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# Population attributable fraction of associated factors to adherence to blood glucose self-monitoring in diabetic type 2 patients treated with insulin or sulfonylureas/meglitinides: The results of DiaCare study in Iran

Amin Mohammadi<sup>1</sup>, Gita Shafiee<sup>2</sup>, Alireza Olyaeemanesh<sup>3</sup>, Rajabali Daroudi<sup>1</sup>, Amirhossein Aghakhani<sup>4</sup>, Ensieh Nasli-Esfahani<sup>5</sup>, Farideh Razi<sup>6</sup>, Ramin Heshmat<sup>2</sup>, Amirhossein Takian<sup>1,3,7</sup>

<sup>1</sup>Department of Health Policy, Management and Economics, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran,

<sup>2</sup>Chronic Diseases Research Center, Endocrinology and Metabolism Research Institute, Tehran University of Medical Sciences, Tehran, Iran, <sup>3</sup>Health Equity Research Center, Tehran University of Medical Sciences, Tehran, Iran, <sup>4</sup>Endocrinology and Metabolism Research Center, Endocrinology and Metabolism Research Institute, Tehran University of Medical Sciences, Tehran, Iran, <sup>5</sup>Diabetes Research Center, Endocrinology and Metabolism Research Institute, Tehran University of Medical Sciences, Tehran, Iran, <sup>6</sup>Metabolomics and Genomics Research Center, Endocrinology and Metabolism Research Institute, Tehran University of Medical Sciences, Tehran, Iran, <sup>7</sup>Center of Excellence for Global Health, Department of Global Health, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran

**Address or correspondence:**  
Dr. Amirhossein Takian,  
Center of Excellence for Global Health, Department of Global Health, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran.  
E-mail: takian@tums.ac.ir  
Dr. Gita Shafiee, Chronic Diseases Research Center, Endocrinology and Metabolism Research Institute, Tehran University of Medical Sciences, Tehran, Iran.  
E-mail: gshafiee.endocrine@gmail.com

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## Abstract:

**BACKGROUND:** Self-monitoring of blood glucose (SMBG) is a part of diabetes management. Numerous investigations have demonstrated inadequate adherence to SMBG. We investigated the level of adherence to SMBG in diabetic type 2 patients treated with insulin or sulfonylureas/meglitinide and the population attributable fraction of associated factors to SMBG in Iran.

**MATERIALS AND METHODS:** This cross-sectional study used data from the population-based study on diabetes care in Iran (DiaCare). Overall, 13392 diabetic persons aged 35–75 years were recruited from urban/rural areas of all 31 provinces of Iran in the DiaCare study. Our samples in the current study consisted of 7,481 individuals who were administered insulin or oral medications required to undertake SMBG. The patients were divided into two groups: the adherence group was those who used insulin and were required to perform SMBG at least twice per day or those who relied on oral medications (sulfonylureas/meglitinides) who were expected to engage in SMBG at least twice a week. Patients who did not meet these requirements were categorized as the nonadherence group. Univariate comparisons and multivariate logistic regression were used to assess the relationships between SMBG adherence and related factors and to calculate the population attributable fraction (PAF); the complex survey design was taken into consideration.

**RESULTS:** A total of 17.8% (1096/7481) of patients were seen to adhere to the SMBG. However, the rate of SMBG adherence was 38.8 percent in patients who used sulfonylureas/meglitinides; only 3.26% of patients on insulin were SMBG adherent. The adherence rates for men and women and also age groups were not statistically significant. The adherence rate in urban regions was 19.31%, while in rural areas, it was 11.51%. The multivariable analysis revealed that the probability of performing SMBG is much higher among married patients (OR = 1.84, 95% CI: 1.05,3.21). In addition, the factors of urbanization (OR = 1.79, 95% CI = 1.15-2.78), university education (OR = 1.99, 95% CI: 1.12, 3.55), and no smoking (OR = 1.78, 95% CI = 1.11,2.86) were also positively associated with the possibility of doing SMBG. Being married showed the highest PAF (PAF = 42.74%), followed by not smoking (PAF = 39.41%) and living in urban areas (PAF = 38.46%). Having an education higher than high school demonstrated the lowest PAF (PAF = 8.78%).

**CONCLUSIONS:** Most patients did not adhere to the suggested practice of SMBG. Factors such as marriage, urbanization, university education, and no smoking were shown to be associated with

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adherence to SMBG with high PAF. We advocate further qualitative and exploratory research to examine the underlying causes of nonadherence to SMBG in Iran.

### Keywords:

Blood glucose self-monitoring, diabetes mellitus type 2, insulin, Iran, meglitinide, sulfonylurea compounds, treatment adherence and compliance

## Introduction

The International Diabetes Federation reported that the prevalence of adult diabetes increased more than twice between 2000 and 2021 and is predicted to grow three times by 2045.<sup>[1]</sup> According to the findings of the Noncommunicable Diseases Risk-Factors Surveillance in Iran (STEPs) study, there was a notable rise in the prevalence of prediabetes (24.8%) and diabetes (14.2%) in Iranian adults aged 25 and above in 2021, compared to STEP's 2016.<sup>[2]</sup>

The primary cause of complications associated with diabetes is uncontrolled blood glucose. Long-term consequences of uncontrolled blood glucose include increased hospitalization and medical expenses, as well as problems with the kidneys, retina, cardiovascular, and nervous system.<sup>[3-5]</sup> To effectively manage diabetes, a variety of interventions are required.<sup>[6]</sup> The key component in preventing the long-term consequences of diabetes is self-management, i.e., self-monitoring of blood glucose (SMBG).<sup>[7,8]</sup> Patients with type 2 diabetes typically engage in fewer self-care activities for a variety of reasons.<sup>[9,10]</sup>

SMBG is a method used by individuals with diabetes to assess their blood glucose levels by using a glucometer. SMBG enables individuals with diabetes to regularly measure their blood glucose levels throughout the day,<sup>[11]</sup> which might facilitate patients in comprehending the impact of dietary modifications, various foods, frequency of eating, and diverse physical activities on their blood glucose levels.<sup>[12]</sup> The analysis of SMBG outcomes allows patients to use hypoglycemic medications, particularly insulin, to mitigate the risk of experiencing hypoglycemia episodes.<sup>[13]</sup>

Research indicates a discernible disparity in HbA1c levels between those who seldom or never monitor their blood glucose and those who engage in blood glucose monitoring 3–4 times daily.<sup>[14]</sup> Previous studies have shown the impact of structured SMBG on both blood sugar management in individuals with diabetes.<sup>[5]</sup> Furthermore, the provision of free test strips proved to be a successful strategy in motivating patients to engage in the management of their diabetes. The provision of free test strips to patients was associated with reduced HbA1c, as well as decreased average blood glucose and insulin dosages.<sup>[15]</sup>

Nevertheless, research conducted in both high and low and middle-income countries (LMICs) has revealed

suboptimal adherence to SMBG. Multiple studies have documented adherence rates below 50% in many countries, including the USA, Latin America, the United Kingdom, Jordan, Cameroon, and China.<sup>[16-21]</sup> In addition, studies have demonstrated a correlation between adherence to SMBG and many parameters, including gender, age, educational attainment, economic level, treatment regimen, frequency of clinic visits, duration of diabetes, and access to glucose test strips.<sup>[22-24]</sup>

Given the greater prevalence of diabetes in Iran compared to the global average, which is projected upward, as well as evidence from prior research endorsing the efficacy and impact of SMBG on blood glucose control, structured SMBG practices are expected to be of considerable advantage for people with diabetes. Based on the investigations, this is the first study of its kind in the field of SMBG, using the data of the DiaCare<sup>[25]</sup> survey that was conducted at the national level in Iran. Our study investigated the current status of adherence to SMBG in diabetic type 2 patients treated with insulin or sulfonylureas/meglitinide and the population attributable fraction of associated factors to SMBG in Iran.

## Materials and Methods

### Study design and setting

This is a cross-sectional study that used data from the population-based study on diabetes care in Iran (DiaCare) in 2022. The details of the DiaCare survey were provided elsewhere in a study profile.<sup>[25]</sup>

### Study participants and sampling

In this study, patients with type 2 diabetes in Iran were examined. The criterion for inclusion in the study was that patients between the ages of 35 and 70 years old had been diagnosed for at least 6 months and were able to respond. In brief, the sample size for the study was 288 participants based on the equation  $N_{srs} = Z^2 \cdot \alpha / [2 \cdot P \cdot (1 - P)] / d^2$  (where  $N$  is the sample size,  $Z$  is the statistic corresponding to level of confidence,  $P$  is expected prevalence, and  $d$  is precision (corresponding to effect size)) for simple random sampling. Therefore, according to the design effect of 1.33, the sample size for cluster sampling is 384, and with a correction of 10% for nonresponse, 432 patients (36 clusters of 12 people in urban and rural

areas of each province) have been calculated. A total of 13392 people (in 31 provinces) participated in the study. Participants were selected from 4 age and gender groups, men and women between 35 and 75 years old.<sup>[25]</sup>

### Data collection tools and technique

We extracted the data from the DiaCare study including information for sociodemographic factors, utilization of diabetic care services, familial history of diabetes, antihyperglycemic medication usage, dietary patterns, physical activity levels, smoking habits, and complications or comorbidity related to diabetes. In addition, anthropometric measurements such as weight, height, waist circumference, and blood pressure were measured based on standard protocol.<sup>[25]</sup> We obtained the biochemical parameters by laboratory testing in a fasting condition according to standard protocols.

The adherence to SMBG was defined based on the SMBG Recommendation Tool guideline which was drafted by The Canadian Diabetes Association.<sup>[26]</sup> According to this guideline, in our study, patients with type 2 diabetes using insulin or oral medications to cause hypoglycemia (e.g., sulfonylureas, meglitinides) were required to undertake SMBG. The patients were divided into two groups: the adherence group was those who used insulin and were required to perform SMBG at least twice per day and those who relied on oral medications (sulfonylureas/meglitinides) who were expected to engage in SMBG at least twice a week. Patients who did not meet these requirements were categorized as the nonadherence group. Age was reported into 4 subgroups (35–44, 45–54, 55–64, and ≥65 years). The patients' residency was stratified into urban or rural areas. Current smoking included any usage of tobacco products like cigarettes or hookah in the last 30 days. The International Physical Activity Questionnaire (IPAQ) was used to measure patients' physical activity. Using the proposed metabolic equivalent of task (MET) score, physical activity was divided into three levels (low, moderate, and high).<sup>[27]</sup> Other variables were assessed by asking about the type of insurance status, history of hypertension, dyslipidemia, family history of diabetes, occupational status, etc.

We used weighted survey statistical methods for the descriptive reports. Since the sampling was done during 2018 and 2019, we used the average population projection of these two consecutive years based on the residential area (rural, urban), sex, and age (35–75 years) from Iran's Statistical Center as a reference population to define weights.<sup>[28]</sup> Quantitative data were presented in terms of the mean and standard deviation (SD). We used the Shapiro–Wilk test to assess the conformity of the data to a normal distribution. The study reported data that deviated from a normal distribution as the

median, accompanied by the interquartile range. The categorical variables were represented as frequency and percentages. Between-group differences in the categorical variables were compared using Pearson's Chi-square, and continuous variables were compared using an independent sample *t*-test or nonparametric Mann–Whitney U test, as appropriate. The variables that exhibited a significant relationship with the performance of SMBG in the univariate models (*P* value of ≤0.2) were included in the multivariate logistic regression model. We also calculated population attributable fraction (PAF) for significant factors in our model. PAF is the proportion of cases for an outcome within a population that can be attributed to a given covariate or risk factor. PAF incorporates both the prevalence and the effect size of the exposure. In the present study, we calculated the PAFs using the following equation:

$$PAF = \frac{P_c \times (OR - 1)}{OR}$$

where is  $P_c$  the prevalence of exposure among cases and OR is the adjusted odds ratio.<sup>[29]</sup> The statistical analyses and survey analysis were conducted using STATA software (Stata Corp. 2015. Stata Statistical Software: Release 14. College Station, TX: Stata Corp LP), and a significance level of 0.05 was used to determine statistical significance. Figure 1 provides a schematic representation of the methodological procedure.

### Ethical considerations

This study received approval from the Ethics Committee of the school of public health of the Tehran University of Medical Sciences (TUMS) (Ethic Code: IR.TUMS.SPH.REC.1401.231).

### Results

The current study included a total of 7,481 individuals who administered insulin or oral medications, out of the initial pool of 13,392 participants who were required to undertake SMBG. Table 1 shows the demographic and baseline characteristics of the patients based on their adherence to SMBG. A total of 17.8% were seen to adhere to the SMBG. However, the rate of SMBG adherence was 21.59 percent in patients who used sulfonylureas/meglitinides; only 3.26% of patients on insulin were SMBG adherent (*P* value < 0.001). The mean age of adherent participants was 54.30 ± 0.88, while the mean age of nonadherent participants was 55.67 ± 0.35 (*P* value < 0.114). The adherence rate for men and women was 17.89% and 17.70%, respectively; however, this was not statistically significant (*P* value < 0.945). The adherence rate in urban regions was 19.31%, while in rural areas, it was 11.51% (*P* value < 0.001). A significant correlation was observed between adherence with

the level of education, access to both basic and supplementary insurance, occupational status, and marital status ( $P$  value  $< 0.001$ ).

Figure 2 presents the prevalence of SMBG adherent patients in provinces of Iran. Kermanshah province had the highest prevalence of SMBG adherent patients (prevalence = 23.45%, 95%CI: 16.85%–31.64%) followed by Tehran province (prevalence = 21.92%, 95%CI: 16.58%–28.40%). Mazandaran province had the lowest prevalence of patients who were adherent (prevalence = 9.95%, 95%CI: 6.22%, 15.54%).

As shown in Table 2, individuals who were adherent to SMBG experienced a notable reduction in the occurrence of hypoglycemia events ( $P$  value  $< 0.001$ ). Overall, adherent patients exhibited lower rates of hypertension, dyslipidemia, CVD history ( $P$  value  $< 0.001$ ), and also family history of diabetes ( $P$  value = 0.006). Our analysis of the clinical factors showed no statistically significant association between BMI, physical activity status, smoking habits, and laboratory tests with SMBG adherence. Nevertheless, individuals with adherence showed a

statistically significant decrease in their serum cholesterol ( $P$  value = 0.003).

Furthermore, Table 3 presents the level of association between the explanatory variables and adherence to SMBG. It shows that the probability of performing SMBG is much higher among married patients (OR = 1.84, 95% CI: 1.05, 3.21,  $P$  value: 0.032). The probability of performing SMBG is also higher among people with university education (OR = 1.99, 95% CI: 1.12–3.55,  $P$  value: 0.02) and also patients who reside in urban areas (OR = 1.79, 95% CI: 1.146, 2.78,  $P$  value: 0.01). In addition, not smoking was also positively associated (OR = 1.78, CI = 1.11, 2.86,  $P$  value: 0.018) with the possibility of doing SMBG. Sex and unemployment status also demonstrated a borderline significant association with SMBG adherence. Being adherent to SMBG was higher among women (OR = 2.42, 95% CI: 0.89–6.56,  $P$  value: 0.083). Conversely, being unemployed was negatively associated with SMBG adherence (OR = 0.43, 95% CI: 0.16, 1.15,  $P$  value = 0.093).

The PAFs for SBMG adherence are also presented in Table 3. Being married showed the highest PAF

**Table 1: Demographics and baseline characteristics of the studied population**

|                                                             | SMBG nonadherence | SMBG adherence | <i>P</i> |
|-------------------------------------------------------------|-------------------|----------------|----------|
| Number (%)                                                  | 6385 (82.20)      | 1096 (17.80)   |          |
| Sex                                                         |                   |                |          |
| Men                                                         | 3248 (82.11)      | 601 (17.89)    | 0.945    |
| Women                                                       | 3137 (82.30)      | 495 (17.70)    |          |
| Age (year)                                                  | 55.67±0.35        | 54.30±0.88     | 0.153    |
| Age groups                                                  |                   |                |          |
| 35-44                                                       | 808 (74.68)       | 143 (25.32)    | 0.114    |
| 45-54                                                       | 2224 (84.04)      | 413 (15.96)    |          |
| 55-64                                                       | 2110 (81.16)      | 350 (18.84)    |          |
| 65+                                                         | 1217 (85.61)      | 187 (14.39)    |          |
| Area                                                        |                   |                |          |
| Urban                                                       | 4511 (80.69)      | 830 (19.31)    | <0.001   |
| Rural                                                       | 1874 (88.49)      | 266 (11.51)    |          |
| Education (years)                                           | 5 (0-9)           | 6 (3-12)       | <0.001   |
| Diabetes Duration (month)                                   | 96 (48-158)       | 96 (60-168)    | 0.553    |
| Occupation                                                  |                   |                |          |
| Employed                                                    | 2052 (81.21)      | 373 (18.79)    | <0.001   |
| Retired                                                     | 1015 (77.93)      | 236 (22.07)    |          |
| Unemployed                                                  | 3262 (84.52)      | 478 (15.48)    |          |
| Marital status                                              |                   |                |          |
| Married                                                     | 5694 (84.93)      | 1010 (15.07)   | 0.011    |
| Single                                                      | 48 (87.27)        | 7 (12.73)      |          |
| Divorced/Widowed                                            | 643 (89.06)       | 79 (10.94)     |          |
| Medical insurance status                                    |                   |                |          |
| Basic insurance                                             | 6228 (82.11)      | 1067 (17.89)   | <0.001   |
| Supplementary insurance                                     | 2075 (81.81)      | 453 (18.19)    | <0.001   |
| Number of times used SMBG per week                          | 1 (0-1)           | 3 (2-4)        | <0.001   |
| Treatment regimen                                           |                   |                |          |
| Sulfonylureas/Meglitinides (with/without other oral agents) | 78.41%            | 21.59%         | <0.001   |
| Insulin (with/without other treatment)                      | 96.74%            | 3.26%          | <0.001   |

Data are presented as number (percent) or median (Inter quartile range). SMBG=self-monitoring of blood glucose

(PAF = 42.74%), followed by not smoking (PAF = 39.41%) and living in urban areas (PAF = 38.46%). Having an

education higher than high school demonstrated the lowest in PAF (PAF = 8.78%).

## Discussion

We aimed to measure the rate of adherence to SMBG in diabetic type 2 patients treated with insulin or sulfonylureas/meglitinide and the population-attributable fraction of associated factors to SMBG in Iran. The rate of adherence to SMBG was 17.80%, which suggests a notable deficiency in the degree of adherence to SMBG in Iran.

One study in Ethiopia in 2022 reported 96% of patients with a low degree of adherence to SMBG,<sup>[30]</sup> mainly attributed to the prevailing socioeconomic conditions, distinguished by low income and a correspondingly low human capital index.<sup>[31]</sup>

Our findings align with the adherence rates reported in 2019 and 2023 in China, 26.2% and 27.5%, respectively.<sup>[32,33]</sup> The observed trend may be related to the similarity between the analyzed specimens and the socioeconomic conditions prevailing in both nations. In Jordan, 59% of patients demonstrated adherence to SMBG,<sup>[17]</sup> which suggests a comparatively more favorable situation compared to Iran. In 2011, when the diabetes control

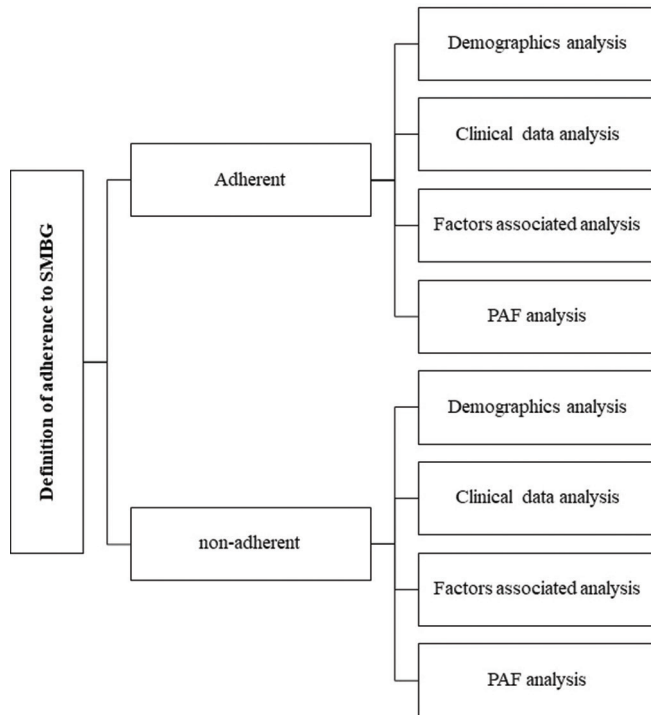


Figure 1: The conceptual framework of study

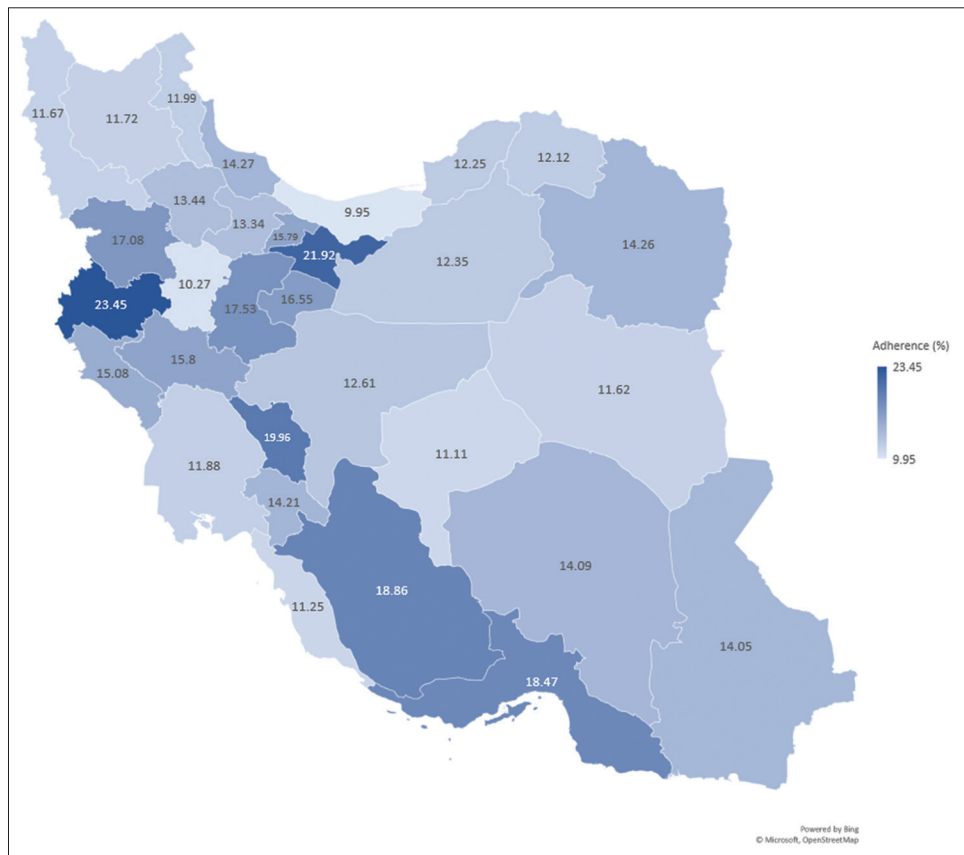


Figure 2: Adherence level based on the provinces of Iran

**Table 2: Clinical data based on SMBG adherence for the studied population**

|                                    | SMBG nonadherence | SMBG adherence | P      |
|------------------------------------|-------------------|----------------|--------|
| Weight                             | 76.58±0.61        | 76.84±1.42     | 0.867  |
| Height                             | 163.54±0.42       | 165.26±0.89    | 0.070  |
| BMI                                | 28.65±0.16        | 28.11±0.41     | 0.247  |
| Smoking                            |                   |                |        |
| No                                 | 5553 (81.03)      | 955 (18.97)    | 0.060  |
| Yes                                | 831 (88.57)       | 141 (11.43)    |        |
| Physical activity                  |                   |                |        |
| High activity                      | 1210 (83.00)      | 202 (17.00)    |        |
| Moderate Activity                  | 1843 (77.52)      | 325 (22.48)    | 0.069  |
| Low activity                       | 3332 (84.99)      | 569 (15.01)    |        |
| SBP                                | 126.78±0.77       | 124.25±1.67    | 0.170  |
| DBP                                | 77.91±0.41        | 78.64±0.96     | 0.463  |
| FBG                                | 180.59±3.56       | 174.93±5.19    | 0.420  |
| HbA1c                              | 9.03±0.11         | 8.88±0.16      | 0.439  |
| TG                                 | 176.97±5.62       | 164.31±8.29    | 0.190  |
| Cholesterol                        | 175.59±1.72       | 163.57±3.77    | 0.003  |
| History of hypoglycemia last month | 1967 (84.78)      | 353 (15.22)    | <0.001 |
| HTN (+)                            | 3293 (82.37)      | 569 (17.63)    | <0.001 |
| History of Dyslipidemia (+)        | 3870 (85.81)      | 640 (14.19)    | <0.001 |
| Family history of DM2 (+)          | 4275 (82.90)      | 747 (17.10)    | 0.006  |
| History of CVD (+)                 | 614 (85.47)       | 112 (14.53)    | <0.001 |
| Visit a physician per year         | 4 (3-10)          | 4 (3-10)       | 0.697  |
| Doing lab tests per year           | 4 (2-4)           | 4 (2-5)        | 0.252  |

Data are presented as number (percent), median (Inter quartile range), and mean±standard error. SMBG=self-monitoring of blood glucose, BMI=body mass index, SBP=systolic blood pressure, DBP=diastolic blood pressure, FBG=fasting blood glucose, TG=triglyceride, HTN=hypertension, DM2=diabetes mellitus type 2, CVD=cardiovascular disease

program was initiated in Jordan, they provided education to patients and their families on self-care practices, as well as promoted the utilization of personal glucometers. This strategy might be a reason to enhance adherence to SMBG in Jordan.

A systematic review conducted in the LMICs revealed that SMBG adherence rates ranged from 13% to 79.9%.<sup>[34]</sup> It is important to note that the criteria used to assess adherence in the reviewed studies differed from those used in our study. Therefore, variations in the definition of adherence across studies might account for the disparities observed in our findings. In the context of HICs, the rate of SMBG adherence was higher compared to Iran. For instance, in England, the adherence rate was reported to be 85%.<sup>[35]</sup> We considered the level of adherence to SMBG in Iran to be below the recommended number of tests proposed by most upstream guidelines such as Canadian and Britain guidelines.<sup>[36-38]</sup>

During the last two decades, the Ministry of Health and Medical Education (MoHME) in Iran has been devising the type 2 diabetes preventive and control program,<sup>[39,40]</sup> i.e., provision of medications, devices, and materials necessary for the control and self-monitoring of diabetes. Given the limited prior evidence on SMBG in Iran, it is challenging to make definitive assertions on the impact of this program on SMBG levels. However, our findings might indicate that despite the implementation

of this program, the adherence to SMBG is far from the anticipated level. One study identified several barriers to the successful implementation of a type 2 diabetes prevention and control program in Iran, i.e., limited financial resources, inadequate staff, inadequate incentives, and insufficient understanding among some healthcare professionals.<sup>[41]</sup>

The analysis of the association between demographic variables and adherence to SMBG revealed statistically significant relationships with several factors, i.e., residing in urban or rural areas, level of education, duration of diabetes, possession of primary and supplementary insurance, and the type of treatment regimen (*P* value <0.001). In line with our research, one study conducted in China showed a robust link between gender, education level, and occupation with the performance of SMBG.<sup>[33]</sup> Another study found that only gender exhibited a statistically significant association with SMBG,<sup>[21]</sup> which was not observed in our study. The results of a study conducted in Sweden to investigate adherence to smbg in patients with type 1 diabetes showed that there is a significant relationship between the level of education and the type of residence, which was similar to our findings.<sup>[42]</sup> In another study, poor adherence was associated with a family history of diabetes, social deprivation, and non-European race.<sup>[43]</sup> Adherence to SMBG was related to perceived positive

**Table 3: Factors associated with adherence to SMBG in studied population and their respective population attributable fraction (PAF)**

| Variable                           | OR    | 95%CI          | P     | PAF (%) | 95% CI        |
|------------------------------------|-------|----------------|-------|---------|---------------|
| Sex                                |       |                |       |         |               |
| Women                              | 2.42  | (0.89, 6.60)   | 0.083 |         |               |
| Age                                |       |                |       |         |               |
| 45-55                              | 0.60  | (0.32, 1.12)   | 0.108 |         |               |
| 55-65                              | 0.71  | (0.39, 1.29)   | 0.26  |         |               |
| 65-75                              | 0.54  | (0.24, 1.24)   | 0.144 |         |               |
| Education                          |       |                |       |         |               |
| Highschool or less                 | Ref   |                |       |         |               |
| College and over                   | 1.99  | (1.12, 3.55)   | 0.02  | 8.78    | (0.55-17.00)  |
| Employment Status                  |       |                |       |         |               |
| Employed                           | Ref   |                |       |         |               |
| Unemployed/homeworker              | 0.43  | (0.16, 1.15)   | 0.093 |         |               |
| Retired                            | 1.13  | (0.62, 2.08)   | 0.686 |         |               |
| Married status                     |       |                |       |         |               |
| No                                 | Ref   |                |       |         |               |
| Yes                                | 1.84  | (1.052, 3.205) | 0.032 | 42.74   | (7.46-78.02)  |
| Basic Insurance                    | 1.13  | (0.35, 3.63)   | 0.842 |         |               |
| Supplementary Insurance            | 0.80  | (0.47, 1.35)   | 0.406 |         |               |
| Area of Residence                  |       |                |       |         |               |
| Rural                              | Ref   |                |       |         |               |
| Urban                              | 1.785 | (1.146, 2.78)  | 0.01  | 38.46   | (19.18-57.74) |
| Current Smoker                     |       |                |       |         |               |
| Yes                                | Ref   |                |       |         |               |
| No                                 | 1.779 | (1.11, 2.86)   | 0.018 | 39.41   | (3.62-75.20)  |
| Lab Visit                          |       |                |       |         |               |
| ≥4 times                           | 1.04  | (0.73, 1.49)   | 0.825 |         |               |
| Diabetes Duration                  |       |                |       |         |               |
| ≤96 months                         | Ref   |                |       |         |               |
| >96 months                         | 0.97  | (0.66, 1.44)   | 0.892 |         |               |
| Family history of DM2              | 0.81  | (0.51, 1.29)   | 0.38  |         |               |
| History of CVD                     | 0.88  | (0.41, 1.89)   | 0.745 |         |               |
| History of dyslipidemia            | 0.72  | (0.45, 1.17)   | 0.188 |         |               |
| History of Hypertension            | 1.22  | (0.78, 1.90)   | 0.385 |         |               |
| Physical Activity                  |       |                |       |         |               |
| High Activity                      | Ref   |                |       |         |               |
| Moderate Activity                  | 1.39  | (0.71, 2.73)   | 0.336 |         |               |
| Low Activity                       | 0.98  | (0.56, 1.71)   | 0.956 |         |               |
| History of Hypoglycemia last month | 0.834 | (0.54, 1.30)   | 0.418 |         |               |

SMBG=self-monitoring of blood glucose, OR=odds ratio, CI=confidence interval, PAF=population attributable fraction

support from partners and intention to perform SMBG, and positive partner support was positively related to intention, action, and planning to adhere to SMBG.<sup>[44]</sup> In a study conducted in Saudi Arabia, the findings showed that 58.5% of participants had moderate adherence to SMBG, while 27.1% had low adherence and 14.3% were highly adherent, and the use of oral medications and insulin injections was associated with higher adherence.<sup>[45]</sup>

The analysis of clinical factors illustrated that adherent patient to SMBG had reduced cholesterol levels and fewer instances of dyslipidemia, hypertension, and hypoglycemia. There was a notable correlation between adherence and factors such as a familial predisposition to

type 2 diabetes and a history of cardiovascular diseases. We found no statistically significant association between BMI, physical activity level, smoking status, annual laboratory testing, and the frequency of visiting doctors per annum. A study conducted in Japan examined the impact of SMBG on metabolic factors, particularly when using the color recording method. This method involved patients recording their blood sugar levels using either blue or red color. The findings indicated that this approach had a positive influence on metabolic variables. The SMBG technique has been shown to lead to improved outcomes in individuals diagnosed with type 2 diabetes, specifically in terms of HbA1c levels, blood pressure (BP), and cholesterol levels.<sup>[46]</sup> The implementation of structured SMBG alongside the

adoption of lifestyle modifications has been shown to yield substantial improvements in metabolic parameters. One meta-analysis examined the impact of SMBG on the improvement of BMI. We identified no significant association in this specific field.<sup>[47]</sup> In a systematic review, the overall effect of SMBG was a statistically significant reduction of 0.39% in HbA1c compared to control groups. This decrease is considered clinically relevant. According to the UK Prospective Diabetes Study, a 0.39% reduction in HbA1c is expected to reduce the risk of microvascular complications by about 14%.<sup>[48]</sup> SMBG was associated with reduced diabetes-related complications and all-cause mortality in type 2 diabetes, and this association persisted in the subgroup of patients not receiving insulin therapy. SMBG may be associated with a healthier lifestyle and/or better disease management.<sup>[24]</sup>

Implementing a structured SMBG and providing patients with proper instruction on the operation of glucometer devices, in addition to effectively using SMBG readings by healthcare workers, holds significant potential for improving metabolic indicators. The utilization of SMBG data allows for the assessment of the impact of diet, physical activity, walking, and exercise on blood glucose levels. This information may be used to improve a patient's lifestyle to their circumstances.<sup>[49]</sup>

By performing multivariate logit regression, we investigated the relationship between demographic variables and adherence to SMBG. The findings showed that the probability of performing SMBG was higher among married patients, university education, patients who reside in urban areas, and no smokers. Sex and unemployment status demonstrated a borderline significant associated with SMBG adherence. Multivariate analysis in another study showed that gender, urban residence, and payment for the test strip were risk factors for nonadherence.<sup>[23]</sup> Although the cost of the test strip was not included in our analysis, that finding is consistent with our study. One study showed that university education, medical insurance, government subsidies, and visiting a diabetes clinic 3 or more times a year had a significant and direct relationship with adherence to SMBG.<sup>[33]</sup> Similar to our findings, the results of these studies highlight the influence of demographic variables on adherence to SMBG. The analysis of variables in another study showed that there was a relationship between gender, education level, family history of diabetes, physical activity, knowledge about glycemic control, and willingness to self-manage diabetes with SMBG.<sup>[11]</sup> Our research shows that in most studies, there is a positive relationship between demographic variables and doing SMBG. This can be due to the differences that exist among different people and some of these variables can enhance the use of SMBG.

According to the findings of the PAF, approximately 42.7% of adherence to SMBG can be attributed to individuals being married. The PAFs for urbanization and no smoking related to adherence to SMBG were estimated to be 38% and 39%, respectively. In addition, having an education higher than high school demonstrated the lowest in PAF (PAF = 8.78%). This means that factors such as marriage, urbanization, no smoker, and university education are important factors for doing SMBG in our diabetic patients.

To the best of our knowledge, this is the first national-level research on the rate of SMBG and the factors that influence its utilization among patients diagnosed with type 2 diabetes in Iran. The study used a substantial sample size, which might have enhanced the accuracy of our findings. In addition, our data analysis revealed the presence of significant variables about adherence to SMBG, which warrants further investigation.

### Limitations and recommendations

Our findings need to be interpreted with some cautions. The study design was cross-sectional, in survey format with a limited number of questions, which might have limited our ability to thoroughly examine the factors contributing to nonadherence to SMBG. Furthermore, this type of study design limits our ability to draw certain conclusions about cause-and-effect relationships and PAFs. Hence, further research using a longitudinal design might bring more insights. In addition, the exclusion of the income variable from the questionnaire was motivated by concerns regarding privacy and informed by past studies' experiences.

Despite its limits, our research has several strengths. Our study is the first of its kind to describe the PAF of important factors for adherence to SMBG among diabetic patients in Iran. Our findings have some merits for informing and guiding the development of effective control policies. By identifying and quantifying the contribution of specific factors, our research provides useful insights that can help public health officials prioritize to reduce diabetic complication with increasing adherence to SMBG among people with diabetes in Iran. Since our samples were from both urban and rural areas, we ensured a diverse and representative cross-section of the community, with good potential for generalizability. Finally, our comprehensive sampling approach enhances the external validity of our research, making it more useful for informing public health strategies and interventions across various demographic groups within the region.

### Conclusions

In summary, our findings indicate a significant lack of adherence to SMBG among people with type 2 diabetes

in Iran. This may emphasize the need for targeted interventions to increase patients' adherence. We advocate for serious reforms in current health policies and practices to ensure the implementation of the most effective diabetes management principles in the country. In particular, we propose prioritizing patients' awareness through education, supporting systems that facilitate consistent monitoring, and simple access to SMBG tools in order to benchmark against best practices. In addition, further research is required to identify underlying factors contributing to nonadherence to SMBG. Given the extensive primary health care (PHC) network in Iran, especially in rural areas, a national strategic plan aimed at the management of diabetes, with a special focus on SMBG, and taking into account the economic, social, and context conditions Iran's culture, is essential.

### Ethical clearance

This study was approved by the ethical committee of Tehran University of Medical Sciences under ethical code no IR.TUMS.SPH.REC.1401.231.

### Abbreviation

SMBG = Self-monitoring of blood glucose  
 STEP<sub>s</sub> = Noncommunicable Diseases Risk-Factors Surveillance in Iran  
 LMICs = Low and middle-income countries  
 IPAQ = The International Physical Activity Questionnaire  
 MET = Metabolic equivalent of task  
 EMRI = Ethics Committee of the Endocrinology and Metabolism Research Institute  
 TUMS = Tehran University of Medical Sciences  
 SD = Standard deviation  
 PAF = Population attributable fraction  
 BMI = Body mass index  
 SBP = Systolic blood pressure  
 DBP = Diastolic blood pressure  
 FBG = Fasting blood glucose  
 TG = Triglyceride  
 HTN = Hypertension  
 DM2 = Diabetes mellitus type 2  
 CVD = Cardiovascular disease.

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### Conflicts of interest

There are no conflicts of interest.

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