ORIGINAL ARTICLE

Behavioral Risk Score for Predicting Well-Controlled HbA1c Level in Diabetes Type 2 Patients

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Background: Diabetes Type 2 is chronic disease that can progress from simple hyperglycemia to severe complications. Many behavioral risks have been discovered for blood sugar prediction.

Objective: To develop a simple behavioral risk scoring to predict well-controlled HbA1c level in diabetes type 2 patients.

Materials and Methods: A total of 140 diabetes type 2 patients were recruited. Patients were interviewed about behavioral factors affecting blood sugar in three months retrospectively. To develop the risk score, risk indicators measured at the time of recruitment were built by logistic regression. Regression coefficients were transformed into item scores and added up to a total score. A risk scoring scheme was developed from behavioral predictors: eating desserts and soft drinks, regular exercise and strict medication intake. The scoring scheme was applied in bootstrap internal validity test to test the model performance.

Results: The scheme explained, by area under the receiver operating characteristic curve (AuROC), 91.6% (95% CI 0.87 to 0.96) of being good diabetic control (HbA1c ≤7%) with good calibration (Hosmer-Lemeshow χ^2=3.61; p=0.61). The likelihood ratio of being good diabetic control (scores greater than or equal to 1) and poor diabetic control (score lower than 1) were 3.83 (95% CI 2.69 to 5.46) and 0.11 (95% CI 0.05 to 0.21), respectively. When applied in bootstrap internal validity test, the score showed good performance with AuROC 88.7% (95% CI 0.81 to 0.93).

Conclusion: A simple and non-invasive scoring scheme of three predictors provides good prediction indices for being good and poor diabetic control patients. This scheme may help clinicians in order to take further appropriate action for diabetic control.

Keywords: Diabetes type 2; HbA1c controlling level; Prediction; Risk scoring

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Diabetes Type 2 is a chronic disease which can progress from simple hyperglycemia to more severe diabetic complications in long term which is a public health problem in Thailand. Misbehaviors play an important role in controlling blood sugar levels. This is a great burden on caregivers and healthcare facilities to treat short-term and long-term complications arising from improper glycemic control.

There are 537 million diabetic patients around the world in 2021 and expected that in the year 2030 there will be 643 million people with diabetes and cause 6.7 million deaths. The Ministry of Public Health, Thailand found that the incidence of diabetes tends to increase steadily. There are 300,000 new patients per year and 3.3 million people with diabetes in the registration system. In 2020, there were 16,388 deaths from diabetes, with a death rate of 25.1 per 100,000 patients. The burden of public health expenditures for diabetes care is as high as 47,596 million Baht per year(1,2). In addition, diabetes is still the main cause of other non-communicable diseases, including heart disease, stroke, hypertension and chronic kidney disease. Factors affecting the incidence of diabetes such as heredity, obesity, age greater than or equal to 45 years, hyperlipidemia, high blood pressure and abnormalities in blood sugar control from other various conditions(3). In order to control blood sugar levels, various behavioral modifications are required, such as proper eating, regular exercise, relaxation, stress reduction and proper drugs use behaviors(4). Behavior modification programs require information about risk behaviors that correlate with accurate blood sugar control. To emphasize the importance of modifying key behaviors in an appropriate order will help the patients to adjust their behaviors correctly

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according to their risks. As a result, patients are able to control their blood sugar levels. The standard of blood sugar control is hemoglobin A1c (HbA1c), however, it is an invasive method with high cost, with potential sampling error and complications. Prediction tools for HbA1c level could be an option to prognosticate patients' blood sugar over three-month period by a simple method to classify diabetic patients to high risk group which could be poor diabetic control in long term. That could assist health care team to manage those patients in proper method to prevent diabetic complications in the future. The present study aimed to develop a simple prediction score to predict HbA1c level over 7% in diabetic patients which is considered as high-risk individuals for poor blood sugar control. This score may help clinicians to arrange proper healthcare service for diabetic patients which could be in poor diabetic control group.

Materials and Methods

The retrospective study for model prediction was conducted by collecting patients' data in the previous 3 months. In addition, the target population was type 2 diabetic patients who got healthcare services at the hospitals and network clinics of Chao Phraya Abhaibhubejhr Hospital, Prachinburi Province, Thailand. The subjects had no serious underlying disease, no mental illness, good communication skill and willing to answer the questionnaire with answering simple questions whether to do it or not, so that was an easy way to ask rural villagers (for example, "Did you have real physically exercise on a regular basis?", "Did you have taken medication as prescribed by your doctor?", "Did you have desserts or sweet soft drink or not?", "Did you have any stress?" or "Did you have enough money to spend in everyday life?). The number of samples needed was 140 cases, calculated by statistical computer program (G*Power, version 3.1) with alpha error of 0.05, power of 0.8, and R^2=0.25. The sample ratio was 1:2 from the prevalence of controllable and uncontrollable diabetic patients in the population. Controllable subjects were defined as those who had HbA1c ≤7%[5,6].

The present study protocol was approved by the Hospital Institutional Review Board (IRB-BHUBEJHR-074). The demographic data were collected including factors related to diabetes care, such as personal factors, behavioral factors and various supports. Statistics for analyzing data was descriptive statistics and inferential statistics with bivariate analysis and multivariate analysis by multiple logistic regression [IBM SPSS Statistics, version 25.0 (IBM Corp., Armonk, NY, USA)].

Variables that might influence outcome were identified and included in the model development. Coefficients of significant variables from multivariable analysis were weighted, transformed to item scores by dividing each regression coefficient with the smallest coefficient in the model and rounding the number to its nearest integer. The received operating characteristic (ROC) illustrated the optimal cutoff score of behavioral factors for controllable and uncontrollable diabetic patient classification.

The area under the receiver operating characteristic curve (AuROC) represented the overall accuracy of behavioral factors score. The validity indexes including sensitivity, specificity, positive and negative predicted values and likelihood ratios were calculated by crosstabs analysis. The score was validated using bootstrap method. The performance and accuracy of the score was evaluated by producing the corresponding ROC curve.

Results

Of 140 diabetic type 2 patients, mean age was 64.5 (SD 10.3) years old, mean body mass index (BMI) was 25.1 (SD 4.7) kg/m² and 30% were male. Patient characteristics in both groups were presented in Table 1. No statistically significant association between controlled HbA1c with marital status, occupation and gender. In addition, no significant mean difference in age, diabetes mellitus duration, and BMI between groups were observed, as presented in Table 2. Uncontrolled diabetic patients had significantly more incorrect medication use and irregular exercise as presented in Table 3. In contrast, no dessert and soft drink in daily food could prevent uncontrolled condition. Meanwhile, other factors such as personal factors, stress, caregiver participation in treatment and expedition to healthcare facilities did not effect blood sugar. The results indicated that abstaining from desserts and soft drinks, regular exercise including comply with medical prescription significantly predicted optimal HbA1c level (Nagelkerke R square=0.65). Especially, sugary diet and exercise had more important role than correct medical use.

After multivariable analysis using backward stepwise logistic regression, there were three variables remained in the model. The prediction scoring system for well controlled diabetic patients (HbA1c ≤7%) is the summation of each point from the following factors; always consuming desserts and

Table 1. Baseline data of cases and controls group

Variables	Glycemic uncontrolled group (n=92) Hemoglobin A1c >7%	Glycemic controlled group (n=48) Hemoglobin A1c ≤7%	Significance
Marital status; n			0.052
Single	10	0	
Married	52	30	
Divorced	30	18	
Occupation; n			0.89
Not working	51	26	
Agriculturist	16	9	
Government Officer	2	1	
Merchant	14	7	
Employee	10	4	
Business owner	0	1	
Sex; n			0.35
Male	30	12	
Female	62	36	
Age (year); mean (SD)	63.1 (10.2)	65.9 (10.3)	0.13
DM duration (year); mean (SD)	8.7 (5.9)	8.6 (5.4)	0.99
BMI (kg/m^2); mean (SD)	25.9 (4.6)	24.3 (4.8)	0.06

DM=diabetes mellitus; BMI=body mass index; SD=standard deviation

Table 2. Correlation of hemoglobin A1c level

Variables	Pearson correlation coefficient	Significance
HbA1c-age	–0.04	0.62
HbA1c-DM duration	0.09	0.26
HbA1c-BMI	0.14	0.09

DM=diabetes mellitus; BMI=body mass index

soft drinks (yes=–4, no=0), regular exercise (yes=3, no=0), including strictness to medical prescription (yes=1, no=0) that presented in Table 4. The point in each factor was derived from weighted coefficient and rounded to its nearest integer as assigned score. The risk scoring system was developed by determining the cutoff according to the discrimination plot and performance of diagnostic parameters in order to identify patients at probability risk of uncontrolled diabetic patients (HbA1c >7%). The cut-off scores of 1 were selected to categorize patients into two groups with high sensitivity and specificity at 0.92 (95% CI 0.85 to 0.96) and 0.76 (95% CI 0.66 to 0.84), respectively, including Youden Index at 0.68[7].

Patients with total scores 1 and over were placed in the well-controlled diabetic patient group (HbA1c ≤7%). The likelihood ratio of being good diabetic control (scores greater than or equal to 1), and poor diabetic control (score lower than 1) were 3.83 (95% CI 2.69 to 5.46) and 0.11 (95% CI 0.05 to 0.21), respectively. By this scoring system and cut-off point,

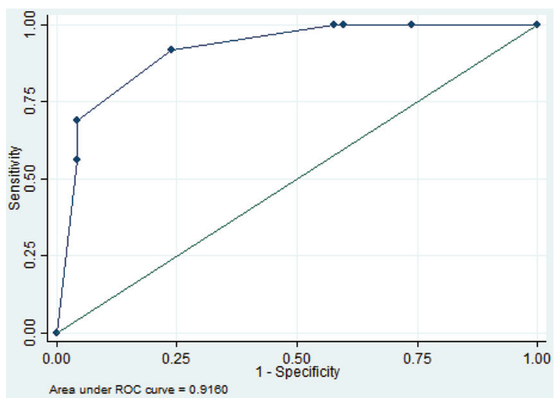

Figure 1. Receiver operator characteristic (ROC) curve of the scoring system in predicting diabetic patients with HbA1c ≤7%.

the score discriminated patients with HbA1c ≤7% from those with HbA1c >7% through well validity (AuROC 91.6%, 95% CI 0.87 to 0.96) (Figure 1) and well-calibrated predictive model (Hosmer-Lemeshow χ^2=3.61, p=0.61). The likelihood ratio of being good diabetic control (scores greater than or equal to 1) and poor diabetic control (score lower than 1) were 3.83 (95% CI 2.69 to 5.46) and 0.11 (95% CI 0.05 to 0.21), respectively.

A bootstrap of 1,000 sampling with replacement was performed for internal validation. The average bias was –0.0036 indicating low bias and good calibration. The bootstrap AuROC was 88.7%

Table 3. Factors affecting hemoglobin A1c level

Variables	Glycemic uncontrolled group (n=92) Hemoglobin A1c >7%; n	Glycemic controlled group (n=48) Hemoglobin A1c ≤7%; n	Crude OR (95% CI)	Adjusted OR (95% CI)
Sex			1.45 (0.66 to 3.18)	-
Male	30	12		
Female (Reference)	62	36		
Comorbid disease			0.71 (0.25 to 2.01)	-
No	10	7		
Yes (Reference)	82	41		
Economic status			1.31 (0.60 to 2.89)	-
Enough money	28	12		
Not enough money (Reference)	64	36		
Medication use			5.89 (2.56 to 13.57)	3.13 (1.04 to 9.48)
Incorrect	53	9		
Correct (Reference)	39	39		
Exercise			19.91 (8.06 to 49.21)	22.37 (6.68 to 74.88)
Irregular	82	14		
Regular (Reference)	10	34		
Dessert and soft drinks			0.02 (0 to 0.08)	0.02 (0 to 0.15)
No	49	47		
Yes (Reference)	43	1		
Stress			0.89 (0.43 to 1.87)	-
No	59	32		
Yes (Reference)	33	16		
Medication caretaker			0.86 (0.28 to 2.62)	-
No	81	43		
Yes (Reference)	11	5		
Expedition to health service			0.52 (0.01 to 19.39)	-
Inconvenient	1	1		
Convenient (Reference)	91	47		

OR=odds ratio; CI=confidence interval

Table 4. Multivariable analysis and risk score for well controlled diabetic patients

Predictors	Coefficient	Adjusted OR	95% CI	p-value	Assigned score
Always consuming desserts and soft drinks	–4.163	0.016	0.002 to 0.150	<0.001	–4
Regular exercise	3.141	23.13	6.926 to 77.248	<0.001	3
Strictness to medical prescription	1.105	3.02	0.999 to 9.124	0.050	1

OR=odds ratio; CI=confidence interval

with 95% bias corrected confidence interval (CI) equivalent to 0.81 to 0.93[8,9].

Discussion

The present study demonstrated the validated behavioral scoring scheme can be used as a screening tool to identify uncontrolled diabetic patient in order to undertake further intervention for further diabetic complications. The present study also looked at some variables other than behavioral variables that had been studied previously. Nevertheless, it was found that they were not significantly associated with diabetic control. Additionally, they were personal factors which were difficult to modify. Therefore, they were not finally brought into the prediction equation.

The present study is the first behavioral risk scoring systemic development for uncontrolled diabetic patients. These scores distinguished the presence of HbA1c >7% in diabetic patients[10]. The strength of the study is a moderate sample size of diabetic patients by statistic calculation. Patients were classified into two groups depending on their likelihood of HbA1c level. A scheme was constructed from three behavioral variables. The score was validated with bootstrap internal validation method and showed similar discriminative power. Therefore, this tool may be useful in clinical decision-making for ambulatory diabetic patients. By using the tool, if the intention was to screen the patients to determine the likelihood of well controlled diabetic patients. The cut-off point with high sensitivity and low specificity could be employed. On the contrary, if the intention was a guide to diagnosis or therapeutic intervention for poor controlled diabetic patients, then the cut-off point with lower sensitivity and higher specificity would be appropriate.

In the present study, the cut-off point was based on assessment of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) with highest Youden Index into two patient groups. With the purpose of using this score to select patient in need of further intervention such as lifestyle counseling, the cut-off point would be score lower than 1. Furthermore, from this method, patients with score greater than or equal to 1 may not require aggressive intervention with proper periodic monitoring.

This scoring model was developed in Thai population in rural area with simple predictors that does not need any complex medical instrument, however, yields a very high AuROC. That is a very convenient, very cheap and useful screening tool for distinguish diabetic patients who need further counseling. In addition, it was profitably validated by bootstrap internal validity test. Nevertheless, several limitations of the present study should be noted. Firstly, the present study included patients from only one rural area setting at hospitals and network clinics in the countryside, thus the findings must be cautiously generalizable to other different area settings. Secondly, those questions did not go into deep details, for instance, "Which exercises did you have?", "How much pills did you have left?", "What desserts did you eat?", or asking with a standard and complicated stress assessment questionnaire that was time-consuming process, together with difficulty to answer and interpretation for rural villagers. Thirdly, the number of patients included in the present study was relatively small according to the opinion of the researcher despite having been standard calculated. A greater number of samples may be used for greater accuracy in further study. In addition, missing data and recall bias together with information bias may have arisen due to retrospective nature. Further larger studies should be performed to determine the discrimination between controlled and uncontrolled diabetic patients, and confirmed these findings. Lastly, this scoring system was internal validated against HbA1c level, which although recognized as a standard screening tool that cannot be used for confirmed diagnosis purposes in external validity test. Future studies to optimize such tool and investigation on its external validity should be mandated for better implementation. As results, these might decrease the diagnostic power of this score. Despite limitations, this model can be applied in particularly clinical settings with minimal cost and easy to use. This may lead to early detection of high-risk patients. When preventive measures are used, disease progression can be retarded, leading to less development of costly complications such as diabetic coma and atherosclerosis in long term.

In conclusion, the present study has developed and validated a simple and noninvasive scoring system based on easy-to-measure variables for poor controlled diabetic individuals. This scoring system has shown simple and good prediction benefits. Physicians can look upon these predictors in diabetic patients for early detection of uncontrolled blood sugar and administrate immediate treatment to avoid long-term complications(11). This scoring system can be used in primary care settings to identify individuals deserved further investigations and interventions to control blood sugar by abstaining from desserts and soft drinks(12), regular exercise(13) including comply with medical prescription(14), which could significantly predict optimal HbA1c level. Additionally, increased awareness among physicians on diabetic patients is important to foster early disease detection with proper management and complication prevention. Public awareness program and blood sugar control campaign should also be considered for disease supervision and prevention of long-term consequences.

What is already known on this topic?

Various factors could affect HbA1c level. Nevertheless, no definite method enabled healthcare team to predict patients' HbA1c. Therefore, risk scoring scheme should be constructed to predict HbA1c level to identify diabetes type 2 patients with poor blood sugar control.

What does this study add?

The present study established a new practical and non-invasive scoring scheme predicting HbA1c level in diabetic patients. The scoring was an initially convenient tool to select individuals deserved further investigations and interventions with acceptable validity indexes.

Conflicts of interest

The author declares no conflict of interest.

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