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The prevalences of impaired fasting glucose and diabetes mellitus in working age men of North China: Anshan Worker Health Survey

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To investigate the prevalence of impaired fasting glucose (IFG) and total diabetes mellitus (DM) including known diabetes and newly diagnosed diabetes in working age men of North China. A cross-section study was conducted at health medical center of Ansteel Group Hospital in Anshan city of China. 37,345 males between 20–60 years of age were recruited in this study. Age-standardized prevalence of IFG and total DM in these working age men were 25.3% and 8.4%, respectively. The prevalence of IFG and total DM increased, as the age progressed. After multinomial logit analysis, age, systolic blood pressure, drinking, smoking, overweight and obesity, total cholesterol, triglycerides, serum creatinine and blood urea nitrogen were independent risk factors for both IFG and DM. The prevalence rate of IFG in Anshan male workers was higher compared with mainland China overall. Diabetes-related education and popularization of DM prevention programs should be actively carried out with age increasing.

With the rapid increasing obesity and lifestyle changing, the number of people diagnosed with diabetes is increasing worldwide¹. Previous study has reported that there would be more than 366 million individuals with diabetes among adults 20 or more years of age in 2030². It has become into one of the fastest growing public health problems in our world. This problem could be more seriously in developing countries³.

As a larger number of population developing country in world, the prevalence of Type 2 diabetes is increasing in China day by day^{4,5}. Several large national cross-sectional surveys have been conducted to estimate the prevalence for diabetes in mainland China^{6,7}. It has been estimated that the number of individuals with diabetes had roughly tripled from 20.8 million in 2000 to 92.4 million in 2007^{6,8}.

As one of components of prediabetes, Impaired Fasting Glucose (IFG) has been paid more attention by researchers. The prevalence of IFG was 10.6% among urban men in 2002⁷ and 15.5% among urban men in 2007⁶. There were more than 430 million workers in China, approximately 80% of them were males (<http://www.stats.gov.cn/tjsj/ndsj/2006/indexeh.htm>). So the investigation for their health is very important. To our knowledge, there were few english literatures to report the prevalence of IFG in working age population. In order to determine the prevalence of IFG and total DM including known diabetes and newly diagnosed diabetes in working age men, we conducted this health survey in industrial city (Anshan).

Results

Total of 37,345 over 20 years (20–60 years old, average age 44.69 ± 8.27 years) male workers were collected from January to December 2011. Among 37,345 male workers, 47.8% of them were aging from 40–49 years. The sample sizes by age groups were shown in Table 1. The descriptive characteristics of the study samples were presented in

Table 1 | Sample size for fasting glucose by age in this survey

Age in Anshan Worker Health Survey in 2011 (years)	N (%)
20–29	1926(5.2)
30–39	7231(19.4)
40–49	17857(47.8)
50–60	10331(27.6)

Table 2. The prevalence rates of the clinical characteristics in different age groups were shown in Table 3. Age-standardized prevalence of IFG and total DM in these working age men were 25.3% and 8.4%, respectively. In total DM, there were 69.1% newly diagnosed and 30.9% known DM, respectively. Figure 1 showed us that the prevalence of IFG and total DM increased, as the age progressed. In addition, we also found that the fasting glucose levels of total subjects and normal group increased with the age progressed. In addition, there is no statistically significant for the interaction between age and BMI status in our study ($p > 0.05$). Multinomial logit models revealed independent risk factors for total DM and IFG (Table 4).

Discussion

To our knowledge, this was the first research to investigate the prevalence rates of IFG and total DM within male workers in one Chinese industrial city. In order to ensure the quality of study, we used fasting venous plasma glucose test instead of fasting capillary plasma to determine glucose concentrations.

Our results found that the age-adjusted prevalence of IFG and total DM was 25.3% and 8.4%, respectively. Another study revealed that the overall prevalence of DM was 11.6% in the Chinese adult population and the prevalence among men was 12.1%. The prevalence of newly diagnosed DM was 8.5% in Chinese males⁹. The difference in the prevalence of DM between this study and our investigation might be attributed to different diagnostic criteria. Our research used WHO criteria, whereas Xu et al. used 2010 ADA criteria⁹, which included a glycosylated hemoglobin (HbA_{1c}) concentration of 6.5% or higher and 2-hour plasma glucose tests for the diagnosis of DM and might have partly contributed to the increased prevalence of DM. Previous larger simple sizes population-based studies in the past decade has reported the prevalence of IFG and DM was 3.2%–8.23% and 2.7%–9.7%, respectively^{6,7,10,11}. During past ten years, there were two national surveys in China^{6,7}. Among Anshan urban workers aged 20–60 years, the prevalence rate of IFG was significantly higher than the prevalence of IFG reported previously from national representative data⁶ both in different age groups and total subjects (Figure 2). The prevalence of IFG (25.3%) in our investigation was also higher than that (7.1%) in China National Nutrition and Health Survey in 2002⁷. The prevalence of IFG increased with age processed, and it was consistent with the results by previous surveys^{6,7}. Hence, we need to educate the people about precautions to be taken with age increasing and urgent attention to develop a public awareness programme is needed.

In 20–39 years age group, the prevalence of total DM in Anshan study was higher than that in China national study⁶. However, the results were just the opposite in 40–60 years age group (Figure 3). It could be due to the higher mean BMI (23.5 kg/m²) within Anshan study in young aged (20–39 years) than that (23.0 kg/m²) in the whole mainland survey⁶. However, the mean BMI (24.0 kg/m²) within Anshan study in middle aged (40–60 years) was lower than that (24.3 kg/m²) in the survey of mainland China⁶. In all subjects, the prevalence of total DM (8.4%) was lower than that (10.6%) within national survey in 2007, but higher than that (3.9%) in Health Survey in 2002.

Results from previous investigations indicated that the prevalence rates of overweight and obesity increased in all age groups and with glucose increasing¹². But it was inconsistent with our investigation.

Table 2 | Clinical characteristics of the survey participants in 2011

	Mean (SD)	n (%)
Age, years	44.69 (8.27)	37,345 (100)
Height, cm	172.50 (4.89)	37,345 (100)
Weight, kg	73.66 (10.46)	37,345 (100)
Systolic BP, mmHg	134.52 (18.98)	37,345 (100)
Diastolic BP, mmHg	85.17 (13.49)	37,345 (100)
BMI, kg/m ²	24.72 (3.10)	37,345 (100)
Total cholesterol, mmol/l	4.92 (0.94)	37,345 (100)
LDL-C, mmol/l	2.76 (0.72)	37,345 (100)
HDL-C, mmol/l	1.33 (0.31)	37,345 (100)
Triglycerides, mmol/l	1.96 (1.84)	37,345 (100)
Fasting glucose, mmol/l	5.62 (1.49)	37,345 (100)
WBC, $\times 10^9/l$	6.42 (1.74)	37,345 (100)
GPT, u/l	28.76 (23.16)	37,345 (100)
GOT, u/l	24.66 (14.14)	37,345 (100)
Scr, $\mu\text{mol/l}$	70.47 (15.88)	37,345 (100)
BUN, $\mu\text{mol/l}$	5.42 (1.36)	37,345 (100)
Smoking	N/A	27,953 (74.9)
Drinking	N/A	28,476 (76.3)

Abbreviation: total cholesterol, TC; high-density lipoprotein cholesterol, HDL-C; low-density lipoprotein cholesterol, LDL-C; triglycerides, TG; serum creatinine, Scr; blood urea nitrogen, BUN; Glutamic-Pyruvic transaminase, GPT; Glutamic-Oxalacetic transaminase, GOT; body mass index, BMI; white blood cell, WBC; blood pressure, BP; standard deviation, SD; Not Applicable, N/A.

Because the characteristics of the current study population is different from other studies, there is no significant trends in prevalence of overweight plus obesity and hyperglycemia in Anshan study.

According to different characteristics due to ethnicity, European type 2 DM patients develop the disease at a higher BMI compared with those of East Asian ancestry¹³. The WHO BMI criteria might not be appropriate for the Chinese population, and therefore, we applied Asia-Pacific BMI criteria for overweight and obesity except for WHO BMI criteria. Our results revealed that overweight and obesity were risk factors for IFG and DM according to both the Asia-Pacific and WHO BMI criteria for overweight and obesity. Epidemiological studies have indicated that overweight plus obesity, hypertension, drinking, smoking and hypercholesterolaemia were risk factors for DM even for IFG^{14–17}. It was consistent with our investigation. In addition, our survey also revealed that lower Scr levels was risk factor for both IFG and DM. It may be due to skeletal muscle mass. Serum creatinine is a possible surrogate marker of skeletal muscle mass. Skeletal muscle is one of the major target tissues for insulin, skeletal muscle mass might be associated with hyperglycemia¹⁸. Surprisingly, our study revealed that higher blood urea nitrogen (BUN) levels was another risk factor for IFG and DM. We reviewed the literatures in Pubmed database, but had not found related reports till now. BUN was considered as a risk factor for diabetes complications such as retinopathy¹⁹ and cataract²⁰.

We found that there was no significant associations of the liver enzymes (Glutamic-Pyruvic transaminase, GPT and Glutamic-Oxalacetic transaminase, GOT levels) with hyperglycemia. However, the study by Schneider et al. suggested that individuals with elevated liver enzymes are at high risk for DM²¹. This controversy needs further research to explain.

Despite the conclusive results that were obtained from this study, there were some shortcomings that should be noted. First, as the reason for limited time of the workers, we did not get a 2 h glucose tolerance test; We could not reveal the true prevalence of DM and impaired glucose tolerance (IGT); Second, because most of workers were men, this study did not investigate female subjects. Third, information on other demographic characteristics such as education level and ethnicity were also collected. Because more than 90% workers were Han ethnicity and 85% of them were primary education levels, we did not analyse these data in this investigation. Fourth, we did not investigate the type of diabetes in this survey.

Table 3 | Prevalence of the clinical characteristics in different age groups (%)

	20–29 years	30–39 years	40–49 years	50–60 years	≥20 years
Based on fasting plasma glucose					
Normal < 5.5 mmol/l	69.3	67.3	66.2	64.6	66.3
Impaired fasting plasma glucose 5.5–6.9 mmol/l	22.9	24.4	25.1	26.3	25.3
Hyperglycaemia ≥ 7 mmol/l	7.8	8.3	8.7	9.1	8.4
BMI < 25 kg/m ²	55.8	55.2	55.8	56.1	55.8
BMI ≥ 25 kg/m ²	44.2	44.8	44.2	43.9	44.2
Systolic BP < 120 mmHg	21.9	21.7	21.3	21.6	21.5
Systolic BP 120–139 mmHg	47.8	46.8	44.6	42.3	44.5
Systolic BP ≥ 140 mmHg	30.3	31.5	34.1	36.1	34
Diastolic BP < 80 mmHg	38.7	36	34.9	34.9	35.3
Diastolic BP 80–89 mmHg	30.8	32.8	32.2	30.8	31.9
Diastolic BP ≥ 90 mmHg	30.5	31.1	32.9	34.3	32.8
TC < 6.2 mmol/l	91.8	92.1	91.3	91.3	91.9
TC ≥ 6.2 mmol/l	8.2	7.9	8.7	8.7	8.1
TG < 2.24 mmol/l	75.7	74.8	74.9	74.6	74.9
TG ≥ 2.24 mmol/l	24.3	25.2	25.1	25.4	25.1
LDL-C < 4.1 mmol/l	96.6	96.5	96.2	96.2	96.3
LDL-C ≥ 4.1 mmol/l	3.4	3.5	3.8	3.8	3.7
HDL-C < 1 mmol/l	10.7	10.9	9.4	9.5	9.7
HDL-C ≥ 1 mmol/l	89.3	89.1	90.6	90.5	90.3
GPT < 40 u/l	82.2	83.3	83.5	84.7	83.2
GPT ≥ 40 u/l	17.5	16.7	16.5	15.3	16.8
GOT < 40 u/l	94	94.9	94.6	94.7	94.5
GOT ≥ 40 u/l	6	5.1	5.4	5.3	5.5
WBC < 4*10 ⁹ /l	4.2	4.5	4.6	4.5	4.4
WBC 4–10*10 ⁹ /l	93.5	92.4	92.1	92.3	92.5
WBC > 10*10 ⁹ /l	2.3	3.1	3.3	3.2	3.1
Scr < 44 μmol/l	0.5	0.3	0.4	0.4	0.4
Scr 44–133 μmol/l	99.3	99.6	99.4	99.5	99.4
Scr > 133 μmol/l	0.2	0.1	0.2	0.1	0.2
BUN < 3.2 μmol/l	2.2	1.8	1.8	2.3	1.9
BUN 3.2–6 μmol/l	73.6	70.4	68.7	70.2	69.7
BUN > 6 μmol/l	24.2	27.9	29.5	27.5	28.4
Smoking	68.7	75.2	74.8	76.1	74.9
Drinking	75.1	77.2	76.1	76.9	76.3

Abbreviation: total cholesterol, TC; high-density lipoprotein cholesterol, HDL-C; low-density lipoprotein cholesterol, LDL-C; triglycerides, TG; serum creatinine, Scr; blood urea nitrogen, BUN; Glutamic-Pyruvic transaminase, GPT; Glutamic-Oxalacetic transaminase, GOT; body mass index, BMI; white blood cell, WBC; blood pressure, BP.

Figure 1 | Mean fasting venous plasma glucose concentrations and their standard deviation by age and subject groups in Anshan Worker Health Survey in 2011.

In conclusion, the prevalence rate of IFG in Anshan male workers was higher compared within mainland Chinese males⁶. The prevalence of DM was higher in young aged adults but lower in middle aged male workers compared with China national survey⁶. We believe this survey is helpful for better understanding of the prevalence and risk factors for IFG and DM in Chinese working age men, and for early detection and prevention.

Methods

Subjects. Anshan is one of the most important industrial cities in North China. At the end of 2010, the population of Anshan city was 3.46 million, of which 1.76 million were men (<http://wenwen.soso.com/z/q21324032.htm>). A total of 42,680 people were selected and invited to participate in the study; 37,345 working age men which belong to 52 organizations of 12 factories completed the study. The overall response rate was 87.5%. The survey was conducted in Health Medical Center of Ansteel Group Hospital. All health medical workers were intensively trained according to the program of this investigation. According to the fasting glucose levels and self-reports, all the subjects were divided into three groups including normal group, IFG group and total DM group.

Data collection. Information on age and health status were obtained using a standardized questionnaire. All participants were asked whether they had previously been diagnosed with diabetes. Blood pressure (BP) was measured in the sitting position (first) and supine position (second) at a 5-min interval using an upright standard sphygmomanometer. Height was measured by using a stadiometer. Weight was measured by using a beam balance scale. Body mass index (BMI) was calculated by dividing weight in kilograms by the square of height in meters.

Table 4 | Multinomial logit models: Odds Ratios for total DM and IFG

	IFG			Diabetes		
	OR	95%CI	P	OR	95%CI	P
Age, per 10 years increment	2.37	2.01–2.89	<0.01	2.68	2.60–2.77	<0.01
Systolic BP, per increase of 10 mmHg	1.34	1.01–1.98	<0.01	1.39	1.11–1.89	0.01
Diastolic BP, per increase of 10 mmHg	1.09	0.67–2.11	0.11	1.12	0.99–1.51	0.06
Overweight and obesity	1.78	1.41–2.24	<0.01	1.83	1.31–2.44	0.03
Overweight and obesity*	1.91	1.52–2.43	<0.01	1.93	1.61–2.51	<0.01
TC, per increase of 0.56 mmol/l	1.42	1.01–1.78	<0.01	1.47	1.21–1.65	<0.01
LDL-C, per increase of 0.56 mmol/l	1.23	0.87–1.51	0.98	1.27	0.98–1.41	0.65
HDL-C, per increase of 0.56 mmol/l	0.62	0.31–1.02	0.13	0.76	0.44–1.12	0.07
TG, per increase of 0.56 mmol/l	1.04	1.01–1.44	<0.01	1.05	0.98–1.24	0.02
GPT, per increase of 10 u/l	0.99	0.86–1.12	0.06	1.03	0.79–1.33	0.06
GOT, per increase of 10 u/l	1.02	0.88–1.45	0.14	1.04	0.98–1.15	0.06
Scr, per decrease of 0.56 mmol/l	1.33	1.05–1.77	<0.01	1.45	1.15–1.69	0.03
BUN, per increase of 0.56 mmol/l	1.41	1.12–1.79	<0.01	1.77	1.01–2.31	<0.01
Height, per increase of 10 cm	0.89	0.76–1.01	0.08	0.86	0.65–1.05	0.11
Weight, per increase of 10 kg	1.01	0.86–1.21	0.06	1.12	0.78–1.41	0.12
WBC, per increase of $1 \times 10^9/l$	0.87	0.65–1.11	0.10	0.76	0.54–1.04	0.15
Smoking	1.12	0.99–1.31	0.06	1.23	1.01–1.42	0.03
Drinking	1.33	1.04–1.63	0.02	1.35	1.11–1.59	0.01

Abbreviation: total cholesterol, TC; high-density lipoprotein cholesterol, HDL-C; low-density lipoprotein cholesterol, LDL-C; triglycerides, TG; serum creatinine, Scr; blood urea nitrogen, BUN; Glutamic-Pyruvic transaminase, GPT; Glutamic-Oxalacetic transaminase, GOT; blood pressure, BP; odds ratios, OR; impaired fasting glucose, IFG; confidence intervals, CI; diabetes mellitus, DM; white blood cell, WBC. Overweight and obesity* were defined as BMI ≥ 23 kg/m² and BMI ≥ 25 kg/m², respectively.

The study was performed in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of China Medical University. All patients provided written informed consent prior to participating in the study.

Laboratory methods. Blood was drawn from the antecubital vein for determinations of total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglycerides (TG), fasting plasma glucose levels, serum creatinine (Scr), BUN, GPT and GOT concentrations in the morning after 8 hours fast. All chemistries were measured at a commercially available laboratory.

Definition of impaired fasting glucose, diabetes mellitus, hypertension and obesity. Diabetes diagnosed according to 1999 WHO criteria²². Newly diagnosed DM was defined as a fasting plasma glucose level ≥ 7 mmol/l; Known DM was defined as patients who were diabetics and pursuing diet, exercise and oral hypoglycemic agents and insulin also. IFG was defined as a fasting plasma glucose level from 5.6 to 6.9 mmol/l²³. Hypertension was defined as a systolic blood pressure (SBP) $\geq$

140 mmHg or a diastolic blood pressure (DBP) ≥ 90 mmHg²⁴. Overweight and obesity²⁵ were defined as BMI ≥ 25 kg/m² and BMI ≥ 30 kg/m², respectively. In addition, according to Committee of the WHO Western Pacific Region suggestion, the Asia-Pacific BMI criteria²⁶ (Overweight and obesity were defined as BMI ≥ 23 kg/m² and BMI ≥ 25 kg/m², respectively.) were applied. Drinking was defined as alcohol intake more than once per month during the past 12 months. Smoking was defined as having smoked 100 cigarettes in one's lifetime and currently smoking cigarettes⁹.

Statistical analysis. The age-standardized prevalence of IFG and total DM was calculated. Mean $\pm$ standard deviation (SD) was used for measurement data. A multinomial logit analysis was applied to estimate the odds ratios (OR) for DM and IFG. Data management and statistical analyses were performed using SPSS statistical software, version 17.0 J (SPSS, Tokyo, Japan) and SUDAAN software, version 10 (Research Triangle Institute). $P < 0.05$ was considered statistically significant. In multinomial logit analysis, P-values were two-tailed.

Figure 2 | Differences in the prevalence of IFG among urban worker men aged 20–60 years between the 2011 Anshan Worker Health Survey and the 2007 China National Survey⁶.

Figure 3 | Differences in the prevalence of DM among urban worker men aged 20–60 years between the 2011 Anshan Worker Health Survey and the 2007 China National Survey⁶.

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Author contributions

L.L., C.Z. and D.S.H. have contributed to the design of the study, analysis and interpretation of data and drafting a part of manuscript. J.Y.W., H.D. and K.Z. also took part in analyzing data, and drafting a part of manuscript. A.W.H.S.G. investigated and collected data. L.L., C.Z. and D.S.H. carried out statistical analysis. L.L. and C.Z. prepared all figures and tables. All authors reviewed the manuscript.

Additional information

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Consortia

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