Public Health Consequences of Terrorism on Maternal–Child Health in New York City and Madrid

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ABSTRACT *Past research provides evidence for trajectories of health and wellness among individuals following disasters that follow specific pathways of resilience, resistance, recovery, or continued dysfunction. These individual responses are influenced by event type and pre-event capacities. This study was designed to utilize the trajectories of health model to determine if it translates to population health. We identified terrorist attacks that could potentially impact population health rather than only selected individuals within the areas of the attacks. We chose to examine a time series of population birth outcomes before and after the terrorist events of the New York City (NYC) World Trade Center (WTC) attacks of 2001 and the Madrid, Spain train bombings of 2004 to determine if the events affected maternal–child health of those cities and, if so, for how long. For percentages of low birth weight (LBW) and preterm births, we found no significant effects from the WTC attacks in NYC and transient but significant effects on rates of LBW and preterm births following the bombings in Madrid. We did find a significant positive and sustained effect on infant mortality rate in NYC following the WTC attacks but no similar effect in Madrid. There were no effects on any of the indicator variables in the comparison regions of New York state and the remainder of Spain. Thus, population maternal–health in New York and Madrid showed unique adverse effects after the terrorist attacks in those cities. Short-term effects on LBW and preterm birth rates in Madrid and long-term effects on infant mortality rates in NYC were found when quarterly data were analyzed from 1990 through 2008/2009. These findings raise questions about chronic changes in the population’s quality of life following catastrophic terrorist attacks. Public health should be monitored and interventions designed to address chronic stress, environmental, and socioeconomic threats beyond the acute aftermath of events.*

KEYWORDS *Terrorism, Infant mortality rate, Birth outcomes*

INTRODUCTION

The question of whether terrorism affects the well-being of entire populations is an intriguing one that has important implications for public health policy and practice. It is well established that individuals who are directly injured by disasters are at risk for a variety of adverse health and mental health outcomes^{1,2}. Questions remain about the extent to which such effects occur at the population level and whether they can be detected by monitoring standard public health indicators. Population-level

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effects reflect a combination of the disaster's *direct* effects on primary victims who were severely exposed and its *indirect* effects on secondary victims in the community at large. Even if they sustain no personal injuries or concrete losses, other members of the stricken community experience economic, environmental, governmental, social, and cultural disruptions ranging from mild to severe³. Primary and secondary victims alike experience multiple inconveniences and declines in opportunities for recreation and leisure. Both are affected by any ensuing environmental toxins, loss of shared or public spaces, community conflicts about appropriate responses, quality of leadership, and reallocations of public resources from one domain (e.g., health) to another (security). Unlike the initial impacts of the event, these collectively experienced stressors are not necessarily obvious or acute; they may emerge and evolve over time, complicating our ability to detect and understand the onset and duration of population-level effects.

The potential of disasters to have indirect effects on health is particularly salient in the context of terrorism⁴⁻⁹. Galea and Resnick⁷ provided a thoughtful discussion of why psychopathology may emerge in the general population in the case of terrorism. In New York after the September 11th attacks, the prevalence of posttraumatic stress disorder was lower among persons exposed only indirectly, but because they composed a large proportion of the population, there were almost as many indirect cases as direct cases. Throughout the New York metropolitan area, people felt terror, helplessness, or horror (criteria for trauma) even if they were not directly affected (by bereavement, job loss, etc.) by the September 11th attacks.

Although the direction of causality remains unclear and controversial, the ubiquity of media images following terrorist attacks further complicates the definition of exposure. Marshall and colleagues¹⁰ proposed that media exposure does not typically result in psychological distress because the viewer does not perceive a personal threat. However, in the case of terrorism, it is quite plausible that the viewer does. Marshall et al.¹⁰ furthermore argued that the objective, observable experience of an event is less important for defining risk than is the subjective, psychological experience of what that event implies for the future, as evidenced in perceptions of threat.

Thus, in the aftermath of terrorism, it is especially critical to monitor the well-being of the entire community or area that was harmed and/or threatened by the attack. Population surveys have been, and will continue to be, our best source of data regarding disaster-related incidence and prevalence of disorders. Like any single method, however, surveys have limitations. Flaws in representativeness, absence of predisaster measures, limited numbers of postdisaster assessments, and sample sizes too small to capture rare but important conditions are common, although not universal, shortcomings¹¹. Analysis of routinely collected public health morbidity and mortality data provides an alternative, complementary approach. Typically, public health data are based on the whole rather than a sample and are available for many years both before and after events. The feasibility of obtaining and analyzing vital statistics for insights into population effects was established in past studies of divorce rates^{12,13}, fertility¹⁴, and suicide rates¹⁵ associated with disasters and terrorist attacks.

Although population health encompasses a range of conditions, we were especially interested in examining the impact of terrorist attacks on maternal-child health, specifically birth outcomes. Two tracks of research influenced this choice. First, past disaster research suggests that women and children are at elevated risk for adverse health outcomes in the aftermath of disasters². Second, several cohort studies of pregnant women¹⁶⁻¹⁹ have indicated that stress during pregnancy is

associated with preterm and low birth weight (LBW) deliveries through established biological pathways²⁰. To date, these studies have mostly emphasized the role of perceived stress and chronic stressors, such as poverty, crowding, interpersonal violence, and work-related stress, but some research has also considered the influence of severe personal life events^{21,22} and even terrorism. On the basis of their review, Ohlsson and Shah²³ concluded that the World Trade Center (WTC) disaster increased the risk of LBW and small-for-gestational-age births in New York. We anticipated that the effects of terrorist attacks on LBW and preterm delivery would emerge fairly soon in response to the acute stressfulness of the post-attack environment. That is, these outcomes can be influenced by short-term changes that occur over the 9-month period of a pregnancy and thus act as an early warning system to presage longer-term health problems experienced by the larger community^{24,25}.

In addition to LBW and preterm birth outcomes, we were interested in the potential for acts of terrorism to influence infant mortality, effects which would be expected to unfold more slowly over time. For decades, the infant mortality rate (IMR) has been used as a proxy for population health around the world^{24,26–28}. Given its frequent use in cross-national comparisons of quality of life, the infant mortality rate could be fundamentally important as an indicator of fleeting or enduring changes in population health.

The analysis of routinely collected public health data is especially promising with regard to its ability to show different patterns or trajectories of change over time. What patterns might be expected for maternal–child health? Norris, Tracy, and Galea²⁹ used longitudinal data from the WTC attacks in New York and a natural disaster in Mexico to discover the most common patterns of psychological symptoms in individuals who experienced these disasters. Trajectories of resistance (no or little distress at any time point), resilience (initial distress followed by rapid decline), recovery (initial distress followed by slower decline), and ongoing dysfunction (initial distress followed by no decline) were all prevalent within both samples. In New York, a delayed dysfunction trajectory (no initial distress followed by later distress) was also evident. Building on this literature, we analyzed population-level health indicators to see if we could interpret these data in relation to the trajectory model of Norris and colleagues.

More specifically, referencing the connection between stress and the poor birth outcomes of low birth weight and preterm birth^{16,18–22}, we predicted that “resilience” would best characterize the population-level trend in preterm or LBW births, which reflects the influence of acute stressors associated with the attack. That is, we expected to see an immediate increase in the incidence of these outcomes after terrorist attacks, followed by a fairly rapid recovery to the baseline pre-event trend. However, we predicted that “delayed dysfunction” would best characterize the trend for infant mortality, which ensues from its major predictors, low birth weight and preterm birth as well as the more insidious changes in the quality of the environment (ongoing toxicity, threat).

To give some perspective to the expectations for change in the IMR, one needs to consider it in the global context. When looking at the ranking of countries for IMR (lowest to highest in a list of 222 countries), we examined the standings for the two countries included in our study. First, the United States ranks 47th worldwide with an IMR at 6.6³⁰. Second, Spain ranks 11th with an IMR of 3.4. Among the global listings, those countries that rank among the best have rates lower than 3.0, suggesting that in our study countries, there is room for improvement or harm.

We examined birth outcome trends for two separate terrorist events—the 2001 WTC attacks in New York City and the 2004 train bombings in Madrid, Spain—and used interrupted time series analyses to determine if the events significantly influenced population maternal–child health. The September 11, 2001 WTC attacks were without precedent in terms of the US experiences with terrorism. As a result of the WTC attacks, there were 2,723 deaths of NYC area inhabitants, workers, and rescuers as well as the destruction of multiple buildings in lower Manhattan³¹. Similarly, the Madrid, Spain March 11, 2004 train bombings caused the largest loss of life from a terrorist attack in European history with 191 deaths and 1,800 injuries³². Thus, we chose two events for study that had significant local, regional, national, and international significance and would be most likely to show an impact at the population level.

METHODS

Data

Our first event for study was the 2001 WTC attacks in NYC. There were 124,023 live births in 2001 and 122,937 live births in 2002 resulting in birth rates of 15.5 and 15.4, respectively³³. Quarterly incident birth-outcome data for the NYC area, consisting of Bronx, Kings, New York, Queens, and Richmond counties, were obtained from the New York City Department of Health and Mental Hygiene for 1990 through 2008 resulting in data for 76 quarters, 47 before the event and 29 after the event. We chose to study the metropolitan area as opposed to limiting it to Manhattan because there were studies on post-attacks birth outcomes that included the entire city and showed significant changes in outcomes³⁴. Data were standardized as rates to control for population size differences. Three birth-outcome indicators, defined by the National Association for Public Health Statistics and Information Systems (www.naphsis.org), were used in the analyses. *Low birth weight rate* was defined as the percentage of live infant births weighing less than 2,500 g at birth. *Preterm birth rate* was defined as the percentage of infants born at less than 37 weeks gestation. *Infant mortality rate* was defined as the number of infant deaths in the first year of life per 1,000 live births. By definition, all rates are given for a geographic area.

Our second event for study was the 2004 train bombings in Madrid, Spain. In Madrid, there were 69,029 live births in 2004 and 69,364 live births in 2005 resulting in birth rates of 12.0 and 11.8, respectively (www.ine.es). Quarterly birth outcome data for rates of LBW births, preterm births, and infant mortality were obtained from the Instituto Nacional de Estadística in Madrid, Spain for the city of Madrid from 1990 through 2009. For this analysis we had data for a total of 80 quarters, 57 before the event and 23 after the event.

Comparable data on birth outcomes were obtained for the remainder of New York state from the New York State Department of Health, and for the remainder of Spain from the Instituto Nacional de Estadística, which served as comparison groups for New York City and Madrid, respectively. We chose these comparison groups because health care funding and policies influencing maternal–child health care practices would be similar within a state rather than across states in the US, and within a country rather than across countries for Spain.

Because of the potential for demographic changes in NYC after the WTC bombings and the effect that might have on the birth outcomes, we examined

migration flows for New York City for 1985 through 2007 with data purchased from the Internal Revenue Service. Limitations of these data included the less-than-100 % representation of all filers and the under- or non-representation of specific non-filing populations such as the elderly and the poor. Similar data for Madrid were not found; however, yearly population data were obtained for the city of Madrid for 1996 through 2010 to assess for an overall change in population between the pre-event and post-event periods.

Interrupted Time Series Analysis

We used interrupted time series analyses to analyze autoregressive integrated moving average (ARIMA) models of a time series variable with an independent variable representing the event to determine the impact of the terrorist attacks on the maternal-child population in the cities of interest. We first plotted the rates of each birth outcome over time to identify trends, seasonality, and other features that might be considered in the modeling process, such as extreme outliers. We then modeled the quarterly rates for each birth outcome indicator over time using standard ARIMA modeling with IBM SPSS statistical package version 19³⁵. ARIMA modeling is a single series method used with time series data to eliminate the correlations of residuals that violate the independence assumption in statistical analysis³⁶. The strongest predictor in a time series is previous time observations and ARIMA modeling summarizes the relationship between the dependent variable—in this case, the three birth outcomes at each of the geographical sites—and time. A unique model was estimated for each dependent variable using differencing, autoregression, and/or moving averages to remove time-related patterning and find a statistically valid and parsimonious model.

ARIMA models are formatted to control three types of noise: (a) trend, which represents any systematic change in the level of a time series, (b) seasonality, which represents a variation in pattern that occurs repeatedly and yearly, and (c) random error, which represents the fluctuations that occur about some mean level, even when controlling the other noise types³⁶. The model has three parameters (p , d , q) that describe the relationships between random shocks and the time series. The parameter p indicates an autoregressive relationship in which a past observation predicts the current observation, the parameter d indicates differencing in the model, and the parameter q indicates the number of moving average components in the model. When a time series has seasonality or yearly recurring changes, the model may also contain the additional parameters of P , D , and Q to specifically control the seasonal noise. Thus, ARIMA models are depicted as (p , d , q) (P , D , Q).

The first step in modeling is to identify the model. In this step, stationarity, in which the correlation of values one time period apart is the same no matter where in the series it occurs, is determined. If non-stationarity (series trend or drift) is present, differencing is applied with the d parameter³⁷. Next, serial dependency is determined which occurs as lags in the autocorrelation function (ACF) that are abrupt or appear as spikes. To correct this, a weighted parameter (q) is applied as a moving average so that successive lags are reduced to zero. This is constrained by the bounds of invertibility which means the parameter must lie between -1 and 1 . Finally, a decaying process in the ACF which occurs exponentially from lag to lag is corrected by the autoregressive parameter (p). This parameter is also constrained to lie between -1 and 1 by the bounds of stationarity. Thus, the parameter is weighted so that the shock is diminished over time.

The second step is to fit the best model to the data considering the principle of parsimony along with statistical sufficiency when selecting the model. In estimating the model, parameters must meet the bounds of stationarity/invertibility and be statistically significant. Finally, diagnostics are applied to assess the quality of the model chosen in relation to the data. In this step, the Q statistic, distributed as a χ^2 with degrees of freedom determined by both the ACF and the autoregressive (p) and/or moving average (q) parameters, acts as a goodness-of-fit statistic so that a non-significant statistic indicates a good fit of the model.

To determine the best fitting model or the “noise” model minus any trend or seasonal systematic variations, we initially used the automatic model-generating function of the SPSS program and then clarified and refined the models through the iterative examination of possible variations using a review and comparison of fit values, parameter estimates, and plots of autocorrelation functions and partial autocorrelation functions. This process was conducted for each birth outcome rate (LBW, preterm birth, and IMR) for each of the two impacted sites (NYC and Madrid). The process was repeated with the New York state and the Spain birth outcomes data. Each birth outcome at a site had its own unique model. For a more detailed description of time series modeling, see McDowall et al.³⁶, Cryer and Chan³⁷, or Kitagawa³⁸.

Next, we defined dummy independent variables for each event that would estimate the impact of the event on the birth-outcome-dependent variables. Overall, a change in a trend may be either abrupt or gradual in onset and either permanent or temporary in duration³⁶. On the one hand, we proposed that the onset of change for LBW and preterm birth would be abrupt, or immediate, affecting women who were pregnant at the time of the attacks. Therefore, the post-event period started with the first quarter after the event and the length of the impact was short-lived, lasting perhaps only one quarter or no longer than 2 or 3 years. On the other hand, we proposed that if there was an effect, the onset of change in the IMR would be abrupt but delayed, given the definition of IMR as infant death in the first year of life; this delay was reflected in the specific dummy variables used to test IMR. The duration of this impact could also be short-lived for one quarter or 1 year or could be longer lasting. Thus, the dummy variables used with the IMR models had an onset that was delayed by 1 year after the event and tested either a short or a sustained duration of impact.

The design of our independent dummy variables allowed us to test for different periods of impact. First, we predicted that the outcomes of LBW and preterm birth rates would have an abrupt, temporary impact or rise in rates. We first tested the “pulse” or point impact of the event lasting for one quarter only. In this case, the WTC attack dummy variable was designed so that ‘0’ was assigned to all 47 pre-event points and to the post-event points that were excluded from the impact period. A ‘1’ was assigned only to the first post-event point; thus, the point of impact occurs only during the first quarter following the event. We then tested for an abrupt permanent impact or a level change. This dummy variable would have ‘0’ assigned to all 47 pre-event time points and ‘1’ assigned to all 29 post-event time points. If results indicated that there was an abrupt temporary impact rather than an abrupt permanent impact, longer-duration temporary impacts would be tested by prolonging the impact period to 1 year after the event, 2 years after the event, and so on. In these cases, ‘0’ was assigned to all 47 pre-event points and to the post-event points that were excluded from the impact period. A ‘1’ was assigned to all of the points that defined the period of impact. For example, to define an abrupt 1 year impact,

the dummy variable had '0' assigned to all points up through quarter three 2001, '1' to the points from quarter four 2001 through quarter three 2002, and then '0' to all points from quarter four 2002 on.

As noted previously, we predicted that if there was an effect, the impact of the event on IMR would be delayed by a year because of the definition of IMR and that the impact could be either short or long lasting. As with the analyses described for the LBW and preterm birth rates, we started testing the shortest period of impact, the "pulse" impact. In this case, '0' was assigned to all 51 pre-event periods up to quarter three 2002 to account for the delay, '1' was assigned to only the next quarter in the sequence, quarter four 2002, and then '0' was assigned to all remaining post-event time points. Next, we tested for an abrupt permanent impact or level change. This dummy variable was assigned '0' for all 51 pre-event time points and '1' for all 25 post-event time points. If results indicated that there was an abrupt temporary impact rather than an abrupt permanent impact, longer-duration temporary impacts were tested by prolonging the impact period to 1 year after the event, 2 years after the event, and so on.

We then designed similar dummy independent variables for Madrid to first indicate an abrupt temporary impact—that is, a dummy variable to measure the "pulse" impact. Next, we designed the variable for an abrupt permanent or level change where '0' was assigned to all pre-event time points and '1' to all post-event time points. We would test for longer periods of temporary change (1 year, 2 years, and so on) if the initial impact assessments indicated there was an abrupt temporary impact and not an abrupt permanent impact. As with the NYC variables, the dummy variables for Madrid were different depending on whether we were testing an abrupt impact on LBW or preterm birth rates (impact at the event) or an abrupt impact on IMR (impact delayed by 1 year).

For birth outcome data to be interpretable, the population should be stable. Using ARIMA to model migration in NYC from 1985 through 2007, we found no significant impact of 9/11 on migration patterns. We did the same type of analyses with yearly birth rates for NYC women from 1969 through 2009 and found no significant impact from 9/11. Finally, we tested the yearly time series of population rates in Madrid 1996–2010 to determine population change in the city pre- and post-event and found no change, although the number of time points in the series was small.

RESULTS

New York City and Madrid

Figure 1a shows the three time series patterns of birth outcomes in NYC with the vertical line indicating the 2001 WTC attacks. Because we were using quarterly data, we have a seasonal component to the patterns. Seasonal decomposition was used to smooth the lines, creating trend lines for the series which are included with the actual rate lines. Upon examining the time series and trend lines, preterm births appear to be stationary until quarter three 2003 when there is a small rise in rates. LBW rates have a shallow downward trend in the early 1990s and then seem to level off. IMR has a distinct downward trend that appears to level off after 2001. Even with visible changes, however, conclusions cannot be drawn because changes could be part of the normal variation in the series. ARIMA modeling takes this into account by removing variations with the unique filters of differencing, moving

FIGURE 1. **a** Quarterly rates and trend lines for quarters in the 1990–2008 period for low birth weight (*purple*), preterm births (*green*), and infant mortality (*orange*) in New York City with the quarter of the World Trade Center attacks marked with the *vertical line*. **b** Quarterly rates and trend lines for quarters in the 1990–2008 period for low birth weight (*purple*), preterm births (*green*), and infant mortality (*orange*) in New York state with the quarter of the World Trade Center attacks marked with the *vertical line*.

averages, and/or autoregression with each dependent variable. Figure 1b shows the three time series patterns and trend lines of birth outcomes in the remainder of New York state, the comparison group.

Figure 2 shows the three time series patterns and trend lines of birth outcomes in Madrid with the vertical line indicating the 2004 train bombings. Preterm birth and LBW rates have an increasing trend prior to the bombings, appear to have a steeper increase after the bombings followed by decreases in both rates. They also appear to have outlier rates early in the time series. IMR has a downward trend that varies in steepness over time. Figure 2b shows the three time series patterns and trend lines of birth outcomes in the remainder of Spain.

We first estimated the univariate ARIMA models for each birth outcome in NYC and Madrid to determine the best parameters for each time series. Table 1 reports the final univariate models for the birth outcomes time series. The seasonal models vary in complexity and fit. According to McDowall and colleagues³⁶, social science time series have parameters that rarely exceed one and this is the case with our study models. However, despite the fact that we have seasonal patterns, the NYC LBW model lacks seasonal parameters. Furthermore, the models for Madrid LBW and preterm birth are controlled to account for extreme outliers. All models have a Q statistic (goodness-of-fit) that is not significant, indicating that the model residuals are not different from white noise, resulting in an acceptable fit of the model. Stationary R^2 values indicate overall variation explained in the model and these values vary widely (0.08 to 0.72).

Using the univariate ARIMA models for NYC (Table 1), we introduced the 9/11 dummy variables to determine if the event had a significant impact on the birth outcome. We used a 1-year delayed dummy variable for IMR. Table 2 reports the results for a “pulse” impact lasting only one quarter or a level change impact sustained through the end of the time series post-event period. Only IMR was significantly impacted by the WTC bombings time period with a level change effect of 0.967 ($p < 0.01$), indicating an abrupt permanent positive change in the rate 1 year after the bombing event date. The IMR ARIMA model was also tested for an abrupt temporary change with the “pulse” or one quarter impact independent variable (delayed by 1 year). This change was not significant ($\omega = 0.118$, $p = 0.820$). However, when a first-order “decay” term (δ), indicating a delay in recovery, was introduced, we obtained an effect of $\omega = 0.969$ ($p = 0.003$) and a decay of $\delta = 0.998$ ($p < 0.001$). According to McDowall and colleagues³⁶, when δ is close to 1, the decay is minimal and the effect remains constant through the post-event period. This provides further support for an abrupt, permanent change in IMR. The model is: $y_t = \delta y_{t-1} + \omega P_t$. At the pulse point of impact, $t = I$ and $P_t = 1$ so that $y_I = \omega$. At the next post-event point, $y_{I+1} = \delta \omega$. At successive points, $y_{I+n} = \delta^n \omega$. Thus, in our case, with $\delta = 0.998$, the impact of $\omega = 0.969$ is sustained through the entire post-event period.

Similar impact assessments were conducted with the univariate ARIMA models for Madrid data using the 2004 train bombings dummy variables. The LBW outcome was significantly impacted following the date of the bombings with both a

a
Quarterly Rates and Trend Lines for Low Birth Weight, Preterm Births, Infant Mortality in New York City with Identification of 2001 World Trade Center Attacks

b
Quarterly Rates and Trend Lines for Low Birth Weight, Preterm Births, Infant Mortality in New York State with Identification of 2001 World Trade Center Attacks

FIGURE 2. **a** Quarterly rates and trend lines for quarters in 1990–2009 period for low birth weight (purple), preterm births (green), and infant mortality (orange) in Madrid with the quarter of the train bombings marked with the vertical line. **b** Quarterly rates and trend lines for quarters in the 1990–2009 period for low birth weight (purple), preterm births (green), and infant mortality (orange) in Spain with the quarter of the train bombings marked with the vertical line.

pulse and a level change of 1.247 ($p < 0.001$; Table 2). In order to explain this finding, we tested the effect with the dummy variables representing individual impacts of 1 year through 5 years. We controlled for significant outliers in all analyses. Positive significant impacts were found for a 1-year period ($\omega = 0.848$, $p < 0.001$) and for a 2-year period ($\omega = 0.575$, $p < 0.01$) post-event. A non-significant impact was found for a 3-year period ($\omega = 0.309$, $p = 0.097$) followed by a significant positive impact for a 4-year period ($\omega = 0.875$, $p < 0.001$) and finally a non-significant impact for a 5-year period ($\omega = 0.387$, $p = 0.092$). We interpreted these findings to mean that there was a bimodal pattern to the significantly elevated LBW rates following the date of the 2004 train bombings. A short-term effect was noted for 2 years post-event, with a diminished impact at 3 years, a resurgence for 4 years and finally a drop at 5 years impact. Thus, using the dummy variables for specific periods of time allowed us to determine the pattern of change over the post-event period much better than using only the pulse and level effect event variables.

When we tested the univariate ARIMA model for Madrid preterm birth rates with the dummy pulse independent variable, we found that the model did not fit ($Q = 27.5$, $df = 15$, $p = 0.025$). An alternative approach was to model the pre-event data only and then use that model to test the intervention with the entire series data. Using this strategy resulted in the ARIMA model (1,1,0) (1,0,1) which fit the entire series ($Q = 15.7$, $df = 15$, $p = 0.405$) and detected a significant, positive pulse effect after the date of the bombings on preterm births ($\omega = 1.324$, $p < 0.01$). We continued to control for significant outliers in these analyses. We found no permanent effect post-bombings on preterm births ($\omega = 0.198$, $p = 0.390$). We then used the dummy variables for periods from 1 through 5 years and found a significant positive impact for a 1-year period ($\omega = 0.651$, $p < 0.05$), a 2-year period ($\omega = 0.972$, $p < 0.01$), a 3-year period ($\omega = 0.739$, $p < 0.05$), and a 4-year period ($\omega = 0.843$, $p < 0.05$). The 5-year period was not significant. Thus, the increase in preterm birth rates following the date of the event was abrupt and temporary, but sustained for a longer period of time than was seen with the LBW rates. There was no effect on the IMR post-bombings (pulse effect = 0.585, $p = 0.587$, level effect = 0.162, $p = 0.488$).

In summary, we were able to detect a positive significant impact on IMR in NYC in the period following the WTC attacks and a similar impact on LBW and preterm births in Madrid in the period following the train bombings. There was an increase in the level or trend of IMR by nearly one death per 1,000 live births following the WTC attacks in NYC, or approximately 120 additional infant deaths. Similarly, there was a temporary increase of 1.2 % in the LBW rate trend (approximately 832 births), and a 1.3 % temporary increase in the preterm birth rates (approximately 901 births) in Madrid following the train bombings.

Finally, Figures 3 and 4 depict the time series for NYC IMR and Madrid LBW. These series use pre-event data to predict post-event rates. The forecasted rates (blue line) are graphed along with the actually occurring rates (red line) to indicate that “forecasted” rates differ from the “observed”. As with previous analyses, the 1-year delay is used for the IMR. Although the stability of predictions diminishes

a**Quarterly Rates and Trend Lines for Low Birth Weight, Preterm Births, Infant Mortality in Madrid with Identification of 2004 Train Bombings** **b****Quarterly Rates and Trend Lines for Low Birth Weight, Preterm Births, Infant Mortality in Spain with Identification of 2004 Train Bombings**

TABLE 1 Univariate ARIMA models for birth-outcome-dependent variables in NYC and Madrid, goodness-of-fit statistics and stationary R^2 for birth-outcome-dependent variables in NYC and Madrid

Sites and outcomes	Model (p, d, q) (P, D, Q)	Q statistics	Stationary R^2
NYC			
LBW	(0,1,1) (0,0,0)	$Q=12.2$ $df=17$ $p=0.786$	0.25
Preterm birth	(1,0,0) (1,0,1)	$Q=13.9$ $df=15$ $p=0.534$	0.08
IMR	(0,1,1) (1,1,1)	$Q=20.1$ $df=15$ $p=0.170$	0.65
Madrid			
LBW	(0,1,1) (1,1,0) ^a	$Q=17.5$ $df=16$ $p=0.354$	0.72
Preterm birth	(1,0,0) (1,0,1) ^a	$Q=16.6$ $df=15$ $p=0.341$	0.55
IMR	(0,1,1) (0,1,1)	$Q=9.9$ $df=16$ $p=0.874$	0.63

^aControlled for outliers

with successive time points, there is a clear deviation between the two post-event lines in Figure 3, with observed IMR rates higher than what would be predicted, had 9/11 not occurred. The broken blue lines represent the upper and lower confidence interval rates for the forecasted rates. For each series, the actual rates exceed or match the upper confidence interval in the quarters immediately following the event date when the prediction is most stable. Similar differences are apparent in Figure 4 with the Madrid LBW data. These graphs provide support for the findings that the rates are significantly higher following the events, at least in the early periods following the events. Additionally, correlations for the pre-event observed and predicted values were 0.94 ($p<0.001$) for NYC IMR and 0.96 ($p<0.001$) for Madrid LBW. The post-event correlations of observed and predicted values dropped to 68 ($p<0.001$) and 0.60 ($p<0.001$), respectively

Comparison Groups

The comparison group for NYC was the remainder of New York state. After fitting univariate ARIMA models, pulse and level effect dummy variables were tested to determine the impact of the WTC bombings on all three birth outcomes. LBW rates ($\omega=0.121$, $p=0.487$), preterm birth rates ($\omega=0.193$, $p=0.608$), and IMR ($\omega=-0.426$, $p=0.550$ pulse effect, $\omega=-0.512$, $p=0.255$ level effect) did not significantly differ in the pre- and post-WTC attack periods. Similar non-significant results were found for the Spain comparison group (LBW: $\omega=-0.1$, $p=0.262$; preterm birth: $\omega=0.162$, $p=0.488$; IMR: $\omega=0.020$, $p=0.947$). Thus, the significant increases seen in the rates in NYC and Madrid were unique to those regions and were not part of a broader trend in the state of NY and the country of Madrid.

DISCUSSION

For two of the most significant terrorist attacks in the US and Europe in recent history, we used population data to test whether terrorism affects population health, and specifically studied the vulnerable population of pregnant women and newborns. Using the post-WTC studies with this population as our guide^{23,39-41}, we predicted that the population of pregnant women who lived in the target cities would experience stress-related reactions that would negatively impact their birth

TABLE 2 ARIMA models, goodness-of-fit, stationary R^2 , and effect coefficient (ω) for the impact assessments of the NYC and Madrid birth outcomes with (a) a pulse or short-term-change-independent variable and (b) a level or permanent (perm)-change-independent variable

Sites and outcomes	ARIMA model	Fit statistics	Stationary R^2	Effect coefficient for event variable
NYC				
LBW pulse and perm	(0,1,1) (0,0,0)	$Q=11.8$ $df=17$ $p=0.812$	0.26	$\omega=0.005$ $p=0.979$
Preterm birth pulse	(1,0,0) (1,0,1)	$Q=12.3$ $df=15$ $p=0.659$	0.09	$\omega=-0.001$ $p=0.992$
Preterm perm	(0,1,1) (1,0,1)	$Q=14.9$ $df=15$ $p=0.462$	0.32	$\omega=-0.026$ $p=0.914$
IMR pulse	(0,1,1) (1,1,1) ^a	$Q=20.4$ $df=15$ $p=0.158$	0.65	$\omega=0.118$ $p=0.820$
IMR perm	(0,1,1) (1,1,1) ^a	$Q=20.7$ $df=15$ $p=0.146$	0.68	$\omega=0.967$ $p=0.003$
Madrid				
LBW pulse	(0,1,1) (1,1,0) ^b	$Q=16.6$ $df=16$ $p=0.410$	0.79	$\omega=1.247$ $p<0.001$
LBW perm	(0,1,1) (1,1,0) ^b	$Q=16.6$ $df=16$ $p=0.410$	0.79	$\omega=1.247$ $p<0.001$
Preterm birth pulse	(1,1,0) (1,0,1) ^b	$Q=15.7$ $df=15$ $p=0.405$	0.40	$\omega=1.33$ $p<0.01$
Preterm birth perm	(1,1,0) (1,0,1) ^b	$Q=12.8$ $df=15$ $p=0.614$	0.51	$\omega=0.198$ $p=0.390$
IMR pulse	(0,1,1) (0,1,1) ^c	$Q=8.4$ $df=16$ $p=0.937$	0.65	$\omega=0.585$ $p=0.587$
IMR perm	(0,1,1) (0,1,1) ^c	$Q=9.1$ $df=16$ $p=0.911$	0.65	$\omega=-0.790$ $p=0.204$

^aDummy variable 1-year delayed so that the intervention =0 for quarter 1, 1990 to quarter 3, 2002 and =1 for quarter 4, 2002 to quarter 4, 2008

^bOutliers controlled

^cDummy variable 1-year delayed so that the intervention =0 for quarter 1, 1990 to quarter 1, 2005 and =1 for quarter 2, 2005 to quarter 4, 2009

outcomes; that is, that LBW and preterm births would increase. As depicted in Table 2, we did not have comparable results across our two events, thus challenging us to interpret these results.

Acts of terrorism specifically target “noncombatants” or ordinary citizens and are intended to create fear and a heightened sense of anxiety that extend beyond the target group and the time of the attack⁴². Thus, we thought it would be likely that increases in LBW and preterm births might be sustained because of this heightened level of anxiety felt by pregnant women even after the event happened. Indeed, we found this to be the case in Madrid, as LBW and preterm birth rates significantly increased by approximately one birth in 100 in Madrid women with a gradual decrease to pre-event levels after 3 and 4 years, respectively. In fact, the length of the temporary increase was longer than we anticipated. Stress experienced at any point during the pregnancy can put women at risk for a LBW or preterm birth^{16–19}. Thus, feelings of fear and anxiety about the uncertainty of recurring terrorist attacks may have affected women in Madrid who became pregnant during a finite period after the attacks.

FIGURE 3. Infant mortality rate in New York City by quarters between 1990 and 2008 with vertical line depiction of the World Trade Center attacks; post-event lines indicate observed (red) and predicted (blue) values with confidence intervals (broken blue) using the pre-event data as the predictor.

On the other hand, the prospect of sustained fear and anxiety coupled with secondary effects following the attack may help to explain the increase in IMR in NYC, a result that is different from that found in Madrid. One important point here is that the two primary predictors of early infant mortality, LBW and preterm birth⁴³, were not elevated in the NYC population after the attacks but were elevated in studies of individual women who were pregnant on 9/11 and were exposed to the attack^{23,39–41,44}.

Given our NYC findings, we need to explore potential long-term direct and indirect effects that could contribute to a population increase in IMR. First, environmental toxins were in the air in the lower Manhattan area following the bombings⁴⁴. According to a report released in 2003 by the Environmental Protection Agency (EPA), the public was misinformed about the level and severity of emissions, the level of asbestos in the dust cloud, and the proper management of indoor contamination in lower Manhattan⁴⁵. That is, emissions were more severe,

FIGURE 4. Low birth weight rate in Madrid by quarters between 1990 and 2009 with vertical line depiction of the 2004 train bombings; post-event lines indicate observed (red) and predicted (blue) values with confidence intervals (broken blue) using the pre-event data as the predictor.

toxic, and long lasting than reported, and proper clean-up instructions for ash and dust found in living and business areas were not communicated to the public. Above-threshold levels of asbestos were found in ambient air samples for several months post-attacks and contaminated dust that settled inside and outside buildings included a harmful combination of building pulverized debris containing glass, fibers, lead, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, polychlorinated furans, and dioxins^{44,46}. Therefore, NYC residents were most likely exposed during the first several months after the WTC collapse to contaminants in ambient air as well as to indoor dust in the clean-up process. Furthermore, because indoor cleaning was inadequate, it is possible that contaminated particles have remained indefinitely in many of the commercial and residential buildings. Although connections between normal air pollutants and infant mortality have been made in population studies done in the US^{47,48}, Mexico City⁴⁹, and Western Europe⁵⁰, the EPA in its report has concluded that the full extent of exposure to early ambient air and ongoing indoor contamination from the WTC collapse is unknown.

What other mechanisms may have been associated with a population increase of one infant death per 1,000 live births over what would have been expected if 9/11 had not occurred? Another consideration might be a drop in the level or quality of services offered to pregnant women because of reallocation of resources from public health to security resulting in a higher rate of late or no prenatal care⁵¹. This time series variable was tested with ARIMA modeling and the 9/11 independent variable, and no change was found in the rates of women who received late or no prenatal care ($\omega = -0.114$, $p = 0.770$) from the pre-event period to the post-event period. However, there are several socioeconomic indicators associated with infant mortality including socioeconomic class⁵², educational attainment⁵³, poverty⁵⁴, and race/ethnicity^{55,56}. Therefore, a unique combination of environmental, health, and socioeconomic factors that impact IMR may have been influenced by the WTC attacks to result in a sustained increase in IMR.

If this argument is valid, why was there not a similar effect in Madrid? Possibly, a similar change in IMR was not observed there because of Spain's previous experiences with terrorist attacks, although past attacks were certainly less severe than the 2004 train bombings. The Global Terrorism Database (GTD) documents 898 attacks in Spain (90 in Madrid) between 1990 and 2007, with a decreasing trend in event frequency over this interval⁵⁷. In contrast, the GTD shows an oscillating trend for the 450 events in the United States (31 in NYC) over this same period. The only previous US event with a significant death toll was the bombing of the Murrah Federal Building in Oklahoma City in 1995. Thus, although both events were serious, the NYC attacks may have resulted in a more fundamental change in the population's quality of life than did the Madrid attacks.

Although studies have documented post 9/11 birth outcome changes in women beyond NYC^{58,59}, the population in the remainder of New York state and the remainder of Spain in our comparison groups did not experience significant birth outcome changes following the terrorist attacks. We cannot conclusively demonstrate a causal relationship between the NYC WTC attacks and the post-attacks increase in infant deaths. Nor can we conclusively demonstrate a causal relationship between the Madrid train bombings and the post-bombings increase in LBW and preterm births. However, the lack of similar relationships in the broader regional

areas of the remainder of New York state and Spain rule out many alternative explanations for the observed changes.

There may be limitations to this study related to the use of interrupted time series analyses. The first potential problem concerns the selection of the comparison areas for NYC and Madrid. We felt that including comparison areas to rule out some historical or unrelated effects in the exposed group was a strength. Ideally, we hypothesized that an impact will be noted in the exposed group while no effect or an opposite effect occurs in the comparison group, which was the case in our study. We may conclude that the comparison groups responded as predicted.

The second potential problem is that to ensure internal validity, the exposed and comparison groups should be similar, ideally at one point in time and across time points⁶⁰. As we noted earlier, we chose the comparison groups based on a belief that similarities would exist in health care policies and entitlements for NYC and New York state, as well as for Madrid and the remainder of Spain. Nevertheless, differences in the event and comparison groups may exist due to the level of urbanization and accompanying social and economic diversities. However, in a time series analysis, each group also serves as its own control because the post-event trend is tested against the pre-event trend for the same geographic area.

A third potential problem is that the length of the time series was based on the availability of data rather than on sophisticated sampling methods. In this type of analysis, results may vary based on the length of the time series. Although we began the time series in each country at 1990 in order to standardize the start point of the series, replicating the analyses after significantly more time has passed would be advisable to see if the results that we found persist.

Our study results can be used to inform health and public policy related to terrorist events. First, we did find negative outcomes for vulnerable groups in the aftermath of terrorism. In Madrid, these effects occurred early and lasted for years before resolving. To address this problem, mental health interventions designed to reduce stress responses should be implemented early and sustained, especially for vulnerable groups. Furthermore, integrating these interventions into existing community services, in this case prenatal clinics, rather than associating them with specific event-related services may help to reach those in the population who are affected but are not seeking event-specific services.

In the case of 9/11, problems related to risk information and communication about environmental toxins did not become apparent until 2 years after the event. The public health repercussions of this failure are unknown but may become apparent as health trends are examined over time. Although we cannot tie our results directly to exposure to toxins after the WTC collapse, more work is needed to study this effect on the health of NYC residents, and especially in vulnerable populations. Nevertheless, it is imperative that all agencies involved in communicating risk and its management after a disaster establish clear strategies for addressing coordination and dissemination of appropriate information to the public.

Future research could fruitfully expand on the findings of our study. It would be useful to know, for example, whether other major disasters, such as Hurricane Katrina, the 2011 Japanese earthquake/tsunami, or the Joplin Missouri tornado, among others, had similar effects. Furthermore, given that infant mortality rates vary by race and socioeconomic position, one might also investigate whether there were significant differences in subgroups of popula-

tions. Finally, research could investigate whether events such as these affect other aspects of public health, by examining other indicators.

ACKNOWLEDGMENTS

This research is based upon work supported by the Science and Technology directorate of the U.S. Department of Homeland Security under Grant Award Number 2008-ST-061-ST0004, made to the National Consortium for the Study of Terrorism and Responses to Terrorism (START, www.start.umd.edu). The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Department of Homeland Security or START. The authors have no conflicts of interest relevant to the subject matter in this manuscript. We would like to acknowledge Sandro Galea, MD, DrPH in the conceptualization and design of this manuscript, and Jessica M. Sherrieb for her work in accessing Spanish data and providing translations.

REFERENCES

1. Bonanno GA, Brewin CR, Kaniasty K, Greca AML. Weighing the costs of disaster. *Psychol Sci Publ Interes*. 2010; 11(1): 1–49.
2. Norris FH, Friedman MJ, Watson PJ, Byrne CM, Diaz E, Kaniasty K. 60,000 disaster victims speak: Part I. An empirical review of the empirical literature, 1981–2001. *Psychiatry*. 2002; 65(3): 207–239.
3. Norris F. Outreach to affected communities. In: Neria Y, Gross R, Marshall R, Susser E, eds. *September 11 2001: treatment, research, and public mental health in the wake of a terrorist attack*. New York: Cambridge University Press; 2006.
4. Bleich A, Gelkopf M, Solomon Z. Exposure to terrorism, stress-related mental health symptoms, and coping behaviors among a nationally representative sample in Israel. *JAMA*. 2003; 290(5): 612–620.
5. Gabriel R, Ferrando L, Cortón ES, et al. Psychopathological consequences after a terrorist attack: an epidemiological study among victims, the general population, and police officers. *Eur Psychiatry*. 2007; 22(6): 339–346.
6. Galea S, Ahern J, Resnick H, et al. Psychological sequelae of the September 11 terrorist attacks in New York City. *N Engl J Med*. 2002; 346(13): 982–987.
7. Galea S, Resnick HS. Posttraumatic stress disorder in the general population after mass terrorist incidents. *CNS spectrums*. 2005; 10(2): 107–115.
8. Schuster MA, Stein BD, Jaycox LH, et al. A national survey of stress reactions after the September 11, 2001, terrorist attacks. *N Engl J Med*. 2001; 345(20): 1507–1512.
9. Silver RC, Holman EA, McIntosh DN, Poulin M, Gil-Rivas V. Nationwide longitudinal study of psychological responses to September 11. *JAMA*. 2002; 288(10): 1235–1244.
10. Marshall RD, Bryant RA, Amsel L, Suh EJ, Cook JM, Neria Y. The psychology of ongoing threat: relative risk appraisal, the September 11 attacks, and terrorism-related fears. *Am Psychol*. 2007; 62(4): 304–316.
11. Norris FH. Disaster research methods: past progress and future directions. *J Trauma Stress*. 2006; 19(2): 173–184.
12. Cohan CL, Cole SW, Schoen R. Divorce following the September 11 terrorist attacks. *J Soc Pers Relat*. 2009; 26(4): 512–530.
13. Nakonezny PA, Reddick R, Rodgers JL. Did divorces decline after the Oklahoma City bombing? *J Marriage Fam*. 2004; 66(1): 90–100.
14. Rodgers JL, John CAS, Coleman R. Did fertility go up after the Oklahoma City bombing? *Demography*. 2005; 42(4): 675–692.

15. Mezuk B, Larkin GL, Prescott MR, et al. The influence of a major disaster on suicide risk in the population. *J Trauma Stress*. 2009; 22(6): 481–488.
16. Dole N, Savitz D, Hertz-Picciotto I, Siega-Riz A, McMahon M, Buekens P. Maternal stress and preterm birth. *Am J Epidemiol*. 2003; 157(1): 14–24.
17. Lobel M, Dunkel-Schetter C, Scrimshaw SC. Prenatal maternal stress and prematurity: a prospective study of socioeconomically disadvantaged women. *Heal Psychol*. 1992; 11(1): 32–40.
18. Rini CK, Dunkel-Schetter C, Wadhwa PD, Sandman CA. Psychological adaptation and birth outcomes. *Heal Psychol*. 1999; 18(4): 333–345.
19. Wadhwa PD, Culhane JF, Rauh V, et al. Stress, infection and preterm birth. *Paediatr Perinat Ep*. 2001; 15: 17–29.
20. Holzman C, Bullen B, Fisher R, Paneth N, Reuss L. Pregnancy outcomes and community health. *Paediatr Perinat Ep*. 2001; 15: 136–158.
21. Hansen Precht D, Kragh Andersen P, Olsen J. Severe life events and impaired fetal growth. *Acta Obstet Gynecol Scand*. 2007; 86(3): 266–275.
22. Sable MR, Wilkinson DS. Impact of perceived stress, major life events and pregnancy attitudes on low birth weight. *Fam Plan Perspect*. 2000; 32(6): 288–294.
23. Ohlsson A, Shah PS. Effects of the September 11, 2001 disaster on pregnancy outcomes. *Acta Obstet Gynecol Scand*. 2010; 90: 6–18.
24. Black RE, Morris SS, Bryce J. Where and why are 10 million children dying every year? *Lancet*. 2003; 361(9376): 2226–2234.
25. Galea S, Ahern J. Distribution of education and population health: an ecological analysis of New York City neighborhoods. *Am J Public Health*. 2005; 95(12): 2198–2205.
26. Wise PH. Confronting racial disparities in infant mortality. *Am J Prev Med*. 1993; 9(6 Suppl): 7.
27. Yankauer A. What infant mortality tells us. *Am J Public Health*. 1990; 80(6): 644–648.
28. Zeitlin J, Wildman K, Bréart G. Perinatal health indicators for Europe. *Eur J Obstet Gynecol Reprod Biol*. 2003; 111: S1–S4.
29. Norris FH, Tracy M, Galea S. Looking for resilience: understanding the longitudinal trajectories of responses to stress. *Soc Sci Med*. 2009; 68(12): 2190–2198.
30. Cental Intelligence Agency. The world fact book. 2009. [https://www.cia.gov/library/publications/the-world-factbook/rankorder/rawdata_2091.txt] Accessed May 18, 2011.
31. Schwartz SP, Li W, Berenson L, Williams RD. Deaths in world trade center terrorist attacks. *MMWR Morb Mortal Wkly Rep*. 2002; 51: 16–18.
32. MiguelTobal JJ, CanoVindel A, GonzalezOrdi H, et al. PTSD and depression after the Madrid March 11 train bombings. *J Trauma Stress*. 2006; 19(1): 69–80.
33. Bureau of Vital Statistics, New York City Department of Health and Mental Hygiene. Summary of vital statistics 2002: New York; 2003.
34. Perlman SE, Friedman S, Galea S, Nair HP, Erös-Sarnyai M, Stellman SD, Hon J, Greene CM. Short-term and medium-term health effects of 9/11. *Lancet*. 2011; 378: 925–934.
35. IBM Corporation. *IBM SPSS Statistics 19.0*. NY: Somers; 2011.
36. McDowall D, McCleary R, Meidinger E, Hay R Jr. *Interrupted time series analysis. Quantitative applications in the social sciences, series no. 07-021*. Beverly Hills: Sage; 1980.
37. Cryer JD, Chan K. *Time series analysis*. New York: Springer; 2010.
38. Kitagawa G. *Introduction to time series modeling*. Boca Raton: CRC; 2009.
39. Berkowitz GS, Wolff MS, Janevic TM, Holzman IR, Yehuda R, Landrigan PJ. The world trade center disaster and intrauterine growth restriction. *JAMA*. 2003; 290(5): 595–596.
40. Engel SM, Berkowitz GS, Wolff MS, Yehuda R. Psychological trauma associated with the World Trade Center attacks and its effect on pregnancy outcome. *Paediatr Perinat Ep*. 2005; 19(5): 334–341.
41. Lipkind HS, Curry AE, Huynh M, Thorpe LE, Matte T. Birth outcomes among offspring of women exposed to the September 11, 2001, terrorist attacks. *Obstet Gynecol*. 2010; 116(4): 917–925.

42. Ruby CL. The definition of terrorism. *Anal Soc Issues Public Policy*. 2002; 2(1): 9–14.
43. McCormick MC, Wise PH. Infant mortality. *Curr Opin Pediatr*. 1993; 5(5): 552–557.
44. Landrigan PJ, Liroy PJ, Thurston G, et al. Health and environmental consequences of the World Trade Center disaster. *Environ Heal Perspect*. 2004; 112(6): 731–739.
45. Tinsley N. EPA's response to the World Trade Center collapse. Washington, DC: US Environmental Protection Agency, Office of the Inspector General. *Evaluation Report*, 00012, 2003.
46. Liroy PJ, Weisel CP, Millette JR, et al. Characterization of the dust/smoke aerosol that settled east of the World Trade Center (WTC) in lower Manhattan after the collapse of the WTC 11 September 2001. *Environ Heal Perspect*. 2002; 110(7): 703–714.
47. Chay K, Greenstone M. The impact of air pollution on infant mortality: evidence from geographic variation in pollution shocks induced by a recession. *The Quarterly Journal of Economics*, August; 2003, 1121–1167.
48. Kaiser R, Romieu I, Medina S, Schwartz J, Krzyzanowski M, Künzli N. Air pollution attributable postneonatal infant mortality in US metropolitan areas. *Environmental Health: A Global Access Science Source*. 2004. Retrieved from <http://www.ehjournal.net/content/3/1/4/>.
49. Loomis D, Castillejos M, Gold DR, McDonnell W, Borja-Aburto VH. Air pollution and infant mortality in Mexico City. *Epidemiology*. 1999; 10: 118–123.
50. Scheers H, Mwalili S, Faes C, Fierens F, Nemery B, Nawrot T. Does air pollution trigger infant mortality in Western Europe? *Environ Heal Perspect*. 2011; 119: 1017–1022.
51. Cramer JC. Social factors and infant mortality: identifying high-risk groups and proximate causes. *Demography*. 1987; 24(3): 299–322.
52. Antonovsky A, Bernstein J. Social class and infant mortality. *Soc Sci Med*. 1977; 11(8–9): 453–470.
53. Singh GK, Yu SM. Infant mortality in the United States. *Am J Public Health*. 1995; 85(7): 957–964.
54. Gortmaker SL. Poverty and infant mortality in the United States. *Am Sociol Rev*. 1979; 44: 280–297.
55. Haynatzka V, Peck M, Sappenfield W, et al. Racial and ethnic disparities in infant mortality rates 1995–1998. *MMWR Morb Mortal Wkly Rep*. 2002; 19(51): 329–332. 343.
56. James SA. Racial and ethnic differences in infant mortality and low birth. *Ann Epidemiol*. 1993; 3(2): 130–136.
57. Global Terrorism Database. [<http://www.start.umd.edu/gtd/>] Accessed June 1, 2011.
58. Eskenazi B, Marks AR, Catalano R, Bruckner T, Toniolo PG. Low birthweight in New York City and upstate New York following the events of September 11th. *Hum Reprod*. 2007; 22(11): 3013–3320.
59. Smits L, Krabbendam L, De Bie R, Essed G, Van Os J. Lower birth weight of Dutch neonates who were in utero at the time of the 9/11 attacks. *J Psychosom Res*. 2006; 61(5): 715–717.
60. Cook TD, Campbell DT. *Quasi-experimentation: design and analysis issues for field settings*. Chicago: Rand McNally; 1979.