

Adolescent prediabetes in a high-risk Middle East country: a cross-sectional study

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Summary

Objective: To estimate the prevalence of prediabetes in adolescents living in a high-risk country and to detect risk factors associated with this disorder.

Design: Survey questionnaire combined with physical measurements and blood sugar determination.

Setting: Doha, capital city of Qatar.

Participants: A total of 1694 male and female students aged 11–18 years without previously diagnosed diabetes enrolled in four schools.

Main outcome measure: Blood sugar measurements. Other measured variables included gender, height, weight, abdominal circumference, country of origin, family history of diabetes and frequency of exercise.

Results: Using a random blood sugar ≥ 7.8 mmol/L or a fasting blood sugar ≥ 5.5 mmol/L as cutpoints, we identified 4.2% of students (56 boys, 15 girls) as probable prediabetics. In a multivariate model, being boys (OR 3.2, 95% CI 1.7–6.2), having a diabetic parent (OR 1.9, 95% CI 1.1–3.2) or having a waist-to-height ratio >0.5 (OR 1.8, 95% CI 1.1–3.0) were significantly associated with being a prediabetic. The parental origin of diabetes had a differential effect upon blood sugar. The mean random blood sugar in students with a maternal inheritance pattern of diabetes was 5.61 mmol/L \pm 1.0, compared to 5.39 mmol/L \pm 0.89 in students with a paternal inheritance pattern ($p = 0.02$).

Conclusions: In a country with a high risk of adult diabetes, we identified 4.2% of students aged 11–18 as being prediabetic. Risk factors associated with prediabetes included male gender, family history of diabetes and waist-to-height ratio >0.5 .

Keywords

diabetes, prediabetes, Middle East, paediatrics, epidemiology, obesity, exercise, risk factors, body mass index

East.^{1,2} In Qatar, where 70% of the population is overweight or obese, the prevalence of diabetes in adults is 15–17%.³ Recognising and developing intervention programs for prediabetes in adolescent populations can potentially reduce the risk of developing diabetes and cardiovascular disease in later life.⁴

The aim of this study was to investigate risk factors associated with prediabetes in students aged 11–18 at four schools in the capital city of Doha in Qatar.

Methods

During 2012, we obtained information on 1694 students, aged from 11 to 18 years representing 99% of enrolled students attending four schools in Doha, the capital city of Qatar. Students with confirmed diabetes were excluded. Qatar Diabetes Association (QDA) staff collected information about age, citizenship status, family history of diabetes and exercise, performed anthropometric measurements and obtained either a random blood sugar or a fasting blood sugar. The data were collected during a health assessment program designed by QDA and the Qatar Supreme Education Council to identify students at a high risk of developing diabetes. The Office of Research Compliance at Weill Cornell Medical College in Qatar reviewed the proposal for secondary research analysis of those data by the authors and determined that such secondary analysis was exempt from Qatari and American human subject protection regulations and therefore did not require review by an institutional review board.

Introduction

The growing burden of obesity has been especially rapid in the energy-rich countries of the Middle

Statistical analysis

The analysis was performed on de-identified information. Age, sex-specific height, weight, body mass

index (BMI) and waist circumference measurements were used to determine mean values and the standard deviation for all parameters. From these data, we calculated the distribution of each variable along with the fifth, 10th, 50th, 75th, 90th and 95th cutpoints.

The *z*-scores for height and BMI were calculated using the 2007 WHO growth reference data for children and adolescents, using WHO AnthroPlus software (<http://www.who.int/growthref/tools/>)⁵ This enabled us to calculate a *z*-score for each student and then to characterise them as underweight (*z*-score < -2), healthy or normal weight (*z*-score -2 to 1), overweight (*z*-score +1 to 2) or obese (*z*-score > 2). The *z*-scores for weight and for waist were calculated based on the distribution of the study population. Excess central adiposity was calculated using sex- and age-specific waist circumference cutpoints based on the National Cholesterol Education Program Adult Treatment Panel (NCEP ATP).⁶ A waist-to-height ratio ≥ 0.5 was used to identify students with excess central fat distribution.⁷

A random blood sugar ≥ 7.8 mmol/L or a fasting blood sugar of ≥ 5.5 mmol/L were the criteria for diagnosing prediabetes.⁸ Familial diabetes was defined as having any first- or second-degree family member with diabetes. Parental diabetes was the most frequent response, but some students listed grandparents, aunts, uncles and, in four instances, cousins. We used daily or less than daily exercise to study the relationship of exercise with other variables. Exercise data were available for 69% of boys but not for girls.

We used Student's *t*-test or Chi-square procedures to study potential risk factors associated with prediabetes, the impact of exercise on other parameters and the association between presence or absence of family history of diabetes and other variables. We used logistic regression to perform multivariate analysis based on models where the univariate association was significant at the 0.10 level. We selected the best performing model as the basis for constructing a receiver operating characteristic (ROC) curve. All statistical procedures were two-sided with a predetermined significance level of <0.05. All analytic procedures were performed using SAS software version 8.2 (SAS Institute, Cary, NC).

Results

The study population consisted of 1694 students aged 11–18 years attending four schools located in Doha, the capital of Qatar. Nineteen students previously diagnosed with diabetes were excluded from the analysis. There were 974 boys, comprising 57.5% of the

Table 1. Summary data for 1694 adolescent school children in Qatar.

Variable	Boys, N = 974 (%)*	Girls, N = 720 (%)
Body weight		
Underweight	49 (5)	24 (3)
Normal weight	479 (49)	379 (53)
Overweight	173 (18)	167 (23)
Obese	273 (28)	150 (21)
Excess central adiposity (ATP criteria)		
Waist-to-height ratio ≥ 0.5	341 (35)	220 (38)
Elevated blood sugar [†]	56 (6)	15 (2)

*Percents are based on total students with available information for specified variable.

[†]Based on a random blood sugar ≥ 7.8 mmol/L or fasting blood sugar ≥ 5.55 .

total group. Of the total group, 988 (58%) were Qatari citizens; 706 students came from other mostly Middle East countries. Table 1 contains summary data for male and female students. For boys, 46% of all students were overweight or obese (95% CI 43–49%); the corresponding figure for girls was 44% (95% CI 40–48%).

Table 2 examines the association between individual variables and blood sugar measurements. We created a separate category for 71 (56 boys, 15 girls) students considered to be prediabetics because random blood sugar levels were ≥ 7.8 mmol/L or fasting blood sugar levels were ≥ 5.55 mmol/L.

We examined the relationship between study variables and exercise in boys. Daily exercise, when compared with less than daily exercise, had a significant beneficial effect on several key anthropometric factors such as weight ($p=0.003$), BMI *z*-score ($p=0.02$), waist-to-height ratio ($p=0.0003$), waist *z*-score ($p=0.0004$) and obesity ($p=0.003$).

We performed multivariate analysis of factors related to prediabetes. Male gender, a positive family history of diabetes, and an elevated waist-to-height ratio were each independently predictive of prediabetes (Table 3). The resultant area under the ROC curve (AUC) for this model was 0.68 (Figure 1). For boys with a diabetic family history and an elevated waist-to-height ratio the probability of having a positive blood sugar compatible with prediabetes was approximately 10%; for girls, the corresponding figure was 3.3%.

Table 2. Association between individual variables and elevated blood sugar as a surrogate measure of prediabetes.

	Normal blood sugar	Elevated random blood sugar ≥ 7.8 mmol/L or fasting blood sugar ≥ 5.55 mmol/L	<i>p</i>
Total subjects	1623 (96%)	71 (4%)	
	Mean \pm SD	Mean \pm SD	
Age	14.6 \pm 1.68	14.6 \pm 1.60	0.81
Height z-score (WHO2007)	-0.49 \pm 1.05	-0.54 \pm 0.91	0.70
Weight z-score (Qatar)	-0.01 \pm 0.99	0.18 \pm 1.11	0.12
BMI z-score (WHO2007)	0.81 \pm 1.68	0.98 \pm 1.80	0.39
Waist z-score (Qatar)	-0.01 \pm 0.99	0.29 \pm 1.02	0.01
Waist-to-height ratio	0.49 \pm 0.09	0.51 \pm 0.09	0.03
	N (%)*	N (%)	
Number of boys	918 (56.6)	56 (78.9)	0.0002
Number with daily exercise	315 (50.0)	27 (58.7)	0.29
Number from Qatar	939 (57.9)	49 (69.0)	0.07
Number with diabetic family history (any relative)	887 (54.7)	50 (70.4)	0.01
Number overweight/obese (WHO 2007)	725 (44.7)	38 (53.5)	0.15
Number obese (WHO 2007)	398 (24.5)	25 (35.2)	0.05
Number with excess central adiposity (ATP criteria)*	242 (16.5)	17 (25.4)	0.07
Number with waist-to-height ≥ 0.5	527 (35.6)	34 (50.7)	0.01

*Percents are based on total students with available information for specified variable.

We performed an analysis of the parental origin of diabetes on blood sugar levels. For this analysis, we used only random blood sugar values because only 56 students (3%) had available data for both fasting blood sugar and parent of origin. Parent of origin appeared to have a differential effect upon random blood sugar values. The mean random blood sugar in 179 adolescents who had a maternal inheritance pattern of diabetes was 5.61 mmol/L \pm 1.0, which was significantly higher than 5.39 mmol/L \pm 0.89 in the 334 adolescents with a paternal inheritance pattern ($p=0.02$). When analysed separately by student gender, the results were similar for female students ($p=0.03$) but were borderline significant for male students ($p=0.06$).

Discussion

Principal findings

In this group of adolescent and teenage students based on blood sugar measurements, we found that 4.2% were prediabetic. Almost half of the students in this group were above normal weight based on WHO criteria. Furthermore, 28% of boys and 21% of girls were obese with similar results for both Qatari and non-Qatari citizens. Compared to a school survey conducted in a similar sample of students carried out a decade earlier, rates for overweight and obesity appear to have increased.¹

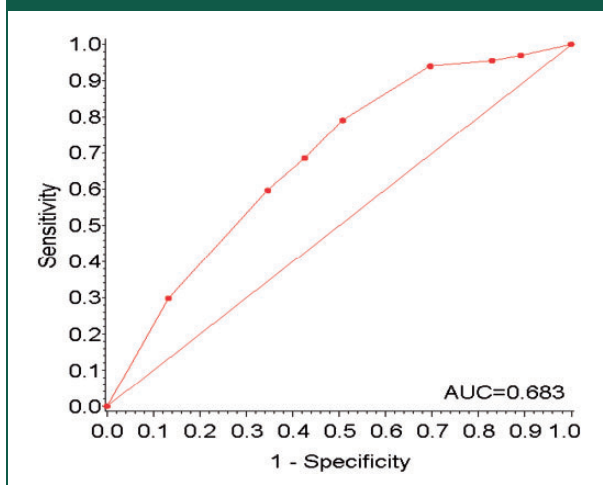
Fifty-six of 798 male students were considered to be prediabetic, compared with 15 of 707 female students (OR = 3.5, $p < 0.001$). The observed excess

Table 3. Multivariate analysis of factors associated with elevated blood sugar* among students in Qatar.

Variable	Reference	Coefficient	OR (95% CI)	p
Intercept		-4.62		
Gender	Boys vs. girls	1.17	3.2 (1.7-6.2)	0.0005
Family history of diabetes	Any vs. none	0.62	1.9 (1.1-3.2)	0.025
Waist-to-height ratio	>0.5 vs. <0.5	0.61	1.8 (1.1-3.0)	0.016

Odds ratios (OR) and 95% confidence intervals (CI) obtained from multivariable logistic regression model.

*Random blood sugar ≥ 7.8 mmol/L or fasting blood sugar ≥ 5.55 mmol/L.

Figure 1. Receiver operating characteristic (ROC) curve of the model to detect elevated blood sugar as a surrogate estimate of prediabetes.

of boys in this study carried out in a student population resembles the excess of male prediabetics and diabetics in other adolescent and adult populations.⁴ In this study, waist circumference, when incorporated into a waist-to-height ratio, proved to be a better predictor of prediabetes than BMI. Our findings agree with accumulating evidence that waist-to-height ratio may be a more useful screening tool than BMI.⁷

With respect to random blood sugar measurements, maternal inheritance of diabetes was more important than a paternal pattern of inheritance. This finding has been observed in some but not all prior reports.⁹⁻¹¹ A combination of gender, waist-to-height ratio and family history of diabetes were the best predictors of prediabetes. An ROC constructed with these three parameters resulted in a plot with an area under the curve (AUC) of 0.68, a result somewhat stronger than the findings in a study using criteria established by the American Diabetic Association which yielded an AUC value of 0.57.

Using our selected cut-off values for random and fasting blood sugar levels, about 6% of male and 2% of female students were identified as prediabetics. The selected cut-offs, for random blood sugar and fasting blood sugar, although somewhat arbitrary, have been previously used for screening purposes in a similarly aged group of adolescents.⁸ Lower cut-offs might have been selected, but the values we selected ensure a clear difference in blood glucose levels between normal and prediabetic subjects.

Self-reported daily exercise compared with less than daily exercise was associated with a gratifying and highly significant reduction in BMI and in central adiposity. Exercise programs, although demanding to perform and monitor, are an essential component of any overall broad-based strategy to lower obesity rates.¹²

Study weaknesses

This study has several weaknesses. The findings might only apply to the Middle East where consanguinity, which could be related to obesity and prediabetes, is prevalent. The sample was not a random sample of the country because all students came from schools in the capital city of Doha. However, since most of the population lives there, we assumed these students are representative of the entire population. Another weakness is that students rather than parents supplied information about the presence or absence of parental diabetes.

Implications

Our study has found that risk factors known to lead to diabetes and other serious adult health problems are already prevalent in adolescent students. The findings imply that the most effective public health strategy for reducing the prevalence of several non-communicable adult diseases will be to target children and adolescents, rather than adults. We identified

male gender, parental history of diabetes, especially maternal diabetes, and an elevated waist-to-height measurement as major predictor variables associated with prediabetes. Including these predictor variables in routine health assessment of children should be given serious consideration. With the proportion of students who are already overweight or obese approaching 50%, and an estimated prediabetes prevalence of 4.2%, reducing the subsequent burden of ill health in adults will require an extensive program of reeducation, focusing on exercise and diet.

Declarations

Competing interests: None declared

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Guarantor: RM

Contributorship: RM, the lead author, developed study and prepared manuscript; ABL developed study, analysed data and edited manuscript; JS edited manuscript; SC developed study, reviewed data and edited manuscript; AA-H developed study and reviewed manuscript; SAM and KGE-N extracted data and edited manuscript; PM performed data analysis and edited manuscript.

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