

Development and Validation of a Risk Score for Diabetes Screening in Oman

Najla A Al-Lawati¹, Helman Alfonso², Jawad Al-Lawati³

¹Department of non-communicable Diseases Control, Directorate General of Primary Health Care, Ministry of Health, Oman.

² Faculty of Health Sciences, School of Public Health, Curtin University

³Directorate General of Primary Health Care, Ministry of Health, Oman.

Received: 2 February 2021

Accepted: 16 May 2021

Corresponding Author: water140@hotmail.co.uk

DOI 10.5001/omj.2021.123

Abstract

Objective: To develop and validate a diabetic risk score model, as a non-invasive and self-administered screening tool, to be used in the general Omani population.

Methods: The World Health Survey (WHS) 2008 data from Oman (n=2,720) was used to develop the risk score model. Multivariable logistic regression with backward stepwise method was implemented to obtain risk factors regression coefficients for gender, age, educational attainment, marital status, place of residence, hypertension, body mass index, waist circumference, tobacco use, daily fruits and vegetables intake and weekly physical activity. The model coefficients were multiplied by a factor of five to allocate each variable category a risk score. The total score was calculated as the sum of these individual scores. The score was validated using another Omani cohort (Sur Survey 2006 dataset, n=1,355)

by calculating the area under the receiver-operating characteristic (ROC) curve (AUC) and optimal score sensitivity and specificity were determined.

Results: A robust diabetes risk score model was produced, which composed of eight variables (age, gender, education level, marital status, place of residence, hypertension, smoking status and body mass index) with an optimal cutoff point of ≥ 15 to classify persons with possible prevalent T2DM. At this cutoff point, the model had a sensitivity of 71.1%, specificity of 74.4% and AUC of 0.80 (95% CI) 0.7–0.82, when internally validated (in the WHS 2008 cohort). When the model was externally validated (using the Sur 2006 cohort), the optimal cutoff point for the score was ≥ 13 , with a lower sensitivity (54%), higher specificity (79%) and an AUC of 0.74 (95% CI 0.70–0.78). In contrast, test of the old Omani, Kuwaiti, Saudi and Finnish diabetes risk scores, in both of our study populations, showed poor performance of these models among Omanis with poor sensitivity (29% to 63.5%) and reasonable specificity (70% to 80%).

Conclusion: The developed diabetes risk score for screening prevalent T2DM, provides an easy-to-use self-administered tool to identify most individuals at risk of this condition in Oman. The score incorporates eight diabetes-associated risk factors that can also act as a tool to increase people's awareness about the importance of diabetes-related risk factors and provide information for policy makers to establish a diabetes prevention programs.

Keywords: type 2 diabetes, risk-score, screening

Introduction

Type 2 diabetes mellitus (T2DM) is a leading public health concern globally and a well-

known cause of premature death. It is mostly a silent disease that leads to several complications if the affected person remains undiagnosed.¹ Globally, 49.7% of all diabetes cases in adults are estimated to be undiagnosed, ranging from 69.2% in Africa, 57% in Asia and 38% in Europe and North America.² An estimated 76.5% of all cases of undiagnosed cases are in low- and middle-income countries.² Based on the Oman World Health Survey 2008 (WHS 2008), the crude prevalence of T2DM in Oman is high (12.3%) with 40.9% undiagnosed.³

The gold standard diagnostic test for T2DM is through biochemical blood tests, including both fasting blood glucose and oral glucose tolerance test (OGTT).^{4,5} However, both tests are invasive, expensive and less feasible for population-based screening.^{6,7} Therefore, finding a simple, cost-effective, non-invasive tool to screen for blood sugar, in order to detect high-risk individuals for T2DM is an imperative aim.^{5,6}

Multivariable diabetes risk scores calculate the risk of developing diabetes in healthy people.⁶ Presently, many risk scores have been developed and validated in different inhabitants, showing good discriminatory capability in populations either for detection of undiagnosed diabetes or the identification of a high-risk group.⁸ A previous effort to develop a tool to identify risk scores for type 2 diabetes in Oman was led in the 1991 National Diabetes Survey data.⁹ However, that tool did not contain variables on physical inactivity or dietary intake of fruits and vegetables.⁹ The high prevalence of undiagnosed diabetes in Oman in the 2008 national survey compelled us to conduct a further study in

this field.¹⁰ The aim of this study was to develop a valid and updated risk scores assessment tool for undiagnosed T2DM in the Omani population using the WHS 2008 dataset.

Methods

We used data from two cross-sectional surveys: the WHS 2008 as the development model, and the Sur Healthy Lifestyle Study of 2006 as the validation model.^{11,12} Sur is a city in Oman located about 200 km east of Muscat, Oman's capital. The WHS 2008 contained 2,720 subjects and the Sur Survey 1,355 subjects after excluding individuals with missing relevant data. The response rate in the former study was 86.3% and in the latter 80.8%. Details of sampling methods for both surveys have been published in details.^{11,12}

To identify prevalent T2DM, both surveys used the World Health Organisation (WHO) criteria (1999), that is, fasting blood glucose ≥ 7 mmol/L.¹³ Additionally, both surveys collected similar data, which included age, sex, education, height, weight, smoking habits, dietary intake, history of hypertension and physical activity except for residential area information which was collected only in WHS 2008.¹¹

The study included Omani nationals aged of 20 years and above in the WHS 2008, which resulted in a sample size of 2,720 subjects after excluding individuals with missing data.¹¹ Eleven independent variables were analyzed in categories to develop the model. The model included gender (male or female), age in two categories (<40 years or ≥ 40 years), education

in two categories (ever having attended school or not), residence (urban or rural), marital status in four categories (never married, married, divorced or widowed) and tobacco use (current user, ex-user or never user). Place of residence was based on the standard definition coined by Oman's National Centre for Statistics and Information (NCSI): urban areas (75% of Omanis live) included four districts of the Capital (Muscat) area and centres of other districts with a stable locality population of 2,500+ persons and at least three basic services (a government school, availability of public electricity, public dispensary or telephone services).¹⁴ Current tobacco use was defined as smoking, sniffing or chewing any tobacco products at the time of the survey. Ex-users were who were not using tobacco products at the time of the survey but used them in the past and never users were subjects who reported to have never used any form of tobacco products in their lifetime.

Obesity measures included body mass index (BMI) (kg/m²), which is calculated by dividing weight in kilograms by the square of height in meters (BMI <25, normal; BMI 25–29.9, overweight; and BMI ≥30; kg/m² obese), as well as waist circumference (WC) (for males, WC <102 or ≥102 cm, and for females, WC <88 or ≥88 cm). In addition, the presence of hypertension was defined as isolated systolic hypertension ≥140 mmHg, isolated diastolic hypertension ≥90 mmHg or combined hypertension ≥140/90 mmHg or on medication for high blood pressure, and calculated by an average of three readings. Physical activity was defined as insufficient (less than 150 minutes per week spent on walking/moderate activity/vigorous activity), sufficient (more than 150 minutes/week walking/moderate activity/vigorous activity), or no physical activity, and fruit and vegetable intake is measured as <5 or ≥5 servings per day). T2DM (outcome) as dependent

variable, was defined as fasting blood glucose ≥ 7 mmol/L, as per WHO guidelines¹³ or self-reported diabetes diagnosed by a physician.

Multivariable logistic regression was conducted on data from the WHS 2008, with T2DM (outcome) as a dependent variable and risk factors with a p-value less than <0.10 , were included as initial independent variables. Backward stepwise elimination method was used to formulate the predicted model. Each β -coefficient was multiplied by the same factor of five to reveal the different weights that each independent variable has with regard to the dependent variable. The score number was rounded to the nearest complete integer, and the individual risk score was the sum of the scores of their variables. Adjusted odds ratio (aOR) as a measure of association with 95% confidence intervals (CI) were determined.

Receiver operation characteristic (ROC) curve was used to evaluate the discrimination of the model developed. This curve plots the sensitivity against 1-specificity (false-positive rate), and the area under the curve (AUC) is generally stated. The greater the area under the curve is, the more accurate the test.^{6,15} A model with perfect discriminative ability has an AUC of 1.0, while an AUC of 0.5 provides no better discrimination than chance. We also used the same method to assess our score discrimination ability by calculating the sensitivity and specificity of the score. Additionally we used the external dataset from the Sur Healthy Lifestyle Survey 2006 cohort to evaluate and validate the discriminatory ability of the developed model by calculating sensitivity, specificity and the AUC.¹²

To compare the performance of the developed model derived from this study with the Omani⁹, Finnish¹⁶, Kuwaiti¹⁷ and Saudi¹⁸ risk scores among Omanis, the logistic regression equations from these models, were applied on the WHS 2008 and the Sur 2006 cohorts' dataset of Oman.^{11,12} The data were analyzed using Stata software (version 13, Stata Corp, Texas, USA). Stata commands *lroc* and *roctab* were used to calculate the sensitivity and the specificity for each score performance using the cutoffs points proposed by the original publications.

Results

Model development

The demographic, and clinical characteristics of the study participants in WHS 2008 is shown in Table 1. Approximately half of the participants were female (52.6%, n=1,430), and nearly two-thirds belonged to the 20-39 age group. There were significant differences in terms of clinical characteristic between males and females, such as hypertension, BMI, WC, physical activity and tobacco use status (p-value<0.001).

Table 1: Baseline demographic and clinical characteristic of participants in the World Health Survey 2008 and Sur Healthy Life Survey 2006, used to develop and validate diabetes risk score, Oman.

	World Health Survey 2008 (n= 2,720)		Sur Survey 2006 (n=1,355)	
	Male	Female	Male	Female
	1,290 (47.4%)	N=1,430 (52.6%)	N=591 (46.6%)	N=764 (56.4%)
Age group (%)				
20-39	776 (60.2)	858 (60.0)	373 (63.1)	546 (71.5)
40-59	324 (25.1)	408 (28.5)	159 (26.9)	177 (23.2)
≥ 60	190 (14.7)	164 (11.5)	59 (10.0)	41 (5.4)
Education (ever schooled) (%)				
Yes	965 (74.8)	854 (59.7)	533 (90.2)	604 (79.2)
No	325 (25.2)	576 (40.3)	58 (9.8)	159 (20.8)

Marital status (%)				
Never married	394 (30.5)	235 (16.4)	184 (31.1)	211 (27.6)
Married	836 (64.8)	929 (65.0)	396 (67.0)	441 (57.7)
Divorced, separated	34 (2.6)	81 (5.7)	8 (1.3)	55 (7.2)
Widowed	26 (2.0)	185 (12.9)	3 (0.5)	57 (7.5)
Residence (%)				
Rural	610 (47.3)	651 (45.5)	-	-
Urban	680 (52.7)	779 (54.5)	-	-
Diabetes status (%)				
No	1,125 (87.2)	1,280 (89.5)	518 (87.6)	648 (84.8)
Yes	165 (12.8)	150 (10.5)	73(12.3)	116 (15.2)
Isolated systolic hypertension (%)				
No	785(61.3)	1,105 (77.8)	529 (89.5)	718 (94.0)
Yes	495 (38.7)	316 (22.2)	62 (10.5)	46 (6.0)
Isolated diastolic hypertension (%)				
No	898 (70.1)	1,179 (83.1)	540 (91.4)	725 (95.1)
Yes	383 (29.9)	240 (16.9)	51 (8.6)	37 (4.9)
Combined hypertension (%)				
No	669 (65.5)	959 (77.0)	479 (87.4)	643 (87.5)
Yes	352 (34.5)	286 (23.0)	69 (12.6)	92 (12.6)
WC* (%)				
Normal	958 (80.50)	567 (42.82)	482 (84.56)	339 (48.3)
High	232 (19.5)	757 (57.2)	88 (15.4)	362 (51.6)
BMI (kg/m²)^a (%)				
BMI <25 kg/m ²	594 (46.9)	595 (43.1)	244 (41.3)	225 (29.4)
BMI 25-29.9kg/m ²	413 (32.60)	405 (29.33)	223 (37.7)	220 (28.8)
BMI ≥30 kg/m ²	381 (27.6)	381 (27.6)	124 (21.0)	319 (41.7)
Tobacco use (%)				
Ex-user/non-user	1,088 (84.3)	1,428 (99.9)	435(73.6)	748(97.9)
Current user	202 (15.7)	2 (0.1)	156 (26.4)	16 (2.1)
Fruits and vegetables, daily serving consumption (%)				
Sufficient ≥5	286 (24.5)	296 (22.7)	64 (10.8)	56 (7.3)
Insufficient <5	880 (75.5)	1,007 (77.3)	527 (89.2)	708 (92.7)
Physical activity (PA) (%)				
Sufficient PA	782 (60.6)	754 (52.7)	541 (91.5)	723 (94.6)
Insufficient PA	137 (10.6)	174 (12.2)	25 (4.2)	35 (4.6)
No PA	371 (28.8)	502 (35.1)	25 (2.3)	6 (0.8)

*WC, Waist circumference, normal for males WC <102 & female WC<88, otherwise considered as high; BMI body mass index; PA, physical activity.

The diabetes risk score was generated using multivariable logistic regression as shown in Table 2. It encompasses gender, age, educational attainment, material status, residence, hypertension status, BMI and tobacco use. Waist circumference, daily consumption of fruit

and vegetable and insufficient physical activity were excluded from the final model in a stepwise fashion as they did not attain the level of statistical significance. The total diabetes risk score was calculated as the sum of the individual scores, and it ranges from 0 to 31 points.

Table 2:

Diabetes risk score predictors by multivariable logistic regression using backward stepwise elimination method, **Oman World Health Survey, 2008.**

	β-Coefficient	aOR (95% CI)[†]	P-Value	score
Intercept	-4.7698			
Sex				
Female	-	Reference		0
Male	0.4089	1.5 (1.1-2.1)	0.017	2
Age group (%)				
≤ 40 years	-	Reference		0
≥ 40 years	1.3967	4.0 (2.6-6.1)	< 0.001	7
Education (ever schooled) (%)				
Yes	-	Reference		0
No	0.4453	1.6 (1.1-2.2)	0.017	2
Marital status (%)				
Never married	-	Reference		0
Married	0.5220	1.7 (0.9-3.1)	0.099	3
Divorced/separated	0.7711	2.2 (0.9-3.1)	0.080	4
Widowed	0.9174	2.5 (1.2-5.3)	0.018	5
Residence (%)				
Rural	-	Reference		0
Urban	0.3682	1.4 (1.1-1.9)	0.015	2
Combined hypertension (%)				
No	-	Reference		0
Yes	0.7437	2.1 (1.5-2.9)	< 0.001	4
*BMI (kg/m²) (%)				
BMI <25 (kg/m ²)	-	Reference		0
BMI 25-29.9(kg/m ²)	0.4089	1.5 (1.05-2.2)	0.028	2
BMI ≥30 (kg/m ²)	0.8364	2.3 (1.6-3.3)	< 0.001	4
Tobacco use status (%)				
Ex or non-user	-	Reference		0
Current user	0.9174	2.6 (1.6-4.1)	< 0.001	5

aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval.

Overall, the prevalence of diabetes was increased in higher risk score categories, by 29.6% and 45.1% in score categories 18-23 and ≥ 24 , respectively (Table 3). In addition, increasing score category was associated with an increased risk of diabetes. For higher score categories (12-17, 18-23, ≥ 24), the aORs (95% CIs) were 15.5 (7.5-32.1), 37.73(18.3-77.8), and 73.5 (30.2-178.8), respectively (Table 3). Similar results were obtained when the analysis was conducted for men and women separately. An increased risk of diabetes was noted in both men and women as the score elevated (data not shown).

Table 3: Overall diabetes prevalence and diabetes risk by score, World Health Survey, 2008 and Sur health lifestyle survey 2006, Oman.

Score	WHS 2008			OR (CI)	Sur 2006			OR (CI)
	Diabetes prevalence		%		Diabetes prevalence		%	
	n	n			n	n		
0-5	724	8	1.10	1	529	33	6.24	1
6-11	785	40	5.10	4.8 (2.2-10.3)	379	35	9.23	1.53 (0.932-2.509)
12-17	671	99	14.75	15.5 (7.5-32.1)	327	71	21.71	4.17 (2.69-6.47)
18-23	344	145	29.65	37.7 (18.3-77.8)	119	50	42.02	10.89 (6.56-18.08)
≥ 24	51	23	45.10	73.5(30.2-178.8)	1	0	0.00	Not defined

CI, confidence interval

Model validation

The baseline demographic and the clinical characteristics of the participants in the Sur survey, distributed by gender, are illustrated in Table 1. More than half of the participants were female 56.4% (n=764), and approximately 70% were in the 20-39 age group.

Despite some differences in the diabetes predictors between WHS 2008 and Sur Healthy Lifestyle Survey 2006, we have applied the developed score to assess how well it predicts the risk of diabetes in a different dataset. The overall prevalence of diabetes was elevated

with increasing risk score, to 21.7% and 42.0% in score categories 12-17 and 18-23, respectively. Additionally, a greater risk of diabetes was associated with an increase in score category. The adjusted odds of having diabetes were 10.9 times greater in the 18-23 category as compared to the 0-5 category (Table 3). Men had a higher risk of diabetes in the 18-23 score category as compared to women: aOR 23.5 vs 10.9. However, as the score category increases, the risk of diabetes becomes greater (data not shown).

ROC curve, as well as measuring AUC was used to assess the internal validation of the proposed score. Our score produced an AUC value of 0.80 (95% CI 0.78-0.82) (Table 4). The cutoff point for the diabetes risk score was calculated based on the probability cutoff value and was ≥ 15 , producing a sensitivity of 71.1% and a specificity of 74.4%. On applying the derivate model equation to the validated sample dataset, the AUC was 0.74, 95% CI 0.70-0.78 (Table 4). A cutoff point for diabetes risk score of ≥ 13 produces a sensitivity of 54% and a specificity of 79% in the same cohort (Figure) and (Table 5).

Table 4: Comparison of performance of the currently developed model with four pre-existing diabetes risk score models to predict prevalent type 2 diabetes in 2 Omani adult cohorts (World Health Survey 2008 and Sur Health lifestyle Project 2006).

Model	WHS 2008			2006 Sur Survey			
	Optimal cutoff point	Sensitivity	Specificity	AUC (95% CI)	Sensitivity	Specificity	AUC (95% CI)
Omani (Current)	≥ 15	71.1%	74.4%	0.80 (0.78-0.82)	54.0%	79.0%	0.74 (0.70-0.78)
Omani Old (Ref #9)	> 10	63.5%	76.9%	0.79 (0.76-0.82)	48.1%	81.8%	0.75 (0.71- 0.79)
Finnish (Ref #16)	≥ 9	37.7%	89.4%	0.79 (0.75-0.83)	43.6%	84.0%	0.70 (0.64 -0.75)
Kuwaiti (Ref #17)	> 32	34.6%	87.1%	0.77 (0.74-0.80)	29.1%	88.8%	0.75 (0.71- 0.79)
Saudi (Ref #18)	> 10	40.0%	87.32%	0.78 (0.75-0.80)	34.9%	91.4%	0.76 (0.72-0.8)

CI, confidence interval; AUC, area under the curve

On testing the performance of first Omani model⁹, Finnish Concise model, Kuwaiti¹⁷ and Saudi¹⁸ risk scores on Oman’s two cohorts (WHS 2008 and Sur 2006), the Finnish, the Kuwaiti and the Saudi models showed similar performance on both Omani cohorts with low sensitivity and high specificity (Table 4).

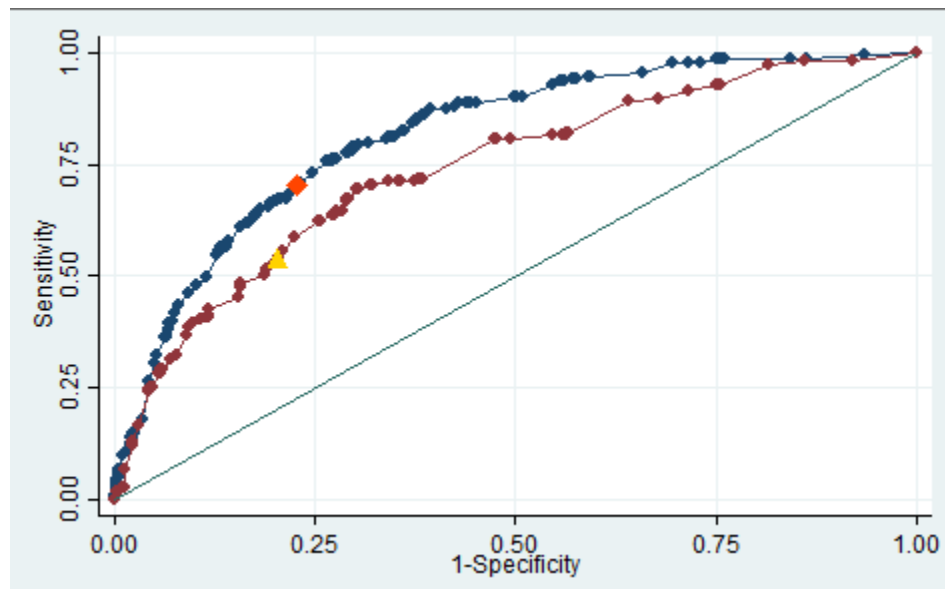


Figure 1: Receiver operation characteristic (ROC) curve showing the performance of the diabetes risk score model in predicting diabetes in the 2008 Oman World Health Survey (WHS 2008) (blue) and the Sur Healthy lifestyle survey 2006 (Sur 2006) (maroon) cohorts. The area under the WHS 2008 curve was 0.80, and the area under Sur 2006 curve was 0.74. An optimal cutoff point for diabetes risk score of ≥ 15 (orange point) produced a sensitivity of 71.1% and a specificity of 74.4% in WHS 2008 cohort, and a cutoff point for diabetes risk score of ≥ 13 (yellow point) produced a sensitivity of 54.0% and a specificity of 79.0% in the Sur 2006 cohort.

Table 5: Type 2 diabetes risk assessment table (Omanis)

Please select the most suitable characteristic for you	
What is your gender?	
Female	<input type="text" value="0"/> points
Male	<input type="text" value="2"/> points
What age are you now?	
≤ 40 years	<input type="text" value="0"/> points
≥ 40 years	<input type="text" value="7"/> points

Did you ever go to government school?

- Yes points
- No points

What is your current marital status?

- Never married points
- Married points
- Divorced/separated points
- Widowed points

Is your place of residence

- Rural points
- Urban points

Combined hypertension (%)

- No
- Yes

What is your body mass index (kg/m²)?

- BMI <25 (kg/m²) points
- BMI 25-29.9(kg/m²) points
- BMI ≥30 (kg/m²) points

Are your:

- Ex or non-user of tobacco points
- Current user of tobacco points

Add total Score Points

Example of how to use the Risk Score table:

A female (0 points) who is 50 years of age (7 points), did not go to schools for education (2 points), is widow now (5 points), lives in rural area (0 points), has systolic hypertension (4 points), with BMI of 26 Kg/m² (2 points) and never smoked in her life (0 points) will get a total risk score of 20 and is therefore at high risk of having type 2 diabetes mellitus.

Interpretation: A total score of <15 points, individual is at low risk of having diabetes. A total score of ≥15 points, individual is at high risk of having type 2 diabetes mellitus.

Discussion

Our study provides an updated and simple risk assessment screening tool for type 2 diabetes mellitus based on causal risk factors that could be self-administered in community-based settings in developing countries. In our model, all regression coefficients were multiplied by a factor of five to allocate each variable category a risk score. The

resulted risk score ranged from a minimum of zero to a maximum of 31, when score were summed for all individual risk factors. In addition to using similar demographic variables as in previous reports in the populations of Oman, Finland and the UK, respectively,^{9,16,19} our instrument introduced new variables consisting of eight modifiable and non-modifiable risk factors, whereas Kuwait's risk score, for example, had only four variables.¹⁷

Although only modifiable risk factors can be addressed by prevention programs, the non-modifiable risk factors, such as age and gender, are significant components in determining an individual's risk and are widely used in risk prediction models for diabetes mellitus.²⁰ According to the American Diabetes Association, people should be screened by the age of 45, even without co-existing risk factor.²¹ We found that age was the most significant predictor for diabetes, and those who were 40 years of age and above had a four times higher risk as compared to those who were below 40 years of age. We also found gender was associated significantly with the risk of diabetes, in contrast to the Omani score, in which gender was not a significant predictor.⁹

Similar to previous studies, high blood pressure, a modifiable risk factor, was a significant predictor of diabetes in our tool. A study by Conen et al.²² has shown that high blood pressure is a strong predictor for diabetes incidence in healthy middle-aged persons. Diabetes and hypertension often occur together in a subject, and are correlated with obesity as a part of metabolic syndrome.²³ We found that the risk of diabetes is increased by two fold among hypertensive patients. Similar results were reported by Al-Lawati⁹ and by

Lindström¹⁶ who found in a Finnish score that the risk of diabetes was doubled in patients with hypertension.

Contrary to the Omani score, in which both waist circumference and BMI have been independently associated with diabetes⁹ our study showed only BMI but not waist circumference as a significant predictor for diabetes. Similarly, the Cambridge diabetes risk score included only BMI as a significant predictor.¹⁹

Unlike the previous Omani score, in which no information was available for dietary intake or physical inactivity, we were able to incorporate physical inactivity and dietary intake into our model development.⁹ However, these variables did not attain the level of significance and were excluded from the final model. In the Finnish diabetes risk score, both factors were also shown not to be significant predictors, but were kept in the model mainly to increase awareness of the modifiable risk factors.¹⁶

To our knowledge, our diabetes risk score is the first study including marital status to estimate the risk of diabetes in the Middle East. Marital status has been previously associated with diabetes.²⁴ Our finding that widowed individuals had a 2.5 times higher risk than unmarried individuals was consistent with the findings of the Cornelis et al. study in the US.²⁵

In addition, our study was among only a few taking into account education level in the diabetes risk assessment.^{20,26} We illustrated that the risk of diabetes was doubled in illiterate people as compared to educated people. Similar findings were reported by Çevik et al. in a population-based study conducted in Turkey.²⁷

Several studies have shown that tobacco use increases the risk of developing diabetes^{20,28} and it has been included in previously reported risk scores, such as Australian and Saudi risk scores.^{18,29} Similarly, we found tobacco users had a 2.5 times higher risk than non-users. Prior diabetes risk scores in Oman and Kuwait did not include tobacco use.^{9,17}

We also report an increased prevalence of diabetes in urban compared to rural areas (13.50% vs. 9.4%, P-value < 0.001). A systematic review of the prevalence of diabetes in Gulf countries demonstrated that prevalence of diabetes was higher in urban areas.³⁰ Unfortunately, we were unable to include data on the residential area during the model validation, as no information was provided in the model validation Sur survey on the residence area of participants.

Overall, in comparison with the existing scores, based on demographic information, anthropometric measurements and medical history, our score showed consistent associations with most of these variables.³¹ We consider our risk score to be more comprehensive through its inclusion of eight modifiable and non-modifiable risk factors, some of which, such as marital status, had not previously been included previous diabetes

risk scores. The performance of risk-prediction scores is commonly judged based on their sensitivity, specificity and AUC.³² The performance of existing risk scores has shown mixed results in identifying high-risk individuals. For example, the Finnish diabetes score had a high sensitivity (81%) and specificity (76%).¹⁶ The Kuwaiti and Saudi diabetes risk scores had higher sensitivity (87% and 76.5%, respectively) and lower specificity (64% and 52.1%, respectively).^{17,18} The first Omani score was reported to have a sensitivity of 78.6% and a specificity of 73.4%.⁹ Our score was in between the above-mentioned models, with a sensitivity of 71.1% and a specificity of 74.4%.

Our risk score produced a high AUC (0.80) when applied to the WHS 2008. Comparable results have been reported from the Finnish diabetes risk score (AUC: 0.85).¹⁶ The AUC of the Saudi risk score was 0.69.¹⁸ Therefore, our model performed well in its discrimination ability.

Overall, we have tested our score performance in the WHS 2008 sample and showed that it was internally valid based on its sensitivity, specificity and AUC curves. The majority of risk score studies reported discrimination (AUC) as a measure of performance, while only a few studies reported both the discrimination and calibration parameters.⁶

Nonetheless, our model displayed lower external validity when it was applied to the Sur Health Survey 2006, as demonstrated by a decline in AUC value (0.74), low sensitivity (54.0%) and reasonable specificity (79.0%). Lower external validity can be, totally or

partially, explained by the differences in the characteristics of the population.³³ An example is the Finnish diabetes risk score, which was validated in the Philippine population, where the discrimination power was lower (ROC: 0.74).⁵ In our study, we found statistically significant differences in the demographic and clinical characteristics between the two surveys of Oman, regarding almost all of the variables. In addition, we did not apply our fully predicted model because the Sur survey was lacking information on residential area, which might partially explain the lower score performance.

Furthermore, the suitability of the risk score in a population is determined by the prevalence of the diabetes risk factor in that population, and the degree of association between the risk factors and diabetes.^{19,34} We found in the Sur 2006 survey that the association between diabetes and tobacco use was not significant, while it was significant in the WHS 2008. Although tobacco use was not a significant predictor, we still applied the proposed model to the Sur survey. This could also explain the lower score performance.

The main strength of our study is that the diabetes risk score was developed from a population-based study, which reduced selection bias. To our knowledge, this is the second diabetes risk score for the Omani population that was developed based on simple demographic, anthropometric and clinical characteristics.⁹ Our comprehensive score included traditional modifiable risk factors as well as introduced new variables, such as education, marital status and residence area. The aim was to increase awareness of modifiable risk factors and the importance of having a healthy lifestyle when the risk score is implemented practically in community screening of diabetes.

However, some limitations of this study need to be considered. First, a family history of diabetes is an important risk factor, and it was not included in the risk score, because no information was available in the used dataset. This factor reveals the genetic predisposition toward developing diabetes.¹⁶ However, lifestyle modification can reduce diabetes incidence even in genetically susceptible individuals.¹⁶ Second, we were not able to apply fully our predicted model, as the Sur 2006 survey did not collect information on residential area. Third, we excluded a large number of observations (736 subjects, 20.9%) because the outcome of diabetes was unknown. A disproportionate number (63%) of that unknown diabetes status was from subjects below 40 years of age, as these individuals are at a lower risk of diabetes. This might have introduced a differential bias, as it is possible that the health status of the responders differs from the potential health of those who did not participate, and thus results would be biased toward a healthier population. Fourth, our risk score was based on the analysis of secondary data from a cross-sectional WHS 2008, and the information from the original survey was collected on self-reported chronic diseases, which might have introduced a potential for volunteer bias, possibly toward a healthier population. Fifth, the lack of longitudinal data in this study is a limitation. The cross-sectional data provide only the association of prevalent cases of T2DM with the risk score, rather than identifying incidence cases. Therefore, it cannot be used to estimate the risk of future disease.³⁵ However, many studies have shown good validation among similar risk scores, even in a cross-sectional setting. Although the Cambridge diabetes risk score was developed from a cross-sectional survey, it performed moderately well in predicting diabetes risk in a prospective cohort with a follow up of 4.8 years.¹⁹

In conclusion, we developed a comprehensive predicted diabetes risk score based on demographic and anthropometric measurements that are readily available in primary health care. It is a unique score as it includes eight modifiable and non-modifiable risk factors with good sensitivity and specificity, To date, this is the second non-invasive, simple and safe instrument developed for the Omani population, as diabetes is a major health concern in Oman, and there has been a steady rise in its prevalence over the last two decades.

Acknowledgement

We would like to thank the Directorate of Planning in Ministry of Health in Sultanate of Oman, for providing us with the survey data.

References

1. Mirahmadizadeh A, Fathalipour M, Mokhtari AM, Zeighami S, Hassanipour S, Heiran A. The prevalence of undiagnosed type 2 diabetes and prediabetes in Eastern Mediterranean region (EMRO): A systematic review and meta-analysis. *Diabetes Res Clin Pract* 2020;160:107931.
2. Cho NH, Shaw JE, Karuranga S, Huang Y, da Rocha Fernandes JD, Ohlrogge AW, et al. IDF Diabetes Atlas: Global estimates of diabetes prevalence for 2017 and projections for 2045. *Diabetes Res Clin Pract* 2018;138:271-281.
3. Al-Riyami A, Abdelaty MA, Jaju S, Morsi M, Al-Kharusi H, Al-Shekaili W. World Health Survey 2008. Available from Department of Research, Directorate General of Planning, Ministry of Health, Oman 2012.

4. Beagley J, Guariguata L, Weil C, Motala AA. Global estimates of undiagnosed diabetes in adults. *Diabetes Research and Clinical Practice* 2014;103:150-160.
5. Ku GMV, Kegels G. The performance of the Finnish Diabetes Risk Score, a modified Finnish Diabetes Risk Score and a simplified Finnish Diabetes Risk Score in community-based cross-sectional screening of undiagnosed type 2 diabetes in the Philippines. *Primary Care Diabetes* 2013;7:249-259.
6. Buijsse B, Simmons RK, Griffin SJ, Schulze MB. Risk Assessment Tools for Identifying Individuals at Risk of Developing Type 2 Diabetes. *Epidemiologic Reviews* 2011;33:46-62.
7. Phillips CM, Kearney PM, McCarthy VJ, Harrington JM, Fitzgerald AP, Perry IJ. Comparison of Diabetes Risk Score Estimates and Cardiometabolic Risk Profiles in a Middle-Aged Irish Population. *PLoS ONE* 2013;8:e78950.
8. Brown N, Critchley J, Bogowicz P, Mayige M, Unwin N. Risk scores based on self-reported or available clinical data to detect undiagnosed Type 2 Diabetes: A systematic review. *Diabetes Research and Clinical Practice* 2012;98:369-385.
9. Al-Lawati JA, Tuomilehto J. Diabetes risk score in Oman: a tool to identify prevalent type 2 diabetes among Arabs of the Middle East. *Diabetes Res Clin Pract* 2007;77:438-444.
10. Al-Lawati JA, Panduranga P, Al-Shaikh HA, Morsi M, Mohsin N, Khandekar RB, et al. Epidemiology of Diabetes Mellitus in Oman, Results from two decades of research. *Sultan Qaboos University Medical Journal* 2015;15:e226-233.
11. Al Riyami A, Elaty MA, Morsi M, Al Kharusi H, Al Shukaily W, Jaju S. Oman world health survey: part 1 - methodology, sociodemographic profile and epidemiology of non-communicable diseases in oman. *Oman Med J* 2012;27:425-443.
12. Al-Farsi M, El-Melighy M, Mohammed S, Ali L. Healthy lifestyle study: Assessment of lifestyle risk factors among Sur city population. Oman: Ministry of Health, 2006.
13. World Health Organization. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus provisional report of a WHO consultation. Geneva: World Health Organization, 1999. WHO/NCD/NCS/99.2.

14. National Centre for Statistics & Information. Selected data and indicators from the results of general populations, housing and establishments census, 1993, 2003, 2010. In: General Census of Population, Housing & Establishments, eds. Muscat: National Centre for Statistics & Information; 2010.
15. Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology* 1982;143:29-36.
16. Lindstrom J, Tuomilehto J. The diabetes risk score: a practical tool to predict type 2 diabetes risk. *Diabetes Care* 2003;26:725-731.
17. Al Khalaf MM, Eid MM, Najjar HA, Alhajry KM, Doi SA, Thalib L. Screening for diabetes in Kuwait and evaluation of risk scores. *East Mediterr Health J* 2010;16:725-731.
18. Memish ZA, Chang JL, Saeedi MY, Al Hamid MA, Abid O, Ali MK. Screening for Type 2 Diabetes and Dysglycemia in Saudi Arabia: Development and Validation of Risk Scores. *Diabetes Technol Ther* 2015;17:693-700.
19. Rahman M, Simmons RK, Harding A-H, Wareham NJ, Griffin SJ. A simple risk score identifies individuals at high risk of developing Type 2 diabetes: a prospective cohort study. *Family Practice* 2008;25:191-196.
20. Sun F, Tao Q, Zhan S. An accurate risk score for estimation 5-year risk of type 2 diabetes based on a health screening population in Taiwan. *Diabetes Research and Clinical Practice* 2009;85:228-234.
21. American Diabetes Association. Standards of medical care in diabetes--2013. *Diabetes Care* 2013;36 Suppl 1:S11-66.
22. Conen D, Ridker PM, Mora S, Buring JE, Glynn RJ. Blood pressure and risk of developing type 2 diabetes mellitus: The Women's Health Study. *European Heart Journal* 2007;28:2937-2943.
23. Bozorgmanesh M, Hadaegh F, Ghaffari S, Harati H, Azizi F. A simple risk score effectively predicted type 2 diabetes in Iranian adult population: population-based cohort study. Vol 212011.

24. Choi B, Shi F. Risk factors for diabetes mellitus by age and sex: results of the National Population Health Survey. *Diabetologia* 2001;44:1221-1231.
25. Cornelis MC, Chiuve SE, Glymour MM, Chang S-C, Tchetgen Tchetgen EJ, Liang L, et al. Bachelors, Divorcees, and Widowers: Does Marriage Protect Men from Type 2 Diabetes? *PLoS ONE* 2014;9:e106720.
26. Alghadir A, Awad H, Al-Eisa E, Alghwiri A. Diabetes risk 10 years forecast in the capital of Saudi Arabia: Canadian Diabetes Risk Assessment Questionnaire (CANRISK) perspective. *Biomedical Research* 2014;25:88-96.
27. Çevik AB, Karaaslan MM, Koçan S, Pekmezci H, Şahin SB, Kırbaç A, et al. Prevalence and screening for risk factors of type 2 diabetes in Rize, Nourtheast Turkey: findings from a population-based study. *Primary care diabetes* 2016;10:10-18.
28. Spijkerman AM, van der AD, Nilsson PM, Ardanaz E, Gavrila D, Agudo A, et al. Smoking and long-term risk of type 2 diabetes: the EPIC-InterAct study in European populations. *Diabetes Care* 2014;37:3164-3171.
29. Chen L, Magliano DJ, Balkau B, Colagiuri S, Zimmet PZ, Tonkin AM, et al. AUSDRISK: an Australian Type 2 Diabetes Risk Assessment Tool based on demographic, lifestyle and simple anthropometric measures. *Medical Journal of Australia* 2010;192:197-202.
30. Alhyas L, McKay A, Majeed A. Prevalence of Type 2 Diabetes in the States of The Co-Operation Council for the Arab States of the Gulf: A Systematic Review. *PLoS ONE* 2012;7:e40948.
31. Ayensa-Vazquez JA, Leiva A, Tauler P, Lopez-Gonzalez AA, Aguilo A, Tomas-Salva M, et al. Agreement between Type 2 Diabetes Risk Scales in a Caucasian Population: A Systematic Review and Report. *J Clin Med* 2020;9.
32. Bhowmik B, Akhter A, Ali L, Ahmed T, Pathan F, Mahtab H, et al. Simple risk score to detect rural Asian Indian (Bangladeshi) adults at high risk for type 2 diabetes. *Journal of Diabetes Investigation* 2015;6:670-677.

33. Liu M, Pan C, Jin M. A Chinese Diabetes Risk Score for Screening of Undiagnosed Diabetes and Abnormal Glucose Tolerance. *Diabetes Technology & Therapeutics* 2011;13:501-507.
34. Zhang M, Zhang H, Wang C, Ren Y, Wang B, Zhang L, et al. Development and Validation of a Risk-Score Model for Type 2 Diabetes: A Cohort Study of a Rural Adult Chinese Population. *PLoS ONE* 2016;11:e0152054.
35. Gray LJ, Davies MJ, Hiles S, Taub NA, Webb DR, Srinivasan BT, et al. Detection of impaired glucose regulation and/or type 2 diabetes mellitus, using primary care electronic data, in a multiethnic UK community setting. *Diabetologia* 2012;55:959-966.