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# BMJ Open

## Diabetes in the suburbs of Beijing: epidemiology and risk factors: a retrospective cohort study

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4 **1. Diabetes in the suburbs of Beijing: epidemiology and risk**  
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7 **2 factors: a retrospective cohort study**  
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4 25 **Abstract**

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6 26 **Objective** We aimed to detect the incidence and risk factors of type 2 diabetes  
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8 27 mellitus (T2DM) development in the suburbs of Beijing.

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10 28 **Design** Cohort study with record linkage to incidence data.

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12 29 **Setting** We performed a 5-year follow-up study in a randomly selected suburban  
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14 30 population including 1,114 subjects aged  $\geq 18$  years living in the suburbs of Beijing.

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16 31 **Participants** 118 subjects with T2DM in baseline according to the 1999 WHO  
17  
18 32 criteria were excluded, and 895 subjects attended the follow-up assessment in 2012.  
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20 33 The non-diabetic subjects at baseline were classified into two groups: normal glucose  
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22 34 tolerance (NGT) group (n=673) and impaired glucose regulation (IGR) group (n=222),  
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24 35 the incidence and risk factors of diabetes development in each group were  
25  
26 36 investigated.

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28 37 **Outcome measures** a structured questionnaire of sociodemographic characteristics,  
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30 38 height, weight, waist circumference, hip circumference and blood pressure, oral  
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32 39 glucose tolerance test, serum lipid levels.

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34 40 **Results** Out of the 895 non-diabetic subjects, 67 developed diabetes with 29 in NGT  
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36 41 group and 38 in IGR group respectively after 5-year follow-up, giving a overall 5-year  
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38 42 cumulative incidence of diabetes of 13%. The incidence of diabetes was 15.5 cases  
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40 43 per 1000 person-years, while 8.9 cases per 1000 person-years in NGT group and 35.7  
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42 44 cases per 1000 person-years in IGR group ( $P < 0.01$ ,  $RR = 4.03$ ,  $95\%CI: 2.58-9.29$ ).

43  
44 45 Binary logistic regression analysis showed that the risk factors of diabetes  
45  
46 46 development included FPG in NGT group, while gender, WHR, FPG and DBP in IGR  
47  
48 47 group.

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50 48 **Conclusions:** During a mean follow-up of 5.0 years, the incidence of T2DM in the  
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52 49 suburbs of Beijing was 15.5 per 1000 person-years. Early prevention of diabetes  
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54 50 should focus on IGR subjects. Elevated FPG predicted diabetes development for both  
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56 51 NGT and IGR subjects. Female, overweight/obesity and DBP were risk factors for  
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58 52 diabetes development in IGR subjects.  
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### **Strengths and limitations of this study**

- Provide new data on the incidence of T2DM in the Beijing area.
- The increase in the FPG level is a strong predictor of diabetes development.
- A cohort selected by multiple stage sampling at baseline.
- A relatively long follow-up period.
- The limitation is that many variables assessed as risk factors were not updated regularly and the data were collected only at the baseline investigation and at the end of the study.

66

## 67 **Introduction**

68 Diabetes mellitus is a clinical syndrome characterized by disordered  
69 glycometabolism. The lack and/or insufficiency of insulin induces metabolic disorders  
70 related to saccharides, lipids, proteins, water and electrolytes, resulting in  
71 hyperglycemia as the main clinical feature. Long-term hyperglycemia leads to  
72 macrovascular and microvascular complications, which may result in disability and  
73 death.<sup>1,2</sup> Diabetes is increasingly prevalent, affecting 451 million (8.4%) adults  
74 worldwide, and these figures are expected to increase to 693 million (9.9%) by 2045.<sup>3</sup>  
75 Type 2 diabetes mellitus (T2DM) accounts for over 90% of diabetes cases. Diabetes,  
76 as a leading cause of death,<sup>1,3,4</sup> is becoming a public issue and placing a heavy burden  
77 on the health care system.<sup>5</sup> In 2017, approximately 5 million deaths of adults  
78 worldwide were attributed to diabetes, and the global healthcare expenditure  
79 associated with people with diabetes was estimated to be \$850 billion.<sup>3</sup>  
80 As T2DM is usually asymptomatic, it can remain undiagnosed for many years.  
81 Almost half of all people (49.7%) living with diabetes were undiagnosed in 2017.<sup>3</sup>  
82 Accordingly, screening for prediabetes/T2DM and preventing the evolution of  
83 diabetes in individuals with risk factors are essential. Currently, it is believed that the  
84 risk factors related to the development of T2DM may include age, body mass index  
85 (BMI), body fat distribution, family history of diabetes, history of cardiovascular  
86 disease (CVD), history of gestational diabetes mellitus (GDM), race/ethnicity, diet,  
87 physical inactivity, hypertension, dyslipidemia and prediabetes.<sup>4,6-14</sup> Some studies  
88 demonstrated that birth weight,<sup>15,16</sup> income,<sup>17</sup> socioeconomic status,<sup>18,19</sup> working  
89 hours,<sup>19,20</sup> occupation<sup>21</sup> and genetic factors<sup>22-24</sup> might also contribute to the  
90 development of T2DM.  
91 Along with the process of urbanization, the aging of the population, changes in  
92 lifestyle, and the increasing prevalence of obesity and overweight, the prevalence of  
93 diabetes in China has increased over the past three decades. The prevalence of

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4 94 diabetes in China was 0.67% in 1980,<sup>25</sup> 2.12% in 1995,<sup>26</sup> 5.5% in 2001,<sup>27</sup> 9.7% in  
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6 95 2008,<sup>28</sup> 9.7% in 2010<sup>29</sup> and 10.4% in 2013.<sup>30</sup> As the capital, there is limited  
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8 96 information regarding the incidence of diabetes and prediabetes in Beijing. Certain  
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10 97 studies have suggested that there might be different diabetic risk patterns in Asian  
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12 98 populations.<sup>31-34</sup>

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14 99 The objective of this study is to determine the incidence of and risk factors for T2DM  
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16 100 in the suburbs of Beijing.

## 17 101 **Materials and Methods**

### 18 102 **Study population**

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22 103 The study population was residents living in the suburbs (Huairou, Pinggu and  
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24 104 Hepingli) of Beijing. Individuals aged 18 years or older who were willing to  
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26 105 participate and provided informed consent were eligible to participate in the study.  
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28 106 Pregnant women were excluded from the study.

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30 107 We performed a 5-year perspective cohort study. Patients or the public were not  
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32 108 involved in the design, or conduct, or reporting, or dissemination plans of our  
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34 109 research. The baseline survey occurred from June 2007 to September 2008 by a  
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36 110 random sampling method with a follow-up examination from May to July 2012. All  
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38 111 subjects were asked to undergo a personal interview, physical examination and blood  
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40 112 test. Subjects with T2DM at baseline were excluded, and the nondiabetic subjects at  
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42 113 baseline were divided into the normal glucose tolerance (NGT) group and the  
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44 114 impaired glucose regulation (IGR) group. We analyzed the incidence and risk factors  
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46 115 of diabetes development in each group. Diabetes mellitus was defined according to  
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48 116 the 1990 WHO criteria or the self-reported prior diagnosis of diabetes with current  
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50 117 medication use. IGR was determined if the subjects had a fasting plasma glucose  
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52 118 (FPG) level of 6.1-6.9 mmol/L and/or a 2-hour plasma glucose level of 7.8-11.0  
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54 119 mmol/L.

### 55 120 **Data collection**

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4 121 **Sociodemographic characteristics**—Data were collected with a structured  
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6 122 questionnaire via a face-to-face interview to assess general information (gender, age,  
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8 123 nationality, education status, occupation, per capita income), personal history  
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10 124 (smoking history, alcohol history, physical activity, dietary habits), family history  
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12 125 (diabetes mellitus, hypertension, hyperlipidemia, myocardial infarction, stroke,  
13  
14 126 obesity), and history of current illness (diabetes, hypertension, hyperlipidemia, and  
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16 127 cardiovascular, cerebrovascular diseases, kidney diseases). Subjects who were  
17  
18 128 diagnosed with T2DM between recruitment and the end of follow-up were asked to  
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20 129 report the date of diagnosis.

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22 130 **Anthropometric measurements** — Subjects were examined for height, weight, waist  
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24 131 circumference (WC), hip circumference (HC) and blood pressure. All subjects were  
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26 132 asked to take off their shoes, socks, hats and coats, stand erectly and look straight  
27  
28 133 forward with their arms relaxed and their heels together. Height was measured in  
29  
30 134 centimeters using a height bar, and weight was measured in kilograms using a digital  
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32 135 weighing scale. The WC was the circumference of the waist at the horizontal line of  
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34 136 the umbilicus measured in centimeters using a measuring tape, and the HC was the  
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36 137 circumference of hips at the horizontal line of the anterior superior spine measured in  
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38 138 centimeters using a measuring tape. BMI was calculated as weight in kilograms  
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40 139 divided by the square of height in meters ( $\text{kg}/\text{m}^2$ ), while the waist-to-hip ratio (WHR)  
41  
42 140 was calculated as WC (cm) divided by HC (cm). The blood pressure values used were  
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44 141 an average of three measurements, which were taken 2 min apart using a mercury  
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46 142 sphygmomanometer. The subjects were asked to stop smoking and consuming alcohol  
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48 143 the day before the examination and to sit quietly in a chair for at least 5 min in the  
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50 144 half-hour before the measurement with their arms bare and placed at the chest level.

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52 145 **Laboratory examination** — Venous blood samples after 8-14 hours of fasting were  
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54 146 obtained from subjects for the measurement of FPG, total cholesterol (TC),  
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56 147 triglycerides (TGs), high-density lipoprotein cholesterol (HDL-C) and low-density  
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58 148 lipoprotein cholesterol (LDL-C). Venous blood samples, after a 75 g oral glucose  
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4 149 load, were obtained to measure 2-hour plasma glucose (PG2h). Subjects were  
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6 150 instructed to maintain normal physical activity without dietary limit (the intake of  
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8 151 saccharides should be no less than 150 g per day) before proceeding with the oral  
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10 152 glucose tolerance test.

### 11 153 **Statistical analysis**

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14 154 The differences in continuous and categorical variables between the NGT group and  
15  
16 155 IGR group were examined using the t test and the  $\chi^2$  test statistic, respectively.  
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18 156 Kaplan-Meier survival estimates were used to calculate the 5-year cumulative  
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20 157 incidence of T2DM. The log-rank test was used to compare the survival curves. The  
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22 158 Mantel-Haenszel  $\chi^2$  test of trends was used to analyze the ordinal data. Binary logistic  
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24 159 regression analyses were used to estimate the odds ratio and 95% confidence interval  
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26 160 for the development of diabetes. All analyses were performed using SPSS statistical  
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28 161 software version 17.0, and a P value<0.05 was considered statistically significant.

### 29 162 **Results**

#### 30 163 **Characteristics of the study population at baseline**

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34 164 A total of 1,114 residents participated in the study, and 1,014 subjects completed the  
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36 165 follow-up, with an overall response rate of 91.0%. After eliminating 118 subjects who  
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38 166 were diagnosed with diabetes at baseline and one subject with severe data deficiency,  
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40 167 895 subjects (308 men and 587 women) with a mean age of 48.1±11.9 years were  
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42 168 included in the analysis, with 673 in the NGT group and 222 in the IGR group. The  
43  
44 169 baseline characteristics of the 895 subjects in the study are shown in Table 1.  
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46 170 Continuous variables are expressed as the mean±standard deviation (sd) and were  
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48 171 examined using the t test, while categorical variables are expressed as percentages and  
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50 172 were examined using the  $\chi^2$  test. There was no significant difference between the NGT  
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52 173 group and the IGR group in gender, height, family history of T2DM, smoking history,  
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54 174 alcohol history, exercise time, diastolic blood pressure (DBP) or HDL-C. The  
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56 175 differences between the two groups in age, weight, BMI, WC, WHR, systolic blood  
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4 176 pressure (SBP), FPG, PG2h, TGs, TC, LDL-C and duration of follow-up was  
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6 177 statistically significant.

### 7 178 **Incidence of T2DM**

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10 179 During the follow-up, T2DM developed in 67 subjects, 29 in the NGT group and 38  
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12 180 in the IGR group, resulting in T2DM onset rates of 15.45, 8.86 and 35.67 per 1,000  
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14 181 person-years in the total study population, the NGT group and the IGR group,  
15  
16 182 respectively (Table 2). The difference in the incidence of T2DM between the NGT  
17  
18 183 group and the IGR group was statistically significant ( $\chi^2=37.38$ ,  $P<0.01$ ,  $RR=4.03$ ,  
19  
20 184 95% CI: 2.58-9.29).

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22 185 The 5-year cumulative incidence of T2DM was 13%, with 10% in the NGT group and  
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24 186 20% in the IGR group. The mean follow-up duration was 5.008 years (SE=0.013,  
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26 187 95% CI: 4.982-5.033), with 5.003 years (SE=0.012, 95% CI: 5.010-5.056) in the NGT  
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28 188 group and 4.933 years (SE=0.038, 95% CI: 4.859-5.007) in the IGR group. Using the  
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30 189 log-rank test, we found that the cumulative incidence of T2DM in the IGR group was  
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32 190 significantly higher than that in the NGT group ( $\chi^2=36.905$ ,  $P<0.0001$ ). The results  
33  
34 191 of the Kaplan-Meier survival analyses are shown in Figure 1.

### 35 36 192 **Analyses of the risk factors for diabetes development**

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38 193 The results of binary logistic regression analyses for the development of T2DM in the  
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40 194 NGT and IGR groups are shown in Table 3. FPG contributed to the development of  
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42 195 T2DM in the NGT group, and the OR was 6.111 (1.379, 27.070;  $P=0.017$ ). Gender,  
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44 196 WHR, DBP, and FFB contributed to the development of T2DM in the IGR group, and  
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46 197 the ORs were 7.293 (1.074, 49.549,  $P=0.042$ ), 2.874E8 (8.386, 9.847E15;  $P=0.028$ ),  
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48 198 1.068 (1.009, 1.130;  $P=0.024$ ) and 7.243 (2.314, 22.673;  $P=0.001$ ), respectively. The  
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50 199 increase in exercise time slightly decreased the risk of T2DM in the IGR group, with  
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52 200 an OR of 0.923 (0.847, 1.005;  $P=0.066$ ).

### 53 54 201 **Discussion**

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56 202 The prevalence of diabetes mellitus has been increasing markedly in recent decades.  
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58 203 Among adults aged from 20-79 years in 2017, there were an estimated 425 million  
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4 204 cases of diabetes<sup>3</sup>. However, the astonishing prevalence may be partly attributable to  
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6 205 the increase in population and the prolongation of the life-span.<sup>35</sup> Accordingly, we  
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8 206 studied the growing trend of T2DM by investigating the cumulative incidence of  
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10 207 T2DM. Our results showed that 15.45 new cases of diabetes per 1,000 people-years  
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12 208 were diagnosed during the five-year observation period (2007-2012). This marked  
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14 209 trend is consistent with diabetes incidence rates worldwide, such as those described in  
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16 210 the ATTICA study in Greece (12.9 cases per 1,000 person-years from 2002 to 2012)<sup>36</sup>  
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18 211 and those described in a study conducted in Mexico (12.7 cases per 1,000 person-  
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20 212 years from 1990 to 2008).<sup>37</sup> The incidence rate found in our study is lower than that in  
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22 213 a study of Pima Indians (23.5 cases per 1,000 person-years during 1991 to 2003)<sup>38</sup> and  
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24 214 in a study conducted in northern Spain (95.2 cases per 1,000 person-years during  
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26 215 1998 to 2005)<sup>39</sup> and is higher than that observed in a study conducted in Iran (10.6  
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28 216 cases per 1000 person-years from 1999 to 2011)<sup>40</sup> and in the SUPREME-DM project  
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30 217 in the USA (11.5 cases per 1000 person-years from 2006 to 2011).<sup>41</sup> The T2DM  
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32 218 incidence in the suburbs of Beijing is higher than that identified in the investigation  
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34 219 conducted by Wang C et al in a Chinese population in 2010 (9.5 cases per 1000  
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36 220 person-years in men and 9.2 in women).<sup>42</sup> This difference may partly be due to the  
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38 221 relatively higher standard of living in the suburbs of Beijing.  
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40 222 The development of diabetes is based on the interaction between genes and lifestyle  
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42 223 and environmental factors.<sup>43,44</sup> Compared with the NGT group that had an incidence  
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44 224 of 8.86 cases per 1,000 person-years, the IGR group (35.67 cases per 1,000 person-  
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46 225 years) had a higher incidence rate (RR=4.03, 95% CI: 2.58-9.29, P<0.01). In our  
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48 226 study, the development of diabetes was mainly the consequence of elevated FPG in  
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50 227 the NGT group. Diabetes development was mainly associated with sex (female),  
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52 228 abnormal WHR, elevated DBP and elevated FPG in the IGR group. The increase in  
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54 229 the FPG level was a strong predictor of diabetes development in both the NGT group  
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56 230 and the IGR group, with 6.111- and 7.243-times increased risk per unit increase,  
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58 231 respectively.  
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232 In our study, the WHR measurement was found to predict diabetes risk. Some studies  
233 have declared that WHR, as an obesity indicator, was superior to BMI and WC.<sup>45,46</sup> A  
234 meta-analysis demonstrated that either BMI or WC (WHR) predicted or was  
235 independently associated with type 2 diabetes, regardless of the controversial findings  
236 regarding which one was better.<sup>47</sup>

237 Age and family history of diabetes were widely believed to be risk factors for diabetes  
238 development.<sup>4,6-14</sup> However, we found only an increasing trend of diabetes  
239 development in the elderly population and in subjects with a family history of  
240 diabetes ( $P > 0.05$ ). This finding might be related to the short period of follow-up and  
241 the subjects' unawareness of their family history of diabetes.

242 There is evidence that T2DM can be prevented in high-risk individuals by a lifestyle  
243 program of regular exercise.<sup>48,49</sup> Surprisingly, our study found that exercise did not  
244 exert a beneficial effect on diabetes incidence, a finding similar to that of the  
245 ATTICA study.<sup>36,50</sup> However, we did find a decreasing trend in diabetes incidence  
246 with increasing exercise time. The increase in exercise time slightly decreased the risk  
247 of T2DM in the IGR group, with an OR of 0.923 (0.847, 1.005;  $P=0.066$ ).

248 The strengths of our study are that the study was based on a cohort selected by  
249 multiple stage sampling at baseline with a relatively long follow-up period. The  
250 limitation is that many variables assessed as risk factors were not updated regularly,  
251 which might have changed during the follow-up period, and the data were collected  
252 only at the baseline investigation and at the end of the study.

### 253 **Conclusions**

254 During a mean follow-up of 5.0 years, the incidence of T2DM in the suburbs of  
255 Beijing was 15.45 cases per 1000 person-years, which was relatively higher than the  
256 incidence in many other areas worldwide. Compared with the NGT subjects, the IGR  
257 subjects were more susceptible to T2DM. To prevent diabetes development, all  
258 subjects should pay special attention to elevated FPG. In addition, sex, WHR, and  
259 DBP were predictors of T2DM in IGR subjects.

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4 260 The findings in this study provide new data on the incidence of T2DM in the Beijing  
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6 261 area. The predictors of T2DM reported in the present study may be conducive to  
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8 262 formulating a protocol for diabetes prevention.  
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### 10 263 **Authors' contributions**

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14 264 Conceptualization, B.Z.; Data curation, H.Z.; Formal analysis, H.Z.; Investigation,  
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16  
17 265 L.X. and X.Z.; Methodology, B.Z.; Project administration, L.X., X.Z. and B.Z.;  
18  
19  
20 266 Writing – original draft, L.X. and X.Z.; Writing – review & editing, B.Z.. All authors  
21  
22  
23 267 read and approved the final manuscript, as well as the submission of this work. B.Z.  
24  
25  
26 268 supervised and managed the data. B.Z. is the guarantor of this work.  
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### 30 270 **Conflicts of interest**

31  
32 271 The authors declare that they have no conflicts of interest.  
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34 272

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37  
38 274 The study was supported by grants from the 11th five-year national science and  
39  
40 275 technology support program (2009BAI80B04).  
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42 276

### 43 277 **Ethics approval**

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45 278 Ethical approval was gained from Ethics Committee of Clinical Trials of  
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47  
48 279 Drugs/Devices in China-Japan Friendship Hospital (2011-049).  
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281 **Table 1 Comparison of characteristics of the NGT and IGR subjects at baseline**

Variable at baseline	NGT group (n=673)	IGR group (n=222)	t or $\chi^2$ , <i>P</i> value
Gender (%male)	34.9	32.9	0.306, 0.625
Age (years)	46.75±11.57	52.01±12.03	-5.813, 0.000
Height (cm)	161.85±7.94	161.18±7.83	1.092, 0.275
Weight (kg)	64.32±10.75	67.49±11.05	-3.777, 0.000
BMI (kg/m <sup>2</sup> )	24.52±3.40	25.93±3.50	-5.332, 0.000
WC (cm)	83.04±9.75	86.82±9.20	-5.075, 0.000
WHR	0.87±0.07	0.89±0.06	-3.495, 0.000
SBP (mmHg)	119.71±18.37	125.18±20.13	-3.582, 0.000
DBP (mmHg)	78.02±11.21	79.75±12.66	-1.843, 0.066
FPG (mmol/L)	5.25±0.42	5.82±0.61	-15.875, 0.000
PG2h (mmol/L)	5.90±1.01	8.29±1.52	-26.692, 0.000
TGs (mmol/L)	1.42±1.17	1.61±1.08	-2.165, 0.031
TC (mmol/L)	4.56±0.92	4.84±0.95	-3.865, 0.000
HDL-C (mmol/L)	1.35±0.34	1.34±0.36	0.464, 0.643
LDL-C (mmol/L)	2.77±0.77	3.08±0.81	-4.648, 0.000
Exercise duration (hours)	5.85±11.81	5.59±8.06	0.305, 0.761
FH of T2DM (%)	15.5	21.4	3.722, 0.068
Smoking history (%)	22.4	20.7	0.286, 0.641
Alcohol history (%)	27.9	28.8	0.076, 0.796
Years of follow-up (year)	4.85±0.32	4.79±0.56	2.081, 0.038

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4 282 BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; SBP,  
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6 283 systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose;  
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8 284 PG2h, 2-hour plasma glucose; TC, total cholesterol; TGs, triglycerides; HDL-C, high-  
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10 285 density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; FH,  
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12 286 family history. Exercise duration is expressed as hours per week.  
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60288 **Table 2. The incidence of T2DM during the follow-up**

	Cases of diabetes	Follow-up (person- years)	Incidence (per 1,000 person-years)
NGT group	29	3,271.5	8.86
IGR group	38	1,065.3	35.67
Total	67	4,336.8	15.45

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291 **Table 3. Multivariate logistic regression model for the development of T2DM**

	NGT group		IGR group	
	OR (95% CI)	<i>P</i> value	OR (95% CI)	<i>P</i> value
Sex	0.375 (0.067, 2.103)	0.265	7.293 (1.074, 49.549)	0.042
Age (years)	1.013 (0.962, 1.068)	0.615	1.019 (0.964, 1.077)	0.499
Weight (kg)	1.044 (0.927, 1.175)	0.478	1.056 (0.929, 1.200)	0.402
BMI (kg/m <sup>2</sup> )	0.934 (0.653, 1.336)	0.710	0.971 (0.661, 1.427)	0.881
WC (cm)	1.073 (0.936, 1.230)	0.311	0.904 (0.748, 1.092)	0.295
WHR	0.006 (0.000, 7058.081)	0.473	2.874E8 (8.386, 9.847E15)	0.028
SBP (mmHg)	1.013 (0.976, 1.052)	0.492	0.992 (0.958, 1.026)	0.637
DBP (mmHg)	0.955 (0.890, 1.024)	0.198	1.068 (1.009, 1.130)	0.024
FPG (mmol/L)	6.111 (1.379, 27.070)	0.017	7.243 (2.314, 22.673)	0.001
TC (mmol/L)	2.719 (0.917, 8.067)	0.071	0.814 (0.141, 4.699)	0.818
TGs (mmol/L)	0.996 (0.589, 1.684)	0.989	0.926 (0.491, 1.749)	0.813
HDL-C (mmol/L)	2.536 (0.519, 12.395)	0.250	0.622 (0.071, 5.460)	0.669
LDL-C (mmol/L)	0.604 (0.206, 1.769)	0.358	1.070 (0.181, 6.321)	0.941
Exercise duration (hours)	1.013 (0.947, 1.084)	0.707	0.923 (0.847, 1.005)	0.066
FH of T2DM	1.868 (0.492, 7.090)	0.358	2.062 (0.656, 6.478)	0.215
Smoking history	0.766 (0.186, 3.162)	0.713	1.591 (0.346, 7.317)	0.551
Alcohol history	0.726 (0.202, 2.610)	0.624	1.685 (0.458, 6.203)	0.432

292 BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; SBP,  
 293 systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose;  
 294 TC, total cholesterol; TGs, triglycerides; HDL-C, high-density lipoprotein cholesterol;  
 295 LDL-C, low-density lipoprotein cholesterol; FH, family history. Gender was defined  
 296 as male (n=1) or female (n=2), FH of T2DM was defined as no (n=1) or yes (n=2),

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297 smoking history was defined as no (n=1) or yes (n=2), and alcohol history was  
298 defined as no (n=1) or yes (n=2). Exercise duration was expressed as hours per week.  
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4 302 **Figure legend**

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6 303 Figure 1. Cumulative incidence of T2DM in the NGT group and the IGR group (log-  
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8 304 rank test:  $\chi^2=36.905$ ,  $P<0.0001$ )

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310 **References**

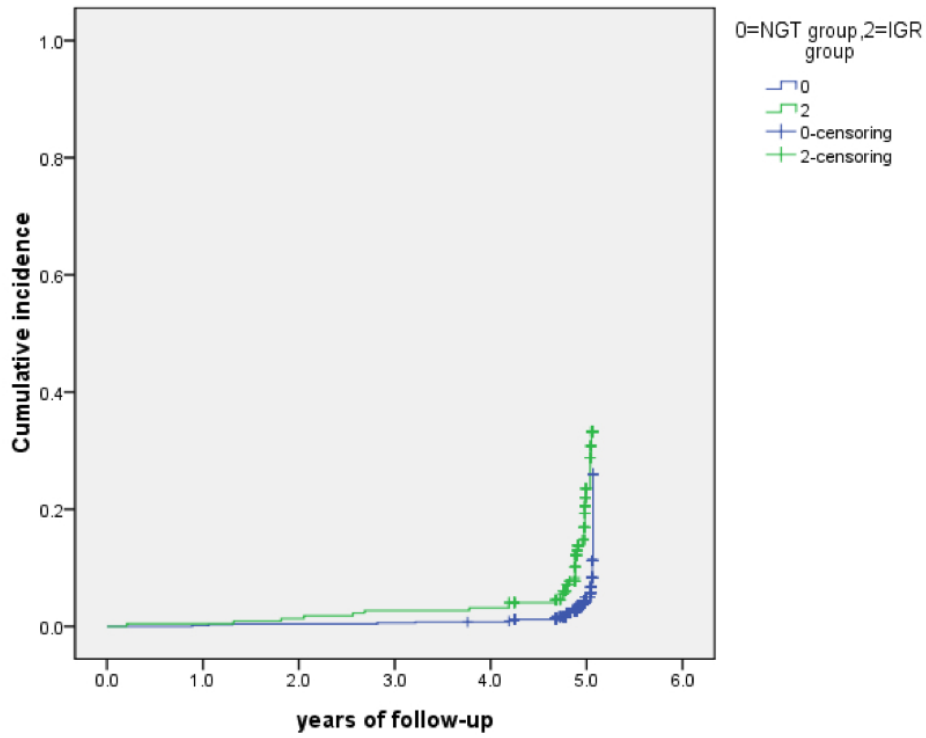
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STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	7
		(b) For matched studies, give matching criteria and number of exposed and unexposed	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, explain how loss to follow-up was addressed (e) Describe any sensitivity analyses	8
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	8
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	8
Outcome data	15*	Report numbers of outcome events or summary measures over time	9

1	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9
2			(b) Report category boundaries when continuous variables were categorized	
3			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
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9	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
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11	<b>Discussion</b>			
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13	Key results	18	Summarise key results with reference to study objectives	9
14	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
15				
16	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10
17				
18				
19	Generalisability	21	Discuss the generalisability (external validity) of the study results	11
20				
21	<b>Other information</b>			
22	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12
23				
24				

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.

# BMJ Open

## Epidemiology and risk factors for diabetes in the suburbs of Beijing: a retrospective cohort study

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-041526.R1
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<b>Primary Subject Heading</b>:	Epidemiology
Secondary Subject Heading:	Diabetes and endocrinology
Keywords:	General diabetes < DIABETES & ENDOCRINOLOGY, EPIDEMIOLOGY, PUBLIC HEALTH

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4 **1. Epidemiology and risk factors for diabetes in the suburbs of**  
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7 **2 Beijing: a retrospective cohort study**  
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4 24 **Abstract**

5 25 **Objective** We aimed to detect the incidence and risk factors of type 2 diabetes  
6 mellitus (T2DM) development in the suburbs of Beijing.  
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10 27 **Design** Cohort study with record linkage to incidence data.

11 28 **Setting** We performed a 5-year follow-up study in a randomly selected suburban  
12 population including 1,114 subjects aged  $\geq 18$  years living in the suburbs of Beijing.  
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16 30 **Participants** 118 subjects with T2DM at baseline according to the 1999 WHO criteria  
17 were excluded, and 895 subjects attended the follow-up assessment in 2012. The non-  
18 diabetic subjects at baseline were classified into two groups: normal glucose tolerance  
19 (NGT) group (n=673) and impaired glucose regulation (IGR) group (n=222). The  
20 incidence and risk factors of diabetes development in each group were investigated.  
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26 32 **Outcome measures** A structured questionnaire about sociodemographic  
27 characteristics, height, weight, waist circumference, hip circumference, blood  
28 pressure, oral glucose tolerance test, and serum lipid levels.  
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33 33 **Results** Out of the 895 non-diabetic subjects, 67 developed diabetes with 29 in the  
34 NGT group and 38 in the IGR group respectively after a 5-year follow-up, producing  
35 an overall 5-year cumulative incidence of diabetes of 13%. The incidence of diabetes  
36 was 15.5 cases per 1000 person-years, 8.9 cases per 1000 person-years in the NGT  
37 group and 35.7 cases per 1000 person-years in the IGR group ( $P < 0.01$ ;  $RR = 4.03$ ;  
38 95%  $CI: 2.58-9.29$ ). Binary logistic regression analysis showed that the risk factors for  
39 diabetes development included fasting plasma glucose (FPG) in the NGT group, and  
40 sex, the waist-to-hip ratio (WHR), FPG and diastolic blood pressure (DBP) in the IGR  
41 group.  
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51 47 **Conclusions:** During a mean follow-up of 5.0 years, the incidence of T2DM in the  
52 suburbs of Beijing was 15.5 per 1000 person-years. Early prevention of diabetes  
53 should focus on IGR subjects. Elevated FPG predicted diabetes development for both  
54 NGT and IGR subjects. Female sex, overweight/obesity and DBP are risk factors for  
55 diabetes development in IGR subjects.  
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### **Strengths and limitations of this study**

- Provides new data on the incidence of T2DM in the Beijing area.
- Has a longitudinal design.
- Selects a cohort by multiple-stage sampling at baseline.
- Has a relatively long follow-up period.
- Has the limitation that many variables assessed as risk factors were not updated regularly, and the data were collected only at the baseline investigation and at the end of the study.

view only

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**66 Introduction**

67 Diabetes mellitus is a clinical syndrome characterized by disordered  
68 glycometabolism. The lack and/or insufficiency of insulin induces metabolic disorders  
69 related to saccharides, lipids, proteins, water and electrolytes, resulting in  
70 hyperglycemia as the main clinical feature. Long-term hyperglycemia leads to  
71 macrovascular and microvascular complications, which may result in disability and  
72 death.<sup>1,2</sup> Diabetes is increasingly prevalent, affecting 463 million (9.3%) adults  
73 worldwide, and these figures are expected to increase to 700 million (10.9%) by  
74 2045.<sup>3</sup> Type 2 diabetes mellitus (T2DM) accounts for over 90% of diabetes cases.  
75 Diabetes, as a leading cause of death,<sup>1,3,4</sup> is becoming a public issue, placing a heavy  
76 burden on the health care system.<sup>5</sup> In 2017 approximately 5 million adult deaths  
77 worldwide were attributed to diabetes,<sup>6</sup> and the global healthcare expenditure  
78 associated with people with diabetes in 2019 was estimated to be USD 760 billion.<sup>7</sup>  
79 Because T2DM is usually asymptomatic, it can remain undiagnosed for many years.  
80 Almost half of all people (50.1%) living with diabetes were undiagnosed in 2019.<sup>3</sup>  
81 Accordingly, screening for prediabetes/T2DM and preventing the evolution of  
82 diabetes in individuals with risk factors are essential. Currently, the risk factors  
83 related to T2DM development may include age, the body mass index (BMI), body fat  
84 distribution, a family history of diabetes, a history of cardiovascular disease (CVD), a  
85 history of gestational diabetes mellitus (GDM), race/ethnicity, diet, physical  
86 inactivity, hypertension, dyslipidemia and prediabetes.<sup>4,8-16</sup> Some studies have  
87 demonstrated that birth weight,<sup>17,18</sup> income,<sup>19</sup> socioeconomic status,<sup>20,21</sup> working  
88 hours,<sup>21,22</sup> occupation<sup>23</sup> and genetic factors<sup>24-26</sup> might also contribute to T2DM  
89 development .  
90 In addition to the process of urbanization, the population aging, changes in lifestyle,  
91 and increasing prevalence of obesity and overweight, the prevalence of diabetes in  
92 China has increased over the past three decades. The prevalence of diabetes in China



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4 93 was 0.67% in 1980,<sup>27</sup> 2.12% in 1995,<sup>28</sup> 5.5% in 2001,<sup>29</sup> 9.7% in 2008,<sup>30</sup> 9.7% in  
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6 94 2010<sup>31</sup> and 10.4% in 2013.<sup>32</sup> As the capital city, limited information is available  
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8 95 regarding the incidence of diabetes and prediabetes in Beijing. Certain studies have  
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10 96 suggested that different diabetic risk patterns might exist in Asian populations.<sup>33-36</sup>  
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12 97 This study aimed to determine the incidence of and risk factors for T2DM among  
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14 98 Chinese adults in the suburbs of Beijing.

## 99 **Materials and Methods**

### 100 **Study population**

101 The study population comprised residents living in the suburbs (Huairou, Pinggu and  
102 Hepingli) of Beijing. The three suburbs were randomly selected from the Beijing  
103 countryside. Individuals aged 18 years or older who were willing to participate and  
104 provided informed consent were eligible to participate in the study. People with a  
105 history of diabetes were excluded from the study. Pregnant women were also  
106 excluded from the study.

107 We performed a 5-year perspective cohort study. The baseline survey occurred from  
108 June 2007 to September 2008 using a random sampling method with a follow-up  
109 examination from May to July 2012. All the subjects were asked to undergo a  
110 personal interview, physical examination and blood test [including an oral glucose  
111 tolerance test (OGTT)]. Through OGTT, subjects with diabetes at baseline were  
112 excluded, and the nondiabetic subjects at baseline were divided into the normal  
113 glucose tolerance (NGT) group and impaired glucose regulation (IGR) group. We  
114 analyzed the incidence and risk factors of diabetes development in each group.  
115 Diabetes mellitus was defined according to the 1990 WHO criteria or self-reported  
116 prior diagnosis of diabetes with current medication use. IGR was determined if the  
117 subjects had a fasting plasma glucose (FPG) level of 6.1–6.9 mmol/L and/or a 2-hour  
118 plasma glucose level of 7.8–11.0 mmol/L.

### 119 **Data collection**

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4 120 **Sociodemographic characteristics**—The data were collected by trained staff using a  
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6 121 structured questionnaire via a face-to-face interview to assess general information  
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8 122 (sex, age, nationality, education status, occupation, and per capita income), personal  
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10 123 history (smoking history, alcohol history, physical activity, and dietary habits), family  
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12 124 history (diabetes mellitus, hypertension, hyperlipidemia, myocardial infarction,  
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14 125 stroke, and obesity), and history of current illness (diabetes, hypertension,  
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16 126 hyperlipidemia, cardiovascular, cerebrovascular diseases, and kidney diseases).  
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18 127 Subjects who were diagnosed with T2DM between recruitment and the end of follow-  
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20 128 up were asked to report the date of diagnosis.

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22 129 **Anthropometric measurements** — The subjects were examined for height, weight,  
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24 130 waist circumference (WC), hip circumference (HC) and blood pressure. All the  
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26 131 subjects were asked to remove their shoes, socks, hats and coats, stand erectly and  
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28 132 look forward with their arms relaxed and their heels together. Height was measured in  
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30 133 centimeters using a height bar, and weight was measured in kilograms using a digital  
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32 134 weighing scale. The WC is the circumference of the waist at the horizontal line of the  
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34 135 umbilicus measured in centimeters using a measuring tape, and the HC is the  
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36 136 circumference of hips at the horizontal line of the anterior superior spine measured in  
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38 137 centimeters using a measuring tape. The BMI was calculated as weight in kilograms  
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40 138 divided by the square of height in meters ( $\text{kg}/\text{m}^2$ ), while the waist-to-hip ratio (WHR)  
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42 139 was calculated as WC (cm) divided by HC (cm). The blood pressure values used were  
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44 140 an average of three measurements, which were measured 2 min apart using a mercury  
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46 141 sphygmomanometer. The subjects were asked to stop smoking and consuming alcohol  
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48 142 the day before the examination and to sit quietly in a chair for at least 5 minutes  
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50 143 before the measurement with their arms bare and placed at the chest level. All the  
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52 144 clinical staff members were trained to measure blood pressure and obtain  
53  
54 145 anthropometric measurements.

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56 146 **Laboratory examination** — All the subjects were invited to undergo a blood test  
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58 147 (including an OGTT) at the baseline and the end of follow-up. Venous blood samples  
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4 148 after 8–14 hours of fasting were obtained from the subjects to measure FPG, total  
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6 149 cholesterol (TC), triglycerides (TGs), high-density lipoprotein cholesterol (HDL-C)  
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8 150 and low-density lipoprotein cholesterol (LDL-C). Venous blood samples, after a 75 g  
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10 151 oral glucose load, were obtained to measure the 2-hour plasma glucose (PG2h). The  
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12 152 subjects were instructed to maintain normal physical activity without dietary limit (the  
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14 153 intake of saccharides should be no less than 150 g per day) before proceeding with the  
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16 154 OGTT.

### 17 18 155 **Statistical analysis**

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20 156 We used the P-P plot to test the normality of the numerical variables. The differences  
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22 157 in continuous and categorical variables between the NGT and IGR groups were  
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24 158 examined using t test and the  $\chi^2$  test statistic, respectively. Kaplan–Meier survival  
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26 159 estimates were used to calculate the 5-year cumulative incidence of T2DM. The log-  
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28 160 rank test was used to compare the survival curves. The Mantel–Haenszel  $\chi^2$  test of  
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30 161 trends was used to analyze the ordinal data. Binary logistic regression analyses were  
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32 162 used to estimate the odds ratio and 95% confidence interval for diabetes development.  
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34 163 All the analyses were performed using SPSS statistical software version 17.0, and a P  
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36 164 value < 0.05 was considered statistically significant.

### 37 38 165 **Patient and Public Involvement**

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40 166 Patients or the public were not involved in the design, or conduct, or reporting, or  
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42 167 dissemination plans of our research.

### 43 44 168 **Results**

#### 45 46 169 **Characteristics of the study population at baseline**

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48 170 In total, 1,114 residents participated in the study, and 1,014 subjects completed the  
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50 171 follow-up, with an overall response rate of 91.0%. After eliminating 118 subjects who  
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52 172 were diagnosed with diabetes at baseline and one subject with severe data deficiency,  
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54 173 895 subjects (308 men and 587 women) with a mean age of  $48.1 \pm 11.9$  years were  
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56 174 included in the analysis, with 673 in the NGT group and 222 in the IGR group. The  
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58 175 baseline characteristics of the 895 subjects in the study are shown in Table 1.  
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4 176 Continuous variables were expressed as means±standard deviation (sd) and were  
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6 177 examined using a t test, while categorical variables were expressed as percentages and  
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8 178 were examined using the  $\chi^2$  test. No significant difference was found between the  
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10 179 NGT group and the IGR group in sex, height, family history of T2DM, smoking  
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12 180 history, alcohol history, exercise time, diastolic blood pressure (DBP) or HDL-C.  
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14 181 Age, weight, BMI, WC, WHR, systolic blood pressure (SBP), FPG, PG2h, TGs, TC  
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16 182 and LDL-C in the IGR group were significantly higher than those in the NGT group.

### 183 **Incidence of T2DM**

184 During the follow-up, T2DM developed in 67 subjects, 29 in the NGT group and 38  
185 in the IGR group, resulting in T2DM onset rates of 15.45, 8.86 and 35.67 per 1,000  
186 person-years in the total study population, NGT group and IGR group, respectively  
187 (Table 2). The difference in the incidence of T2DM between the NGT group and IGR  
188 group was statistically significant ( $\chi^2=37.38$ ;  $P<0.01$ ;  $RR=4.03$ ; 95% CI: 2.58-9.29).  
189 The 5-year cumulative incidence of T2DM was 13%, with 10% in the NGT group and  
190 20% in the IGR group. The mean follow-up duration was 5.008 years (SE=0.013;  
191 95% CI: 4.982–5.033), with 5.003 years (SE=0.012; 95% CI: 5.010–5.056) in the  
192 NGT group and 4.933 years (SE=0.038; 95% CI: 4.859–5.007) in the IGR group.  
193 Using the log-rank test, we found that the cumulative incidence of T2DM in the IGR  
194 group was significantly higher than that in the NGT group ( $\chi^2=36.905$ ;  $P<0.0001$ ).  
195 The results of the Kaplan–Meier survival analyses are shown in Figure 1.

### 196 **Analyses of the risk factors for diabetes development**

197 The results of binary logistic regression analyses for T2DM development in the NGT  
198 and IGR groups are shown in Table 3. FPG contributed to T2DM development in the  
199 NGT group, and the OR was 6.111 (1.379, 27.070;  $P=0.017$ ). Sex, WHR, DBP, and  
200 FPB contributed to T2DM development in the IGR group, and the ORs were 7.293  
201 (1.074, 49.549;  $P=0.042$ ), 2.874E8 (8.386, 9.847E15;  $P=0.028$ ), 1.068 (1.009, 1.130;  
202  $P=0.024$ ) and 7.243 (2.314, 22.673;  $P=0.001$ ), respectively. The increase in exercise

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4 203 time slightly decreased the risk of T2DM in the IGR group, with an OR of 0.923  
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6 204 (0.847, 1.005; P=0.066).

## 7 205 **Discussion**

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9 206 The prevalence of diabetes mellitus has been increasing markedly in recent decades.  
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11 207 Among adults aged 20–79 years in 2019, there were an estimated 463 million cases of  
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13 208 diabetes<sup>3</sup>. However, the striking prevalence may be partly attributable to the increase  
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15 209 in population and prolongation of the life-span.<sup>37</sup> Accordingly, we studied the  
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17 210 growing trend of T2DM by investigating the cumulative incidence of T2DM. Our  
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19 211 results showed that 15.45 new cases of diabetes per 1,000 people-years were  
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21 212 diagnosed during the five-year observation period (2007–2012). This marked trend is  
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23 213 consistent with diabetes incidence rates worldwide, such as those described in the  
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25 214 ATTICA study in Greece (12.9 cases per 1,000 person-years from 2002 to 2012)<sup>38</sup>  
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27 215 and those described in a study conducted in Mexico (12.7 cases per 1,000 person-  
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29 216 years from 1990 to 2008).<sup>39</sup> The incidence rate found in our study is lower than that in  
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31 217 a study of Pima Indians (23.5 cases per 1,000 person-years during 1991 to 2003)<sup>40</sup> and  
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33 218 in a study conducted in northern Spain (95.2 cases per 1,000 person-years during  
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35 219 1998 to 2005)<sup>41</sup> and is higher than that observed in a study conducted in Iran (10.6  
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37 220 cases per 1000 person-years from 1999 to 2011)<sup>42</sup> and in the SUPREME-DM project  
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39 221 in the USA (11.5 cases per 1000 person-years from 2006 to 2011).<sup>43</sup> The T2DM  
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41 222 incidence in the suburbs of Beijing is higher than that identified in the investigation  
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43 223 conducted by Wang C et al in a Chinese population in 2010 (9.5 cases per 1000  
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45 224 person-years in men and 9.2 in women).<sup>44</sup> This difference may partly be due to the  
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47 225 relatively higher standard of living in the suburbs of Beijing.  
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49 226 Diabetes development is based on the interaction between genes and lifestyle and  
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51 227 environmental factors.<sup>45,46</sup> Compared with the NGT group that had an incidence of  
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53 228 8.86 cases per 1,000 person-years, the IGR group (35.67 cases per 1,000 person-  
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55 229 years) had a higher incidence rate (RR=4.03;95% CI: 2.58–9.29;P<0.01). In our  
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57 230 study, diabetes development was mainly the consequence of elevated FPG in the NGT  
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4 231 group. Diabetes development was mainly associated with sex (female), abnormal  
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6 232 WHR, elevated DBP and elevated FPG in the IGR group. The increase in the FPG  
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8 233 level was a strong predictor of diabetes development in both the NGT group and IGR  
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10 234 group, with 6.111- and 7.243-fold increased risk per unit increase, respectively.  
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12 235 In our study, the WHR measurement was found to predict diabetes risk. Some studies  
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14 236 have declared that WHR, as an obesity indicator, is superior to BMI and WC.<sup>47,48</sup> A  
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16 237 meta-analysis demonstrated that either BMI or WC (WHR) predicted or was  
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18 238 independently associated with type 2 diabetes, regardless of the controversial findings  
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20 239 regarding which was better.<sup>49</sup>  
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22 240 Age and family history of diabetes are considered risk factors for diabetes  
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24 241 development.<sup>4,8-16</sup> However, we found only an increasing trend of diabetes  
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26 242 development in the elderly population and subjects with a family history of diabetes  
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28 243 ( $P > 0.05$ ). This finding might be related to the short period of follow-up and the  
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30 244 subjects' unawareness of their family history of diabetes.  
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32 245 There is evidence that T2DM can be prevented in high-risk individuals by a lifestyle  
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34 246 program of regular exercise.<sup>50,51</sup> Surprisingly, our study found that exercise did not  
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36 247 exert a beneficial effect on diabetes incidence, a finding similar to that in the ATTICA  
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38 248 study.<sup>38,52</sup> However, we found a decreasing trend in the diabetes incidence with  
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40 249 increasing exercise time. The increase in exercise time slightly decreased the risk of  
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42 250 T2DM in the IGR group, with an OR of 0.923 (0.847, 1.005;  $P = 0.066$ ).  
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44 251 The strength of our study is that it was based on a cohort selected by multiple stage  
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46 252 sampling at baseline with a relatively long follow-up period. A limitation is that many  
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48 253 variables assessed as risk factors were not updated regularly, and might have changed  
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50 254 during the follow-up period. Additionally, the data were collected only at the baseline  
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52 255 investigation and at the end of the study.  
53  
54 256 **Conclusions**  
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56 257 During a mean follow-up of 5.0 years, the incidence of T2DM in the suburbs of  
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58 258 Beijing was 15.45 cases per 1000 person-years, which was relatively higher than that  
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4 259 in many other areas worldwide. Compared with the NGT subjects, the IGR subjects  
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6 260 were more susceptible to T2DM. To prevent diabetes development, all the subjects  
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8 261 should be evaluated for elevated FPG. Additionally, sex, WHR, and DBP were  
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10 262 predictors of T2DM in IGR subjects.

11 263 The findings in this study provide new data on the incidence of T2DM in the Beijing  
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13 264 area. The predictors of T2DM reported in the present study may be conducive to  
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15 265 formulating a protocol for diabetes prevention.

### 18 19 266 **Authors' contributions**

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23 267 Conceptualization, B.Z.; Data curation, H.Z.; Formal analysis, H.Z.; Investigation,  
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25 268 L.X. and X.Z.; Methodology, B.Z.; Project administration, L.X., X.Z. and B.Z.;  
26  
27  
28 269 Writing – original draft, L.X. and X.Z.; Writing – review & editing, B.Z.. All authors  
29  
30 270 read and approved the final manuscript, as well as the submission of this work. B.Z.  
31  
32 271 supervised and managed the data. B.Z. is the guarantor of this work.

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### 36 37 38 273 **Conflicts of interest**

39  
40 274 The authors declare that they have no conflicts of interest.

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45 276 **Competing interests** None declared.

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### 56 57 282 **Ethics approval**

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59 283 Ethical approval was obtained from the Ethics Committee of Clinical Trials of  
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284 Drugs/Devices in China-Japan Friendship Hospital (2011-049).

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286 **Data availability statement**

287 All data included in this study are available from the corresponding author on  
288 reasonable request.

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For peer review only



291 **Table 1 Comparison of the characteristics of the NGT and IGR subjects at**  
 292 **baseline**

Variable at baseline	NGT group (n=673)	IGR group (n=222)	t or $\chi^2$ , <i>P</i> value
Sex(%male)	34.9	32.9	0.306, 0.625
Age (years)	46.75±11.57	52.01±12.03	-5.813, <0.001
Height (cm)	161.85±7.94	161.18±7.83	1.092, 0.275
Weight (kg)	64.32±10.75	67.49±11.05	-3.777, <0.001
BMI (kg/m <sup>2</sup> )	24.52±3.40	25.93±3.50	-5.332, <0.001
WC (cm)	83.04±9.75	86.82±9.20	-5.075, <0.001
WHR	0.87±0.07	0.89±0.06	-3.495, <0.001
SBP (mmHg)	119.71±18.37	125.18±20.13	-3.582, <0.001
DBP (mmHg)	78.02±11.21	79.75±12.66	-1.843, 0.066
FPG (mmol/L)	5.25±0.42	5.82±0.61	-15.875, <0.001
PG2h (mmol/L)	5.90±1.01	8.29±1.52	-26.692, <0.001
TGs (mmol/L)	1.42±1.17	1.61±1.08	-2.165, 0.031
TC (mmol/L)	4.56±0.92	4.84±0.95	-3.865, <0.001
HDL-C (mmol/L)	1.35±0.34	1.34±0.36	0.464, 0.643
LDL-C (mmol/L)	2.77±0.77	3.08±0.81	-4.648, <0.001
Exercise duration (hours)	5.85±11.81	5.59±8.06	0.305, 0.761
FH of T2DM (%)	15.5	21.4	3.722, 0.068
Smoking history (%)	22.4	20.7	0.286, 0.641
Alcohol history (%)	27.9	28.8	0.076, 0.796
Years of follow-up (year)	4.85±0.32	4.79±0.56	2.081, 0.038

293 BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; SBP,  
 294 systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose;

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295 PG2h, 2-hour plasma glucose; TC, total cholesterol; TGs, triglycerides; HDL-C, high-  
296 density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; FH,  
297 family history. Exercise duration is expressed as hours per week.  
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299 **Table 2. Incidence of T2DM during the follow-up**

	Cases of diabetes	Follow-up (person- years)	Incidence (per 1,000 person-years)
NGT group	29	3,271.5	8.86
IGR group	38	1,065.3	35.67
Total	67	4,336.8	15.45

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302 **Table 3. Multivariate logistic regression model for T2DM development**

	NGT group		IGR group	
	OR (95% CI)	<i>P</i> value	OR (95% CI)	<i>P</i> value
Sex	0.375 (0.067, 2.103)	0.265	7.293 (1.074, 49.549)	0.042
Age (years)	1.013 (0.962, 1.068)	0.615	1.019 (0.964, 1.077)	0.499
Weight (kg)	1.044 (0.927, 1.175)	0.478	1.056 (0.929, 1.200)	0.402
BMI (kg/m <sup>2</sup> )	0.934 (0.653, 1.336)	0.710	0.971 (0.661, 1.427)	0.881
WC (cm)	1.073 (0.936, 1.230)	0.311	0.904 (0.748, 1.092)	0.295
WHR	0.006 (0.000, 7058.081)	0.473	2.874E8 (8.386, 9.847E15)	0.028
SBP (mmHg)	1.013 (0.976, 1.052)	0.492	0.992 (0.958, 1.026)	0.637
DBP (mmHg)	0.955 (0.890, 1.024)	0.198	1.068 (1.009, 1.130)	0.024
FPG (mmol/L)	6.111 (1.379, 27.070)	0.017	7.243 (2.314, 22.673)	0.001
TC (mmol/L)	2.719 (0.917, 8.067)	0.071	0.814 (0.141, 4.699)	0.818
TGs (mmol/L)	0.996 (0.589, 1.684)	0.989	0.926 (0.491, 1.749)	0.813
HDL-C (mmol/L)	2.536 (0.519, 12.395)	0.250	0.622 (0.071, 5.460)	0.669
LDL-C (mmol/L)	0.604 (0.206, 1.769)	0.358	1.070 (0.181, 6.321)	0.941
Exercise duration (hours)	1.013 (0.947, 1.084)	0.707	0.923 (0.847, 1.005)	0.066
FH of T2DM	1.868 (0.492, 7.090)	0.358	2.062 (0.656, 6.478)	0.215
Smoking history	0.766 (0.186, 3.162)	0.713	1.591 (0.346, 7.317)	0.551
Alcohol history	0.726 (0.202, 2.610)	0.624	1.685 (0.458, 6.203)	0.432

303 BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; SBP,  
304 systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose;  
305 TC, total cholesterol; TGs, triglycerides; HDL-C, high-density lipoprotein cholesterol;  
306 LDL-C, low-density lipoprotein cholesterol; FH, family history. Sex is defined as  
307 male (n=1) or female (n=2), FH of T2DM is defined as no (n=1) or yes (n=2),

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4 308 smoking history was defined as no (n=1) or yes (n=2), and alcohol history was  
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6 309 defined as no (n=1) or yes (n=2). Exercise duration is expressed as hours per week.  
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313 **Figure legend**

314 Figure 1. Cumulative incidence of T2DM in the NGT and IGR groups (log-rank test:

315  $\chi^2=36.905;P<0.0001$ )

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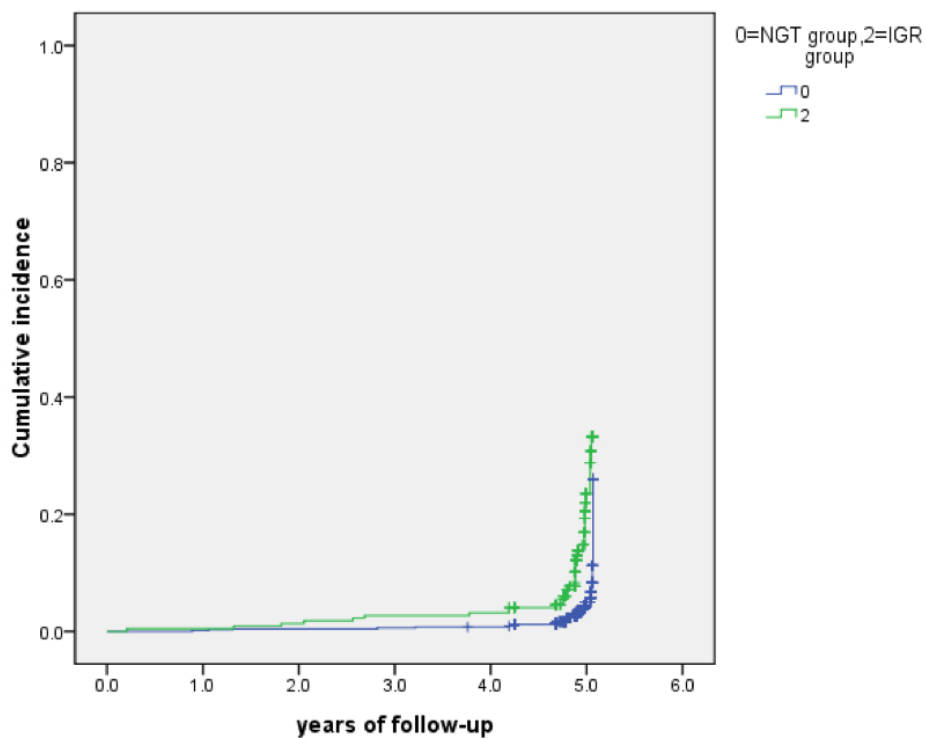


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STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	7
		(b) For matched studies, give matching criteria and number of exposed and unexposed	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, explain how loss to follow-up was addressed (e) Describe any sensitivity analyses	8
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	8
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	8
Outcome data	15*	Report numbers of outcome events or summary measures over time	9

1	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9
2			(b) Report category boundaries when continuous variables were categorized	
3			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
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9	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
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11	<b>Discussion</b>			
12				
13	Key results	18	Summarise key results with reference to study objectives	9
14	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
15				
16	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10
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19	Generalisability	21	Discuss the generalisability (external validity) of the study results	11
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21	<b>Other information</b>			
22	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12
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\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.

# BMJ Open

## Epidemiology and risk factors for diabetes in the suburbs of Beijing: a retrospective cohort study

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<b>Primary Subject Heading</b>:	Epidemiology
Secondary Subject Heading:	Diabetes and endocrinology
Keywords:	General diabetes < DIABETES & ENDOCRINOLOGY, EPIDEMIOLOGY, PUBLIC HEALTH

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4 **1. Epidemiology and risk factors for diabetes in the suburbs of**  
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7 **2 Beijing: a retrospective cohort study**  
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12 4 Lingding Xie\*,<sup>1</sup> Xu Zhao\*,<sup>2</sup> Bo Zhang,<sup>1</sup> Haiqing Zhu <sup>3</sup>  
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4 24 **Abstract**

5 25 **Objective** We aimed to detect the incidence and risk factors of type 2 diabetes  
6 mellitus (T2DM) development in the suburbs of Beijing.  
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10 27 **Design** Cohort study with record linkage to incidence data.

11 28 **Setting** We performed a 5-year follow-up study in a randomly selected suburban  
12 population including 1,114 subjects aged  $\geq 18$  years living in the suburbs of Beijing.  
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16 30 **Participants** 118 subjects with T2DM at baseline according to the 1999 WHO criteria  
17 were excluded, and 895 subjects attended the follow-up assessment in 2012. The non-  
18 diabetic subjects at baseline were classified into two groups: normal glucose tolerance  
19 (NGT) group (n=673) and impaired glucose regulation (IGR) group (n=222). The  
20 incidence and risk factors of diabetes development in each group were investigated.  
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26 32 **Outcome measures** A structured questionnaire about sociodemographic  
27 characteristics, height, weight, waist circumference, hip circumference, blood  
28 pressure, oral glucose tolerance test, and serum lipid levels.  
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33 33 **Results** Out of the 895 non-diabetic subjects, 67 developed diabetes with 29 in the  
34 NGT group and 38 in the IGR group respectively after a 5-year follow-up, producing  
35 an overall 5-year cumulative incidence of diabetes of 13%. The incidence of diabetes  
36 was 15.5 cases per 1000 person-years, 8.9 cases per 1000 person-years in the NGT  
37 group and 35.7 cases per 1000 person-years in the IGR group ( $P < 0.01$ ;  $RR = 4.03$ ;  
38 95%  $CI: 2.58-9.29$ ). Binary logistic regression analysis showed that the risk factors for  
39 diabetes development included fasting plasma glucose (FPG) in the NGT group, and  
40 sex, the waist-to-hip ratio (WHR), FPG and diastolic blood pressure (DBP) in the IGR  
41 group.  
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51 51 **Conclusions:** During a mean follow-up of 5.0 years, the incidence of T2DM in the  
52 suburbs of Beijing was 15.5 per 1000 person-years. Early prevention of diabetes  
53 should focus on IGR subjects. Elevated FPG predicted diabetes development for both  
54 NGT and IGR subjects. Female sex, overweight/obesity and DBP are risk factors for  
55 diabetes development in IGR subjects.  
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### **Strengths and limitations of this study**

- This study is a retrospective cohort survey of the incidence of T2DM and risk factors in the suburbs of Beijing.
- Has a longitudinal design.
- Selects a cohort by multiple-stage sampling at baseline.
- Has a relatively long follow-up period.
- limitations include that many variables assessed as risk factors were not updated regularly, and the data were collected only at the baseline investigation and at the end of the study.

view only

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**66 Introduction**

67 Diabetes mellitus is a clinical syndrome characterized by disordered  
68 glycometabolism. The lack and/or insufficiency of insulin induces metabolic disorders  
69 related to saccharides, lipids, proteins, water and electrolytes, resulting in  
70 hyperglycemia as the main clinical feature. Long-term hyperglycemia leads to  
71 macrovascular and microvascular complications, which may result in disability and  
72 death.<sup>1,2</sup> Diabetes is increasingly prevalent, affecting 463 million (9.3%) adults  
73 worldwide, and these figures are expected to increase to 700 million (10.9%) by  
74 2045.<sup>3</sup> Type 2 diabetes mellitus (T2DM) accounts for over 90% of diabetes cases.  
75 Diabetes, as a leading cause of death,<sup>1,3,4</sup> is becoming a public issue, placing a heavy  
76 burden on the health care system.<sup>5</sup> In 2017 approximately 5 million adult deaths  
77 worldwide were attributed to diabetes,<sup>6</sup> and the global healthcare expenditure  
78 associated with people with diabetes in 2019 was estimated to be USD 760 billion.<sup>7</sup>  
79 Because T2DM is usually asymptomatic, it can remain undiagnosed for many years.  
80 Almost half of all people (50.1%) living with diabetes were undiagnosed in 2019.<sup>3</sup>  
81 Accordingly, screening for prediabetes/T2DM and preventing the evolution of  
82 diabetes in individuals with risk factors are essential. Currently, the risk factors  
83 related to T2DM development may include age, the body mass index (BMI), body fat  
84 distribution, a family history of diabetes, a history of cardiovascular disease (CVD), a  
85 history of gestational diabetes mellitus (GDM), race/ethnicity, diet, physical  
86 inactivity, hypertension, dyslipidemia and prediabetes.<sup>4,8-16</sup> Some studies have  
87 demonstrated that birth weight,<sup>17,18</sup> income,<sup>19</sup> socioeconomic status,<sup>20,21</sup> working  
88 hours,<sup>21,22</sup> occupation<sup>23</sup> and genetic factors<sup>24-26</sup> might also contribute to T2DM  
89 development .  
90 In addition to the process of urbanization, the population aging, changes in lifestyle,  
91 and increasing prevalence of obesity and overweight, the prevalence of diabetes in  
92 China has increased over the past three decades. The prevalence of diabetes in China

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4 93 was 0.67% in 1980,<sup>27</sup> 2.12% in 1995,<sup>28</sup> 5.5% in 2001,<sup>29</sup> 9.7% in 2008,<sup>30</sup> 9.7% in  
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6 94 2010<sup>31</sup> and 10.4% in 2013.<sup>32</sup> As the capital city, limited information is available  
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8 95 regarding the incidence of diabetes and prediabetes in Beijing. Certain studies have  
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10 96 suggested that different diabetic risk patterns might exist in Asian populations.<sup>33-36</sup>  
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12 97 This study aimed to determine the incidence of and risk factors for T2DM among  
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14 98 Chinese adults in the suburbs of Beijing.

## 99 **Materials and Methods**

### 100 **Study population**

101 The study population comprised residents living in the suburbs (Huairou, Pinggu and  
102 Hepingli) of Beijing. We used a multistage, stratified sampling method to randomly  
103 select the three suburbs from the Beijing countryside.<sup>30</sup> The details of its sampling  
104 methods have been described previously.<sup>30</sup> Individuals aged 18 years or older who  
105 were willing to participate and provided informed consent were eligible to participate  
106 in the study. People with a history of diabetes were excluded from the study. Pregnant  
107 women were also excluded from the study.

108 We performed a 5-year retrospective cohort study. The baseline survey occurred from  
109 June 2007 to September 2008 using a random sampling method with a follow-up  
110 examination from May to July 2012. All the subjects were asked to undergo a  
111 personal interview, physical examination and blood test [including an oral glucose  
112 tolerance test (OGTT)]. Subjects diagnosed as diabetes by OGTT at baseline were  
113 excluded. The nondiabetic subjects at baseline were divided into the normal glucose  
114 tolerance (NGT) group and impaired glucose regulation (IGR) group according to  
115 OGTT. We analyzed the incidence and risk factors of diabetes development in each  
116 group. Diabetes mellitus was defined according to the 1990 WHO criteria or self-  
117 reported prior diagnosis of diabetes with current medication use. IGR was determined  
118 if the subjects had a fasting plasma glucose (FPG) level of 6.1–6.9 mmol/L and/or a  
119 2-hour plasma glucose level of 7.8–11.0 mmol/L. NGT was defined as FPG less than  
120 6.0mmol/L and a 2-hour plasma glucose level less than 11.1mmol/L.

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4 121 **Data collection**

5 122 **Sociodemographic characteristics**—The data were collected by trained staff using a  
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8 123 structured questionnaire via a face-to-face interview to assess general information  
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10 124 (sex, age, nationality, education status, occupation, and per capita income), personal  
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12 125 history (smoking history, alcohol history, physical activity, and dietary habits), family  
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14 126 history (diabetes mellitus, hypertension, hyperlipidemia, myocardial infarction,  
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16 127 stroke, and obesity), and history of current illness (diabetes, hypertension,  
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18 128 hyperlipidemia, cardiovascular, cerebrovascular diseases, and kidney diseases).  
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20 129 Subjects who were diagnosed with T2DM between recruitment and the end of follow-  
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22 130 up were asked to report the date of diagnosis.

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24 131 **Anthropometric measurements** — The subjects were examined for height, weight,  
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26 132 waist circumference (WC), hip circumference (HC) and blood pressure. All the  
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28 133 subjects were asked to remove their shoes, socks, hats and coats, stand erectly and  
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30 134 look forward with their arms relaxed and their heels together. Height was measured in  
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32 135 centimeters using a height bar, and weight was measured in kilograms using a digital  
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34 136 weighing scale. The WC is the circumference of the waist at the horizontal line of the  
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36 137 umbilicus measured in centimeters using a measuring tape, and the HC is the  
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38 138 circumference of hips at the horizontal line of the anterior superior spine measured in  
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40 139 centimeters using a measuring tape. The BMI was calculated as weight in kilograms  
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42 140 divided by the square of height in meters ( $\text{kg}/\text{m}^2$ ), while the waist-to-hip ratio (WHR)  
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44 141 was calculated as WC (cm) divided by HC (cm). The blood pressure values used were  
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46 142 an average of three measurements, which were measured 2 min apart using a mercury  
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48 143 sphygmomanometer. The subjects were asked to stop smoking and consuming alcohol  
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50 144 the day before the examination and to sit quietly in a chair for at least 5 minutes  
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52 145 before the measurement with their arms bare and placed at the chest level. All the  
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54 146 clinical staff members were trained to measure blood pressure and obtain  
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56 147 anthropometric measurements.  
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4 148 **Laboratory examination** —All the subjects were invited to undergo a blood test  
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6 149 (including an OGTT) at baseline. The nondiabetic subjects at baseline undergo a  
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8 150 secondary blood test (including an OGTT) at the end of follow-up. Venous blood  
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10 151 samples after 8–14 hours of fasting were obtained from the subjects to measure FPG,  
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12 152 total cholesterol (TC), triglycerides (TGs), high-density lipoprotein cholesterol (HDL-  
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14 153 C) and low-density lipoprotein cholesterol (LDL-C). Venous blood samples, after a  
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16 154 75 g oral glucose load, were obtained to measure the 2-hour plasma glucose (PG2h).  
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18 155 The subjects were instructed to maintain normal physical activity without dietary limit  
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20 156 (the intake of saccharides should be no less than 150 g per day) before proceeding  
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22 157 with the OGTT.

### 23 24 158 **Statistical analysis**

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26 159 We used the P-P plot to test the normality of the numerical variables. The differences  
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28 160 in continuous and categorical variables between the NGT and IGR groups were  
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30 161 examined using t test and the  $\chi^2$  test statistic, respectively. Kaplan–Meier survival  
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32 162 estimates were used to calculate the 5-year cumulative incidence of T2DM. The log-  
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34 163 rank test was used to compare the survival curves. The Mantel–Haenszel  $\chi^2$  test of  
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36 164 trends was used to analyze the ordinal data. Binary logistic regression analyses were  
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38 165 used to estimate the odds ratio and 95% confidence interval for diabetes development.  
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40 166 All the analyses were performed using SPSS statistical software version 17.0, and a P  
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42 167 value<0.05 was considered statistically significant.

### 43 44 168 **Patient and Public Involvement**

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46 169 Patients or the public were not involved in the design, or conduct, or reporting, or  
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48 170 dissemination plans of our research.

### 49 50 171 **Results**

#### 51 52 172 **Characteristics of the study population at baseline**

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54 173 In total, 1,114 residents participated in the study, and 1,014 subjects completed the  
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56 174 follow-up, with an overall response rate of 91.0%. After eliminating 118 subjects who  
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58 175 were diagnosed with diabetes by OGTT at baseline and one subject with severe data  
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4 176 deficiency, 895 subjects (308 men and 587 women) with a mean age of 48.1±11.9  
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6 177 years were included in the analysis, with 673 in the NGT group and 222 in the IGR  
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8 178 group. The baseline characteristics of the 895 subjects in the study are shown in Table  
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10 179 1. Continuous variables were expressed as means±standard deviation (sd) and were  
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12 180 examined using a t test, while categorical variables were expressed as percentages and  
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14 181 were examined using the  $\chi^2$  test. No significant difference was found between the  
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16 182 NGT group and the IGR group in sex, height, family history of T2DM, smoking  
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18 183 history, alcohol history, exercise time, diastolic blood pressure (DBP) or HDL-C.  
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20 184 Age, weight, BMI, WC, WHR, systolic blood pressure (SBP), FPG, PG2h, TGs, TC  
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22 185 and LDL-C in the IGR group were significantly higher than those in the NGT group.

### 186 **Incidence of T2DM**

187 During the follow-up, T2DM developed in 67 subjects, 29 in the NGT group and 38  
188 in the IGR group, resulting in T2DM onset rates of 15.45, 8.86 and 35.67 per 1,000  
189 person-years in the total study population, NGT group and IGR group, respectively  
190 (Table 2). The difference in the incidence of T2DM between the NGT group and IGR  
191 group was statistically significant ( $\chi^2=37.38$ ;  $P<0.01$ ;  $RR=4.03$ ; 95% CI: 2.58-9.29).  
192 The 5-year cumulative incidence of T2DM was 13%, with 10% in the NGT group and  
193 20% in the IGR group. The mean follow-up duration was 5.008 years (SE=0.013;  
194 95% CI: 4.982–5.033), with 5.003 years (SE=0.012; 95% CI: 5.010–5.056) in the  
195 NGT group and 4.933 years (SE=0.038; 95% CI: 4.859–5.007) in the IGR group.  
196 Using the log-rank test, we found that the cumulative incidence of T2DM in the IGR  
197 group was significantly higher than that in the NGT group ( $\chi^2=36.905$ ;  $P<0.0001$ ).  
198 The results of the Kaplan–Meier survival analyses are shown in Figure 1.

### 199 **Analyses of the risk factors for diabetes development**

200 The results of binary logistic regression analyses for T2DM development in the NGT  
201 and IGR groups are shown in Table 3. FPG contributed to T2DM development in the  
202 NGT group, and the OR was 6.111 (1.379, 27.070;  $P=0.017$ ). Sex, WHR, DBP, and  
203 FPB contributed to T2DM development in the IGR group, and the ORs were 7.293

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4 204 (1.074, 49.549; P=0.042), 2.874E8 (8.386, 9.847E15; P=0.028), 1.068 (1.009, 1.130;  
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6 205 P=0.024) and 7.243 (2.314, 22.673; P=0.001), respectively. The increase in exercise  
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8 206 time slightly decreased the risk of T2DM in the IGR group, with an OR of 0.923  
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10 207 (0.847, 1.005; P=0.066).

## 11 208 **Discussion**

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14 209 The prevalence of diabetes mellitus has been increasing markedly in recent decades.  
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16 210 Among adults aged 20–79 years in 2019, there were an estimated 463 million cases of  
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18 211 diabetes<sup>3</sup>. However, the striking prevalence may be partly attributable to the increase  
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20 212 in population and prolongation of the life-span.<sup>37</sup> Accordingly, we studied the  
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22 213 growing trend of T2DM by investigating the cumulative incidence of T2DM. Our  
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24 214 results showed that 15.45 new cases of diabetes per 1,000 people-years were  
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26 215 diagnosed during the five-year observation period (2007–2012). This marked trend is  
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28 216 consistent with diabetes incidence rates worldwide, such as those described in the  
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30 217 ATTICA study in Greece (12.9 cases per 1,000 person-years from 2002 to 2012)<sup>38</sup>  
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32 218 and those described in a study conducted in Mexico (12.7 cases per 1,000 person-  
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34 219 years from 1990 to 2008).<sup>39</sup> The incidence rate found in our study is lower than that in  
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36 220 a study of Pima Indians (23.5 cases per 1,000 person-years during 1991 to 2003)<sup>40</sup> and  
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38 221 in a study conducted in northern Spain (95.2 cases per 1,000 person-years during  
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40 222 1998 to 2005)<sup>41</sup> and is higher than that observed in a study conducted in Iran (10.6  
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42 223 cases per 1000 person-years from 1999 to 2011)<sup>42</sup> and in the SUPREME-DM project  
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44 224 in the USA (11.5 cases per 1000 person-years from 2006 to 2011).<sup>43</sup> The T2DM  
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46 225 incidence in the suburbs of Beijing is higher than that identified in the investigation  
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48 226 conducted by Wang C et al in a Chinese population in 2010 (9.5 cases per 1000  
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50 227 person-years in men and 9.2 in women).<sup>44</sup> This difference may partly be due to the  
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52 228 relatively higher standard of living in the suburbs of Beijing.  
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54 229 Diabetes development is based on the interaction between genes and lifestyle and  
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56 230 environmental factors.<sup>45,46</sup> Compared with the NGT group that had an incidence of  
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58 231 8.86 cases per 1,000 person-years, the IGR group (35.67 cases per 1,000 person-  
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4 232 years) had a higher incidence rate (RR=4.03;95% CI: 2.58–9.29;P<0.01). In our  
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6 233 study, diabetes development was mainly the consequence of elevated FPG in the NGT  
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8 234 group. Diabetes development was mainly associated with sex (female), abnormal  
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10 235 WHR, elevated DBP and elevated FPG in the IGR group. The increase in the FPG  
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12 236 level was a strong predictor of diabetes development in both the NGT group and IGR  
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14 237 group, with 6.111- and 7.243-fold increased risk per unit increase, respectively.  
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16 238 In our study, the WHR measurement was found to predict diabetes risk. Some studies  
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18 239 have declared that WHR, as an obesity indicator, is superior to BMI and WC.<sup>47,48</sup> A  
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20 240 meta-analysis demonstrated that either BMI or WC (WHR) predicted or was  
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22 241 independently associated with type 2 diabetes, regardless of the controversial findings  
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24 242 regarding which was better.<sup>49</sup>  
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26 243 Age and family history of diabetes are considered risk factors for diabetes  
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28 244 development.<sup>4,8-16</sup> However, we found only an increasing trend of diabetes  
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30 245 development in the elderly population and subjects with a family history of diabetes  
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32 246 (P>0.05). This finding might be related to the short period of follow-up and the  
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34 247 subjects' unawareness of their family history of diabetes.  
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36 248 There is evidence that T2DM can be prevented in high-risk individuals by a lifestyle  
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38 249 program of regular exercise.<sup>50,51</sup> Surprisingly, our study found that exercise did not  
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40 250 exert a beneficial effect on diabetes incidence, a finding similar to that in the ATTICA  
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42 251 study.<sup>38,52</sup> However, we found a decreasing trend in the diabetes incidence with  
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44 252 increasing exercise time. The increase in exercise time slightly decreased the risk of  
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46 253 T2DM in the IGR group, with an OR of 0.923 (0.847, 1.005; P=0.066).  
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48 254 The strength of our study is that it was based on a cohort selected by multiple stage  
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50 255 sampling at baseline with a relatively long follow-up period. A limitation is that many  
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52 256 variables assessed as risk factors were not updated regularly, and might have changed  
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54 257 during the follow-up period. Secondly, the follow-up could not be random due to the  
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56 258 limitations of the conditions. Additionally, the data were collected only at the baseline  
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58 259 investigation and at the end of the study.  
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## 260 **Conclusions**

261 During a mean follow-up of 5.0 years, the incidence of T2DM in the suburbs of  
262 Beijing was 15.45 cases per 1000 person-years, which was relatively higher than that  
263 in many other areas worldwide. Compared with the NGT subjects, the IGR subjects  
264 were more susceptible to T2DM. To prevent diabetes development, all the subjects  
265 should be evaluated for elevated FPG. Additionally, sex, WHR, and DBP were  
266 predictors of T2DM in IGR subjects.

267 The findings in this study provide new data on the incidence of T2DM in the Beijing  
268 area. The predictors of T2DM reported in the present study may be conducive to  
269 formulating a protocol for diabetes prevention.

## 270 **Authors' contributions**

271 Conceptualization, B.Z.; Data curation, H.Z.; Formal analysis, H.Z.; Investigation,  
272 L.X. and X.Z.; Methodology, B.Z.; Project administration, L.X., X.Z. and B.Z.;  
273 Writing – original draft, L.X. and X.Z.; Writing – review & editing, B.Z.. All authors  
274 read and approved the final manuscript, as well as the submission of this work. B.Z.  
275 supervised and managed the data. B.Z. is the guarantor of this work.

## 277 **Conflicts of interest**

278 The authors declare that they have no conflicts of interest.

280 **Competing interests** None declared.

## 282 **Funding statement**

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284 Technology Support Program (2009BAI80B04).

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286 **Ethics approval**

287 Ethical approval was obtained from the Ethics Committee of Clinical Trials of  
288 Drugs/Devices in China-Japan Friendship Hospital (2011-049).

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290 **Data availability statement**

291 All data included in this study are available from the corresponding author on  
292 reasonable request.

293

295 **Table 1 Comparison of the characteristics of the NGT and IGR subjects at**  
 296 **baseline**

Variable at baseline	NGT group (n=673)	IGR group (n=222)	t or $\chi^2$ , <i>P</i> value
Sex(%male)	34.9	32.9	0.306, 0.625
Age (years)	46.75±11.57	52.01±12.03	-5.813, <0.001
Height (cm)	161.85±7.94	161.18±7.83	1.092, 0.275
Weight (kg)	64.32±10.75	67.49±11.05	-3.777, <0.001
BMI (kg/m <sup>2</sup> )	24.52±3.40	25.93±3.50	-5.332, <0.001
WC (cm)	83.04±9.75	86.82±9.20	-5.075, <0.001
WHR	0.87±0.07	0.89±0.06	-3.495, <0.001
SBP (mmHg)	119.71±18.37	125.18±20.13	-3.582, <0.001
DBP (mmHg)	78.02±11.21	79.75±12.66	-1.843, 0.066
FPG (mmol/L)	5.25±0.42	5.82±0.61	-15.875, <0.001
PG2h (mmol/L)	5.90±1.01	8.29±1.52	-26.692, <0.001
TGs (mmol/L)	1.42±1.17	1.61±1.08	-2.165, 0.031
TC (mmol/L)	4.56±0.92	4.84±0.95	-3.865, <0.001
HDL-C (mmol/L)	1.35±0.34	1.34±0.36	0.464, 0.643
LDL-C (mmol/L)	2.77±0.77	3.08±0.81	-4.648, <0.001
Exercise duration (hours)	5.85±11.81	5.59±8.06	0.305, 0.761
FH of T2DM (%)	15.5	21.4	3.722, 0.068
Smoking history (%)	22.4	20.7	0.286, 0.641
Alcohol history (%)	27.9	28.8	0.076, 0.796
Years of follow-up (year)	4.85±0.32	4.79±0.56	2.081, 0.038

297 BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; SBP,  
 298 systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose;

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299 PG2h, 2-hour plasma glucose; TC, total cholesterol; TGs, triglycerides; HDL-C, high-  
300 density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; FH,  
301 family history. Exercise duration is expressed as hours per week.  
302

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303 **Table 2. Incidence of T2DM during the follow-up**

	Cases of diabetes	Follow-up (person- years)	Incidence (per 1,000 person-years)
NGT group	29	3,271.5	8.86
IGR group	38	1,065.3	35.67
Total	67	4,336.8	15.45

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306 **Table 3. Multivariate logistic regression model for T2DM development**

	NGT group		IGR group	
	OR (95% CI)	<i>P</i> value	OR (95% CI)	<i>P</i> value
Sex	0.375 (0.067, 2.103)	0.265	7.293 (1.074, 49.549)	0.042
Age (years)	1.013 (0.962, 1.068)	0.615	1.019 (0.964, 1.077)	0.499
Weight (kg)	1.044 (0.927, 1.175)	0.478	1.056 (0.929, 1.200)	0.402
BMI (kg/m <sup>2</sup> )	0.934 (0.653, 1.336)	0.710	0.971 (0.661, 1.427)	0.881
WC (cm)	1.073 (0.936, 1.230)	0.311	0.904 (0.748, 1.092)	0.295
WHR	0.006 (0.000, 7058.081)	0.473	2.874E8 (8.386, 9.847E15)	0.028
SBP (mmHg)	1.013 (0.976, 1.052)	0.492	0.992 (0.958, 1.026)	0.637
DBP (mmHg)	0.955 (0.890, 1.024)	0.198	1.068 (1.009, 1.130)	0.024
FPG (mmol/L)	6.111 (1.379, 27.070)	0.017	7.243 (2.314, 22.673)	0.001
TC (mmol/L)	2.719 (0.917, 8.067)	0.071	0.814 (0.141, 4.699)	0.818
TGs (mmol/L)	0.996 (0.589, 1.684)	0.989	0.926 (0.491, 1.749)	0.813
HDL-C (mmol/L)	2.536 (0.519, 12.395)	0.250	0.622 (0.071, 5.460)	0.669
LDL-C (mmol/L)	0.604 (0.206, 1.769)	0.358	1.070 (0.181, 6.321)	0.941
Exercise duration (hours)	1.013 (0.947, 1.084)	0.707	0.923 (0.847, 1.005)	0.066
FH of T2DM	1.868 (0.492, 7.090)	0.358	2.062 (0.656, 6.478)	0.215
Smoking history	0.766 (0.186, 3.162)	0.713	1.591 (0.346, 7.317)	0.551
Alcohol history	0.726 (0.202, 2.610)	0.624	1.685 (0.458, 6.203)	0.432

307 BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; SBP,  
308 systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose;  
309 TC, total cholesterol; TGs, triglycerides; HDL-C, high-density lipoprotein cholesterol;  
310 LDL-C, low-density lipoprotein cholesterol; FH, family history. Sex is defined as  
311 male (n=1) or female (n=2), FH of T2DM is defined as no (n=1) or yes (n=2),

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6 313 defined as no (n=1) or yes (n=2). Exercise duration is expressed as hours per week.  
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317 **Figure legend**

318 Figure 1. Cumulative incidence of T2DM in the NGT and IGR groups (log-rank test:

319  $\chi^2=36.905;P<0.0001$ )

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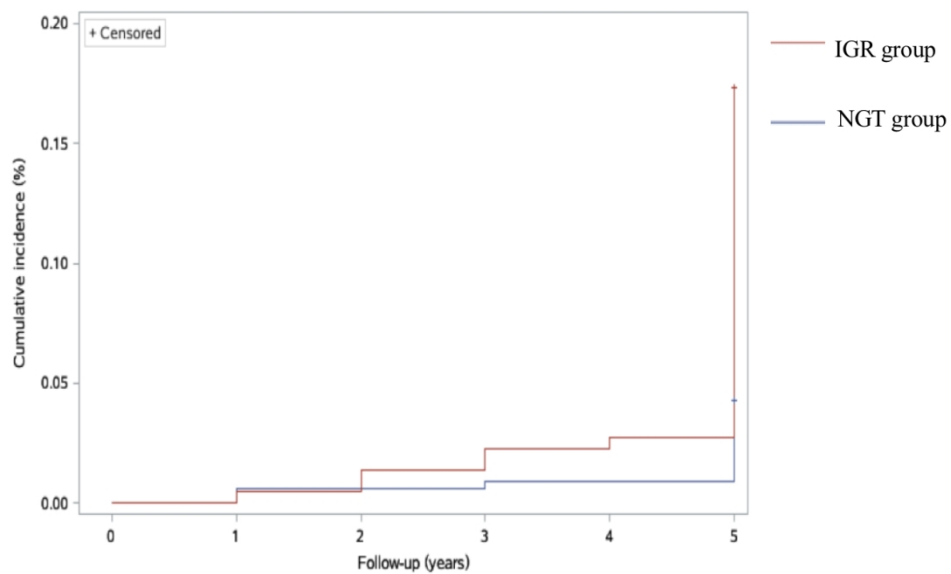
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STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

	Item No	Recommendation	Page No
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	7
		(b) For matched studies, give matching criteria and number of exposed and unexposed	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) If applicable, explain how loss to follow-up was addressed (e) Describe any sensitivity analyses	8
<b>Results</b>			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	8
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	8
Outcome data	15*	Report numbers of outcome events or summary measures over time	9

1	Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9
2			(b) Report category boundaries when continuous variables were categorized	
3			(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
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9	Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9
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11	<b>Discussion</b>			
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13	Key results	18	Summarise key results with reference to study objectives	9
14	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
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16	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10
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19	Generalisability	21	Discuss the generalisability (external validity) of the study results	11
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21	<b>Other information</b>			
22	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12
23				
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\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at <http://www.strobe-statement.org>.