Preplanned Studies

Different Percentile Regression of Blood Glucose Among Adolescents Aged 12−20 — United States, 1999−2018

Yuehua Hu[1,2]; Junting Liu[3]; Hongyan Yao[1]; Dapeng Yin[1]; Jian Zhang[5,#]; Guoshuang Feng[4,2,#]

Summary

What is already known on this topic?

The incidence of diabetes is on the rise in the world, and it is increasingly affecting young people. The American Diabetes Association (ADA) has published the 2020 Diabetes Medical Standard, but there is no blood glucose standard for teenagers by age and sex.

What is added by this report?

In this study, quantile regression was used to analyze the data of National Health and Nutrition Examination Survey (NHANES) and found that blood glucose varied significantly based on demographics.

What are the implications for public health practice?

This study provides reference for formulating the normal ranges of adolescent blood glucose and helping to screen out high-risk groups at an early stage for key interventions. The quantile regression method can give a set of curves, which could better describe the situation.

As the burden of disease increases, there is a growing awareness of the dangers of elevated blood glucose (*1*). The incidence of diabetes among adolescents is increasing year over year, and the average annual growth rate of diabetes among children and adolescents in the United States is 2.3%. Elevated blood glucose has many hazards if not treated in time and regularly as it will not only affect the growth and development of children but also cause complications such as diabetic ketoacidosis and cataracts. In severe cases, it can lead to blindness and psychological disorders for children (*2*). Obesity is thought to be the catalyst for diabetes which can lead to an increase in blood glucose in individuals. A close relationship has been observed in recent decades between rising rates of obesity and an increased incidence of type-2 diabetes among adolescents (*3*–*4*). In the 2020 diabetes medical standard published by the American Diabetes Association (ADA), Body Mass Index (BMI) is the primary risk factor in the screening and diagnosis of adolescent type-2 diabetes (*5*). This paper used the blood glucose data of 7,786 adolescents aged 12–20 years from 1999 to 2018 of the National Health and Nutrition Examination Survey (NHANES). Quantile regression was used to analyze the blood glucose of adolescents to explore the influence of gender on blood glucose under different quantiles. At the same time, the results of model correction of BMI were also analyzed. The blood glucose of the female 15-year-old group was close to the normal distribution, and the blood glucose of adolescents of men and women of other ages did meet the normal distribution and was not suitable for typical linear regression analysis. The regression coefficients of gender factors in different ages and quantiles were obtained through the two models and revealed that male blood glucose was higher than female blood glucose and all age groups were statistically significant (P<0.05). A picture of regression coefficients based on different scales showed a downward trend in regression coefficient with the increase of age. There is an urgent need to set up standards for adolescent blood glucose according to various ages and genders.

The NHANES is a sustained survey project implemented by the US CDC since 1999, which uses a much more complex stage probability sampling to sample the American population (*6*–*7*). A cycle takes two years and is designed to assess the health and nutritional status of adults and children in the United States. The data of the project is free to the public, and no additional ethics application is required. In this study, the blood glucose data of 12–20 years old adolescents from 1999 to 2018 in NHANES was used for analysis, and 7,786 individuals had suitable data.

The statistical analysis was carried out with SAS software package (version 9.4, 100 SAS Campus Drive Cary, NC 27513). Quantile regression does not require the distribution of data but requires the minimization of residual error. Different estimators of regression coefficients under different quantiles reflect that explanatory variables have different effects on different levels of explanatory variables. Quantile regression integrates the concept of the quantile into ordinary linear regression. However, the conclusion no longer only reflects the central position but can reflect the whole distribution situation. Model one was a single factor quantile regression analysis without any controlling factors, and model two was a multivariate quantile regression analysis after controlling BMI.

According to ADA's medical standards for diabetes in 2020, the normal range of adult blood glucose is 70–100 mg/dL. In this dataset, the blood glucose level in the 1st percentile was 72 mg/dL, the 85th percentile was 100 mg/dL, and their middle position was in the 42nd percentile. Therefore, the regression equation was established at the five percentiles of P_1, P_{42}, P_{50}, P_{85}, and P_{90}, and the partial regression coefficients under different quantile regression were recorded. The inspection level α was set to 0.05.

The analysis showed that for adolescents aged 12–20 years, the distribution of blood glucose levels at different ages varied (Table 1). By analyzing the regression coefficients of gender factors at different ages and different quantiles, gender factors in each age group of 12–20 years old were found to be statistically significant except in the P_1, and the blood glucose level were higher in males than in females. After controlling for BMI, Model two found that the decrease in blood glucose levels was inconsistent with Model 1, such that for the 12-year-old age group, the regression coefficients for gender of Model 1 and Model 2 at P_{42} were –2.7 and –3.1, respectively; at P_{50}, the gender factor was –2.8 and –3.07, respectively; and at P_{85}, the gender factor was –4.0 and –4.1, respectively (Table 2). Other age groups also show the same phenomenon.

DISCUSSION

A set of curves obtained by quantile regression can provide enough information to study the complete picture of conditional distribution of dependent variables. This study found different genders had statistically significant effects on blood glucose at different percentiles, and blood glucose levels were different at different ages using percentile regression analysis. This suggests that the study of adolescent blood glucose or the preparation of adolescent blood glucose standards should be adjusted based on age and gender.

The prevalence of global juvenile diabetes has been increasing dramatically, especially during the past three or four decades, leading to a global epidemic that leaves diabetes as one of the most common and serious diseases facing humans (*8*). Some studies (*9*) showed that the fasting blood glucose level of boys was higher than that of girls (P<0.05), and there were some differences in the fasting blood glucose level of different age groups (P<0.001). Zhao et al. also pointed out that gender had a certain impact on the correlation between blood glucose and blood lipids (*10*), and patients of different genders should be targeted to monitor and control blood glucose levels. Hou et al. proposed in 2016 that adolescent obesity increased the risk of glycosylated hemoglobin for the diagnosis of diabetes in adulthood after adjusting for and controlling for

TABLE 1. Different percentiles of blood glucose in American teenagers aged 12–20 years.

Age (years)	Total				Male				Female			
	n	P_{25}	P_{50}	P_{75}	n1	P_{25}	P_{50}	P_{75}	n2	P_{25}	P_{50}	P_{75}
12	1,001	88.5	93.7	98.0	463	90.0	95.0	99.7	538	87.7	92.3	96.4
13	914	88.0	93.0	98.0	466	90.0	95.0	99.5	448	86.2	92.0	96.0
14	902	87.8	92.1	97.3	407	89.2	95.0	100.0	495	86.0	90.3	95.0
15	838	87.0	92.0	97.0	419	89.7	95.0	99.0	419	85.0	89.5	94.4
16	1,032	86.0	91.0	97.0	481	89.0	95.0	99.0	551	83.0	98.0	93.0
17	934	86.0	91.0	96.0	465	87.3	93.0	98.0	469	85.0	89.4	93.9
18	909	86.2	92.0	97.0	502	88.0	93.0	98.8	407	84.8	90.0	95.0
19	873	87.0	91.6	97.1	456	89.3	94.0	99.7	417	84.7	89.0	94.2
20	383	85.3	91.0	97.0	181	89.0	95.0	102.3	202	83.7	88.5	93.0
12–20	7,786	87.0	92.0	97.0	3,840	89.0	94.0	99.0	3,946	85.0	90.0	95.0

Note: P_{25}, P_{50} and P_{75} represent the 25th, 50th, and 75th percentiles, respectively. The unit of blood glucose level in each percentile in the table is mg/dL

TABLE 2. Regression coefficient of gender factors of American teenagers aged 12–20 under different ages and quantiles.

Age (years)	Quantile (Model 1 *)							Quantile (Model 2 †)						
	P_1 (95% CI)	P_{25} (95% CI)	P_{42} (95% CI)	P_{50} (95% CI)	P_{75} (95% CI)	P_{85} (95% CI)	P_{90} (95% CI)	P_1 (95% CI)	P_{25} (95% CI)	P_{42} (95% CI)	P_{50} (95% CI)	P_{75} (95% CI)	P_{85} (95% CI)	P_{90} (95% CI)
12	−1.3 (−12.2, 9.6)	−2.3 (−3.5, −1.1)	−2.7 (−3.7, −1.7)	−2.8 (−3.9, −1.7)	−3.3 (−4.6, −2.1)	−4 (−5.6, −2.4)	−4.2 (−5.7, −2.7)	−2.5 (−13.4, 8.3)	−2.7 (−4.1, −1. 3)	−3.1 (−4.2, −2)	−3.0 (−4.2, −1.8)	−3.3 (−4.5, −2.1)	−4.1 (−5.8, −2.4)	−4.5 (−6.3, −2.8)
13	−0.2 (−5.7, 5.3)	−3.8 (−5.1, −2.5)	−3.5 (−4.7, −2.3)	−4.0 (−5.2, −2.8)	−3.5 (−5.0, −2.0)	−3.6 (−5.4, −1.8)	−4.1 (−6, −2.2)	−5.5 (−9.7, −1.3)	−4.4 (−6.0, −2.7)	−3.5 (−4.9, −2.2)	−3.7 (−4.9, −2.4)	−3.1 (−4.5, −1.7)	−3.6 (−5.4, −1.8)	−4.1 (−6.5, −1.7)
14	−6.0 (−17.9, 5.9)	−3.2 (−4.3, −2.1)	−4.1 (−5.3, −2.9)	−4.7 (−5.8, −3.6)	−5.0 (−6.3, −3.7)	−4.8 (−6.3, −3.3)	−4.1 (−6.6, −1.6)	−4.5 (−13.2, 4.2)	−3.3 (−4.3, −2.3)	−4.4 (−5.5, −3.4)	−4.7 (−6.1, −3.3)	−4.4 (−5.8, −3.0)	−4.7 (−6.3, −3.2)	−5.0 (−7.2, −2.8)
15	−4.3 (−13.4, 4.8)	−4.7 (−6.3, −3.1)	−5.2 (−6.6, −3.8)	−5.5 (−6.7, −4.3)	−4.6 (−5.8, −3.4)	−5.0 (−7.2, −2.8)	−5.0 (−6.9, −3.1)	−7.0 (−14.9, 1.0)	−4.3 (−5.9, −2.7)	−5.4 (−6.7, −4.2)	−5.7 (−6.8, −4.5)	−4.9 (−6.2, −3.7)	−5.3 (−7, −3.7)	−5.5 (−8.1, −2.9)
16	−8.3 (−17.6, 1.0)	−6.0 (−7.8, −4.2)	−5.5 (−6.8, −4.2)	−5.6 (−6.8, −4.4)	−6.0 (−7.2, −4.9)	−6 (−7.9, −4.1)	−6.5 (−8.2, −4.8)	−6.8 (−15.5, 1.9)	−6.4 (−7.9, −4.8)	−5.1 (−6, −4.2)	−5.5 (−6.7, −4.4)	−6.4 (−7.4, −5.4)	−5.5 (−7.5, −3.6)	−5.9 (−7.2, −4.5)
17	0.3 (−7.2, 7.8)	−2.3 (−4.0, −0.7)	−3.1 (−4.3, −1.9)	−3.6 (−4.3, −2.9)	−4.1 (−5.8, −2. 5)	−4.6 (−6.1, −3.1)	−4.8 (−6.6, −3)	−1.4 (−7.7, 4.9)	−3.0 (−4.3, −1.6)	−3.3 (−4.6, −2)	−3.3 (−4.3, −2.3)	−4.0 (−5.7, −2.3)	−4.7 (−6.4, −2.9)	−4.9 (−7.5, −2.4)
18	−6.3 (−16.1, 3.5)	−3.2 (−4.9, −1.5)	−3.6 (−4.7, −2.5)	−3.4 (−4.5, −2.3)	−3.8 (−5.2, −2.4)	−4.0 (−5.9, −2.1)	−4.0 (−6.3, −1.7)	−6.8 (−17, 3.4)	−3.8 (−5.2, −2.4)	−3.2 (−4.3, −2.1)	−3.2 (−4.6, −1.9)	−4.1 (−5.7, −2.4)	−4.4 (−5.9, −2.9)	−4.0 (−6.9, −1.1)
19	−6.5 (−14.8, 1.8)	−4.5 (−5.8, −3.2)	−4.5 (−5.8, −3.2)	−5.0 (−6.5, −3.5)	−5.5 (−6.8, −4.2)	−4.0 (−6.2, −1.8)	−5.0 (−7.5, −2.5)	−3.6 (−9.1, 1.8)	−4.5 (−5. 9, −3.1)	−4.9 (−6, −3.8)	−5.1 (−6.6, −3.7)	−4.5 (−6.1, −2.9)	−5.1 (−6.8, −3.4)	−4.8 (−7.2, −2.3)
20	2.9 (−35.3, 41.1)	−5.3 (−7.2, −3.4)	−7.0 (−9.8, −4.2)	−6.7 (−9, −4.4)	−9.0 (−12.0, −6.0)	−9.0 (−11.2, −6.8)	−9.3 (−13.9, −4.7)	1.0 (−24.6, 26.5)	−4.9 (−7.0, −2.7)	−6.3 (−8.4, −4.2)	−7.1 (−9, −5.1)	−8.5 (−10.7, −6.3)	−8.6 (−11.3, −5.9)	−7.9 (−10.1, −5.8)
12–20	−1.9 (−4.2, 0.4)	−3.6 (−7.2, −3.1)	−4.3 (−4.9, −3.8)	−4.0 (−4.3, −3.7)	−4.0 (−4.4, −3.6)	−4.4 (−5.3, −3.5)	−4.7 (−5.8, −3.6)	−2.6 (−4.9, −0.3)	−3.9 (−4.4, −3.5)	−4.3 (−4.7, −3.9)	−4.4 (−4.9, −4)	−4.4 (−4.9, −4.0)	−4.6 (−5.3−3.9)	−5.3 (−6.1−4.5)

* Model 1: Single factor analysis;
† Model 2: adjusting for BMI;
Notes: 1) The regression coefficient in this table means the change value of blood sugar when males compared with females
2) If the range of 95%CI includes 0, there is no statistical significance; If the range of 95%CI does not include 0, it is statistically significant.

confounders [(OR (95% CI): 5.93 (3.06–1.49)] (*11*). The conclusion is that obesity from adolescence to adulthood is a risk factor for adult diabetes, and controlling adolescent obesity is highly necessary for the early prevention and treatment of diabetes.

This study was subject to some limitations. The dataset had possible limitations due to the historicity and purpose of the data and also potentially due to some incompleteness in data disclosure. Furthermore, blood glucose is influenced by more factors beyond age and gender, such as race, nationality, lifestyle, genetic background, as well as sample size and quality control during data collection.

Adolescent obesity is of high clinical and public health importance for glycemic impact. Strengthening the detection of blood glucose and blood lipids in overweight and obese children and taking comprehensive intervention measures as early as possible will benefit children's health and reduce the incidence of diabetes. Standards need to be established for adolescent blood glucose and adjusted according to different ages and genders.

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Corresponding authors: Jian Zhang, zhjian6708@126.com; Guoshuang Feng, glxfgsh@163.com.

[1] Office of Epidemiology, Chinese Center for Disease Control and Prevention, Beijing, Chinaevention, Beijing, China; [2] Beijing Advanced Innovation Center for Big Data-Based Precision Medicine, Beihang University & Capital Medical University, Beijing, China; [3] Epidemiology Office, Children's hospital capital institute, Beijing, China; [4] Big Data and Engineering Research Center, Beijing Children's Hospital, Capital Medical University, National Center for Children's Health, Beijing, China; [5] National Institute Nutrition and Health, Chinese Center for Disease Control and Prevention, Beijing, China.

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