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Characteristics of blood glucose distribution in a health examination population in Sichuan (2009–2017)

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Abstract

The prevalence of diabetes mellitus and impaired fasting glucose is rapidly increasing in the recent years. Hyperglycemia associated atherosclerosis and other complications are posing a serious threat to human health. The present study aimed to analyze the blood glucose distribution characteristics within a large size of health examination population of Sichuan province, China.

This was a retrospective study conducted in 878,019 subjects (483,914 males and 394,105 females) aged more than 18 years old from the Health Examination Center at West China Hospital, Sichuan University during 2009 to 2017. The blood glucose levels were compared in different age groups and different years.

The blood glucose levels were significantly increased in recent years. The percentage of cases with high glucose levels was significantly higher in males than that in females since 2009 to 2017. Moreover, the blood glucose levels and the percentage of high glucose levels in aged population were significantly higher than those in younger population every year.

The health examination population showed increased percentage of blood glucose levels, and so regular physical examination and glucose control are highly important in aged population.

Abbreviation: FBG = fasting blood glucose.

Keywords: blood glucose distribution, fasting blood glucose, health examination population, hyperglycemia

1. Introduction

With recent economic development and cultural changes in China, the prevalence and incidence of diabetes mellitus have been significantly increased.[1] According to a national epidemiological study conducted in China in 2010, the estimated prevalence of diabetes and prediabetes in adults was 11.6% and 50.1%.[2] With the improvement in economy and changing lifestyles, the incidence of diabetes will increase by 12.1% in 2030, which remains similar to that in other countries.[3] It is well known that ischemic heart disease and stroke are the major risk factors in patients with diabetes. The comorbidities associated with diabetes have become a serious threat to public health, causing socioeconomic burden.[4] The increased patients with diabetes have also contributed to the growth of health expenditure in China. Health expenditure on diabetes was USD 8.65 billion in 2008 (0.21% of GDP).[5] Many studies have reported that treatment of diabetes and other complications has become a major public health challenge.[6,7] Therefore, more and more research should focus on controlling hyperglycemia and blood glucose levels.[8,9]

Early detection, diagnosis, and treatment are important for the prevention of diabetes-related atherosclerosis and other complications. Regular health examination is an important approach for early detection of blood glucose abnormalities. Hence, this study aimed to analyze the blood glucose levels from 2009 to 2017 in Sichuan province to explore the characteristics of blood glucose distribution among the health examination population to control the glycemic levels.

2. Materials and methods

2.1. Study population

During 2009 to 2017, information of subjects was collected from the Health examination center at the West China Hospital, Sichuan University. The data regarding the blood glucose levels of

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FD and XN contributed equally to this study.

The study was approved by the Institutional Ethics Committee of West China Hospital of Sichuan University and complied with Declaration of Helsinki (reference no. 193, 2016). As this study was retrospective in nature, we removed the name and ID of the subjects and the results were non-traceable to individual patients, informed consent for the use of samples was not needed.

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The authors have no conflicts of interest to disclose.

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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subjects were obtained from the hospital's laboratory information system. The basic information of subjects, including name, age, gender, identification number, diagnosis, and the blood glucose values was collected. Before evaluating the results, the exclusion criteria were as follows: The subjects had a recent history of infection, such as upper respiratory tract infection, influenza, pneumonia; subjects with a history of diabetes, renal insufficiency (creatinine >133 umol/L), liver dysfunction (with more than 4 times the upper limit of normal aspartate aminotransferase and/or alanine aminotransferase). Excel 2016 was used to remove the subjects whose blood glucose concentration were more than mean ± 4 standard deviations (mean ± 4 SD). Finally, the study involved 878019 subjects (483,914 males and 394,105 females) aged >18 years old. This retrospective study has been approved by the ethics committee of the West China Hospital, Sichuan University has approved, and this study was carried out in accordance with the approved guidelines.

2.2. Glucose measurement

A total of 5 mL venous blood samples were collected from the participants after an overnight fast and were centrifuged at 3000 r/min for 15 minutes. The serum was taken for measurement. Fasting blood glucose (FBG) was measured by hexokinase method (cobas 8000, ROCHE, Germany). Subjects with FBG levels between 3.0 and 5.9 mmol/L were considered as normal, while with levels >5.9 mmol/L were considered as abnormally high. Sample collection and laboratory testing were carried out in accordance with the standard operating procedure. Internal quality control data were obtained during the study to ensure the reliability of blood glucose measurement results. Strict calibration and preventive maintenance on the instruments were carried out by the laboratory every month. The programs of the College of American Pathologists external quality assessment were used to ensure the accuracy and reliability of the results.

2.3. Statistical analyses

All statistical analyses were done by Excel 2016 and SPSS 20.0. Before analyzing the data, Excel 2016 was used to remove the values with more than 4 standard deviations (±4 SD). A *P*-value of less than 0.05 was considered to be statistically significant. The results are expressed as medians and values of 25 to 75 percentiles. Statistical significance of the data was measured by Wilcoxon test for non-normally distributed ones and Chi-square test was used for categorical variables.

3. Results

3.1. Characteristics of FBG in health examination population

In the present study, a total of 878019 cases aged greater than 18 years (483,914 males and 394,105 females) were recruited from 2009 to 2017. Among these subjects, 787,460 (89.69%) had normal levels of FBG. The percentage of males with normal blood glucose levels was 86.78%, which was lower than that in females (Table 1). Health examination in this population revealed that the levels of glucose in the year 2009 were 5.14 (4.84, 5.60) mmol/L, and these were increased by 5.26 (4.89, 5.73) mmol/L from 2009 to 2015. In 2016 and 2017, the blood glucose levels have been decreased by 5.11(4.78, 5.60) mmol/L (Table 2).

3.2. The characteristics of FBG levels between males and females

Among the health examination population, there were 419,959 males (86.78%) and 367,501 females (93.25%) with normal glucose levels. The FBG levels in different years (200–2017) were higher in males than that of females (Table 2).

Among the cases with high levels of glucose >5.9 mmol/L, there were 11.63% males and 6.61% females in the year 2009. The percentage was increased by 15.65% among males and 8.48% among females in the year 2013. From 2014, the percentage was decreased by 11.92% in males and by 5.51% in females (Fig. 1). Moreover, the percentage of males with high glucose levels was significantly higher than those in females every year (all $P < .001$).

3.3. The characteristics of FBG levels among different ages

Regarding the FBG levels among different ages, the population was divided based on age into 7 groups. The levels of glucose were 4.83 (4.58, 5.10) mmol/L in individuals <30 years old, and were 5.52(5.11, 6.15) mmol/L in 70 to 80 age group (Table 3). The glucose levels were higher in aged individuals than younger population every year (Table 4). The tendency of glucose levels in different age groups remained the same in different years

Table 1

The characteristics of all health examination population and the people with normal FBG.

	Health examination population, N			Cases with normal glucose, N (%)		
	Males	Females	Overall	Males	Females	Overall
2009	23,916	18,219	42,135	21,134 (88.37)	17,015 (93.39)	38,149 (90.54)
2010	32,743	25,910	58,653	28,697 (87.64)	24,201 (93.40)	52,898 (90.19)
2011	35,411	28,153	63564	30,493 (86.11)	25,963 (92.22)	56,456 (88.82)
2012	42,143	32,849	74,992	36,638 (86.94)	30,692 (93.43)	67,330 (89.78)
2013	50,464	40,355	90,819	42565 (84.35)	36,933 (91.52)	79498 (87.53)
2014	37,605	31,806	69,411	31,781 (84.51)	29,174 (91.72)	60,955 (87.82)
2015	83024	67,120	150,144	71,344 (85.93)	62,181 (92.64)	133,525 (88.93)
2016	88,396	71,789	160,185	77,851 (88.07)	67,730 (94.35)	145,581 (90.88)
2017	90,212	77,904	168,116	79,456 (88.08)	73,612 (94.49)	153,068 (91.05)
Total	483,914	394,105	878,019	419,959 (86.78)	367,501 (93.25)	787,460 (89.69)

FBG = fasting blood glucose.

Table 2

The characteristics of FBG among the health examination population (2009–2017).

Year	Overall (mmol/L)	Male (mmol/L)	Female (mmol/L)	P*
2009	5.14 (4.84, 5.60)	5.19 (4.85, 5.64)	5.13 (4.83, 5.52)	<.001
2010	5.21 (4.88, 5.63)	5.24 (4.88, 5.69)	5.18 (4.86, 5.57)	<.001
2011	5.24 (4.90, 5.68)	5.26 (4.90, 5.74)	5.18 (4.87, 5.61)	<.001
2012	5.18 (4.83, 5.67)	5.20 (4.85, 5.69)	5.14 (4.81, 5.55)	<.001
2013	5.25 (4.95, 5.73)	5.32 (4.96, 5.80)	5.24 (4.92, 5.65)	<.001
2014	5.25 (4.91, 5.73)	5.29 (4.92, 5.80)	5.23 (4.90, 5.65)	<.001
2015	5.26 (4.89, 5.73)	5.29 (4.93, 5.78)	5.22 (4.89, 5.64)	<.001
2016	5.15 (4.77, 5.62)	5.16 (4.80, 5.66)	5.10 (4.78, 5.52)	<.001
2017	5.11 (4.78, 5.60)	5.15 (4.81, 5.65)	5.08 (4.76, 5.49)	<.001

* Compared FBG levels between males and females.

(Supplement Fig. 1, http://links.lww.com/MD/F202). The percentage of high glucose levels was significantly higher in aged population when compared to those in younger individuals, and also the percentage of males was higher than females (Fig. 2).

4. Discussion

The present study included 878,019 individuals aged 18 to 96 undergoing health examination in the West China Hospital, Sichuan University during 2009 to 2017. This large sample data showed high blood glucose distribution and high percentage of glucose levels in both males and females in the local population. All samples were measured in the West China Hospital, Sichuan University to support the accuracy and stability of the results.

This study showed that the levels of blood glucose were increased year by year in both males as well as females, and similarly the percentage of high glucose levels was also increased from 2009 to 2015. However, the above changes showed a downward trend from 2015 to 2017. This study also revealed that the levels of blood glucose in males were higher than those in females. This finding was similar to that of the previous study, in which a high incidence of diabetes mellitus was observed in males than in females.[10] The possible reason for this might be due to the habits of alcohol consumption, smoking in males,[11] the differences between women and men in the prevalence of overweight and obesity and, potentially more importantly, the sex dimorphism in body composition and fat distribution may be involved.[12] In addition, it is noteworthy that the percentage of high glucose and blood glucose levels in aged population was higher than that in younger population. There are several reasons for these findings. First, the oxidative phosphorylation dysfunction of islet cells demonstrated a down-regulation in the amount as well as secretory functions, resulting in elevated glucose levels with age.[13] This was similar to that described in the previous studies.[14,15] Second, the blood glucose levels reached a peak at the age of 71 to 80 due to hormone levels and other factors.[16] After 80 years of age, the glucose metabolism is reduced, and so the levels of blood glucose were decreased.[17]

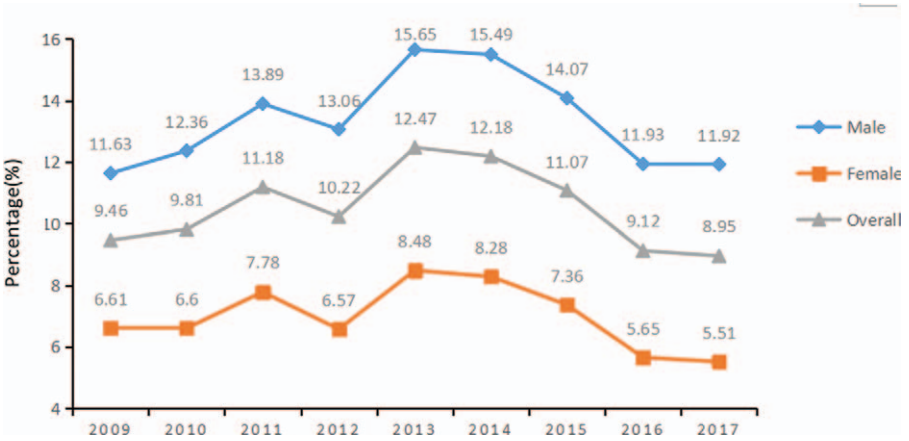

Figure 1. Trends of the percentage of people with blood glucose levels of more than 5.9 mmol/L in both genders. The percentage of high blood glucose levels was increased since 2009, and reached peak in 2013 in both males as well as females. Also the percentage in males was significantly higher when compared with that in females every year.

Table 3

The FBG levels in different ages of health examination population.

Age	Number	Minimum (mmol/L)	P25 (mmol/L)	Median (mmol/L)	P75 (mmol/L)	Maximum (mmol/L)
≤30	140,317	3.10	4.58	4.83	5.10	9.68
31–40	224,249	3.09	4.67	4.94*	5.24	9.93
41–50	246,845	3.08	4.47	5.04*	5.40	9.98
51–60	150,056	3.17	4.86	5.20*	5.65	9.98
61–70	66,907	3.33	5.00	5.37*	5.91	10.00
71–80	37,567	3.38	5.22	5.52*	6.15	9.99
>80	12,078	3.45	5.08	5.49*	6.13	9.83

P25 = 25th percentiles, P75 = 75th percentiles.
* Compared with the levels of FBG in age ≤30 yr, and showed significant difference.

Table 4

The characteristics of glucose among the health examination population in different ages (2009–2017).

		Male				Female			
	Age	N	P25 (mmol/L)	Median (mmol/L)	P75 (mmol/L)	N	P25 (mmol/L)	Median (mmol/L)	P75 (mmol/L)
2009	≤30	3505	4.61	4.86	5.14	3586	4.53	4.78	5.03
	31–40	6076	4.67	4.95	5.27	4623	4.62	4.86	5.11
	41–50	6641	4.74	5.06	5.45	4861	4.67	4.93	5.22
	51–60	4134	4.85	5.19	5.66	2765	4.83	5.13	5.48
	61–70	1965	4.97	5.34	5.92	1414	5.01	5.36	5.81
	71–80	1323	5.04	5.44	6.02	836	5.10	5.44	6.02
	>80	272	5.07	5.48	6.02	134	5.06	5.38	5.98
2010	≤30	4885	4.64	4.91	5.19	5261	4.56	4.80	5.04
	31–40	8325	4.72	5.00	5.32	6778	4.65	4.90	5.17
	41–50	9606	4.78	5.12	5.50	7357	4.71	4.98	5.27
	51–60	5322	4.87	5.24	5.71	3643	4.87	5.17	5.53
	61–70	2505	5.04	5.42	5.98	1854	5.02	5.37	5.84
	71–80	1719	5.06	5.49	6.06	877	5.13	5.49	6.01
	>80	381	5.07	5.48	6.05	140	5.09	5.52	6.14
2011	≤30	4729	4.66	4.93	5.21	5066	4.60	4.84	5.10
	31–40	8593	4.73	5.03	5.36	7083	4.67	4.93	5.21
	41–50	11,100	4.80	5.14	5.56	8158	4.71	4.98	5.29
	51–60	5858	4.91	5.27	5.76	4129	4.88	5.20	5.59
	61–70	2697	5.01	5.39	5.98	2128	5.04	5.37	5.87
	71–80	1915	5.12	5.56	6.16	1345	5.15	5.51	6.06
	>80	519	5.09	5.52	6.12	244	5.07	5.44	6.13
2012	≤30	5764	4.61	4.89	5.17	6739	4.54	4.79	5.05
	31–40	10,257	4.70	4.99	5.31	8280	4.63	4.89	5.16
	41–50	12,995	4.77	5.11	5.51	9685	4.67	4.95	5.25
	51–60	6824	4.86	5.23	5.75	4419	4.84	5.14	5.52
	61–70	3187	4.96	5.36	5.97	2139	4.96	5.32	5.78
	71–80	2281	5.05	5.44	6.10	1288	5.04	5.47	6.02
	>80	835	4.99	5.38	6.01	299	5.00	5.45	6.07
2013	≤30	6358	4.70	4.96	5.24	7360	4.63	4.87	5.12
	31–40	11,862	4.78	5.07	5.38	9990	4.71	4.96	5.24
	41–50	14,766	4.86	5.18	5.59	11396	4.77	5.05	5.35
	51–60	9197	4.97	5.35	5.86	6259	4.92	5.23	5.61
	61–70	4203	5.11	5.49	6.07	3009	5.10	5.45	5.92
	71–80	2985	5.20	5.62	6.29	1912	5.19	5.60	6.16
	>80	1093	5.13	5.59	6.19	429	5.14	5.50	6.18
2014	≤30	4770	4.67	4.93	5.23	5897	4.61	4.86	5.13
	31–40	9169	4.75	5.04	5.38	8639	4.71	4.96	5.23
	41–50	10,343	4.83	5.17	5.58	7988	4.75	5.03	5.34
	51–60	6946	4.90	5.29	5.82	4996	4.87	5.19	5.58
	61–70	3369	5.02	5.43	6.04	2572	5.04	5.41	5.87
	71–80	2109	5.16	5.61	6.32	1329	5.18	5.55	6.13
	>80	899	5.13	5.58	6.22	385	5.15	5.60	6.27
2015	≤30	11,210	4.63	4.90	5.18	13697	4.57	4.81	5.06
	31–40	20,738	4.72	5.01	5.32	17228	4.67	4.93	5.20
	41–50	23,908	4.80	5.13	5.53	18302	4.75	5.02	5.33
	51–60	15,970	4.92	5.30	5.81	10387	4.88	5.18	5.56
	61–70	6179	5.04	5.45	6.04	4631	5.06	5.41	5.89
	71–80	3634	5.19	5.64	6.35	2239	5.16	5.58	6.20
	>80	1385	5.18	5.58	6.22	636	5.16	5.60	6.27
2016	≤30	11,612	4.54	4.79	5.05	13818	4.48	4.72	4.96
	31–40	22,107	4.63	4.90	5.20	18978	4.58	4.82	5.08
	41–50	24,930	4.71	5.03	5.42	19624	4.64	4.90	5.20
	51–60	17,384	4.81	5.18	5.70	11514	4.76	5.05	5.42
	61–70	7221	4.93	5.30	5.90	4951	4.92	5.27	5.73
	71–80	3647	5.02	5.48	6.22	2251	5.05	5.44	6.06
	>80	1495	4.98	5.42	6.10	653	5.00	5.48	6.16
2017	≤30	11,796	4.52	4.77	5.03	14264	4.46	4.69	4.93
	31–40	23,475	4.63	4.90	5.20	22048	4.56	4.80	5.06
	41–50	24,933	4.72	5.03	5.43	20252	4.63	4.89	5.19
	51–60	17,593	4.82	5.19	5.71	12716	4.75	5.03	5.40
	61–70	7360	4.92	5.30	5.88	5523	4.91	5.24	5.70
	71–80	3537	5.03	5.46	6.20	2340	5.04	5.42	6.03
	>80	1518	5.02	5.43	6.09	761	4.99	5.47	6.11

P25 = 25th percentiles, P75 = 75th percentiles.

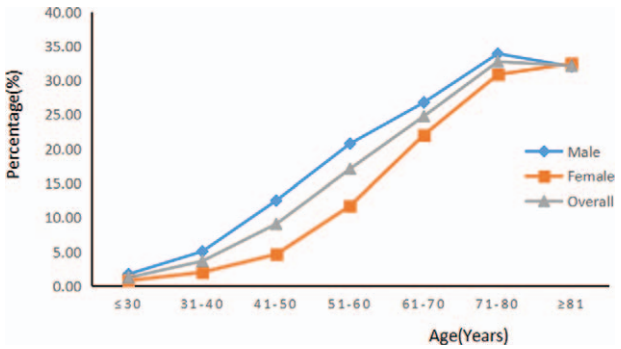

Figure 2. Trends of the percentage of people with blood glucose levels of more than 5.9mmol/L in different age groups. The percentage of high glucose levels in aged population is significantly higher than that in younger people. Also the percentage of males was higher than females, respectively ($P < .001$).

With rapid economic growth and associated industrialization, urbanization, and lifestyle changes (i.e., increased intake of high-calorie, high fat, high-sugar diets and decreased physical activity), prediabetes and diabetes have reached epidemic proportions in Chinese population. In our study, the percentage of population with high levels of blood glucose was increased in both males and females year by year up to 2015. A national study regarding the prevalence of diabetes in the Chinese adult population suggested that there might be 113.9 million with diabetes and 493.4 million with prediabetes.[2] Also the prevalence of diabetes in young patients has been significantly increasing in the recent years.[18] It is not just the people with diabetes who develop hyperglycemia, but there are certain other illnesses such as hypokalemia caused due to growth hormone tumor and aldosterone tumor, presence of some excess hormones (such as growth hormone, glucagon, cortisol, and catecholamines) in the body, in sepsis and certain infections, intracranial diseases (such as encephalitis, brain tumors, cerebral hemorrhage, and meningitis) and bulimia that might cause hyperglycemia.[19] Therefore, regular physical examination is an important method for early detection of abnormal blood glucose levels, which assists in taking active medical measures for correcting the blood glucose levels.

As the data was obtained through laboratory information system system, this study adopted screening intervention research method in the epidemiological survey to analyze the variations in the trends of blood glucose concentrations in different genders, different age groups and different years. One of the most important reasons for using big data is due to its accuracy of clinical trial results. To ensure the quality of the data that we collected, sample processing was conducted in accordance with the standard operating procedures of the laboratory. To ensure the reliability of the measurement results, the internal quality control data was verified during the study process.

However, there are some limitations to our study. The information regarding diet and exercise of health examination population were missed. The relationship between blood glucose levels and the above related factors was not explored. Our study was a single-center study. Despite these limitations, the screening intervention study included a large sample size. These results reflect the characteristics of blood glucose distribution and are noteworthy for the public to pay more attention for glucose control.

In summary, the glucose levels in males were higher than those in females. The rate of hyperglycemia increased with age but it declined in people over the age of 80. The levels of blood glucose were increased from 2009 to 2015, while it decreased from 2016 to 2017. It is necessary to take steps to control glucose levels in adults, especially in males and the aged population who are younger than 80 years old. The public should pay more attention on early education and intervention to prevent the development of hyperglycemia.

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