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Original Article

Long-term impact of earthquake stress on fasting glucose control and diabetes prevalence among Chinese adults of Tangshan

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Abstract: Objective: To investigate the long-term influence of stresses from the 1976 Tangshan earthquake on blood glucose control and the incidence of diabetes mellitus in Chinese people of Tangshan. Methods: 1,551 adults ≥ 37 years of age were recruited for this investigation in Tangshan city of China, where one of the deadliest earthquakes occurred in 1796. All subjects finished a questionnaire. 1,030 of them who experienced that earthquake were selected into the exposure group, while 521 were gathered as the control group who have not exposed to any earthquake. The numbers of subjects who were first identified with diabetes or had normal FBG but with diabetic history were added for the calculation of diabetes prevalence. Statistic-analysis was applied on the baseline data, and incidences of IFG as well as diabetes among all groups. Results: Statistic comparisons indicate there is no significant difference on average fasting glucose levels between the control group and the exposure group. However, the prevalence of IFG and diabetes among the exposure group displays significant variance with the control group. The prevalence of diabetes among exposure groups is significantly higher than the control group. Women are more likely to have diabetes after experiencing earthquake stresses compared to men. The earthquake stress was linked to higher diabetes incidence as an independent factor. Conclusions: The earthquake stress has long-term impacts on diabetes incidence as an independent risk factor. Emerging and long-term managements regarding the care of IFG and diabetes in populations exposed to earthquake stress should be concerned.

Keywords: Tangshan earthquake, stress, fasting blood glucose, impaired fasting glucose, diabetes mellitus

Introduction

Stress is a wide range of physiological responses to environmental stimuli and usually accompanied with various hormone releases from the body, such as catecholamine and endogenous opiates. Those hormones are found with the ability to elevate circulating blood glucose levels [1, 2], which is the main characterization of diabetes mellitus. Thus, theoretically, a link between stress and diabetes may exist. Over decades, researchers have been attempting to prove this linkage and understand the underlying mechanisms [1-4]. Their studies have been well reviewed and discussed in the paper by Kraner JR, et al [5], concluding that the major weakness of previous studies is without mirroring stresses from the real world of their subjects.

Nature disasters, like earthquakes, provide good examples of acute and chronic stresses from the real world. The long-term impact of earthquake stresses on the incidence of diabetes remains uncharacterized, although the immediate effect of earthquake on diabetic patients has been explored [6, 7]. The 1976 Tangshan earthquake hit north of China with the epicenter at the city of Tangshan on July 28, 1976, killed hundreds of thousands of people, and put all the survivors in dramatic trauma stresses, such as severe damage of their houses and permanent loss of their relatives.

The objective of this study is to investigate the long-term impact of stresses from the 1976 Tangshan earthquake on the occurrences of impaired fasting glucose (IFG) and diabetes mellitus among those survivors. The association of stress from relative loss in that earthquake with IFG and onset of diabetes is also explored.

Methods

Study participants

Our data were derived from the database of Kailuan Medical Examination Center, and included Kailuan workers who had physical examinations from September 2013 to December 2013 in this center. The subjects were divided to exposure group and control group, based on whether they had experienced the 1976 Tangshan Earthquake. The inclusion criteria for the exposure group were that subjects had experienced the Tangshan Earthquake in 1976, with the age between 37 and 60 years old. Of the 1043 subjects in the exposure group, 13 were excluded from the final analysis with 3 participants having secondary diabetes and 10 with loss of blood glucose results. The number of exposed subjects included in the analysis was 1030. We divided these subjects to two subgroups, relative-lost group (509) and relative-unlost group (521), according to whether they had relatives lost in the earthquake. The average age was 45 years old in both subgroups. Subjects in the control group were selected from those who had physical examinations from September 2013 to December 2013, aged between 37 to 60 years old and had not experienced the Tangshan Earthquake, and matched with the exposure group in age. The average age of 521 subjects in the control group was 46 years old.

Patients with acute disease, trauma surgery, severe liver disease, secondary diabetes and diagnosed mental disease were excluded from the study. Subjects who had experienced some huge unfortunate accidents were also excluded. No pregnant women were included in the study.

The study was approved by the Research Ethics Board of First Affiliated Hospital of Hebei Medical University. All subjects signed their informed consents with a research staff before enrollment.

Questionnaires

The questionnaire we used was designed based on the life event scale (LES), which included the especially stressful events in life that would have a severe and long-time impact on people. Some of the most stressful events were death of spouse, parent or child, divorce, lost of job, difficulty in financial state, accident or natural disaster (e.g., fire, flood), being robbed or hijacked, etc. The questionnaire was finished by subjects all with the guidance of investigators, who received unified professional trainings. During answering the questions, the subjects with memory deterioration gained assistance from their accompanying relatives to remove the potential bias.

Medical examination

The items measured in the medical examination included: height, weight, waist, body mass index (BMI = weight/height^2) (kg/m^2) and blood pressure. Blood pressure was recorded after the subject had sat quietly for at least five minutes. Emptying of bladder was required. No caffeine or tobacco products were allowed for at least 30 minutes before blood pressure measurement.

Clinical index

Fasting blood glucose (FBG) was tested with blood samples drawn after overnight starvation for 8-10 hours without food intake except water. IFG was defined as an intermediate level between normal and diabetic glucose levels, reflecting the impairment of glycemic regulation on FBG level. The standard to determine IFG was based on the criteria (5.6 mmol/L $\leq$ FBG < 7 mmol/L) modified by ADA in 2003 [8]. The FBG level was also utilized to identify whether the subject has diabetes according to the criteria (FBG $\geq$ 7.0 mmol/L) introduced by the American Diabetes Association (ADA) in 1999 [9]. Measures for blood fat levels were applied on total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C).

Statistical analysis

The dataset of oracle 10.2 was created using two-server data entry and edit checks, and was output as a DBF file. The software of SPSS 13.0 was used to perform statistical analysis on the data. One-way ANOVA was performed to compare the continuous variables over the three groups. Fisher's Least Significant Difference (LSD) procedure was used to conduct pairwise

Table 1. Baseline characteristics of study subjects

Characteristics	Mean (SD)/Frequency (%)			F/χ^2	*P* value
	Relative-unlost (n = 521)	Relative-lost (n = 509)	Control (n = 521)		
Age (years)	45 ± 7	45 ± 8	46 ± 8	2.046	0.130
Gender				35.034	< 0.0001
Female	166 (31.9%)	172 (33.8%)	97 (18.6%)		
Male	97 (18.6%)	337 (66.2%)	42 (81.4%)		
Education				36.273	< 0.0001
Primary school	33 (6.3%)	24 (4.7%)	26 (4.9%)		
Middle school	305 (58.5%)	342 (67.2 %)	315 (60.4%)		
High school	118 (22.6%)	108 (21.2%)	87 (17.0%)		
Undergraduate and above	62 (11.9%)	34 (6.6%)	91 (17.4%)		
Waist (cm)	84.6 ± 10.2	84.9 ± 10.1	85.8 ± 10.3	2.045	0.130
BMI (kg/m^2)	24.7 ± 3.5	24.8 ± 3.5	25.0 ± 3.2	1.092	0.336
SBP (mmHg)	120.4 ± 17.7	121.2 ± 19.1	122.4 ± 17.9	1.575	0.207
DBP (mmHg)	78.2 ± 9.8	78.7 ± 10.7	79.8 ± 10.5	3.312	0.037
Family history of diabetes				0.411	0.663
Yes	43(8.2%)	35 (6.9%)	37 (7.1%)		
No	478 (91.8%)	474 (93.1%)	484 (92.9%)		
Smoker				0.078	0.962
Yes	277 (53.1%)	272 (53.4%)	274 (52.6%)		
No	244 (46.8%)	237 (46.6%)	247 (47.4%)		
Alcohol consumption				9.261	0.159
Never	207 (39.7%)	207 (40.7 %)	185 (35.5%)		
Used to	22 (4.2%)	18 (3.5%)	18 (3.5%)		
Occasionally	189 (36.3%)	158 (31.0%)	185 (35.5%)		
Daily	103 (19.8%)	126 (24.8%)	133 (25.5 %)		
Exercise				4.399	0.355
Yes	473 (90.8%)	472 (92.7%)	480 (92.1%)		
No	48 (9.2%)	37 (7.3%)	41 (7.9%)		
LgTG[a]	44.59 ± 8.70	44.61 ± 7.68	43.58 ± 7.72	3.065	0.252
TC (mmol/L)[b]	5.12 ± 0.97	5.09 ± 0.87	5.00 ± 1.19	2.050	0.129
LDL-C (mmol/L)[c]	2.15 ± 0.57	2.15 ± 0.56	2.25 ± 0.62	5.065	0.006
HDL-C (mmol/L)[d]	1.54 ± 0.35	1.57 ± 0.37	1.54 ± 0.39	0.909	0.403

[a]Logarithm of triglyceride; [b]Total cholesterol; [c]low-density lipoprotein cholesterol; [d]high-density lipoprotein cholesterol.

comparison. Logarithm transformation was applied to triglyceride levels because normality was not met. For the dichotomous and categorical variables, Pearson's chi-squared test was performed across groups. Finally, we conducted logistic regression analysis to determine the significant predictors for the incidence of diabetes.

Results

Characteristics of study subjects

The characteristics of participants collected 37 years after the Tangshan Earthquake are shown in **Table 1**. The study consisted of 1551 randomly selected adults, aged between 37 to 54 years old. Most of the participants were men with education less than undergraduate and no family history of diabetes, who drank alcohol and didn't take a lot of physical exercise.

Most of the characteristics listed below did not differ across the three cohorts (P > 0.05), except for the gender, education level and average diastolic blood pressure (P < 0.0001 for gender; P < 0.0001 for education level; P = 0.037 for DBP). The proportion of subjects with undergraduate degree for the control group

Table 2. FBG, incidence of IFG and incidence of diabetes in three groups

Predictor	Exposed		Control	F/χ²	P
	Relative-unlost (n = 521)	Relative-lost (n = 509)	(n = 521)		
Fasting blood glucose (mean ± SD)	5.4 ± 1.3	5.2 ± 1.7	5.2 ± 1.4	2.113	0.121
Incidence of IFG frequency (%)	122 (23.4%)	99 (19.4%)	90 (17.3%)	6.301	0.043
Incidence of diabetes Frequency (%)	37 (7.1%)	38 (7.5%)	21 (4.0%)	6.356	0.042

Table 3. Incidence of diabetes in female and male

Gender	Exposed		Control	χ^2	P
	Relative-unlost (n = 521) frequency (%)	Relative-lost (n = 509) frequency (%)	(n = 521)		
Female	5 (3.0%)	10 (5.8%)	0 (0%)	9.317[a]	0.009
Male	21 (5.0%)	31 (9.2%)	28 (8.3%)	5.527	0.063

[a]Based on Fisher's exact test.

Table 4. The association between incidence of diabetes and number of lost relatives

No. of lost relatives	N	Incidence of diabetes Frequency (%)	χ^2	P
1	215	14 (6.5%)	3.682	0.159
2	158	9 (5.7%)		
≥ 3	134	15 (11.2%)		

was 17.4%, significantly higher than those for the relative-unlost group and relative-lost group (11.9%, 6.6% respectively). The mean diastolic blood pressure for the relative-unlost group was the lowest (78.2 ± 9.8 mmHg), compared to the relative-lost relatives (78.7 ± 10.7 mmHg) and control group (79.8 ± 10.5 mmHg).

Comparisons on FBG and incidence of IFG and diabetes

FBG, incidence of IFG and incidence of diabetes in three groups are shown in **Table 2**. No significant difference on the average FBG was seen across three cohorts, although the average FBG for exposed relative-unlost group was slightly higher than that for the other two groups (P = 0.121). However, the incidences of IFG and Diabetes for the exposure groups were significantly higher than that for control group (P = 0.043 for IFG; P = 0.042 for diabetes).

Comparisons on incidence of diabetes after stratification by gender

Within the female participants, the incidence of diabetes was significantly higher in the exposure cohort who lost their relatives (5.8%), compared to the relative-unlost group (3.0%) and control group (0%) (P = 0.009). Although incidences of diabetes for the male subjects were not statistically significantly different, relative-lost group still showed a higher diabetes incidence than the other two groups. **Table 3** also shows a roughly 2-fold change for men to have diabetes compared with women.

The association between incidence of diabetes and number of lost relatives

The relative-lost cohort was further categorized into three subgroups with 1 lost relative, 2 lost relatives and 3 or more lost relatives. An obviously consistent trend of diabetes incidence with the number of lost relative was seen in **Table 4**. However, the incidence of diabetes did not statistically significantly differ with the number of lost relative (χ^2 = 3.682, P = 0.159).

Logistic regression analysis on predictors of diabetes

First, simple logistic regression analysis was performed for each of the traditional predictors of diabetes, with incidence of diabetes as the dependent variable and each predictor as the independent variable. Then, we included all the significant factors in to the multiple logistic regression model and used backward selection method to determine the best model for the prediction of diabetes.

Logistic Regression analysis on stress from earthquake and other predictors of diabetes are shown in **Table 5**. The results of multiple logistic regression analysis show that stress from the loss of relatives is also a significant predictor on the incidence of diabetes, besides

Table 5. Logistic Regression analysis on stress from earthquake and other predictors of diabetes

Predictor	B	SE	Wald	df	*P*	OR	95.0% CI
Intercept	-9.985	1.229	66.020	1	0.000		
Age	0.039	0.014	8.175	1	0.004	1.040	1.012~1.068
Gender	0.802	0.377	4.530	1	0.033	2.231	1.066~4.670
Alcohol consumption			6.520	3	0.089		
Used to	-0.021	0.484	0.002	1	0.965	0.979	0.379~2.529
Occasionally	-0.770	0.324	5.657	1	0.017	0.463	0.245~0.873
Daily	-0.417	0.310	2.314	1	0.128	0.624	0.340~1.146
Waist	0.042	0.011	13.576	1	0.000	1.043	1.020~1.066
Triglyceride	0.387	0.081	23.011	1	0.000	1.473	1.257~1.726
Blood pressure	0.702	0.242	8.436	1	0.004	2.018	1.256~3.240
Stress from earthquake			7.752	2	0.021		
Relative-unlost	0.622	0.306	4.128	1	0.042	1.863	1.022~3.394
Relative-lost	0.835	0.303	7.605	1	0.006	2.304	1.273~4.170

the traditional predictors (age, gender, waist, triglyceride, blood pressure) (Wald-value = 7.752, P = 0.021). Age, waist, triglyceride, blood pressure and stress from the loss of relatives are significant risk factors of diabetes (β = 0.039 for age; β = 0.042 for waist; β = 0.387 for triglyceride; β = 0.702 for blood pressure). The chance of having diabetes is significantly higher for women than men (Wald-value = 4.530, P = 0.033). Although alcohol consumption has no significant effect on incidence of diabetes, moderate alcohol consumption is still shown to be a protective factor of diabetes (Wald-value = 6.520, P = 0.089).

Discussion

The diabetic population of the world is predicted with an increase from 285 million adults in 2010 to 439 million by 2030 [10]. The diabetes rate of Chinese population has reached the highest in the world based on a most recent investigation [11]. Efforts employed in seeking causative factors of diabetes are highly demanded both in China and worldwide according to such situation. In this study, incidences of IFG and diabetes among the exposure group are both significantly higher than the control group, which demonstrates the earthquake stress, even 37 years post exposure, still as an associated risk factor of diabetes.

The conclusion of this investigation is consistent with previous studies, which explored the linkage of stress from natural disasters to diabetes and its complications [12-14]. Indian individuals who experienced tsunami were found with having massive mental pressure and higher incidences of IFG and diabetes [12]. People with type I diabetes were more likely to be negatively affected on glycemic control and life quality when exposed to the 1999 Marmara earthquake in Turkey [13]. Specific diabetes care was also encouraged by a recent Japanese study on earthquake stress and diabetes management after the Great East Japan Earthquake in 2013 [14].

The relative-lost group has the highest prevalence of IFG and diabetes in this study. Futher inspection on the association between the number of relatives lost and the occurrence of diabetes implies individuals with 3 or more relatives lost in the earthquake are more likely to have diabetes. Relative loss and severe housing damage from the 1995 Kobe earthquake resulted in very low scores in self-reporte health status and elevated HbAlc levels, an indicator of diabetes management, in Japanese diabetes patients [15]. Similar findings were also reported about the relation of the exposure intensity to earthquake stresses, relative losses included, and onsets of diseases following the 1998 earthquake in Armenia [16]. Overall, evidences from this study and others implicate the earthquake stress from relative loss has long-term influence on the mental and physical health of survivors.

In this study, the effect of earthquake stresses was found being more prominent in women than men, which is also consistent with other studies [17, 18]. After the Great East Japan Earthquake, the female survivors were more sensitive to the stresses from the earthquake and with worse glycemic control [17], which may be explained by their more vulnerable responses on aberrant hypothalamic-pituitary-adrenal (HPA) axis to stress compared to male [19]. Another association between phobic anxiety symptoms and diabetes incidences was also proposed with women rather than men by Farvid MS, et al [18]. Therefore, long-term attention and related interventions regarding the specific care of women are necessary if exposed to natural disasters, like earthquakes.

This investigation repeatedly proved that people with elder age, high TC levels, high TG levels, oversized waist, and abnormal systolic pressures are more likely to have diabetes, which is also consistent with previous studies [20-22]. In the meanwhile, moderate alcohol consumption was found with beneficial effects on diabetes prevention by this study and others [23].

Responses to acute stress often accompany with a transient elevation of blood glucose in high organisms, while sustaining exposure to long-term psychological stress leads to the onset and development of diabetes [24, 25]. The underlying mechanism could be interpreted by stress hormones produced by from the HPA. Massive stress hormones induced by acute or chronic stresses may cause transient or long period of blood sugar increase [26]. As demonstrated by this study, natural disasters, like the 1976 Tangshan earthquake, might play as long-term stressors in affecting the afflicted people mentally and physically for lifelong. Thus, the regarding interventions to prevent the incidence of diabetes are very important for people exposed to traumatic stresses.

The limitations of this investigation include restricted sample size and specific subject group, who were only recruited from current employee of Kailuan Group Company Limited. Furthermore, years of follow-up are needed to uncover the long-term effect of earthquake stress on diabetes incidence, since the characteristic of diabetes changes with age.

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Disclosure of conflict of interest

None.

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