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# Translational Epidemiology and the Application of Public Health Surveillance: Diabetes Mellitus and Mental Distress in New York City before and After the September 11, 2001 Attacks

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## Abstract

**Objective:** We aimed to test the hypothesis that there were significant increases in the prevalence of diabetes mellitus (DM) and mental distress from 1999 to 2009 in the state of New York (NY), and that these increases may be partly attributable to the catastrophic event of the September 11, 2001 attacks in central NY City (NYC) as compared to the other counties in the state of NY (RNY).

**Study Design:** A cross-sectional analysis.

**Methods:** Data (n=60,286) from 1999-2009 Behavioral Risk Factor Surveillance System in the state of NY were used to examine age-adjusted prevalence of DM in NYC as compared to RNY for three time periods: 1 (1999-2000), 2 (2001-2002, represents the year of the attacks), and 3 (2009). Associations of DM with mental distress and other risk factors were examined cross-sectionally using multiple logistic regression analysis.

**Results:** Residents living in NYC had a significantly higher prevalence of DM and mental distress than those living in RNY ($p<0.001$). Age-adjusted prevalence of DM was 7.1% vs. 5.3% in period 1, 8.0% vs. 6.2% in period 2, and 10.3% vs. 7.5% in period 3 for NYC versus RNY, respectively. The corresponding values of the prevalence of mental distress were 13.0% vs. 11.1%, 14.3% vs. 11.9%, and 16.6% vs. 12.4%, for study periods 1 to 3 respectively. Using the combined data (1999-2009), multivariate logistic regression analysis indicate that the prevalence of DM was significantly associated with mental distress, being overweight, obesity, smoking and lower socioeconomic status (SES).

**Conclusion:** The prevalence of DM and mental distress significantly increased from 1999 to 2009 in NYC and RNY. Residents who lived in NYC had significantly higher prevalence of DM and mental distress than those living in RNY. Subjects with DM were significantly associated with mental distress, abnormal body weight, smoking and lower SES. The significantly increased trend in DM and its risk factors including mental distress from 2001-2002 to 2009 may be partially explained by a possible middle and long-term impact of the September 11, 2001 attacks.

## INTRODUCTION

Despite decades of advances in our understanding of human biology and the emergence of powerful new technologies, such as genomics and bioinformatics, the transformation of scientific discoveries and advances into effective health interventions remains limited [1,2]. There is an urgent need for a strong translational research (TR) agenda [2-4]. Recent emphasis on TR is highlighting the role of epidemiology and large-scale population health surveillance systems in translating scientific discoveries into public health action. For example, Khoury and his colleagues proposed the applications of epidemiology in TR through 4 phases (designed T1-T4), illustrated by examples from human genomics. In T1, epidemiology explores the role of a basic scientific discovery in applying in practice (such as a new biomarker used in risk prediction and prevention), in T4, epidemiology helps assess the impact of candidate marker applications on population outcomes [2]. McNabb and colleagues discussed a concept framework of public health surveillance (detection, registration, reporting, confirmation, analysis, and

feedback) and its application in health sector reform [5]. In the Ogilvie and colleagues study, they addressed two research gaps in population translational research, the first between basic research and early clinical trials, and the second between health technology assessment and healthcare delivery [6]. The principal of these proposed concepts and frameworks are derived from the natural history of the development of disease. In public health, although a systematic surveillance system on behavior risk and disease status started in middle 1980s in the United States, the translation of data from large-scale surveillance systems to health practice remains under study, and calls for redesigning public health surveillance in an eHealth world [1]. In the present study, we aimed to demonstrate how translational epidemiology applies in public health preparedness research using a statewide surveillance data on the prevalence of diabetes mellitus (DM) and mental distress in New York state. Of many chronic diseases, the prevalence of DM is increasing in the United States and it poses a serious health and economic consequence for the nation. Data from the 2011 National Diabetes Fact Sheet indicates that about 18.8 million people have been diagnosed with DM, and an additional 7.0 million are afflicted but undiagnosed [7]. In 2007, the national cost of DM was estimated to be $174 billion. This estimate included $116 billion in excess medical expenditures attributed to DM, as well as $58 billion in reduced national productivity [7]. Although risk factors for DM have been continuously explored, there is limited translational research applied theory-based hypothesis to test the immediate, middle and long term impacts of the September 11, 2001 attacks in New York City on population health. In the present study, similar to the population bottleneck theory (a sharp change in size of a population due to environmental stochastic events, and followed by a recovery) [8] we hypothesized that a sudden increase in the prevalence of DM and mental distress was due to the catastrophic event of the September 11, 2001 attacks, follow-up by a short-period reduction that represented a natural recovery. We tested two specific hypotheses: (1) there was an overall significant increasing trend of the prevalence of DM and mental distress from 1999 to 2009, with an increase after the September 11 attacks (Figure 1). (2) we further tested that the prevalence of DM was significantly associated with mental distress in the study participants, after adjustment for social demographic factors, smoking status and body weight. Because several studies have suggested that DM is significantly associated with mental health [9-14].

## METHODS

### Study Design and sample size

We used data from the New York 1999-2009 Behavioral Risk Factor Surveillance System (BRFSS), the largest statewide population-based survey [15]. The BRFSS is a serial cross-sectional telephone survey of randomly selected noninstitutionalized adults aged ≥18 years and over. The BRFSS is conducted annually with participants who have landline telephone services in the state. The sample of telephone numbers is updated quarterly to include newly connected phone lines, and each month a stratified subsample is drawn to ensure that results will represent the full adult population as accurately as possible [15]. The BRFSS is the only available source of timely, accurate data on health conditions and health-related behaviors covering a statewide sample from across New York State. The survey instruments consist of a set of core section and state-specific modules. The core section, designed by the Centers for Disease Control and Prevention (CDC), includes questions regarding demographic information and general health status. Data on behavioral risk factors and self-reports of physician-diagnosis of chronic diseases (such as DM) are included in the core section or in optional sections (modules). Verbal consent was obtained from all participants and survey procedures followed the ethical standards, and the BRFSS has been approved by the CDC's Institutional Review Board [15].

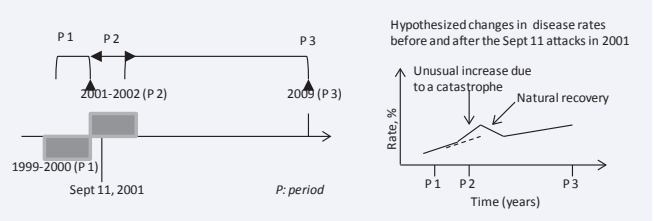


**Figure 1** The Study logic model.

To increase the sample size for the present analysis, we combined every two consecutive years (sample size), 1999-2000 (n=5,900), 2001-2002 (n=8,289), 2003-2004 (n=11,469), 2005-2006 (n=13,539), 2007-2008 (n=14,343), and with the exception of 2009 (n=6,746) because 2010 BRFSS data was not yet available at the time of data analysis.

### Measures

All measures in the BRFSS were conducted using standard instruments and were based on participants' self-reports. The reliability and validity of these measures have been examined and reported as moderate to high, and are generally considered to be valid and reliable in comparison with other surveys and models of administration [16]. A detailed description of the survey design and methods is available elsewhere [15]. The main study variables included in the present analysis are described below.

Participants were classified as having DM according to their self-report of physician diagnosis of the disease (yes or no). Mental distress was measured using the survey module "Healthy Days". Individual participants were asked the following question: "Thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?" [17]. In the analysis, a subject with mental distress was defined as one who reported having ≥ 10 days of being mentally unhealthy in the past 30 days. This cutoff point was the upper 90$^{th}$ percentile distribution of the total participants [15]. We further estimated a dose-response relationship between the number of days experiencing mental distress and prevalence of DM. In the analysis, we categorized the days experiencing mental health problems into three groups: 0-1, 2-9, and ≥10 days. We further included demographic and behavior risk factors in the analysis as they are important covariates in the study of DM and mental distress. Demographic variables: age (years), sex, race/ethnicity (White, Black, Hispanic and the others), participants'

education attainment (school-years ≤10, 11-14, and ≥15), body weight status, and cigarette smoking status were included. Body weight status was assessed using body mass index (BMI), estimated by weight in kilograms divided by the squared value of height in meters. BMI was categorized using the World Health Organization's criteria, with a BMI of <18.5 kg/m$^2$ as underweight, a BMI of 18.5-24.9 kg/m$^2$ as normal weight, a BMI of 25-29.9 kg/m$^2$ as overweight, and a BMI ≥30 kg/m$^2$ as obese. Participants' tobacco smoking status was classified as never or ever smoker (including current and former smokers). The inclusion of former and current smoking in the same group takes into account that having ever smoked has a long-term effect on human health, although there is a certain risk reduction of disease after smoking cessation [18-21]. Separate analyses for those with current, former, and never smoking status were also conducted with similar results observed. We stratified our data analysis for the two geographic regions of the state of New York (NY): New York City (NYC), and the other counties of NY (RNY). The NYC includes five counties (boroughs): New York (Manhattan), Kings (Brooklyn), Queens, Bronx and Richmond (Staten Island). The other 57 counties of the state of NY are grouped as RNY.

### Statistical analysis

Figure 1 depicts the study logic model and analysis framework. A serial analysis was conducted to test the study hypothesis. In the first group analysis, age-specific prevalence of DM and mental distress and their 95% confident intervals (CI) were calculated using the direct standard method with the U.S. 2000 population as the standard population and using Keyfitz's method for the estimate of 95%CI. [22]. Differences in the prevalence of DM and mental distress were examined between period 1 (1999-2000) and period 2 (2001-2002), and between period 2 and period 3 (2009). In the second group analysis, we estimated the odds ratio of social demographic factors, regions (NYC vs. NY), mental distress (yes vs. no), and time trend (taking year period 2 as the baseline) for the prevalence of DM. In the third group analysis, we examined dose-response relationships between mental distress and the risk of having DM between regions (NYC and RNY). Three sets of logistic regression models were conducted: Model 1 adjusted for age, sex, and race/ethnicity. Model 2 further adjusted for marital status, education level, tobacco smoking, and BMI. Model 3 added survey years into Model 2 in order to control changes due to survey years. The purpose of these adjustments was to test the independent associations of the changes in the study outcomes with survey years, and between DM with mental distress.

All statistical analyses were performed using SAS software version 9.2 (SAS Institute, Cary, NC, 2008). Because the BRFSS surveys applied multistage and complex study designs (i.e., cluster, strata, and weight), SAS analyses for the complex sample survey procedures were used to produce weighted estimates which accounted for sampling errors [23-25]. A two-sided P value of 0.05 was considered statistically significant.

## RESULTS

Table 1 describes the basic characteristics of participants in the total sample of NY BRFSS from 1999 to 2009. The proportions of participants aged 60 and older were higher in recent survey years. The proportions by sex and race/ethnicity were similar across the survey years.

### Trends of the prevalence of DM by regions

Figure 2 depicts an increasing age-adjusted prevalence trend between 2001-2002 and 2003-2004, and followed by a decreasing trend after 2003-2004 until 2005-2006 in mental distress, and 2007-2008 in DM, and then an increasing trend in both the conditions. These non-linear changes in the prevalence of DM and mental distress were stronger in NYC, where the September 11, 2001 attacks occurred, than RNY. There was a sharp increase in the prevalence of DM and mental distress in recent years in NYC.

Figures 3 A, B and C map the overall significantly increased trends ($p<0.01$) of the prevalence of DM from periods 1, 2, and 3 for both NYC and RNY. These corresponding values of age-adjusted prevalence of DM were 7.1% vs. 5.3% in period 1 (1999-2000, Fig 3 A), 7.86% vs. 6.22% in period 2 (2002-2002, Figure 3 B), and 10.29% vs. 7.47% in period 3 (2009, Fig 3 C) for the NYC versus the RNY, respectively. Similarly, the prevalence of age-adjusted mental distress significantly increased in both NYC and RNY ($p<0.01$). The prevalence of mental distress was 13.0% vs. 11.1% in period 1 (1999-2000), 14.29% vs. 11.86% in period 2 (2001-2002), and 16.5% vs. 12.43% in period 3 (2009) for NYC versus RNY, respectively.

**Table 1:** Basic Characteristics of participants in New York Behaviour Risk Surveillance System Surveys.

| | 1999 - 2000 | | 2001 – 2002 | | 2003 – 2004 | | 2005 – 2006 | | 2007 – 2008 | | 2009 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Rate, % | (SEP) | Rate, % | (SEP) | Rate, % | (SEP) | Rate, % | (SEP) | Rate, % | (SEP) | Rate, % | (SEP) |
| Age=60,% | 23.86 | (0.65) | 23.51 | (0.59) | 22.97 | (0.45) | 23.50 | (0.45) | 24.12 | (0.39) | 24.62 | (0.62) |
| Males, % | 47.26 | (0.77) | 47.19 | (0.60) | 47.37 | (0.49) | 47.77 | (0.59) | 47.70 | (0.54) | 47.80 | (0.87) |
| Race/Ethnicity, % | | | | | | | | | | | | |
| White | 67.36 | (0.76) | 63.77 | (0.70) | 61.81 | (0.56) | 61.74 | (0.60) | 61.61 | (0.65) | 61.26 | (0.96) |
| Black | 12.44 | (0.53) | 11.71 | (0.48) | 12.30 | (0.40) | 12.08 | (0.41) | 13.81 | (0.48) | 13.68 | (0.73) |
| Hispanic | 14.56 | (0.61) | 16.35 | (0.58) | 17.01 | (0.51) | 16.52 | (0.51) | 15.74 | (0.52) | 16.14 | (0.79) |
| Others | 5.65 | (0.38) | 8.18 | (0.35) | 8.88 | (0.37) | 9.66 | (0.39) | 8.84 | (0.40) | 8.92 | (0.69) |
| Crude and total rate | | | | | | | | | | | | |
| DM | 6.01 | (0.37) | 6.96 | (0.32) | 7.50 | (0.30) | 7.86 | (0.29) | 8.33 | (0.26) | 8.79 | (0.47) |
| Mental Distress | 11.63 | (0.50) | 12.48 | (0.44) | 13.27 | (0.40) | 12.87 | (0.43) | 12.45 | (0.41) | 13.62 | (0.62) |

DM: Diabetes mellitus, defined as self-report of physician diagnosis of DM. Mental Distress: defined for those with the number of mentally unhealthy ≥ 10 days in past 30 days

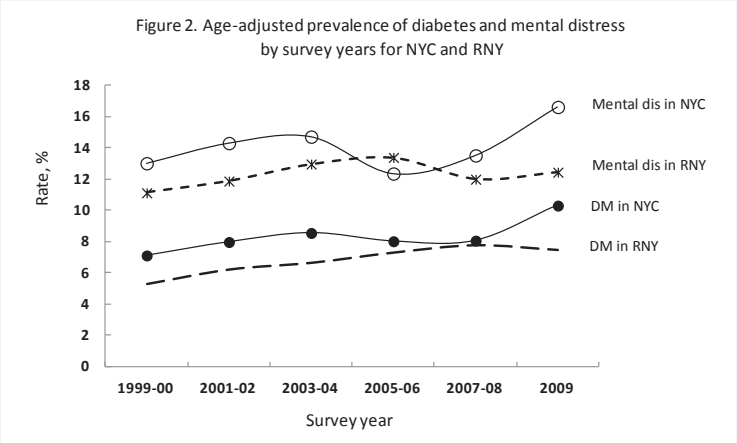


**Figure 2** Age-adjusted prevalence of diabetes and mental distress by survey years for New York City (NYC) and the other counties in the State of New York (RNY).

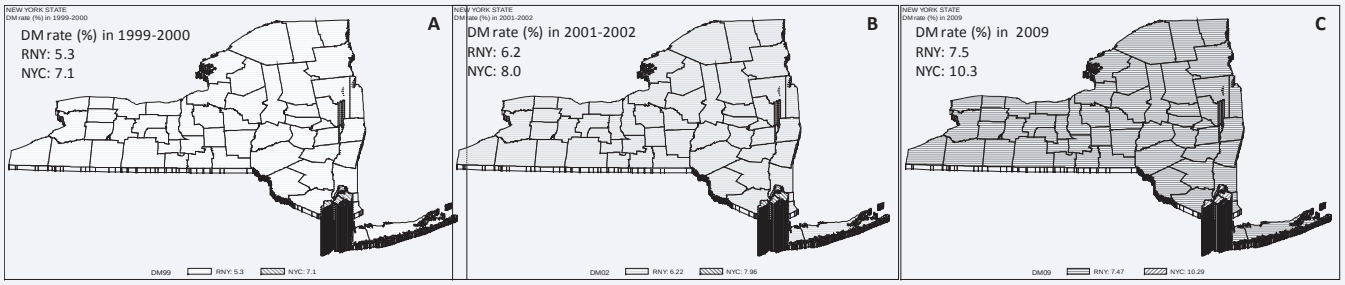


**Figure 3** Age-adjusted prevalence of diabetes mellitus in New York City (NYC) and the other counties in the State of New York (RNY) in 1999-2000 (A), in 2001-2002 (B), and in 2009 (C).

### Determinants of the prevalence of DM

Table 2 shows that the odds of having DM were significantly associated with increased age, being male, and belonging to a minority group. Subjects with higher educational level had a lower risk of the prevalence of DM. Subjects who ever smoked and were overweight or obese had significantly higher odds of having hypertension. The most important findings are that subjects living in NYC had a 19% higher odds of having DM than those living in RNY (OR=1.19, 95%CI: 1.10-1.29); 74% higher odds of having DM for those with mental distress versus those without (OR=1.74, 95%CI: 1.55-1.94); and 33% higher odds of having DM for those living in 2009 versus those living in 2001-2002. No significant interaction effect of regions (NYC and RNY) and mental distress on DM was observed.

### Dose-response relationship between the number of days with mental distress and DM

Table 3 shows that there were significant associations between increased days of having mental distress and the odds of having DM in both NYC and RNY (test for trends of ORs, $p<0.001$). These associations were stronger among residents living in NYC than those living in RNY (assessed by the values of odds ratios).

## DISCUSSION

The study extended previous research approaches by testing hypothesis-driven questions using data from a routine health surveillance system. This study demonstrates that there were significant increases in the prevalence of DM from 1999 to 2009 in the state of NY. Residents living in NYC had a higher prevalence of DM than those living in RNY. Similar trends of the prevalence of mental distress were observed in NYC and RNY. The results showed that the prevalence of DM and mental distress were higher in 2001-2002 than 1999-2000, and then decreased in a short period after 2003-2004. After adjustment for age, sex, race/ethnicity and regions, the prevalence of DM was significantly associated with mental distress, the survey periods and the other covariates. These findings are consistent with previous studies, [12,21,26,27] and add new evidence that an increased prevalence of DM and mental distress between 2001-2002 and 2003-2004 may be partly explained by the catastrophic event of the September 11, 2001 attacks in NYC.

BRFSS, coordinated by the CDC, is conducted annually in each state of the U.S. It provides timely health information to state health policy makers and professionals [15,16,26]. After the attacks on September 11, 2001, three States (New York, New Jersey, and Connecticut) in the U.S. immediately added several research instruments in the fourth quarter (October to December) of their 2001 BRFSS surveys in order to address a possible immediate effect of the September 11 attacks on populations' health [28]. Findings from previous reports provided evidence for the short-term effects of the attacks on stress, depression, and increased the frequency of tobacco smoking among smokers and the amount of alcohol consumption among drinkers following the September 11 attacks, 2001 [28,29]. However, no study was

**Table 2:** Multivariable adjusted Odds ratios of risk factors for diabetes mellitus.

| | Diabetes mellitus OR (95%CI) | *p* |
|---|---|---|
| Demographic factors | | |
| Age (≥60 vs. <60 yrs) | 4.83 (4.46 - 5.22) | <.0001 |
| Sex (Male vs. female) | 1.20 (1.11 - 1.31) | <.0001 |
| Marital (Married vs. Not) | 1.06 (0.98 - 1.13) | 0.137 |
| Race (Ref: White) | | |
| Black | 2.23 (1.99 - 2.51) | <.0001 |
| Hispanic | 1.64 (1.44 - 1.86) | <.0001 |
| Others | 1.60 (1.37 - 1.86) | <.0001 |
| Education, (Ref: ≤ 11yrs) | | |
| 12 to 14 | 0.70 (0.62 - 0.78) | <.0001 |
| ≥15 | 0.51 (0.45 - 0.58) | <.0001 |
| Smoking | | |
| Ever vs. Never | 1.16 (1.08 - 1.25) | 0.0001 |
| BMI, (Ref: 18.5-24 kg/m2) | | |
| <18.5 | 0.77 (0.50 - 1.18) | 0.229 |
| 25-29 | 1.68 (1.50 - 1.88) | <.0001 |
| ≥30 | 4.58 (4.10 - 5.11) | <.0001 |
| New York region | | |
| NYC vs. RNY | 1.19 (1.10 - 1.29) | <.0001 |
| Mental distress | | |
| ≥10 d vs. <10 d per 30 days | 1.19 (1.10 - 1.29) | <.0001 |
| Survey years | | |
| 1999-2000 | 0.89 (0.76 - 1.04) | 0.151 |
| 2001-2002 | 1 | |
| 2003-2004 | 1.15 (1.01 - 1.30) | 0.032 |
| 2005-2006 | 1.21 (1.07 - 1.37) | 0.003 |
| 2007-2008 | 1.28 (1.13 - 1.43) | <.0001 |
| 2009 | 1.33 (1.15 - 1.55) | 0.0002 |
| Test for trend, p-value | <0.001 | |

Ref: Reference; BMI: Body Mass Index

NYC: New York City; RNY: The other counties in the state of New York

conducted to examine the middle and long term effects using data from a decade of surveillance. In the present study, we filled the gap by identifying that the prevalence of DM and mental distress in NYC had changed before and after the September 11 attacks. Results of our study show an increased trend after the attacks. Similar findings were reported from the Ford and colleagues' study [29]. Our study further suggests that there was a decreased trend from 2003-2004 to 2005-2006 in DM, and from 2003-2004 to 2007-2008 in mental distress in NYC (Figure 2). This decreased trend may be partly attributable to a recovery with time after a sudden negative event. It should be noted that there was an increased trend in the prevalence of mental distress from 2005-2006, and in DM from 2007-2008 to 2009 among residents living in NYC. This increase may be partly attributable to a serious middle and long-term impact of the September 11 attacks in 2001 on population health in NYC. These changes were different in RNY (Figure 2), which may partly support that the September 11 attacks had a serious and stronger impact on the residents of NYC.

The association between DM and mental distress has been reported by several studies [9-11,13,14]. Findings of our present study added new evidence of a dose-response relationship between increased odds of having DM and increased days of having mental distress. For example, NYC residents who reported having mental distress for 10 or more days had 1.62 times higher odds of having DM than those who reported having no or only 1 day mental distress during the past 30 days (Table 3). Although we are unable to interpret any cause-effect association using the present data because of its cross-sectional study design, our findings are consistent with and support previous observational studies [9-11,13,14].

In the present study, several limitations should be kept in mind when interpreting the results. First, sampling selection and information biases may have occurred in the population based study [30]. For example, in the BRFSS, information on landline telephones are updated quarterly, however, households without landline telephone service and those who used cell phone only, or were unable or unwilling to participate in a telephone survey due to a serious health condition or any other reasons were excluded. This may lead to an underestimation of the study exposure and outcomes. Second, unexpected changes in the surrounding environment, such as the recent years' economic recession may partly influence the accuracy of participants' health and their responses to the surveys; therefore information bias may exist. Furthermore, individuals who experienced the September 11 attacks might have moved out of NYC after the attacks, which may lead to selection bias of the study population [28]. These limitations warrant not only caution in interpreting the results, but also call for improving the surveillance survey system for health assessments that comprehensively and accurately respond to emergency health issues [1,30]. Third, in the study, data on the distance between the place where the September 11 attacks occurred and the place where the participants lived in NYC are not available. We are unable to test a dose-response relationship between the distance of the exposure and the study outcomes, and we are unable to control this variable in data analyses. Lastly, because BRFSS is conducted using a serial cross-sectional study design, individual participants were not followed on the basis of a prospective study design. Therefore, findings of the present study do not demonstrate a cause-effect relationship, although there is evidence that shows that subjects with mental distress have a significantly higher risk of developing DM. Further longitudinal studies are needed to confirm these findings [31].

Despite the aforementioned limitations, the present study has several advantages. First, it addresses translational research from data to test new health problems. Second, data from BRFSS is the only state-wide population based survey that monitors

**Table 3:** Multivariable adjusted odds ratios of mental distress in relation to diabetes mellitus.

| Mental distress | Model 1 OR (95%CI) | Model 2 OR (95%CI) | Model 3 OR (95%CI) |
|---|---|---|---|
| **NY City** | | | |
| 0-1 d/30 | 1 | 1 | 1 |
| 2-9 d/30 | 1.28 (1.02 - 1.60) | 1.21 (0.96 - 1.52) | 1.20 (0.96 - 1.13) |
| ≥10 d/30 | 1.95 (1.59 - 2.40) | 1.62 (1.29 - 2.04) | 1.62 (1.29 - 2.03) |
| *test for trend, p* | <0.001 | <0.001 | <0.001 |
| **The other counties of NY** | | | |
| 0-1 d/30 | 1 | 1 | 1 |
| 2-9 d/30 | 1.07 (0.94 - 1.23) | 1.05 (0.91 - 1.21) | 1.05 (0.91 - 1.21) |
| ≥10 d/30 | 1.83 (1.59 - 2.09) | 1.53 (1.32 - 1.77) | 1.52 (1.32 - 1.76) |
| *test for trend, p* | <0.001 | <0.001 | <0.001 |

Model 1: Adjusted for age, sex, race/etnicity.

Model 2: Adjusted for coveriate in model 1 plus marital, education and smoking status and BMI

Model 3: Adjusted for coveriate in model 2 plus survey years

residents' health annually since middle 1980s. The survey designs and procedures have been well standardized by the Centers for Disease Control and Prevention of the U.S. The main survey instruments used in the BRFSS have been tested and validated by a number of studies [15,16,26]. Third, the present study offers an effort to test changes in DM and mental distress over the specific 10-year period that includes the time point of the September 11 attacks. Findings of the study add new and important evidence to the body of literature and raises new research questions. Last, by testing the differences between NYC and RNY, we can examine differences in health between urban and rural areas. In conclusion, findings from the present study support the hypothesis that in addition to an immediate effect, the catastrophic event of the September 11 attacks in 2001 may have a middle and long-term effect on the changes in the prevalence of DM and mental distress in NYC.

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Authors' contribution: L.L. contributed the analysis design, conducted data analysis and drafted the manuscript. W.Z. P.C. and Z.L. contributed to data management and analysis, and Z.L. assisted with mapping figures using GIS. W.Z., P.P., Y.A, P.C., Z.L., S.M.K., and E.S. provided critical review and comments for important intellectual content of the manuscript.

## ETHICAL APPROVAL

In BRFSS, verbal consents were obtained for all participants, and all survey procedures were approved and followed the ethical standards of the CDC's Institutional Review Board.

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