The related factors of pre-diabetes among adolescents in Qingdao, China

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Research article

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Abstract

Background: To analyze the related factors of pre-diabetes among adolescents.

Methods: 588 students were selected by convenient sampling method from Qingdao for questionnaires, physical examination and biochemical examination. Multivariate analysis was carried out to analyze the related factors among adolescents.

Results: Overweight/obesity, central obesity, family history of diabetes, weekly frequency of moderate to vigorous physical exercise <7 days, weekly frequency of sugar-sweetened beverage consumption <7 days were statistically difference in the prevalence of prediabetes among boys. Family history of diabetes, weekly screen time ≥ 14 h, weekly frequency of fast food consumption ≥ 7 days were significantly difference in the prevalence of diabetes among girls.

Conclusions: Our study find that prediabetes among adolescents in Qingdao is becoming a vital health issue. This requires us to avoid obesity and develop a healthy lifestyle

Background

Pre-diabetes, also known as impaired glucose regulation (IGR), is characterized by insulin secretion dysfunction and insulin resistance[1], including three states: impaired fasting glucose (IFG), impaired glucose tolerance (IGT), IFG and IGT. The diagnostic criteria of the World Health Organization (WHO)[2] are: IFG means that fasting plasma glucose (FPG) 6.1-7.0mmol/L, and 2 hours blood glucose (2hPG) after 75g oral glucose tolerance test (OGTT) <7.8 mmol/L. IGT refers to FPG <7.0 mmol/L, and 2hPG after 75g OGTT 7.8-11.1mmol/L. The diagnostic criteria of the American Diabetes Association (ADA)[3] are: IFG 5.6-6.9mmol/L, 2hPG 7.8-11.0mmol/L, and hemoglobin A1c (HbA1C) 5.7%-6.4%. In recent years, the proportion of adolescents with pre-diabetes among adolescents has been increasing. According to statistics, the proportion of pre-diabetes among adolescents in the United States from 1999 to 2014 was 15.5%[4]. The proportion of pre-diabetes among non-diabetic adolescents in the United States from 1994 to 2008 accounted for 36.6%[5].

With the increasing prevalence of adolescent obesity, the prevalence of adolescent diabetes is increasing globally [6-8]. In Thailand, the incidence of adolescent diabetes increased from 10%-15% in 1995 to 35% -40% in 2014 [9]. During the United States from 2001 to 2009, the prevalence of adolescents with type 1 diabetes increased by 21.1% and the prevalence of type 2 diabetes increased by 30.5% [10]. Pre-diabetes is an abnormal state of glucose metabolism between normal glucose metabolism and diabetes. It is an inevitable stage of diabetes and the most important risk factor for diabetes. It is reported that about 5% -10% in the pre-diabetes population of people will progress to diabetes within 1 year [11], a prospective study showed that the pre-diabetes population had a higher proportion of diabetes (74%) than those with normal glucose metabolism (48.7%)[12]. Diabetes is one of the three major diseases that threaten the health of adolescents. It is an

irreversible lifelong disease and requires lifelong treatment once develops, which not only causes serious complications such as macrovascular and microvascular diseases, but also bring huge economic burden to individuals and countries. Pre-diabetes is a reversible stage and is the only stage we have learned that may turn blood sugar back to normal. If we can understand the influencing factors affecting the pre-diabetes, then doing effective health education and intervention for this stage of the population, it will prevent the progression of pre-diabetes to irreversible diabetes, then reduce the harm caused by diabetes, improve the quality of life of patients and reduce the economic burden of patients and countries.

Although pre-diabetes is asymptomatic, it is not a harmless state. It causes a reduction in the volume of gray matter, which affects the brain, leading to cognitive impairment[13]. In the implantation of teeth, it increases the risk of inflammation of the soft tissue and alveolar bone damage due to its hyperglycemia [14]. Pre-diabetes is associated with the development of cardiovascular disease, which increases the risk of cardiovascular disease such as stroke and coronary heart disease [15], and increases the risk of macrovascular and microvascular disease [16]. Pre-diabetes will increase the risk of liver fibrosis [17]. In addition, pre-diabetes is also associated with poor prognosis of a variety of diseases, such as increasing adverse prognosis of ischemic stroke[18] and mortality of infective endocarditis[19]. Thus, the purpose of this study was to analyze related factors associated with pre-diabetes in adolescents in Qingdao, China.

Methods

Subjects

During 2018, we obtained information on 588 students aged from 12 to 18 years attending 3 junior high schools and 2 senior high schools in Qingdao, China. Students with confirmed diabetes were excluded. All participants and parents signed informed consent. This study was approved by the Ethics Committee of the Affiliated Hospital of Qingdao University.

Research methods

Questionnaire data

We used questionnaire to collect demographic information, including age, sex, family history of diabetes, weekly frequency of fast food consumption (≥ 7 day per week and < 7 day per week), weekly frequency of sugar-sweetened beverage consumption (≥ 7 day per week and < 7 day per week), weekly screen time (≥ 14 hours per week and < 14 hours per week), and weekly frequency of moderate to vigorous physical exercise (≥ 7 days per week and < 7 days per week). All data were collected by well-trained research staff members.

Anthropometry

Anthropometric variables, including height, weight, waist circumference (WC), blood pressure (BP) were measured by research staff members obtaining the nurse qualification certificate. Height and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively. WC were measured to the nearest 0.1 cm. Average BP

was computed by averaging 2 measurements of systolic blood pressure (SBP) and diastolic blood pressure (DBP). Body mass index (BMI) was calculated by weight (kg) divided by the square of height (m).

Laboratory data

Each student collected a ≥ 8 h fasting blood specimen. FPG level were measured by hexokinase.

Definitions

A fasting blood sugar of ≥ 5.5 mmol/L was the criteria for diagnosing pre-diabetes[20]. Family history of diabetes was defined as having any first- or second-degree family member with diabetes. The screen time was referred to the time of watching TV, using computer and using smartphone. The moderate to vigorous physical exercise was referred to that which can lead to an increase in sweat, breathing, and heartbeat. A BMI above the 85th percentile for this particular age group was considered overweight/obesity[21]. A WC above the 90th percentile for this particular age group was considered central obesity [22]. A DBP and/or SBP above the 95th percentile for this particular age group was considered hypertension [23]. A waist-to-height ratio ≥ 0.5 was used to identify students with excess central fat distribution.

Statistics Analysis

The data were statistically analyzed by SPSS 23.0 software. The qualitative data were described by frequency and composition ratio. The quantitative data were described by mean $\pm$ standard deviation ($\bar{x}\pm s$). Logistic regression model was used to conduct multivariate analysis of variables. $P < 0.05$ was considered statistically significant.

Results

Profile of study participants by gender

A total of 588 students in this research (278 boys and 310 girls). The students were between 12 and 18 years of age (mean = 15.02 ± 1.81). The prevalence of normal blood glucose was 81.1%, and that of pre-diabetes was 18.9%. Table 1 contains summary data for boys and girls. There were no significant differences in overweight/obesity, central obesity, waist-to-height ratio, hypertension, family history of diabetes, weekly screen time, weekly frequency of fast food consumption. The girls had significantly higher weekly frequency of moderate to vigorous physical exercise ($\chi^2=27.045$, $P<0.001$), elevated blood sugar ($\chi^2=4.931$, $P=0.026$) compared with boys. The boys had significantly higher weekly frequency of sugar-sweetened beverage consumption ($\chi^2=27.713$, $P<0.001$) compared with girls.

Table 1 Profile of study participants by gender

Virables	Boys n=278	Girls n=310	χ^2	P value
Overweight/obesity			0.033	0.856
no	218	245		
yes	60	65		
Central obesity			0.036	0.849
no	237	266		
yes	41	44		
waist-to-height ratio			0.283	0.595
<0.5	241	264		
≥0.5	37	46		
Hypertension			3.234	0.072
no	208	251		
yes	70	59		
family history of diabetes			2.957	0.086
no	235	245		
yes	43	65		
weekly screen time			1.999	0.157
≥14h per week	53	74		
<14h per week	225	236		
weekly frequency of moderate to vigorous physical exercise			27.045	<0.001
≥7 days per week	76	33		
<7 day per week	202	277		
weekly frequency of sugar-sweetened beverage consumption			27.713	<0.001
≥7day per week	189	267		
<7 day per week	89	43		
weekly frequency of fast food consumption			0.442	0.506
≥7 days per week	126	149		
<7 day per week	152	161		
Elevated blood sugar			4.931	0.026
no	215	262		
yes	63	48		

Table 2 shows the gender-wise breakdown of prediabetes in relation to the presence or absence of various risk factors. Multivariate analysis was carried out separately in girls and boys. Overweight/obesity ($OR=2.734$, $95\%CI=1.351-5.534$), central obesity ($OR=4.180$, $95\%CI=1.865-9.369$), family history of diabetes ($OR=3.105$, $95\%CI=1.392-6.924$), weekly frequency of moderate to vigorous physical exercise <7days ($OR=4.250$, $95\%CI=1.751-10.315$), weekly frequency of sugar-sweetened beverage consumption <7days ($OR=2.276$, $95\%CI=1.149-4.505$) were statistically difference in the prevalence of prediabetes among boys. Family history of diabetes ($OR=3.511$, $95\%CI=1.768-6.973$), weekly screen time ≥14h ($OR=2.102$, $95\%CI=1.035-4.268$), weekly frequency of fast food consumption ≥7days ($OR=2.058$, $95\%CI=1.050-4.036$) were significantly difference in the prevalence of diabetes among girls.

Table 2 prevalence of risk factors contributing to prediabetes in boys and girls

Virables	OR	95%CI
prevalence of prediabetes in boys		
Overweight/obesity		
no	1.000	
yes	2.734	1.351-5.534 ^a
Central obesity		
no	1.000	
yes	4.180	1.865-9.369 ^a
waist-to-height ratio		
<0.5	1.000	
≥0.5	1.535	0.548-4.297
Hypertension		
no	0.531	0.257-1.094
yes	1.000	
family history of diabetes		
no	1.000	
yes	3.105	1.392-6.924 ^a
weekly screen time		
<14h per week	0.501	0.239-1.049
≥14h per week	1.000	
weekly frequency of moderate to vigorous physical exercise		
<7 days per week	4.250	1.751-10.315 ^a
≥7 days per week	1.000	
weekly frequency of sugar-sweetened beverage consumption		
<7 days per week	2.276	1.149-4.505 ^a
≥7 days per week	1.000	
weekly frequency of fast food consumption		
<7 days per week	0.976	0.505-1.884
≥7 days per week	1.000	
prevalence of prediabetes in girls		
Overweight/obesity		
no	1.000	
yes	1.662	0.777-3.555
Central obesity		
no	1.000	
yes	1.205	0.439-3.308
waist-to-height ratio		
<0.5	1.141	0.434-2.997
≥0.5	1.000	
Hypertension		
no	1.000	
yes	1.078	0.434-2.676
family history of diabetes		
no	1.000	
yes	3.511	1.768-6.973 ^a
weekly screen time		
<14h per week	1.000	
≥14h per week	2.102	1.035-4.268 ^a
weekly frequency of moderate to vigorous physical exercise		
<7 days per week	1.533	0.412-5.703
≥7 days per week	1.000	

weekly frequency of sugar-sweetened beverage consumption		
<7 days per week	1.000	
≥7 days per week	0.940	0.348-2.539
weekly frequency of fast food consumption		
<7 days per week	1.000	
≥7 days per week	2.058	1.050-4.036 ^a

Discussion

In this study, those who with pre-diabetes accounted for 18.9% of non-diabetic adolescents. Previous studies[5] showed that those who with pre-diabetes accounted for 36.6% of non-diabetic adolescents in the United States from 1994 to 2008. Different prevalence of prediabetes may because of the sampling method, participant age, ethnicity region, or sampling size. Furthermore, the results may have been overestimated because only one blood sample was collected to measure fasting blood glucose levels in this study.

The study found that the prevalence of prediabetes among boys were higher than girls which was similar to the results of previous studies[20, 24]. This phenomenon may be caused by hormones[25]. An animal experiment showed that ovary and estrogen can increase brown tissue in the body[26], while the activity of brown tissue can reduce insulin resistance[27]. Moreover there are also some research studies show that there is no significant gender difference in the prevalence of prediabetes among adolescents[28]. This indicates that the prevalence of prediabetes in gender is needed a lot of research in the later stage to explore.

Multivariate analysis showed that overweight/obesity, central obesity, family history of diabetes, weekly frequency of moderate to vigorous physical exercise <7 days per week, weekly frequency of sugar-sweetened beverage consumption <7 days per week were high-risk groups in pre-diabetes among boys. Family history of diabetes, weekly screen time ≥14h per week, weekly frequency of fast food consumption ≥7 days per week were high-risk groups in pre-diabetes among girls. Previous studies[29] showed that those who with abnormal homeostasis model assessment of insulin resistance(HOMA-IR) have a higher prevalence of prediabetes among boys and those who with 12-19years old, acanthosis nigricans, family history, overweight, abdominal obesity, and abnormal HOMA-IR have a higher prevalence of prediabetes among girls. Ravinder Mantani[30] concluded that gender, family of diabetes and waist-to-height ratio>0.5 were risk factors with prediabetes among adolescents. Chen CM[28] thought that male, age, family dietary environment, overweight/obesity, cardio-metabolic(high TG, low HDL-C, high BP) were related factors of prediabetes among adolescents.

Previous studies[31-35] showed that insulin resistance index increasing significantly with overweight/obese, waist circumference increasing, and physical exercise decreasing. Diabetes has a high degree of genetic heterogeneity, while family history is an important indicator of genetic factors. Diabetic family has a similar genetic background, so there will be obvious family aggregation. Pre-diabetes is a necessary stage of diabetes,

so it may have a common pathogenesis with diabetes. In addition, Mohammad Almari et al[34] found that the impact of family history of diabetes on pre-diabetes in adolescents was related to gender, for example, mothers with diabetes may increase the risk of pre-diabetes in their sons and fathers with diabetes may increase the risk of pre-diabetes in his daughter. Claire M Nightingale et al [36] found that the level of insulin resistance with those average daily screen time >3h was higher than those with average daily screen time< 1h. The study of Henderson et al[37] showed that insulin sensitivity decreasing by 5% for every 1h increasing in screen time. Jiantao Ma[38] showed that excessive intake of sugar-sweetened beverages was associated with increasing risk of pre-diabetes ($P < 0.001$) and increasing insulin resistance index ($P = 0.006$). When the body ingests too much sugar-sweetened beverages, it will increase the fat synthesis in the liver. During the progress, the sugars can be converted into substances that impair insulin sensitivity such as diacylglycerol. Sairaman Nagarajan[39] shows that healthy food availability was associated with a decreased adjusted prevalence of prediabetes in adolescents.

This study has several limitations. First, the study is a cross-section study, so it can not explain the causal relationship between pre-diabetes and these factors. Second, the sample selected from Qingdao has regional limitations and the sample size is limited. In the later stage, it is still necessary to expand the sample size and conduct multi-center cooperation research to explore the relationship between adolescents and pre-diabetes.

Conclusions

In conclusion, our study find that prediabetes among adolescents in Qingdao is becoming a vital health issue. This requires us to avoid obesity and develop a healthy lifestyle.

Declarations

Abbreviations

IGR: impaired glucose regulation; IFG: impaired fasting glucose; IGT: impaired glucose tolerance; FPG: fasting plasma glucose; 2hPG: 2 hours blood glucose; OGTT: oral glucose tolerance test; ADA: American Diabetes Association; HbA1C: hemoglobin A1c; WC: waist circumference; BP: blood pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: Body mass index; HOMA-IR: homeostasis model assessment of insulin resistance

Ethics approval and consent to participate

The ethics were approved by the Ethics Committee of Affiliated Hospital of Qingdao University , and written informed consent was obtained from all of the participants and their parents before data collection.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare no conflict of interest

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No

Authors' contributions

LW had the original idea for the study, and, with all co-authors, carried out the design. YW and BW carried out the analyses and drafted the manuscript. HX and WJ provided valuable insight regarding the methodological approach and organization of the manuscript. All authors read and approved the final manuscript.

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