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Analysis of blood glucose distribution characteristics in a health examination population in Chengdu (2007–2015)

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Abstract

With socioeconomic growth and cultural changes in China, the level of blood glucose may have changed in recent years. This study aims to detect the blood glucose distribution characteristics with a large size of health examination population.

A total of 641,311 cases (360,259 males and 281,052 females) more than 18 years old during 2007 to 2015 were recruited from the Health Examination Center at West China hospital, Sichuan University.

The percentage of cases with abnormal glucose level and the mean level of glucose were significantly increased since 2007 to 2015 overall. The percentage of cases with abnormal glucose level in males was significantly higher than that in females every year, and the percentage of cases with abnormal glucose level in aged population was higher than the young population. In addition, the mean level of glucose was higher in aged population with normal level of glucose than the young population with normal level of glucose, and the mean level of glucose was higher in males with normal level of glucose than the females with normal level of glucose.

The population showed an increased level of blood glucose. Some preventive action may be adopted early and more attention can be paid to them.

Abbreviations: DM = diabetes mellitus, HbA1c = hemoglobin a1c, IGT = impaired glucose tolerance.

Keywords: blood glucose, health examination, public health

1. Introduction

Diabetes mellitus (DM) prevalence and incidence are growing steadily for several decades, leading to large increases in the total burden of diabetes-related morbidity. The annual cost of diabetes has been estimated to be $245 billion in the United States[1] and $548 billion worldwide.[2] In the 1980s, the Chinese Government initiated a series of political and economic reforms that have led to phenomenal socioeconomic growth, technological advancement, and cultural changes. These rapid changes in lifestyle may have contributed to the dramatic increase in diabetes prevalence from 0.9% in 1980[3] to 11.6% in 2010.[4] A Chinese national survey in 2010 showed that the prevalence of type 2 diabetes was 4.5% in person aged 18 to 29 years and 6.6% in those aged 30 to 39 years. With respect to the person under the age of 40 years, about 40% to 50% had prediabetes.[4] Type 2 diabetes has overtaken type 1 diabetes as the predominant form of diabetes in children in Taiwan and Hong Kong,[5] similar to that in the western countries.[6] Together with the prevalence of gestational diabetes of 8.1% to 10.9%[7,8] and childhood obesity of 5.5%,[9] early onset type 2 diabetes substantially up-regulates the risk of premature mortality and multiple morbidities partly due to long disease duration[10,11] suboptimal management,[12] and has become into a major public health challenge.[10] Therefore, early detection, diagnosis, and treatment are of importance for the prevention and control of DM.

Regular health examination is an important way for early detection of DM and glucose intolerance. In the present study, we analyzed the fasting blood glucose from 2007 to 2015 in West China Hospital, Chengdu, so as to reveal the blood glucose distribution characteristics among the health examination population.

2. Methods

2.1. Study population

The following methods were carried out in accordance with the approved guidelines. A total of 641,311 cases more than 18 years old during 2017 to 2015, included 360,259 males (45.03 ± 13.96 years) and 281,052 females (42.52 ± 13.64 years) were recruited from the Health Examination Center at West China Hospital, Sichuan University. Peripheral blood was collected from all

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Table 1

Characteristics of all the health examination population and the cases with normal level of fasting blood glucose.

Year	Cases, N			Cases with normal glucose, N (%)		
	Males	Females	Overall	Males	Females	Overall
2007	16,975	11,876	28,851	15,936 (93.88)	11,548 (97.24)	27,484 (95.26)
2008	19,787	15,445	35,232	18,038 (91.16)	14,696 (95.15)	32,734 (92.91)
2009	24,188	18,251	42,439	21,707 (89.74)	17,281 (94.68)	38,988 (91.87)
2010	31,881	24,497	56,378	28,503 (89.40)	23,244 (94.89)	51,747 (91.79)
2011	35,767	28,114	63,881	31,452 (87.93)	26,369 (93.79)	57,821 (90.51)
2012	42,510	32,766	75,276	37,722 (88.73)	31,147 (95.06)	68,869 (91.49)
2013	57,094	44,725	101,819	49,618 (86.90)	41,924 (93.74)	91,542 (89.91)
2014	77,795	62,296	140,091	67,389 (86.62)	58,449 (93.82)	125,838 (89.83)
2015	54,262	43,082	97,344	47,273 (87.12)	40,546 (94.11)	87,819 (90.22)
Total	360,259	281,052	641,311	317,638 (88.17)	265,204 (94.36)	582,842 (90.88)

participants. The corresponding protocol was approved by the Ethics of Research Committee of the West China Hospital, Sichuan University. Informed and written consent was obtained from all participating subjects.

2.2. Collection of laboratory data and glucose measurement

Data about demographic and laboratory features were collected from hospital records or by questionnaire. The blood samples were withdrawn from the antecubital vein of subjects in fasting status, and the level of fasting blood glucose of each individual was detected by hexokinase method by Roche cobase 702. Cases having serum level of fasting blood glucose between 2.2 and 6.1 mmol/L were considered as normality, while serum level of fasting blood glucose <2.2 or >6.1 mmol/L were considered as abnormality.[13–15] In addition, the level of glycosylated hemoglobin a1c (HbA1c) was detected by high performance liquid chromatography (HLC-723G7; Tosoh, Tokyo, Japan), which was certified by the National Glycohemoglobin Standardization Program.[16] The level of HbA1c higher than 6.5% was considered abnormality.[17]

2.3. Statistical analysis

All statistical analyses were done by SPSS 10.01. With respect to the results expressed as mean ± standard deviation, the statistical significance of the data was determined by Student *t* test, analysis of variance analysis, or multiple comparisons (SNK-q test). The difference between percentages of males and females having normal glucose level was compared using Chi-squared test. To describe the level of fasting blood glucose, we noted the maximum, minimum, mean, and standard deviation. Significance was defined as $P < .05$.

Table 2

Characteristics of fasting blood glucose among all the health examination population (2007–2015).

Year	Number	Minimum, mmol/L	Maximum, mmol/L	Mean, mmol/L	Standard deviation
2007	28,851	2.40	21.60	4.81	1.04
2008	35,232	1.54	31.75	5.06	1.15*
2009	42,439	2.70	35.01	5.23	1.17*
2010	56,378	2.27	37.09	5.24	1.10*
2011	63,881	1.68	25.80	5.30	1.16*
2012	75,276	1.42	25.58	5.24	1.12*
2013	101,819	2.35	27.87	5.33	1.17*
2014	140,091	2.05	26.22	5.36	1.19*
2015	97,344	2.34	27.67	5.33	1.20*

* Compared with the level of glucose in year 2007, and showed significant difference.

3. Results

3.1. Characteristics of the health examination population and the fasting blood glucose

In the present study, a total of 641,311 cases over than 18 years old including 360,259 males (45.03 ± 13.96 years) and 281,052 females (42.52 ± 13.64 years) were recruited (Table 1). Among these population, we found that the mean level of glucose in year 2007 was 4.81 mmol/L, and the mean level was significantly increased from 2007 to 2015 ($F = 897.23$, $P < .001$), by which the level was 5.33 mmol/L in year 2015. When discussed the glucose level between year 2008 and 2007, there was significant difference. Similarly, the other 7 year's glucose level was significantly higher than that in 2007, respectively (Table 2).

In year 2015, there were 45,575 participants examining the level of HbA1c. We found that 27,109 were males and 18,466 were females, and the percentage of cases had normal level of HbA1c was 85.98% in males and 92.33% in females (Table 3). Among all the cases, the minimum level of HbA1c was 2.9%, the maximum level of HbA1c was 15.9%, and the mean level of HbA1c was 5.45 ± 0.31%.

3.2. Differences between males and females having normal glucose level

There were 317,638 males (88.17%) and 265,204 females (94.36%) showing with normal level of glucose (Table 1), and the percentage of males having normal glucose level was significantly lower than that in the females overall ($\chi^2 = 7305.2$, $P < .001$). With respect to different years (2007–2015), the percentage of males having normal glucose level was also significantly lower

Table 3

Characteristics of all the health examination population and the cases with normal level of glycosylated hemoglobin a1c (HbA1c) in year 2015.

Cases, N			Cases with normal HbA1c, N (%)		
Male	Female	Overall	Male	Female	Overall
27,109	18,466	45,575	23,308 (85.98)	17,050 (92.33)	40,358 (88.55)

Table 4

Characteristics of the cases with normal level of glucose in different sex.

Sex	Year	Number	Minimum, mmol/L	Maximum, mmol/L	Mean, mmol/L	Standard deviation
Males	2007	15,936	2.40	6.10	4.67	0.49
	2008	18,038	2.89	6.10	4.85	0.49*
	2009	21,707	2.70	6.10	5.02	0.45*
	2010	28,503	2.27	6.10	5.05	0.45*
	2011	31,452	2.54	6.10	5.07	0.46*
	2012	37,722	2.36	6.10	5.04	0.46*
	2013	49,618	2.73	6.09	5.10	0.45*
	2014	67,389	2.35	6.09	5.12	0.45*
	2015	40,546	2.87	6.10	5.09	0.45*
Females	2007	11,548	3.10	6.10	4.61	0.43
	2008	14,696	2.84	6.10	4.81	0.46*
	2009	17,281	2.76	6.10	4.95	0.42*
	2010	23,244	2.33	6.10	4.97	0.42*
	2011	26,369	2.54	6.10	5.00	0.43*
	2012	31,147	2.67	6.10	4.95	0.43*
	2013	41,924	2.35	6.09	5.01	0.43*
	2014	58,449	2.52	6.09	5.04	0.42*
	2015	40,546	2.87	6.10	5.01	0.43*

* Compared with the level of glucose in year 2007, and showed significant difference.

than that in the females every year, respectively (all $P < .01$, data not shown). To further discuss the level of glucose in different sex, we examined the level of glucose both in males and females every year. Results showed that the mean level was significantly increased from 2007 to 2015 both in males and females (Table 4). These data indicated that the mean level of glucose was higher in males compared with that in females every year.

Regarding the level of glucose among different ages, we divided the ages into 8 groups. As in Table 5, the mean level of glucose increased from 4.39 mmol/L in year 2007 to 4.77 mmol/L in year 2015 in group 1. The mean level of glucose was significantly increased from 2008 to 2015 when compared with 2007, respectively. The results of other 7 groups were similar to group 1. These data suggested that the level of glucose was gradually increased year by year in each group, and the level of glucose was higher in aged cases compared with the young population every year overall, for instance, the mean level of glucose was 4.39 mmol/L in group 1, and the mean level was 4.90 mmol/L in group 8 in year 2007. To discuss the difference of cases having normal HbA1c level among different ages, we also divided the ages into 8 groups in year 2015. Results indicated that the mean level of HbA1c was $5.15 \pm 0.28\%$ in group 1, and the mean level was gradually increased from group 2 to group 8 when compared with group 1 (Table 6).

3.3. Differences between males and females with abnormal glucose level

There were 42,621 males (11.83%) and 15,848 females (5.64%) showing with abnormal serum level of glucose. With respect to the glucose level <2.2 mmol/L, there were 1 male and 1 female in year 2008, 1 female in year 2011, 2 males and 1 female in year 2012, and 1 male in year 2014. According to the cases with higher level of glucose than 6.1 mmol/L, we found that the percentage was 6.12% among males, while the percentage was 2.76% among females in year 2007. However, the percentage was gradually increased and up-regulated to 12.88% among males, 5.89% among females in year 2015 (Fig. 1). In addition, the percentage was significantly higher in males compared with that in females every year, respectively (all $P < .001$). To discuss the percentage of abnormal glucose level among different ages, we also divided the ages into 8 groups. As in Fig. 2, the difference of percentage of abnormal glucose level in each year among different groups was significant, respectively (all $P < .001$). For instance, groups 1 and 2 were lower than the other groups every year, and the percentage of abnormal glucose level in groups 3 to 8 was gradually increased year by year overall. Similarly, the percentage of cases having level of HbA1c higher than 6.5% was 13.51% in male, and 7.05% in female in year 2015. To discuss the percentage of abnormal HbA1c level among different ages, we also divided the ages into 8 groups in year 2015. Results indicated that the percentage of cases having abnormal HbA1c level was comparable between group 1 (1.75%) and group 2 (0.68%). However, the percentage was significantly increased from group 3 to group 8 when compared with the percentage in group 1, respectively (all $P < .05$, data not shown).

4. Discussion

The present study was conducted in 641,311 persons with health examination higher than 18 years old from Chengdu City in Sichuan province and the surrounding areas during 2007 to 2015. This was a large sample size study, with subjects from the same area, supporting the accuracy and stability of the results. This investigation discussed the serum level of fasting blood glucose both in males and females year by year, and found that the percentage of cases with abnormal glucose level and the mean level of glucose were increased since 2007 to 2015 overall. This study also revealed that the percentage of abnormal glucose level in males was higher than that in females every year. It is noteworthy that the percentage of cases with abnormal glucose level in aged populations was higher than the young population, and the mean level of glucose was higher in the aged population with normal level of glucose than the young population with normal level of glucose. These findings are interesting, and suggested that the mean level of glucose was gradually up-regulated since 2007 to 2015, and the males may have higher serum levels of glucose than females.

The findings in this study may correlate with several reasons. First, oxidative phosphorylation dysfunction of islet cells, with a down-regulation in the amount and secretory functions, results in glucose elevation with age,[18] similar to a study in Song et al,[19] who indicated a strong increasing tendency of glucose with age, and the prevalence of impaired fasting glucose was positively correlated with age, where the glucose of males reached a peak at the age of 65, while it always continued increasing in females. This was partly similar to our study, by which the level of glucose was higher in aged population and reached a peak at group 7 (71–80 years). In addition, some studies found a higher incidence of DM in men than women.[20–22] Habits such as alcohol consumption, smoking, increased age, and physical activity levels may result in the up-regulation of DM in males.[14,23,24] Moreover, it has been accepted that life and job stress are much higher in males than in females in China, less attention has been paid to them, and an unhealthy lifestyle might also result in a rise in blood glucose. Because of the specificity and acceptability in health examination population, the present study failed to analyze the causality relationship between blood glucose and related factors. Second, increased level of glucose may correlate with socioeconomic growth, the rapid adoption of energy-dense foods. Importantly, these significant changes may lead to serious

Table 5

Characteristics of the cases with normal level of glucose in different ages.

Age	Year	Number	Minimum, mmol/L	Maximum, mmol/L	Mean, mmol/L	Standard deviation
18–20 (group 1)	2007	102	3.60	5.50	4.39	0.38
	2008	140	3.59	6.08	4.58	0.42*
	2009	178	3.88	5.76	4.77	0.36*
	2010	213	3.15	5.99	4.77	0.43*
	2011	200	3.88	5.97	4.74	0.36*
	2012	197	3.77	5.83	4.73	0.37*
	2013	276	3.59	5.95	4.80	0.42*
	2014	364	2.80	5.97	4.84	0.43*
	2015	224	3.70	6.04	4.77	0.39*
21–30 (group 2)	2007	4337	2.40	6.10	4.48	0.40
	2008	5493	2.84	6.09	4.67	0.43*
	2009	7589	2.76	6.09	4.83	0.38*
	2010	10,276	2.80	6.10	4.86	0.39*
	2011	10,929	3.02	6.10	4.90	0.40*
	2012	14,363	2.36	6.10	4.85	0.40*
	2013	18,454	2.35	6.09	4.89	0.40*
	2014	26,824	2.35	6.09	4.95	0.40*
	2015	17,531	3.18	6.10	4.88	0.40*
31–40 (group 3)	2007	8472	2.40	6.10	4.56	0.42
	2008	10,017	3.01	6.10	4.75	0.44*
	2009	11,027	3.08	6.10	4.92	0.41*
	2010	14,947	2.43	6.10	4.96	0.41*
	2011	15,618	2.54	6.10	4.98	0.43*
	2012	17,992	2.67	6.10	4.94	0.42*
	2013	23,955	2.92	6.09	5.00	0.41*
	2014	34,781	2.81	6.09	5.04	0.42*
	2015	23,201	2.74	6.10	4.99	0.41*
41–50 (group 4)	2007	6798	2.86	6.10	4.66	0.46
	2008	8173	3.03	6.10	4.84	0.47*
	2009	10,060	2.70	6.10	5.00	0.44*
	2010	14,083	2.76	6.10	5.03	0.44*
	2011	16,486	3.13	6.10	5.04	0.45*
	2012	2073	2.91	6.10	5.01	0.45*
	2013	26,739	2.81	6.09	5.07	0.44*
	2014	35,185	2.52	6.09	5.20	0.44*
	2015	24,691	2.34	6.10	5.07	0.43*
51–60 (group 5)	2007	3979	2.70	6.10	4.76	0.49
	2008	4869	3.04	6.10	4.96	0.47a
	2009	5823	3.22	6.10	5.11	0.44a
	2010	7246	3.07	6.10	5.14	0.44a
	2011	8341	3.02	6.10	5.16	0.45a
	2012	9003	2.87	6.10	5.13	0.45a
	2013	12,404	2.80	6.09	5.19	0.44a
	2014	17,390	3.12	6.09	5.20	0.44a
	2015	13,501	2.46	6.10	5.18	0.45a
61–70 (group 6)	2007	2212	3.00	6.10	4.89	0.50
	2008	2547	3.06	6.10	5.09	0.48*
	2009	2560	3.45	6.10	5.22	0.43*
	2010	3068	2.27	6.10	5.25	0.44*
	2011	3577	3.39	6.10	5.25	0.44*
	2012	3924	3.60	6.10	5.21	0.44*
	2013	5374	2.73	6.09	5.29	0.43*
	2014	6495	3.18	6.09	5.29	0.43*
	2015	4933	2.98	6.10	5.28	0.43*
71–80 (group 7)	2007	1337	2.90	6.10	4.90	0.51
	2008	1280	3.42	6.10	5.14	0.47*
	2009	1509	3.79	6.10	5.27	0.44*
	2010	1654	2.33	6.10	5.29	0.46*
	2011	2213	2.54	6.10	5.31	0.45*
	2012	2534	2.38	6.10	5.25	0.46*
	2013	3426	3.14	6.09	5.34	0.42*
	2014	3688	2.52	6.09	5.34	0.43*
	2015	2827	2.99	6.10	5.33	0.43*
>80 (group 8)	2007	247	3.80	6.10	4.90	0.51

Age	Year	Number	Minimum, mmol/L	Maximum, mmol/L	Mean, mmol/L	Standard deviation
	2008	215	3.08	6.09	5.19	0.50*
	2009	242	3.99	6.10	5.29	0.43*
	2010	260	3.74	6.10	5.26	0.45*
	2011	457	3.48	6.10	5.26	0.45*
	2012	683	3.26	6.10	5.20	0.49*
	2013	914	3.29	6.09	5.29	0.44*
	2014	1111	2.78	6.09	5.31	0.44*
	2015	911	2.60	6.10	5.32	0.46*

* Compared with the level of glucose in year 2007, and showed significant difference.

Table 6

Characteristics of the cases with normal level of glycosylated hemoglobin a1c (HbA1c) in different ages in year 2015.

Age	Number	Minimum, %	Maximum, %	Mean, %	Standard deviation
18–20 (group 1)	55	4.80	6.00	5.15	0.28
21–30 (group 2)	4631	4.50	6.00	5.19	0.27
31–40 (group 3)	9662	4.50	6.00	5.26	0.30
41–50 (group 4)	13,452	4.50	6.00	5.35	0.31
51–60 (group 5)	7808	4.50	6.00	5.47	0.31
61–70 (group 6)	2742	4.50	6.00	5.55	0.30
71–80 (group 7)	1445	4.50	6.00	5.60	0.29
>80 (group 8)	563	4.60	6.00	5.62	0.27

diabetes or prediabetes. In a national study discussing the prevalence of diabetes and glycemic control in the Chinese adult population, the estimated prevalence of diabetes among a representative sample of Chinese adults was 11.6% and the prevalence of prediabetes was 50.1%, suggesting that this may represent up to 113.9 million Chinese adults with diabetes and 493.4 million with prediabetes. In our study, the proportion of population with abnormal level of glucose and the mean level of glucose were increased year by year overall. Therefore, preventive interventions for cases with high level of glucose or aged cases should be used as early as possible. The Da Qing Diabetes Prevention Program was the first randomized study conducted in China that has revealed significant benefits of lifestyle modification on down-regulating the risk of progression from impaired glucose tolerance (IGT) to diabetes.[25] This program showed that after 6 years of active intervention, the risk of progression to diabetes was down-regulated by 51% in comparison with the control group irrespective of obesity status at baseline. This benefit persisted after 20 years with an annual incidence of diabetes of 7% in the intervention group compared with 11% in the control group. Moreover, in the Finnish Diabetes Prevention Study, a total of 522 middle-aged, overweight subjects with IGT were randomized to receive personalized counseling for promoting healthy lifestyle. After a mean follow-up duration of 3.2 years, the risk to develop diabetes was down-regulated by 58% in the intervention group.[26] Furthermore, a study of the Diabetes Prevention Program involving 3234 American adults with impaired fasting glycemia or IGT reported that the incidence of diabetes was down-regulated by 58% with lifestyle intervention and 31% with metformin after 2.8 years of intervention, in comparison with the control group.[27] Collectively, these encouraging results have provided support for us though the present study did not discussed the prevalence of diabetes or prediabetes, the current findings have revealed that the percentage of cases with abnormal glucose level has increased year by year, and the mean level of glucose has up-regulated since 2007 to 2015. Consequently, we should pay attention to this health examination population, and some preventive action may be adopted early.

Figure 1. Trends of the percentage of cases with fasting blood glucose more than 6.2 mmol/L in different sex. Percentages of male and female with fasting blood glucose more than 6.2 mmol/L were both gradually increased since 2007 to 2015 overall. The percentage of male with fasting blood glucose more than 6.2 mmol/L was higher than that in female every year (**$P < .001$).

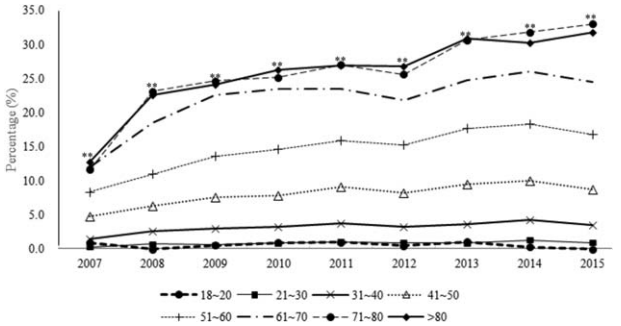

Figure 2. Trends of the percentage of cases with fasting blood glucose more than 6.2 mmol/L in different ages. The percentage of cases with fasting blood glucose more than 6.2 mmol/L in group 1 (18–20 year) and group 2 (21–30 year) was comparable every year. The percentage of cases with fasting blood glucose more than 6.2 mmol/L was gradually increased in groups 3 to 8 from 2007 to 2015 overall. Cases with older age showed significantly higher percentages than that in younger age every year (**$P < .001$).

There are several limitations in the present study, such as representativeness, missing biochemical indexes, and missing information of diet and exercise. In addition, our study failed to explore the causality relationship between blood glucose and related factors because of inherent limitations of the cross-sectional study. Despite these limitations, this study was a large sample size investigation, with subjects from the same area, supporting the accuracy and stability of the results. Moreover, the results of this study are noteworthy for government for early education and intervention.

In summary, increased percentage of cases with abnormal glucose and mean level of glucose were observed in a large population of adults. It is necessary to take action for health examination population, especially aged population, and screen high-risk groups and adopt appropriate preventive measures early.

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