97.3
Yes	62	2.7
Inpatient service		
No	2012	92.3
Yes	171	7.7

[a] Single includes not married, divorced, and widowed
[b] Quintile 1 (Q1) was the lowest income and Q4 was the highest income, with Q3 bing a medium-level income

The Frequency of Blood Glucose Monitoring

Of the total 2183 participants, 51.4 and 48.6% had their blood monitored by professionals more than once a month and once or less than once a month, respectively. In the latter category, 41.0% had tested their blood glucose more than once every 6 months and 4.7% had their blood glucose level tested once or less than once every 6 months. Of the participants, 1.9% had tested their blood glucose less than once a year and 1.0% had never tested their blood glucose (Table 2).

Factors Associated with Frequency of Blood Glucose Monitoring

The results of the univariate and multivariate analyses are shown in Table 3. In the multivariate analysis, we analyzed the 18 factors itemized in section "Independent variable"; of these, 11 were associated with blood glucose monitoring in the univariate analysis. The only variables not significantly associated with blood glucose monitoring were employment status, exercise, disease duration, and diabetes-related education ($P > 0.05$). Participants who had a higher education ($P < 0.001$), lived in urban areas (odd ratio [OR] 2.83; 95% confidence interval [CI] 1.75, 4.57), had a higher household income ($P < 0.05$), had a poor or normal self-reported health condition ($P < 0.05$), had physical examinations (OR 1.56; 95% CI 1.06, 2.31), took an anti-diabetic drug or had injected insulin in the past 2 weeks (OR 2.95; 95% CI

Table 2 The frequency of blood glucose monitoring by professionals in Shandong, China, 2016

Frequency	*N*	Percentage of participants
More than once a month	1197	51.4
More than once every 6 months	819	41.0
Once every 6 months or less	98	4.7
Less than once a year	43	1.9
Never	26	1.0
Total	2181	100.0

1.38, 6.30), and had diabetic comorbidity (OR 1.28; 95% CI 1.06, 1.69) had more often monitored their blood glucose compared to their counterparts.

DISCUSSION

With the emergence of such social phenomena as rapid economic development, urbanization, an increasingly aged population, and changes in people's lifestyle, diabetes has become a major chronic disease that threatens human health worldwide [30, 31]. The prevalence of diabetes has increased rapidly during the past decades [32]. Previous studies have shown that an increased monitoring frequency is associated with a decrease in blood glucose level, and the association between self-monitoring frequency and glycemic control has been definitely confirmed in patients with diabetes [22]. Blood glucose monitoring is therefore indispensable in any comprehensive management program aimed at the prevention and treatment of diabetes.

According to the 2015 edition of the Guidelines for Blood Glucose Monitoring in China [7], people who use lifestyle intervention or oral hypoglycemic drugs to manage their diabetes should monitor their blood glucose at least twice a week on average. In our study we focused only on blood glucose monitoring performed in professional laboratories. Many diabetic patients, especially in rural areas, do not practice SMBG. On the other hand, SMBG can only improve a patient's blood glucose level if the patient is able to measure his/her blood glucose accurately, interpret the measurements, and then make the correct decision based on these values. Thus, the monitoring of blood glucose levels in laboratories by professionals is also necessary because the professionals can provide advice on controlling blood glucose and also assist with the interpretation of results. Previous studies focused on the SMBG, such as the study of Tingting et al. showed that the average monthly self-glycemic monitoring frequency was 10.03 times among the 289 patients surveyed [7]. Skelly and colleagues showed that 76.7% of patients tested their blood glucose at least once a week [14]. However, we did not find similar research involving the frequency of blood glucose monitoring in laboratories. Our study showed that only 54.8% of the participants had tested their blood glucose more than once per month, indicating that blood glucose monitoring of diabetic patients in Shandong Province is at a low level.

The results of our study showed that the frequency of blood glucose monitoring was lower in illiterate participants than in those with a high school education and above; these findings are consistent with those of Adams et al. [19]. It is possible that patients with a relatively lower education may have difficulty in understanding both the importance of blood glucose monitoring and how to self-monitor. Equally, a low education may lead to a low income. This finding implies a need for physicians to pay more attention to glucose monitoring in diabetes patients with a lower education.

We found that the frequency of blood glucose monitoring was significantly lower among participants from rural areas than among those from urban areas. This finding suggests that the difference in socioeconomic development and quality of healthcare services between rural and urban areas may explain the observed difference in frequency of blood glucose monitoring. Another possible explanation is that the annual household income and diabetes-related education in the urban diabetic patients of our study

Table 3 Logistic regression analysis of factors affecting patients' blood glucose monitoring by professionals in Shandong, China, 2016

Characteristics	More than once a month (weight%)	Once or less than once a month (weight%)	Univariate analysis			Multivariate analysis		
			P	Odds ratio	95% Confidence ratio	*P*	Odds ratio	95% Confidence interval
Gender								
Male	54.9	45.1		1			1	
Female	49.6	50.4	0.044	0.81	0.66–0.99	0.159	0.83	0.65–1.08
Age (years)								
≤ 60	51.2	48.8		1			NA	
61–70	51.5	48.5	0.891	1.02	0.81–1.27			
> 70	51.4	48.2	0.948	1.00	0.77–1.32			
Marital status								
Single[a]	52.3	47.7		1			NA	
Married	52.0	48.0	0.199	1.19	0.91–1.58			
Education								
Illiterate	47.6	52.4		1			1	
Primary school	51.9	48.1	0.928	1.02	0.65–1.61	0.448	0.84	0.54–1.33
Junior school	60.0	40.0	0.061	1.63	0.98–2.73	0.243	1.33	0.82–2.16
High school and above	67.7	32.3	< 0.001	2.31	1.63–3.29	0.043*	1.46	1.09–2.17
Employment status								
Unemployed	55.9	44.1		1			1	
Employed	46.8	53.2	0.017	0.69	0.52–0.93	0.118	0.80	0.61–1.06
Family size								
≤ 3	50.5	49.5		1			NA	
> 3	57.2	42.8	0.221	1.31	0.84–2.04			
Residence								
Rural	47.8	52.2		1			1	
Urban	78.3	21.7	< 0.001	3.94	2.69–5.75	< 0.001*	2.83	1.75–4.57
Household income[b]								
Q1	43.9	56.1		1			1	
Q2	48.9	51.1	0.220	1.22	0.88–1.69	0.275	1.17	0.088–1.58
Q3	51.4	48.6	0.053	1.35	0.99–1.84	0.102	1.24	0.96–1.60

Table 3 continued

Characteristics	More than once a month (weight%)	Once or less than once a month (weight%)	Univariate analysis			Multivariate analysis		
			P	**Odds ratio**	**95% Confidence ratio**	***P***	**Odds ratio**	**95% Confidence interval**
Q4	65.2	34.8	0.001	2.39	1.51–3.79	0.019*	1.54	1.08–2.17
Exercise								
No	46.2	53.8		1			NA	
Yes	47.5	52.5	0.077	1.29	0.97–1.71			
Self-reported health								
Good	57.6	42.4		1			1	
Ordinary	49.4	50.6	0.001	0.72	0.59–0.87	0.019*	0.72	(0.55–0.94)
Poor	49.8	50.2	0.067	0.73	0.52–1.02	0.040*	0.75	(0.57–0.99)
Physical examination								
No	40.7	59.3		1			1	
Yes	52.8	47.2	0.017	1.63	1.10–2.42	0.026*	1.56	1.06–2.31
Body mass index								
< 18.5	39.6	60.4		1			1	
18.5–23.99	46.3	53.7	0.363	1.32	0.71–2.42	0.425	1.28	0.68–2.40
24–27.99	54.1	45.9	0.038	1.80	1.04–3.13	0.065	1.68	0.97–2.91
≥ 28	54.5	45.5	0.052	1.83	0.99–336	0.064	1.77	0.96–3.26
Duration of diagnosis (years)								
≤ 5	47.0	53.0		1			1	
6–10	51.3	48.7	0.149	1.19	0.94–1.52	0.432	1.11	0.85–1.46
> 10	57.2	42.8	0.034	1.51	1.03–2.19	0.260	1.23	0.85–1.78
Type of diabetes								
I	23.9	76.1		1			NA	
II	54.0	46.0	0.900	1.02	0.74–1.41			
Insulin injections								
No	23.9	76.1		1			1	
Yes	54.0	46.0	< 0.001	3.73	2.33–5.97	0.007*	2.95	1.38–6.30
Diabetes-related education								
No	32.1	67.9		1			1	
Yes	54.5	45.5	< 0.001	2.53	1.88–3.42	0.191	1.37	0.85–2.22
Comorbidity								

Table 3 continued

Characteristics	More than once a month (weight%)	Once or less than once a month (weight%)	Univariate analysis			Multivariate analysis		
			P	Odds ratio	95% Confidence ratio	*P*	Odds ratio	95% Confidence interval
No	50.0	50.0		1			1	
Yes	58.6	41.4	0.020	1.42	1.06–1.91	0.045*	1.28	1.06–1.69
Outpatient service								
No	51.3	48.7		1		NA		
Yes	53.4	46.6	0.815	1.09	0.53–2.22			
Inpatient service								
No	50.8	49.2		1			1	
Yes	58.1	41.9	0.014	1.34	1.06–1.68	0.160	1.22	0.92–1.61

*Significantly associated with blood glucose monitoring at $P < 0.05$
NA Not applicable
[a] Single includes not married, divorced, and widowed
[b] Quintiles as defined in Table 1

were higher than those in rural patients. In China, the quality of healthcare in urban areas is far above that in rural regions. Therefore, we should improve the quality of the healthcare services in rural regions along with providing more diabetes-related education for diabetic patients in rural regions.

Consistent with the finding of Yuan et al., our study also shows that economic status is the most significant factor affecting blood glucose monitoring of diabetes in Shandong Province [22]. In China, the cost of monitoring blood glucose and of acquiring a glucose meter and strips for diabetes is largely paid for by the patients themselves, leading to many patients not conducting regular blood glucose monitoring. Therefore, we hope that the national health insurance agency will reimburse the cost of monitoring blood glucose in laboratories and the acquisition of a glucose meter and strips with the aim to reduce the economic burden of diabetes.

In our survey, participants with frequent physical examinations had monitored their blood glucose level more often than those with less frequent physical examinations. People who undergo frequent physical examinations will be better able to recognize the significance of blood glucose levels and identify abnormal levels early. We recommend that the government provide more publicity and education about the advantages of frequent physical examinations.

Participants with a diabetes duration of > 10 years monitored their blood glucose more often than those with a disease duration of ≤ 5 years. Interestingly, multivariate analysis of the logistic regression showed that disease duration was not associated with the frequency of blood glucose monitoring to any great degree. We found that diabetes patients with complications monitored their blood glucose more often than patients with no complications. One explanation is that patients with longer disease duration may have more complications, so they may pay more attention to blood glucose monitoring.

There are a number of limitations to this study. First, this study was cross-sectional, and we could not directly assess cause-and-effect relationships of demographic and disease characteristics with the frequency of monitoring or adherence. Second, the age distribution of our study was uneven, and most of the participants were elderly, which may have introduced bias into the results. Finally, in this study we focused on blood glucose monitoring in laboratories by professionals and did not take the SMBG into account, which will be remedied in our follow-up study.

CONCLUSIONS

The results of our study show that the level of blood glucose monitoring is still low in diabetic patients in Shandong Province in China. The patients who have a relatively lower education background were found to be less likely to be adherent, which implies a need for physicians to pay more attention to the monitoring in such patients. The government should reimburse the cost of monitoring blood glucose in laboratories, blood glucose meters, and strips, and encourage regular physical examinations.

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Disclosures. Abdul Marouf Raoufi, Xue Tang, Zhengyue Jing, Xinyi Zhang, Qiongqiong Xu and Chengchao Zhou have nothing to disclose.

Compliance with Ethics Guidelines. The study protocol for this study involving human participants was approved by the Ethical Committee of Shandong University School of Public Health and was in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The investigation was conducted after the informed consent of all participants was obtained.

Data Availability. Please contact the corresponding author for data requests.

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