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Original Article

The risk factors for self-monitoring of blood glucose among individuals diagnosed with type 2 diabetes in Saudi Arabia

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ABSTRACT

Background: Lack of self-monitoring of blood glucose (SMBG) is a known risk factor for controlling type 2 diabetes mellitus (T2DM). Nevertheless, little research has been conducted on SMBG among Saudis with T2DM. **Aim:** The study aimed to investigate personal and cognitive-perceptual factors for SMBG among Saudis with T2DM guided by Health Promotion Model. **Methods:** A cross-sectional study was conducted with a sample size of 808 Saudi adults with T2DM utilizing secondary data from the Saudi Health Interview Survey for 2013. **Statistical Analysis:** Bivariate and multivariate logistic regressions were applied to examine the risk factors for SMBG among Saudis with T2DM. **Results:** The prevalence of SMBG was 55.5% in Saudi adults with T2DM. In the multivariate analysis, obesity (adjusted prevalence ratio [APR] = 1.20), middle (APR = 1.30) and higher (APR = 1.49) education where predictors of SMBG, whereas shorter diabetes duration (APR = 0.78 for <5 years and 0.78 for 5–9 years) and Eastern region (APR = 0.66) were inversely associated with SMBG. **Conclusions:** The study suggested the future design of interventional programs related to self-care practices should focus on diabetic individuals with low education, obesity, and longer duration of diabetes, and regional differences, specifically when considering limited access to health care during the COVID-19 pandemic. In addition, longitudinal studies with a large sample size at national and regional levels are needed to further examine the personal and psychological risk factors in Saudis with T2DM.

Keywords: Prevalence, risk factors, Saudi Arabia, self-monitoring, type 2 diabetes mellitus

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INTRODUCTION

The number of diabetic individuals in Saudi Arabia (SA) has exceeded 4 million in 2019 which was two-fold since 2010.[1,2] The prevalence of undiagnosed diabetic cases was estimated to be 1.67 million, a 50% increase since 2011; therefore, the cases of diabetes are expected to reach 8 million if the current situation remains the same.[2,3] The increase in diabetic cases in SA has impacted the country's human power and economy. The diabetes-related deaths accounted for 19% of 116,934 crude deaths in 2015,[4] and diabetes was among the top four leading cause of death in the country.[5] Estimated average annual cost of diabetes was $1172 with estimated total cost of $5 billion in 2019.[2] The burden of diabetes in SA is evident.

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The management of diabetes is another important issue that needs to be tackled by the health-care system. Two-thirds of Saudis with type 2 diabetes mellitus (T2DM) had poor glycemic control, HbA1c 7% or more.[6] The significance of this percentage is that those with uncontrolled diabetes are subject to develop the complications related to diabetes and eventually death.[7-9] The complexity of diabetes stems from the diversity and nature of the factors associated with it that can be known or hidden and is unique at the individual level; however, T2DM can be prevented.

Self-monitoring of blood glucose (SMBG) is one of the behavioral factors that can help diabetic individual to

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control their diabetes. SMBG is vital in managing diabetes and determining the appropriate doses, especially for those who are on insulin treatment.[10] Few studies were conducted in SA showed variation in the prevalence of SMBG that ranges from 22% to 90%.[11-15] These studies were local and conducted in different cities in SA. Therefore, the study aimed to identify the prevalence and risk factors for SMBG among Saudis with T2DM at the national level, utilizing Health Promotion Model as the conceptual framework.[16] The study answered two research questions: first, what personal factors were associated with SMBG in Saudis with T2DM? second, what cognitive-perceptual factors were associated with SMBG in Saudis with T2DM after adjusting for personal factors?

METHODS

Study design

A retrospective, cross-sectional study was performed utilizing the Saudi Health Interview Survey (SHIS) data of 2013. The SHIS is a nationally representative data that covers all the 13 administrative regions in SA for individuals aged 15 years or older. Further details about the SHIS design and ethical approval can be found elsewhere.[17] In this study, 808 participants from the SHIS data were included who reported to have T2DM and their ages were 18 years or older. The study followed the Strengthening the Reporting of Observational Studies in Epidemiology checklist.[18] The study is a secondary analysis and was approved by the Institutional Review Board at Old Dominion University.

Variables

There were 17 variables included in the study and the extraction of the variables followed the modified HPM model [Figure 1], which breaks down the variables into three main categories. First, personal factors included age, gender, family history, diabetes duration, obesity, marital status, education, income, region of residence, and perceived health status (PHS) which were used as the independent variables in the study. The age factor was categorized into ≥54 years old and <54 years old.[6] Family history was defined whether each participant had a family member who was diagnosed with diabetes including parents, children, brothers, and/or sisters. The diabetes duration was classified into <5 years, 5–9 years, and ≥10 years. Obesity was defined as a body mass index (BMI) of ≥30. Marital status was defined as married or others (e.g., never married, separated, divorced, or widowed). Education was categorized into low (primary school or below), middle (intermediate or high school), and high (college degree or higher). Income was classified as low (<$1333), middle (≥$1333 to <$4000), and high (≥ $4000). The region of residence was classified into five groups including central, southern, northern, eastern, and western regions. PHS was a single question to rate participants' health in general and was defined as poor or good using the median split technique. Second, cognitive-perceptual factors included vigorous activity barriers, which was defined as low and high barriers that whether patients' current health limits them from doing vigorous activities, such as running or participating in strenuous sports. House activity barriers were also defined as low and high barriers but related to performing work or household activities. Physical activity barriers are defined as low and high barriers related to doing activities such as standing from a seated position, standing for a long time, and/or stair climbing. Health professional support for treatment (HPST) was related to whether diabetic patients received insulin or medication treatment by health professionals. Health professionals' support lifestyle change was related to whether diabetic patients received treatment or advice for lifestyle change (e.g., stop smoking, lose weight, diet, and exercise). Multiple health care providers (MHPs) were about whether or not participants visit more than one medical doctor or health facility to receive medical care. Finally, SMBG, as outcome variable, the participants were asked whether they monitor their blood sugar level at home or not. Responses with "don't know" or "decline to respond" were considered missing. All variables obtained from SHIS were modified according to the study design. Further details about the classification and coding of the variables are presented in Supplemental Table 1.

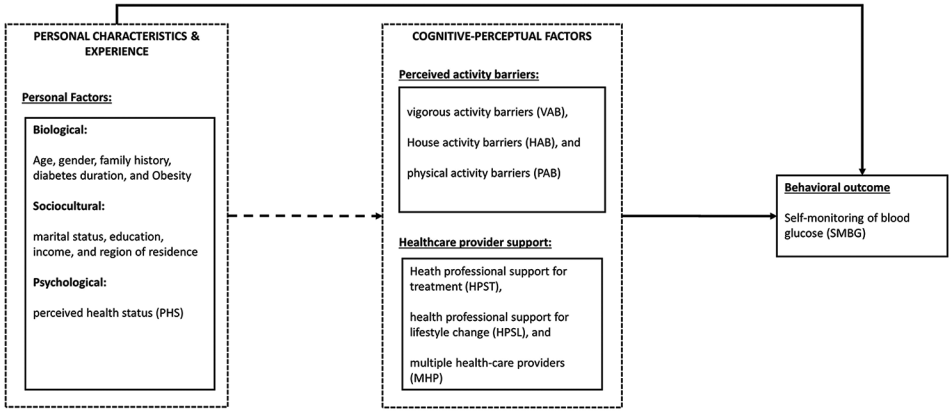

Figure 1: Proposed model for risk factors associated with self-monitoring of blood glucose adapted from Pender's health promotion model

Statistical analysis

To treat missing data, multiple imputation (MI) with a fully conditional specification method was performed.[19] In addition, including all the variables in the MI was necessary to prevent biased estimation of the parameters after MI.[20,21] The study followed the rule of thumb for the number of imputations that depends on the percentage of missing cases.[22] Only pooled imputed data were used in the final analysis after comparing the imputed with the original data for possible variation.

Descriptive analysis was conducted to give an overview of the characteristics of the study population and was presented in numbers and weighted percentages. Bivariate and multivariate logistic regressions were used to address the research questions. The results were presented in prevalence ratio (PR), 95% confidence interval (CI), and *P* with alpha level set at 0.05. The analysis was weighted using poststratification weight to maintain the generalizability of the results to the Saudi national population.[19] To assess multicollinearity, variance inflation factor and tolerance tests were used. The study also used receiver operating characteristics and Wald test for model accuracy and fit, respectively. (IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp.) was used for data preparation (i.e. cleaning, merging, and recoding data) and MI. For the final data analysis, (Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.) was utilized due to the limitations in SPSS to perform this kind of complicated analysis.

RESULTS

The total participant in the study was 808. Fifty multiple imputations were utilized in the analysis according to the percentage of missing cases and the missingness was assumed to be missing at random (MAR). Missing data were high in diabetes duration, income, and family history. Diabetes duration, income, and family history had the highest percentages of missing data at 21.7%, 17.2%, and 15.2%, respectively. The missingness was related to men except women for income, low education, age ≥54 years, and residing in the Central region [Supplemental Tables 2 and 3]. Therefore, 50 multiple imputations were used in the analysis according to the missing cases assuming that the data were MAR. Discrepancy in the data was not detected after MI.

T2DM was more prevalent in men, individuals aged 54 or older, married, obese, low educated, middle income, and those with a family history of diabetes, diabetes duration equal or more than 10 years, good perceived health, and living in the Central region [Table 1]. Self-monitor their blood glucose was 55.4% among Saudis with T2DM.

A total of six factors, in the bivariate analysis, were significantly associated with SMBG among Saudis with T2DM [Table 2]. Family history of diabetes, obesity, middle

Table 1: Characteristics of personal, cognitive-perceptual, and behavioral factors before and after multiple imputations (*n*=808)

Variable	Original data, *n* (weighted %)	Completed data, *n* (weighted %)
Sample size	-	808
Age (years)		
<54	321 (47.9)	324 (47.9)
≥54	481 (52.1)	484 (52.1)
Gender		
Women	331 (38.7)	331 (38.7)
Men	477 (61.3)	477 (61.3)
Family history		
Yes	483 (70.8)	556 (69.7)
No	202 (29.2)	252 (30.3)
Diabetes duration (years)		
<5	211 (36.2)	245 (32.9)
5-9	164 (25.9)	207 (26.7)
≥10	258 (37.9)	356 (40.4)
Obesity		
Yes	409 (53.1)	419 (53.2)
No	381 (46.9)	389 (46.8)
Marital status		
Married	619 (81.5)	621 (81.5)
Others	187 (18.5)	187 (18.5)
Education		
Low	477 (52.8)	477 (52.7)
Middle	221 (34.1)	221 (34.0)
High	108 (13.2)	110 (13.3)
Income		
Low	274 (34.8)	326 (34.8)
Middle	304 (49.5)	364 (49.1)
High	91 (15.7)	118 (16.1)
Region of residence		
Central	181 (34.2)	181 (34.2)
Western	202 (31.0)	202 (31.0)
Eastern	48 (13.9)	48 (13.9)
Northern	153 (8.6)	153 (8.6)
Southern	224 (12.3)	224 (12.3)
PHS		
Poor	179 (17.5)	179 (17.5)
Good	627 (82.5)	629 (82.5)
VAB		
Low	366 (50.6)	374 (50.6)
High	426 (49.4)	434 (49.4)
HAB		
Low	538 (72.3)	555 (72.1)
High	241 (27.7)	253 (27.9)
PAB		
Low	576 (76.6)	580 (76.4)
High	225 (23.4)	228 (23.6)
HPST		
Yes	705 (87.8)	707 (87.8)
No	101 (12.2)	101 (12.2)

Contd...

Table 1: Contd...

Variable	Original data, *n* (weighted %)	Completed data, *n* (weighted %)
HPSL		
Yes	732 (92.3)	740 (92.0)
No	65 (7.7)	68 (8.0)
MHP		
Yes	326 (41.5)	338 (41.2)
No	444 (58.5)	470 (58.8)
SMBG		
Yes	448 (55.4)	450 (55.4)
No	357 (44.6)	358 (44.6)

HAB: House activity barriers, HPSL: Health professional support for lifestyle change, HPST: Health professional support for treatment, MHP: Multiple health-care providers, PAB: Physical activity barriers, PHS: Perceived health status, SMBG: Self-monitoring of blood glucose, VAB: Vigorous activity barriers

and high level of education, and middle and high income had higher PR of SMBG as compared to those with no family history of diabetes, no obesity, low education, and low income, respectively. Oppositely, those living in the eastern region had lower PR of SMBG as compared to those in the central region. Moreover, for cognitive-perceptual factors, only those who received HPST had higher PR of SMBG as compared to those who did not receive HPST.

In the first model of multivariate analysis [Table 3], the results showed that four personal variables were associated with SMBG. The PR of those with shorter diabetes duration (i.e., <5 years and 5–9 years) to self-monitor their blood glucose level was less as compared to those with longer diabetes duration (i.e., ≥10 years), (adjusted PR [APR] = 0.78, 95% CI [0.63, 0.97], and APR = 0.78, 95% CI [0.62, 0.99], respectively). Obese Saudis with T2DM had an adjusted prevalence of SMBG that was 0.22 times greater than nonobese, 95% CI (1.04, 1.44). Those with middle and higher education had an adjusted prevalence of SMBG that was 0.32 and 0.54 greater than those, 95% CI ([1.8, 1.62] and [1.20, 1.98], respectively). The adjusted prevalence of SMBG among Saudis with T2DM was less in the eastern region as compared to the central region (APR = 0.64, 95% [0.43, 0.95]). Other personal factors were not significantly associated with SMBG. In the second model, there was no evidence that there was an association between cognitive-perceptual factors and SMBG as shown. However, middle and higher education and the Eastern region remained consistent predictors of SMBG with the minimal changes in the APR.

DISCUSSION

A significant proportion of Saudis with T2DM (44.6%) did not practice self-monitoring of their blood glucose at home which could lead to unhealthy behaviors. The study confirms the finding from previous local studies that showed high percentages of diabetic patients lack SMBG despite the variation in the study design.[13-16] For example, two studies conducted in the eastern and western regions found that 38% and 57% did not adhere to SMBG, respectively.[14,16]

In this study, obesity was an independent predictor of SMBG showing that a higher proportion of obese Saudis with T2DM adhered to SMBG compared to nonobese. Although several studies conducted in SA did not address the association between obesity or BMI with SMBG,[13,15,23] it is known that obesity is one of the main risk factors for type 2 diabetes and uncontrolled HbA1c, and it is crucial to be treated.[24] Therefore, some randomized trial studies suggested that increase of SMBG levels among obese patients improved both dietary habits and reduction in weight.[25,26] The possible explanation in this study is that those who were obese may experience higher HbA1c levels and may need to reduce their BMI but this requires constant monitoring of their blood glucose level to assess and prevent possible hypoglycemic events when doing exercise or having a strict diet.

Education is also considered an independent predictor of SMBG where Saudis with T2DM who had high level of education adhered to SMBG compared to the low level of education. This finding is supported by Mansouri *et al*.[11] study when they examined noninsulin T2DM patients attending primary healthcare clinic centers in Makkah city. Their results showed those who had higher education significantly associated with adherence to SMBG. In addition, Abdel Gawwad *et al*.[27] conducted a study on patients with T2DM attending diabetic clinic at the university hospital in Riyadh, and they revealed that the odds of patients with higher education were 2.89 times higher to use SMBG as compared to those with lower education. Another study in the Al Madinah region found diabetic patients with formal education had higher mean SMBG score compared to those with no formal education (mean difference = 0.67).[23] It is suggested that individuals with higher level of education may have higher knowledge about disease. For example, two studies found knowledge about diabetes increase adherence to SMBG.[15,28]

The proportion of diabetes duration for the group <5 and 5–9 years were less compared to the >10 years group in adhering to SMBG, which indicates that Saudis with T2DM who had longer duration of diabetes use SMBG for their HbA1c management. Although one study supported these findings,[14] several studies did not find the duration of diabetes to be associated with SMBG.[13,15,23] This could be due to the variation in the study design. For instance, one study only explored the association between diabetes duration and SMBG in the noninsulin group,[13] whereas the other studies included both on insulin and noninsulin.[16] In addition, diabetes duration was not statistically significant in the bivariate analysis which suggested within the group variation after the inclusion in the multivariate analysis. However, individuals with T2DM for longer time may experience more complications, so diabetic individuals may potentially gain benefits from SMBG in maintaining their health.[29]

Table 2: Prevalence ratio, 95% confidence intervals, and *P* value from bivariate analysis of the association between risk factors and self-monitoring of blood glucose among Saudis with type 2 diabetes mellitus (*n*=808)

Variable	SMBG		PR	95% CI	*P*
	Yes *n* (%)	No *n* (%)			
Unweighted sample	450 (55.69)	358 (44.31)			
Weighted sample	401,490 (55.43)	322,884 (44.57)			
Age (years)					
≥54	266 (55.99)	218 (44.01)	Reference		
<54	184 (54.82)	140 (45.18)	0.98	0.83-1.16	0.807
Gender					
Women	178 (55.11)	153 (44.89)	Reference		
Men	272 (55.62)	205 (44.38)	1.01	0.85-1.20	0.915
Family history					
No	123 (47.35)	129 (52.65)	Reference		
Yes	327 (58.93)	229 (41.07)	1.25	1.00-1.55	0.048
Diabetes duration (years)					
≥10	215 (61.46)	141 (38.54)	Reference		
5-9	111 (49.54)	96 (50.46)	0.81	0.63-1.03	0.081
<5	124 (52.78)	121 (47.22)	0.86	0.70-1.06	0.156
Obesity					
No	203 (49.69)	186 (50.31)	Reference		
Yes	247 (60.47)	172 (39.53)	1.22	1.02-1.45	0.026
Marital status					
Others	93 (48.77)	94 (51.23)	Reference		
Married	357 (56.94)	264 (43.06)	1.17	0.93-1.47	0.190
Education					
Low	231 (47.66)	246 (52.34)	Reference		
Middle	139 (60.23)	82 (39.77)	1.26	1.04-1.53	0.017
High	80 (73.93)	30 (26.07)	1.55	1.28-1.88	<0.001
Income					
Low	152 (44.84)	174 (55.16)	Reference		
Middle	220 (58.36)	144 (41.64)	1.30	1.05-1.61	0.015
High	78 (69.40)	40 (30.6)	1.55	1.21-1.98	0.001
Region of residence					
Central	113 (62.41)	68 (37.59)	Reference		
Western	114 (55.57)	88 (44.43)	0.89	0.73-1.09	0.259
Eastern	17 (39.18)	31 (60.82)	0.63	0.41-0.96	0.034
Northern	91 (56.97)	62 (43.03)	0.91	0.74-1.13	0.396
Southern	115 (52.99)	109 (47.01)	0.85	0.69-1.04	0.120
PHS					
Poor	95 (54.44)	84 (45.56)	Reference		
Good	355 (55.64)	274 (44.36)	1.02	0.82-1.27	0.843
VAB					
Low	223 (58.13)	151 (41.87)	Reference		
High	227 (52.65)	207 (47.35)	0.91	0.76-1.08	0.257
HAB					
Low	318 (58.23)	237 (41.77)	Reference		
High	132 (48.19)	121 (51.81)	0.83	0.68-1.01	0.067
PAB					
Low	321 (55.83)	259 (44.17)	Reference		
High	129 (54.11)	99 (45.89)	0.97	0.79-1.18	0.757
HPST					
No	39 (40.52)	62 (59.48)	Reference		
Yes	411 (57.49)	296 (42.51)	1.42	1.10-1.99	0.043

Contd...

Table 2: Contd...

Variable	SMBG		PR	95% CI	*P*
	Yes *n* (%)	No *n* (%)			
HPSL					
No	30 (43.59)	38 (56.41)	Reference		
Yes	420 (56.46)	320 (43.54)	1.30	0.87-1.94	0.208
MHP					
No	251 (53.40)	219 (46.60)	Reference		
Yes	199 (58.31)	139 (41.69)	1.09	0.92-1.30	0.311

Only weighted data were used for the analysis. SMBG: Self-monitoring of blood glucose, CI: Confidence interval, HAB: House activity barriers, HPSL: Health professional support for lifestyle change, HPST: Health professional support for treatment, MHP: Multiple health-care providers, PAB: Physical activity barriers, PHS: Perceived health status, VAB: Vigorous activity barriers, PR: Prevalence ratio

Saudis with T2DM living in the eastern region had low APR in adhering to SMBG compared to the central region. A study was conducted in the eastern region showed nearly 43% had high misconception score about diabetes, and high misconception about diabetes was significantly associated with low adherence to SMBG.[16] Therefore, it may indicated that there was a lack of educational programs that increases the awareness of diabetes in the Eastern region when considering the high percentage (30.1%) of poor glycemic control in that region. Further investigation is vital to know what contributes to the differences between regions.

Family history, income, and HPST factors may play a role in predicting SMBG but were not independent from other variables. Saudis with T2DM who had family history of diabetes had a prevalence of 25% higher in using SMBG compared to those with no family history. This may indicate that it is more likely for a diabetic patient who had a family member affected by diabetes to have better knowledge and experience about diabetes compared to those who do not have. Therefore, they may better adhere to self-management practices including SMBG.

Income also another predictor that may have association but not independently with SMBG, where diabetic patients with middle and high income had higher PR in using SMBG compared to low income. Although the Ministry of Health (MOH) dispenses devices for SMBG to their diabetic patients,[30] it may not be sufficient because there are diabetic patients who had less access to health care as well as the availability of associated supplies with the devices such as strips, batteries, and calibration which are costly. For example, in the United States, the cost of SMBG devices and peripherals reached nearly half a billion dollars in 2002.[31] Therefore, those who are in a good economic status may be able to purchase the device and perform SMBG compared with poor economic status.

HPST factor was also associated with SMBG, showing Saudis with T2DM who got advice from health-care providers for treatment had higher PR (1.42) in using SMBG compared with those do not have support. The results suggested indirect association between HPST and SMBG through supporting those with elevated blood glucose level to take treatment, especially insulin, where continuous monitoring is needed. However, the previously mentioned factors did not show association with SMBG in the presence of other variables suggesting these predictors were of less importance in the study. However, these factors were not independently predicting SMBG.

The study also did not find age and gender associated with SMBG. Although age was not significantly related to SMBG, there was an inconsistency in the existing literature of the association between age and SMBG in SA, where two studies found younger age associated with adherence to SMBG,[13,14] whereas other studies showed no relationship.[23,32] The findings may suggest further subgroup analysis to see whether age is associated with SMBG; however, it is difficult due to the large number of variables and not large sample size. Gender was also not found to be significant predictor of SMBG suggesting that gender differences do not play a major role in the adherence to SMBG. Different findings were observed among existing studies showing more men adhere to SMBG compared to women,[13,32] and one study showed opposite association (e.g. Al Johani[23]) but some others did not establish that association.[14,27] Furthermore, MHPs were not associated with SMBG.

The study had several limitations. First, the variation between diabetic Saudis with who were on insulin treatment versus noninsulin was not addressed in the study because the required data were not available. Second, the study may not be generalized to the national level because the cluster variable was missing from the data which could underestimate the standard errors. Third, the study did not examine the causality because the study design was cross-sectional. The study used data that were collected in 2013; however, to the best of our knowledge, this is the only available national data until now. Fourth, SMBG was measured as dichotomous variable (i.e. two levels, yes and no) which may not present accurate information compared to the frequency of SMBG due to the limited data.

CONCLUSIONS

Continuous monitoring of glucose monitoring has benefits toward controlling poor glycemic control, especially for

Table 3: Adjusted prevalence ratio, 95% confidence intervals, and *P* values from multivariate analysis of the association between personal, cognitive-perceptual factors and self-monitoring of blood glucose among Saudis with type 2 diabetes mellitus (*n*=808)

Variable	Model-1			Model-2		
	AOR	95% CI	*P*	AOR	95% CI	*P*
Age (years)						
≥54	Reference			Reference		
<54	0.86	0.72-1.02	0.085	0.84	0.71-1.00	0.055
Gender						
Women	Reference			Reference		
Men	0.92	0.76-1.12	0.424	0.91	0.76-1.10	0.350
Family history						
No	Reference			Reference		
Yes	1.21	0.98-1.48	0.074	1.21	0.99-1.50	0.068
Diabetes duration (years)						
≥10	Reference			Reference		
5-9	0.78	0.62-0.99	0.039	0.78	0.62-0.98	0.034
<5	0.78	0.63-0.97	0.027	0.80	0.64-1.00	0.052
Obesity						
No	Reference			Reference		
Yes	1.22	1.04-1.44	0.017	1.20	1.01-1.41	0.034
Marital status						
Others	Reference			Reference		
Married	1.07	0.83-1.37	0.618	1.09	0.85-1.39	0.518
Education						
Low	Reference			Reference		
Middle	1.32	1.08-1.62	0.007	1.30	1.06-1.59	0.012
High	1.54	1.20-1.98	0.001	1.49	1.17-1.89	0.001
Income						
Low	Reference			Reference		
Middle	1.13	0.90-1.41	0.294	1.12	0.89-1.41	0.316
High	1.31	0.99-1.72	0.057	1.31	0.99-1.73	0.060
Region of residence						
Central	Reference			Reference		
Western	0.92	0.75-1.12	0.397	0.91	0.74-1.12	0.390
Eastern	0.64	0.43-0.95	0.026	0.66	0.44-0.98	0.042
Northern	1.03	0.83-1.28	0.761	1.03	0.82-1.29	0.810
Southern	0.93	0.75-1.15	0.498	0.92	0.74-1.15	0.485
PHS						
Poor	Reference			Reference		
Good	1.02	0.83-1.26	0.847	1.04	0.83-1.29	0.748
VAB						
Low				Reference		
High				0.93	0.77-1.12	0.445
HAB						
Low				Reference		
High				0.83	0.61-1.12	0.216
PAB						
Low				Reference		
High				1.22	0.92-1.60	0.163
HPST						
No				Reference		
Yes				1.36	0.98-1.90	0.064

Contd...

Table 3: Contd...

Variable	Model-1			Model-2		
	AOR	95% CI	*P*	AOR	95% CI	*P*
HPSL						
No				Reference		
Yes				1.03	0.71-1.50	0.869
MHP						
No				Reference		
Yes				1.06	0.90-1.26	0.464
AUC		0.69			0.71	
Wald test		*F* (16, 789.9)=3.54, *P*<0.001			*F* (6, 790.5)=1.35, *P*>0.05	

CI: Confidence interval, AUC: Area under the receiver operator characteristic curve, HAB: House activity barriers, HPSL: Health professional support for lifestyle change, HPST: Health professional support for treatment, MHP: Multiple health-care providers, PAB: Physical activity barriers, PHS: Perceived health status, VAB: Vigorous activity barriers, AOR: Adjusted odds ratio

those who had fluctuating HbA1c levels. Therefore, the more data that health-care providers have about their patients, the more accurate treatment plans are given to them. In this study, personal factors remain strong predictors of SMBG, and the focus on individualized treatment including appropriate educational programs is fundamental to promote healthy behaviors among Saudis with T2DM. However, the focus should extend to address cognitive-perceptual factors that may play a major role in the treatment process. For example, perceived barriers (e.g., cost of the device and pertaining supplies, lack of knowledge on how to use the device, and pain associated with the use of the device) and self-efficacy of SMBG were important in the self-management behavior. In addition, SMBG may vary in benefits from the insulin and obese group to those on the noninsulin regimen group. Hence, a better collaboration between the healthcare providers will ensure effective promotion of healthy behaviors among diabetic patients, especially during the pandemic (e.g., COVID-19) where limited access to health care is inevitable.

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Conflicts of interest

There are no conflicts of interest.

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Supplemental Table 1: Details of the measures included in the study obtained from the Saudi Health Interview Survey manual

Variable name	Level of measurement	Description based on SHIS	Classification based on the study	Note/ reference
		Personal factors (biological)		
Age	Ordinal	18 and above	'0'=≥54 and '1'=<54	Alsuliman *et al.*[6]
Gender	Nominal	1. Male and 2. Female	'0'=Women and '1'=Men	
Family history	Nominal	"Do your parents (father or mother), children, brothers, or sisters suffer from diabetes?"0. No and 1. Yes answers	'0'=No and '1'=Yes	
Diabetes duration	Ordinal	"In what year did you first receive this diagnosis?" this variable was described as the onset of diabetes and is measured in years (Hijri calendar)	Step 1: Diabetes duration=Year of diagnosis - Survey year Step 2: Classified into three groups: '1'=<5, '2'=5-9 and '3'=≥10	
Obesity	Ordinal	Wight (kg) and height (cm)	Step 1: Calculate BMI=Weight/(height/100)^2 Step 2: BMI is classified into two groups: '0'=Not obese (<30) and '1'=Obese (≥30)	WHO
		Personal (sociocultural)		
Marital status	Nominal	"1. Never married, 2. Currently married, 3. Separated, 4. Divorced and 5. Widowed"	'0'=Others (1, 3, 4, and 5) and '1'=Married	
Education	Ordinal	"1. Can't read or write, 2. Can read and write, 3. Primary school completed, 4. Intermediate school completed, 5. High school completed, 6. College/university completed and 7. postgraduate degree"	'1'=Low (1, 2, and 3), '2'=Middle (4 and 5), and '3'=High (6 and 7)	
Income	Ordinal	Monthly household income: "1. <3000 Riyal, 2. 3000 Riyal to<5000 Riyal, 3. 5000 Riyal to<7000 Riyal, 4. 7000 Riyal to<10000 Riyal, 5. 10000 Riyal to<15000 Riyal, 6. 15000 Riyal to<20000 Riyal, 7. 20000 to<30000, and 8. 30000 Riyal or more"	'1'=Low (1 and 2), '2'=Middle (3, 4 and 5), and '3'=High (6, 7, and 8)	Note: 1 Riyal=0.2667 USD
Region of residence	Nominal	13 regions: 1. Riyadh, 2. Western Region, 3. ALMadina Almonawra, 4. Qaseem, 5. Eastern Region, 6. Aseer/Bisha, 7. Tabouk, 8. Haiel, 9. Northern Borders, 10. Jazan, 11. Najran, 12. AlBaha, 13. AlJouf/Quriat	Classified 13 regions into 5 groups: '1'=Central (1 and 4), '2'=Western (2 and 3), '3'=Eastern (5), '4'=Northern (7, 8, 9, and 13), '5'=Southern (6, 10, 11, and 12)	
		Personal factors (psychological)		
PHS	Ordinal	Self-reported assessment of individual's health (in general): "1. Excellent, 2. Very good, 3. Good, 4. Fair and 5. Poor"	Two groups: '0'=Poor (4 and 5) and '1'=Good (1, 2, and 3)	
		Cognitive-perceptual factors (perceived activity barriers)		
VAB	Ordinal	"Does your health now limit you in doing vigorous activities, such as running, lifting heavy objects, or participating in strenuous sports?": 1. Not at all, 2. Very little, 3. Somewhat, 4. Quite a lot and 5. Cannot do	Two groups: '0'=Low (1 and 2) and '1'=High (3, 4 and 5)	
HAB	Ordinal	"During the past 30 days, how difficult was it to perform your work or house activities?": 1. Without any difficulty, 2. With a little difficulty, 3. With some difficulty, 4. With much difficulty, and 5. Unable to do	Two groups: '0'=Low (1 and 2) and '1'=High (3, 4 and 5)	
PAB	Ordinal	"During the past 30 days, how difficult was it to perform any of the following activities: Walking a short distance, standing from a seated position, standing for a short period of time, climbing one step of stairs?": 1. Without any difficulty, 2. With a little difficulty, 3. With some difficulty, 4. With much difficulty and 5. Unable to do	Two groups: '0'=Low (1 and 2) and '1'=High (3, 4 and 5)	

Contd...

Supplemental Table 1: Contd...

Variable name	Level of measurement	Description based on SHIS	Classification based on the study	Note/ reference
		Cognitive-perceptual factors (healthcare provider support)		
HPST	Nominal	"Are you currently receiving any of the following treatments/advice for diabetes prescribed by a doctor or other health professional?" Two items: Insulin (A): 1. Yes and 0. No medication (B): 1. Yes and 0. No	'0'=No (if A and B=0) and '1'=Yes (if A or B=1)	
HPSL	Nominal	"Are you currently receiving any of the following treatments/advice for diabetes prescribed by a doctor or other health professional?" four items: Diet (A): 1. Yes and 0. No. Lose weight (B): 1. Yes and 0. No. Quit smoking (C): 1. Yes and 0. No. Exercise (D): 1. Yes and 0. No	'0'=No (if A, B, C, and D=0) and '1'=Yes (if A, B, C, or D=1)	
MHP	Nominal	"Is there a clinic, doctor's office, or other place that you usually go to when you are sick or need advice about your health care?" 0. No, 1. One place and 2. More than one place	'0'=No (0 or 1) and '1'=Yes (2)	
		Behavioral outcome		
SMBG	Nominal	"Do you test your blood sugar at home?" 1. Yes and 0. No	'0'=No and '1'=Yes	

SMBG: Self-monitoring of blood glucose, MHP: Multiple health-care providers, HPSL: Health professional support for lifestyle change, HPST: Health professional support for treatment, PAB: Physical activity barriers, HAB: House activity barriers, VAB: Vigorous activity barriers, PHS: Perceived health status, SHIS: Saudi Health Interview Survey, BMI: Body mass index

Supplemental Table 2: Numbers and percentages of missing values in each variable and arranged from highest to lowest

Variable	Missing, *n* (%)
Diabetes duration	175 (21.7)
Family history	123 (15.2)
Income	139 (17.2)
MHP	38 (4.7)
HAB	29 (3.6)
Obesity	18 (2.2)
HPSL	11 (1.4)
VAB	16 (2.0)
PAB	7 (0.9)
age	6 (0.7)
SMBG	3 (0.4)
Marital status	2 (0.2)
Education	2 (0.2)
PHS	2 (0.2)
HPST	2 (0.2)
Gender	0
Region of residence	0

HAB: House activity barriers, HPSL: Health professional support for lifestyle change, HPST: Health professional support for treatment, MHP: Multiple health-care providers, PAB: Physical activity barriers, PHS: Perceived health status, SMBG: Self-monitoring of blood glucose, VAB: Vigorous activity barriers

Supplemental Table 3: Characteristics of missing data for diabetes duration, income, and family history across several personal factors-presented in percentages

Variable	Diabetes duration (%)	Income (%)	Family history (%)
Age (years)			
≥54	14.3	11.1	12.1
<54	7.1	6.1	3.1
Gender			
Men	11.5	6.7	9.5
Women	10.1	10.5	5.7
Education			
Low	14.8	12.9	12.0
Middle	5.5	3.3	2.9
High	1.2	0.7	0.2
Region of residence			
Central	6.8	5.1	4.7
Western	3.2	2.8	3.3
Eastern	2.2	1.5	0.6
Northern	2.6	3.5	4.0
Southern	6.8	4.3	2.6

Age and education had missing values of 6 and 2 respectively