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Original article

Seasonality and temperature effects on fasting plasma glucose: A population-based longitudinal study in China

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Abstract

Aims. – To examine the seasonality and effects of temperature on levels of fasting plasma glucose (FPG).

Methods. – We collected health data from the Kailuan cohort study. FPG, blood pressure and individual information including age, gender, body mass index, smoking status, drinking habit, physical activities, income, work type, education level, and history of diabetes, were collected for each participant. Daily weather conditions were collected during the study period of 2006–2011. A total of 49,417 participants who had three times of health examination were included to the analyses. Generalized additive mixed models were used to examine the effects of temperature and seasonality on FPG levels, while controlling for potential confounders.

Results. – FPG level was higher in winter and spring than that in autumn and summer. For all participants, the FPG winter level increased 0.31 mmol/L [95% confidence interval (CI), 0.28–0.33 mmol/L] in comparison with autumn. The association between temperature and FPG levels was U-shaped. For all participants, the change in FPG levels associated with extreme cold temperature (−6.7 °C), moderate cold temperature (2.4 °C), moderate hot temperature (23.7 °C), and with extreme hot temperature (28.1 °C), in comparison with threshold (18.1 °C) were 0.12 mmol/L (95% CI: 0.10–0.14 mmol/L), 0.10 (95% CI: 0.09–0.12 mmol/L), 0.06 (95% CI: 0.04–0.08 mmol/L), and 0.12 mmol/L (95% CI: 0.08–0.16 mmol/L), respectively.

Conclusion. – The findings suggest that there may be strong relationships between FPG levels and season and ambient temperature. In particular, there were higher FPG levels in the winter and at extreme cold and hot temperatures.

Keywords: Diabetes; Fasting plasma glucose; Seasonality; Temperature effect

1. Background

The fasting plasma glucose (FPG) test is commonly used in the diagnosis of diabetes, which requires people to avoid food consumption at least 8 h before measurement. It is usually performed in the morning, and the presenting level is essential in determining the amount of glucose in the blood [1]. Besides diabetes, which is the most prominent disease triggered by the failure of blood glucose regulation, blood glucose concentration outside the normal range is a predictor of many

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other health problems, such as cardiovascular disease, renal dysfunction, neurological damage and tumour [2–5]. In addition, higher FPG levels below diabetic threshold (7 mmol/L) have been shown to be associated with an increased risk of stroke and myocardial infarction [6]. Conditions influencing a person's blood glucose homeostasis include but are not limited to nutrient intake, alcohol use, physical activity, stress, medications (e.g., insulin injection), illness, and certain state of health such as women's menstrual cycle or pregnancy [7]. In addition, genes are associated with blood glucose levels [8].

Studies have recognised the seasonality in mortality and morbidity of diseases, including diabetes, cardiovascular and respiratory diseases [9–11]. Many attempts have been made to understand this seasonality and to reduce the elevated winter risk of mortality and morbidity, exploring the seasonality in various biomarkers, such as lipids, fibrinogen, and blood pressure [12–16]. A few studies have reported that FPG level was highest in winter among diabetes patients [12,13]. However, no study has been conducted to examine the seasonality in FPG in China, especially for population without diabetes.

In addition, short-term changes in the levels of biomarkers were used to explain the increased risk of health events after exposure to extreme cold and hot ambient temperatures [17]. However, studies on the daily variation of blood glucose driven by ambient temperature changes are limited, although extreme ambient temperatures are associated with the increased risks of daily diabetes mortality [18]. Here, therefore, we report our results on the seasonal variability of FPG levels and the relation with ambient temperature during 2006–2011 in the Kailuan cohort, China.

2. Methods

2.1. Study design and population

The Kailuan study [19] is a prospective community-based cohort study on the workforce of Kailuan Group in Tangshan city, China. Tangshan is a large and modern industrial city located to the southeast of Beijing. The Kailuan community is owned and managed by Kailuan Group, which is a well-known Chinese state-run coal mining enterprise. There are 11 hospitals affiliated to the Kailuan Group responsible for health services of the community. All inhabitants in the community have cost-free medical examinations biennially in these hospitals, including physical examination, and routine blood, urine and biochemical tests. From June 2006 to October 2007, we invited 155,418 residents (current and retired employees of Kailuan Group) with ages of 18 years or above to participate in the study. Among them, a total of 101,510 employees (81,110 men and 20,400 women, 18–98 years of age) agreed and provided written informed consent. They built up the baseline of the Kailuan cohort, during 2006–2007.

The participants were followed up every 2 years after 2007. At baseline and at each follow-up, all participants underwent questionnaire assessment, anthropometric measurement, and health examination (including physical examination and laboratory assessment). The date for health examination was random for each participant, which means the follow-up times for participants might be in different seasons. We employed standard protocols in all the measurements, which were administered by specially trained doctors and nurses. The protocol was approved by the Ethics Committee of Kailuan General Hospital, Beijing Tiantan Hospital, and Beijing Chaoyang Hospital. The study was performed in compliance with the guidelines of the Helsinki Declaration. Written informed consents were obtained from all participants. Each participant was followed up three times during 2006 and 2011. Finally, a total of 49,417 participants who did not have any missing values and had participated three health examinations were included in our study.

2.2. Questionnaire assessment

Well-trained research doctors and nurses administered questionnaires face-to-face. Information obtained included demographic and socioeconomic variables. These variables included age, gender, educational attainment (illiteracy, primary, junior, senior, and diploma or higher), household income (< 600 RMB, 600–800 RMB, 801–999 RMB, and ≥ 1000 RMB per person per month), and marital status (never married, married, divorced, widowed, and remarried), alcohol use (never, former, occasional, and every day), smoking status (never, former, occasional, and every day), physical exercise (none, occasional, and often), work type (office worker and physical worker), salt intake (light salt [salt < 6 g per day], moderate salt [salt 6–12 g per day], and salty [salt > 12 g per day]], history of disease (including diabetes, hypertension, stoke, etc.), and medication use (e.g., diabetes, hypertension, etc.). Adverse events (death, or incidence of disease) in the follow-up years were also collected by questionnaire.

2.3. Anthropometric measurement

Anthropometric indices included height and weight. All the individuals were measured wearing light clothing without shoes and hats. Height was measured to the nearest 0.1 cm using a portable stadiometer and weight was measured to the nearest 0.1 kg using calibrated platform scales. Body Mass Index (BMI, kg/m^2) was calculated as body weight (kg) divided by the square of height (m^2).

2.4. FPG assessment

Blood samples were collected from the antecubital vein in the morning after an overnight fasting period (> 8 h) and transfused into vacuum tubes containing Ethylene Diamine Tetraacetic Acid (EDTA). Tubes were centrifuged at 3000 × g for 10 minutes at room temperature. After separation, plasma samples were frozen as rapidly as possible to −80 °C for storage until laboratory determinations were performed within 4 h. FPG was measured with the hexokinase/glucose-6-phosphate dehydrogenase method. All blood samples were processed and analysed using an auto-analyser (Hitachi 747; Hitachi, Tokyo, Japan) at the central laboratory of Kailuan General Hospital.