

Birth Outcomes Among Offspring of Women Exposed to the September 11, 2001, Terrorist Attacks

Heather S. Lipkind, MD, MS, Allison E. Curry, PhD, Mary Huynh, PhD, Lorna E. Thorpe, PhD, and Thomas Matte, MD, MPH

OBJECTIVE: To evaluate the effects of the September 11, 2001, World Trade Center attacks on birth outcomes.

METHODS: Live singleton births between September 11, 2001, and October 31, 2002, to women enrolled in a World Trade Center Health Registry (the Registry, $n=446$) were compared with births to women residing more than 5 miles from the World Trade Center ($n=49,616$). Birth weight, gestational age, low birth weight, and preterm delivery were evaluated using linear and logistic regression. Births before September 11, 2001, were analyzed to assess possible seasonal biases of associations with pregnancy trimester on September 11. Associations of birth outcomes with September 11–related psychologic stress and physical exposures were assessed among births to women within the Registry ($n=499$).

RESULTS: Birth weight and gestational age distributions were similar for births to women enrolled in the Registry

and comparison births. Although mean gestational age and birth weight varied with trimester on September 11, a similar association was found among births in previous years, consistent with a seasonal effect not related to exposure. Registry-linked births to mothers with probable posttraumatic stress disorder ($n=61$) had a higher odds of low birth weight (adjusted odds ratio [OR] 2.49, 95% confidence interval [CI] 1.02–6.08) and preterm delivery (adjusted OR 2.48, 95% CI 1.05–5.84) compared with births to women without posttraumatic stress disorder.

CONCLUSION: Women who lived, worked, or were near the World Trade Center on or soon after September 11 had pregnancy outcomes similar to women residing more than 5 miles away. However, among exposed women, probable posttraumatic stress disorder was associated with low birth weight and preterm delivery.

(*Obstet Gynecol* 2010;116:917–25)

LEVEL OF EVIDENCE: II

From the Yale School of Medicine, New Haven, Connecticut; the Children's Hospital of Philadelphia, Philadelphia, Pennsylvania; the Health Sciences Department, Lehman College, Bronx, New York; the Epidemiology and Biostatistics Program, City University of New York School of Public Health, Hunter College, New York, New York; and the Urban Public Health Program, Hunter College, City University of New York School of Public Health, New York, New York.

Supported in part by Cooperative Agreement U50/ATU272750 from the Agency for Toxic Substances and Disease Registry, which includes support from the Centers for Disease Control and Prevention's National Center for Environmental Health, and by the New York City Department of Health and Mental Hygiene.

Dr. Curry performed this work while at the New York City Department of Health and Mental Hygiene.

The contents of this article are solely the responsibility of the authors and do not necessarily represent the official views of the Agency for Toxic Substances and Disease Registry.

Corresponding author: Heather S. Lipkind, MD, MS, Department of Obstetrics, Gynecology and Reproductive Sciences, Yale School of Medicine, New Haven, CT; e-mail: hslipkind@yahoo.com.

Financial Disclosure

The authors did not report any potential conflicts of interest.

© 2010 by The American College of Obstetricians and Gynecologists. Published by Lippincott Williams & Wilkins.

ISSN: 0029-7844/10

The September 11, 2001, attacks on the World Trade Center created an acute disaster of unprecedented size in New York City. Air monitoring and evaluation of settled dust indicated that persons in the vicinity of the event potentially were exposed to high levels of particulate matter and other combustion byproducts from pulverization of the buildings, jet fuel fires, and exhaust from gasoline and diesel engines used in recovery operations.^{1,2}

Data on the possible effects of natural and man-made disasters on birth outcomes are limited. Studies have examined the relationship of air pollution to adverse pregnancy outcomes and have shown an effect on preterm delivery and on intrauterine growth restriction.^{3–5} Studies have also shown links between psychologic trauma and adverse pregnancy outcomes.^{6–13}

Studies of birth outcomes after exposures from living or being near the World Trade Center at the time of the attacks have shown inconsistent re-



sults.^{14–19} Berkowitz et al¹⁴ reported a higher proportion of births with intrauterine growth restriction associated with exposure. Lederman et al¹⁷ reported reduced birth weights and also reported that women in the first trimester of pregnancy at the time of September 11 delivered neonates with a shorter gestation as compared with women in later trimesters of pregnancy regardless of proximity to the World Trade Center site.

To evaluate the potential effects of the World Trade Center attacks on birth outcomes while addressing limitations of prior studies, we examined outcomes of live births to women enrolled in the World Trade Center Health Registry. We also evaluated relationships between self-reported measures of dust exposure and psychologic stress on birth outcomes. Finally, to evaluate possible seasonal influence affecting associations between the trimester of pregnancy on September 11 and live birth outcomes, we examined outcomes of live births in an historical comparison group according to trimester of pregnancy on September 11, 1999.

MATERIALS AND METHODS

This study was conducted using data from the World Trade Center Health Registry (the Registry), a voluntary registry established by the New York City Department of Health and Mental Hygiene and the Agency for Toxic Substances and Disease Registry to monitor the physical and mental health impact of September 11. The Registry was established to prospectively monitor the physical and mental health of people with a high probability of direct exposure to September 11 and its aftermath, including rescue, recovery and volunteer workers; persons with a primary residence in lower Manhattan on September 11; office workers; and passersby present in lower Manhattan on the morning of September 11.^{20,21} The Centers for Disease Control and Prevention and New York City Health Department Institutional Review Boards approved the Registry protocols. A Federal Certificate of Confidentiality was obtained as was verbal informed consent. This study was approved by the Institutional Review Board at the New York City Department of Health and Mental Hygiene.

A total of 71,437 people enrolled in the Registry, making it the largest postdisaster registry in US history.²¹ Outreach and multilingual media campaigns encouraged enrollment through a toll-free number or the Registry Web site (classified as “self-identified” enrollees).²² Others were solicited from lists of potentially exposed persons provided by entities such as employers and governmental agencies (classified as

“list-identified”).²⁰ Final registry enrollment was composed of 70% self-identified and 30% list-identified enrollees. Of the 71,437 enrollees, 599 (0.84%) identified themselves as pregnant on September 11, 2001. Both active and passive recruitment methods were used over a 15-month enrollment period from September 5, 2003, through November 20, 2004, during which enrollees completed a baseline interview.

We then used data obtained from the Department of Health and Mental Hygiene’s Office of Vital Statistics. In this study, the “exposed” population of interest was all women within the Registry who gave birth to live singleton neonates in New York City with a gestation that overlapped with the period September 11, 2001, through December 1, 2001, according to the New York City birth certificate files maintained by the New York City Office of Vital Statistics. Our goal was to study live births to women who may have been exposed during or just before conception²³ to the physical or psychologic impact of the attacks either acutely or during the time when fires continued to burn at the World Trade Center site through mid-December.

All women of reproductive age (18–49 years) on September 11 enrolled in the Registry were matched using strict criteria to data from New York City birth certificates to identify live births to women who delivered between September 11, 2001, and October 14, 2002. A pool of potential matches were identified as those records from the Registry and birth records that matched on one of the following criteria: 1) mother’s date of birth, 2) last four digits of Social Security Number, or 3) first four characters of first name and first four characters of last name and month, day, or year of birth. A score was created for each potential match by awarding points for identical or similar values in corresponding fields. Potential matches were then grouped based on which corresponding fields matched.

The comparison group included all women who were not in the Registry, who resided in a New York City census tract greater than 5 miles from the World Trade Center site, and who delivered a live singleton neonate between September 11, 2001, and October 31, 2002.

For consistency with other studies of birth outcomes related to September 11 and to minimize potential errors of vital statistics data, births were excluded from the study for the following reasons: multiple births, gestational age less than 26 weeks or greater than 42 weeks, maternal age younger than 18 or older than 49 years, birth weight less than 500 g or higher than 5,000 g, maternal smoking or pregesta-



tional diabetes noted on the birth certificate, and information on the birth outcomes missing.^{14,16,17} This excluded 45 births out of the original 544 registry births matched (9.0%) and 60,797 in the control group (35.6%). Among the remaining 499 live births linked to women in the Registry, 55 (11.0%) were to rescue and recovery workers (six of these women [1.2%] actually worked on the World Trade Center disaster site), 173 to women residing near the World Trade Center (34.7%), 244 to women who worked in lower Manhattan (including school teachers) (48.9%), and 27 to women who were passersby (5.4%).

The Registry was composed of a highly affluent population with relatively few Medicaid-covered women (53 of 499 [10.6%]) compared with women giving birth overall in New York City (60,557 of 110,173 [54.9%]). To create two comparable groups, our principal analyses excluded births to women with Medicaid as their primary coverage. The final population examined in the primary analysis was 446 women from the Registry compared with 49,616 in the control group. We also performed an analysis on subgroups of Registry-linked births to examine effects of environmental and stress-related exposures on birth outcomes. This analysis included all 499 births to mothers in the Registry regardless of health insurance coverage (Fig. 1).

Birth outcomes examined were birth weight and gestational age at delivery. Each was analyzed as both a continuous measure and classified as low birth weight (less than or equal to 2,500 g) and preterm delivery (less than 37 completed weeks of gestation), respectively. Birth weight, gestational age, and other birth characteristics are collected by the Department of Health and Mental Hygiene during the process of registering births

and issuing birth certificates. The hospital or institution of birth reports birth weight in pounds and ounces or grams. Birth weights less than 1,000 g are verified with the reporting hospital. Clinical estimate of gestation was reported on the birth certificate in completed weeks and is intended to reflect the birth attendant's best estimate of the neonate's gestation taking into consideration all perinatal factors.

All covariates and potential confounders were based on electronic birth record data for both Registry-linked births and controls. Potential confounders included demographic and other maternal and pregnancy characteristics previously shown to be associated with the outcomes of interest. These included maternal race and ethnicity, maternal level of education (high school or less, more than high school), maternal employment, foreign born, parity (nulliparous or multiparous), neonatal sex, maternal age in years (18–34 years, 35+ years), mode of delivery (vaginal or cesarean), and maternal medical risk factors (one or more of: chronic hypertension, eclampsia, preeclampsia, pregnancy-induced hypertension, and gestational diabetes).

Using birth date and clinical estimate of gestational age to estimate the date of conception, the trimester of pregnancy on September 11, 2001, was classified based on computed days of gestation: first trimester less than 92 days, second trimester 92–181 days, third trimester 182 or more days. A fourth category included births resulting from pregnancies conceived between September 12, 2001, and December 31, 2001.²³

To assess associations with both exposure to September 11 and birth outcomes, we generated descriptive statistics and univariable associations for all variables. We performed *t* tests to examine mean gestational age

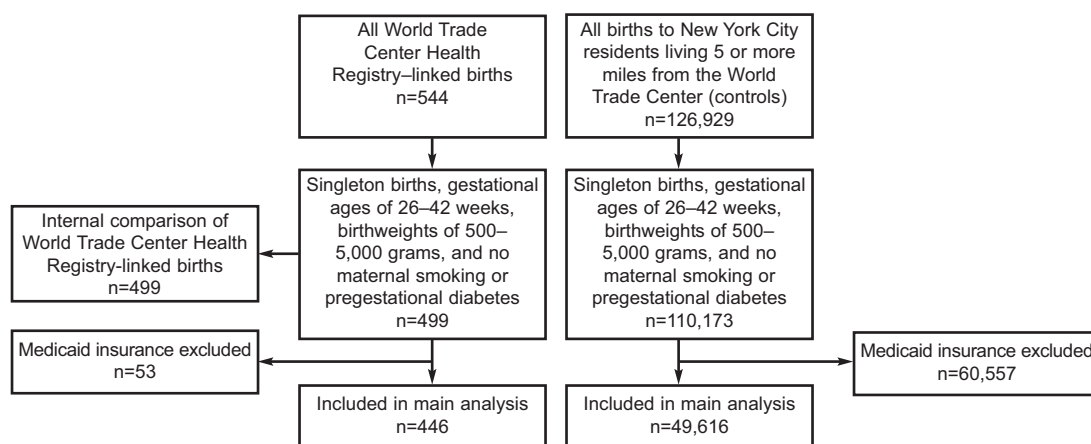


Fig. 1. Study populations: World Trade Center Health Registry-linked births and control births. Includes live births between September 11, 2001, and October 31, 2002.

Lipkind. Birth Outcomes After 9/11. Obstet Gynecol 2010.



and mean birth weight of neonates in the exposure and comparison groups. A multivariable analysis was then performed. Covariates were included in the multivariable model if the univariable chi-square P values were less than .05. The two outcomes, birth weight and gestational age at birth, were analyzed as both continuous variables in linear regression models and as dichotomous outcomes in logistic regression models. We used backward elimination to remove covariates with inconsequential contribution to the model, retaining only those that significantly contributed to final model fit ($P < .05$) using the likelihood ratio test for logistic regression and similar methods for the continuous outcomes.

One prior study found a significant association between trimester of pregnancy on September 11 and birth outcomes regardless of maternal place of residence or employment.¹⁷ To explore whether that association or a similar pattern in our own data might be the result of seasonal effects^{24,25} or other artifacts and unrelated to exposure to the September 11 event, we analyzed outcomes of live births that were conceived and delivered before September 11 and thus could not have been affected by that event. Specifically, we conducted an historical comparison analyzing outcomes in a similar population of non-Medicaid births to New York City residents ($n=60,819$) occurring between September 12, 1999, and October 14, 2000, in relation to trimester on September 11, 1999. We developed multivariable models following the same procedures as in our main analysis.

Within the entire group of 499 births linked to mothers in the Registry population, we evaluated the associations of birth outcomes with experiences and self-reported exposures on or after September 11. Information was obtained from all 499 women during the baseline interview conducted between September 2003 and November 2004. We chose to examine variables that have previously been explored within the Registry and have been found to be associated with higher levels of exposure.

Our primary mental health outcome focused on September 11-related posttraumatic stress symptoms indicative of posttraumatic stress disorder (PTSD). These were assessed with the stressor-specific PTSD Checklist, a 17-item self-report instrument based on Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition diagnostic criteria for PTSD and linked to a specific traumatic exposure, in this case, "the events of September 11." Respondents scored each symptom on a 5-point scale; a 17-item total of 44 or greater was deemed indicative of probable PTSD. The interview occurred 3–4 years after September 11, but all 17 PTSD symptom questions were grounded in

the events of September 11 (eg, flashbacks to the events of September 11) and reported for the last 30 days before interview. Therefore, we measured probable September 11-related PTSD concurrent with the interview. Because interviews occurred 3–4 years after September 11, the PTSD measurement most likely represents individuals for which the events of September continue to have lasting psychologic effects.²⁶

Witnessing horror has also been studied within the Registry as a marker of posttraumatic stress symptoms. Witnessing horror was coded as affirmative if participants reported that they personally saw any of the following on September 11: an airplane hitting the World Trade Center, a building collapsing, people running away from a cloud of dust and debris, anyone who was injured or killed, and people falling or jumping from the World Trade Center towers.²⁷

We examined dust cloud exposure on September 11 because it has also been strongly associated with both adverse physical and mental health outcomes.²⁷ Dust cloud exposure was defined as answering "yes" on the question in the Registry to being caught in the dust or debris cloud on September 11.

We performed a descriptive analysis and developed multivariate models relating September 11 exposures to birth outcomes as continuous or discrete outcomes as previously described adjusting for all covariates identified as significantly associated with the outcome. The covariate maternal race and ethnicity was defined as African American race and all other races given the limited distribution within the Registry population (largely non-Hispanic white). We used the difference in the -2 log likelihood ratios to determine which variables improved model fit and used backward elimination to remove covariates with inconsequential contribution to the model, retaining only those which significantly contributed to final model fit ($P < .05$). All data analysis was conducted using SAS 9.1 (SAS Institute, Cary, NC).

RESULTS

Table 1 displays the maternal demographic, medical, and delivery characteristics of the Registry-linked births and the control births. The former group included 295 (66%) births to women in the Registry who were pregnant on September 11, 2001, and 151 births (34%) to women who were in the registry and conceived between September 12 and December 31, 2001. Compared with the control births, a significantly higher proportion of Registry-linked births had maternal age 35 years or older, finished high school, were US-born, and were employed. In addition,



Table 1. Demographic, Medical, and Delivery Characteristics of the World Trade Center Health Registry-Linked Births and Control Births Between September 11, 2001, and October 31, 2002

	WTCHR (n=446)	Control (2001–2002) (n=49,691)	P
Trimester on 9/11			
Pregnant after 9/11/01 and before 12/31/01	151 (33.9)	16,122 (32.5)	.3
First trimester	107 (24.0)	11,146 (22.5)	
Second trimester	101 (22.7)	10,851 (21.9)	
Third trimester	87 (19.5)	11,497 (23.2)	
Race and ethnicity			
Puerto Rican	46 (10.3)	3,791 (7.6)	<.001
Other Hispanic	34 (7.6)	6,376 (12.9)	
Asian/Pacific Islander	41 (9.2)	6,204 (12.9)	
Non-Hispanic white	236 (52.9)	22,125 (44.6)	
Non-Hispanic African American	89 (20.0)	10,941 (22.1)	
Other	—	104 (0.21)	
Maternal education			
High school graduate or less	50 (11.2)	16,004 (32.3)	<.001
More than high school graduate	395 (88.8)	33,514 (67.7)	
Maternal age (y)			
18–34	273 (61.2)	37,259 (75.1)	<.001
Older than 35	173 (38.8)	12,357 (24.9)	
Primary payer			
HMO or self-insured	155 (34.8)	18,078 (36.4)	.46
Private insurance	291 (65.3)	31,538 (63.6)	
Mother employed	389 (87.2)	31,195 (62.9)	<.001
Foreign-born	125 (28.0)	21,258 (43.0)	<.001
Parity			
Nulliparous	250 (56.0)	24,098 (48.6)	.002
Multiparous	196 (44.0)	25,518 (51.4)	
Delivery mode			
Vaginal	302 (67.7)	36,167 (73.0)	.01
Cesarean	144 (32.3)	13,449 (27.1)	
Neonatal sex			
Male	240 (53.8)	25,437 (51.3)	.28
Female	206 (46.2)	24,179 (48.7)	
Medical risk factors*	31 (7.0)	3,129 (6.1)	.6

WTCHR, World Trade Center Health Registry; HMO, health maintenance organization.

Data are n (%) unless otherwise specified.

* Maternal medical risk factors include chronic hypertension, eclampsia, preeclampsia, pregnancy-induced hypertension, and gestational diabetes.

Registry-linked births were more likely to be to nulliparous mothers and delivered by cesarean. The distributions of trimester on September 11 and the presence of one or more medical risk factors were comparable in both groups.

There was no difference in the mean gestational age and the mean birth weight of neonates in the exposure and the comparison groups in the unadjusted analysis (3,311.8 compared with 3,325.5 g; $P=.59$). There was also no difference in gestational age of delivery (38.9 weeks in both groups, $P=.74$).

In multiple regression analysis, the covariate-adjusted difference in birth weight between Registry-linked births and controls remained not statistically significant (-26.9 g, $P=.29$). Similarly, there was no difference in covariate-adjusted gestational age of

delivery (0.001 weeks, $P=.99$) (Table 2). There was no difference in the odds of low birth weight (less than 2,500 g; adjusted odds ratio [OR] 1.03, 95% confidence interval [CI] 0.7–1.55 or preterm delivery adjusted OR 1.04, 95% CI 0.72–1.50) after adjusting for trimester on September 11, race and ethnicity, education, maternal age, foreign-born, neonatal sex, parity, medical risk factors, and mode of delivery.

Although there was no difference in birth outcomes when comparing the Registry-linked births with controls, gestational age at birth and birth weights varied significantly overall by trimester on September 11; mean gestational age and birth weight were lowest in births with estimated date of conception between September 12, 2001, and December 31, 2001, and highest in those in the third



Table 2. Multiple Regression Results for Outcomes of World Trade Center Health Registry-Linked Births and Control Births Between September 11, 2001, and October 31, 2002*

	Birth Weight			Gestational Age		
	Coefficient	95% CI	P	Coefficient	95% CI	P
WTCHR-linked compared with controls unadjusted	−13.7	−64.2 to 36.8	.59	−0.03	−0.2 to 0.1	.74
Covariate-adjusted results						
WTCHR-linked compared with control	−26.9	−76.3 to 22.5	.29	−0.001	−0.2 to 0.2	0.99
Trimester on 9/11			<.001			<.001
Pregnant after 9/1/01 and before 12/31/01	−82.8	−95.5 to −70.2		−0.4	−0.5 to −0.4	
First trimester	−53.3	−67.5 to −40.0		−0.2	−0.3 to −0.2	
Second trimester	−48.2	−62.1 to −34.4		−0.3	−0.3 to −0.2	
Third trimester	Referent	Referent		Referent	Referent	
Race and ethnicity			<.001			<.001
Hispanic	−80.1	−92.8 to −67.5		−0.3	−0.3 to −0.2	
Asian	−193.1	−209.4 to −176.8		−0.3	−0.3 to −0.2	
African American	−164.1	−176.5 to −151.7		−0.4	−0.4 to −0.3	
Other race	−155.8	−258.2 to 53.4		−0.4	−0.7 to −0.04	
White	Referent	Referent		Referent	Referent	
Maternal education			<.001	†	†	†
High school graduate or less	Referent	Referent				
More than high school graduate	38.8	28.6 to 49.0				
Maternal age (y)	†	†	†			<.001
18–34				Referent	Referent	
Older than 35				−0.1	−0.2 to −0.08	
Mother employed	†	†	†	−0.04	−0.07 to 0.01	.02
Foreign-born	23.2	12.9 to 33.6	<.001	†	†	†
Parity			<.001			<.001
Nulliparous	−91.7	−101.1 to −82.3		0.08	0.05 to 0.1	
Multiparous	Referent	Referent		Referent	Referent	
Delivery mode			<.001			<.001
Vaginal	Referent	Referent		Referent	Referent	
Cesarean	29.4	18.8 to 39.9		−0.3	−0.3 to −0.3	
Neonatal sex			<.001			<.001
Male	114.0	104.7 to 123.3		−0.1	−0.1 to −0.04	
Female	Referent	Referent		Referent	Referent	
Medical risk factors†	−171.5	−190.7 to −152.3	<.001	−0.9	−1.0 to −0.89	<.001

CI, confidence interval; WTCHR, World Trade Center Health Registry.

* Model adjusted for all noted variables in the model, except where indicated as not included.

† Variable not included in model.

‡ Maternal medical risk factors include chronic hypertension, eclampsia, preeclampsia, pregnancy-induced hypertension, and gestational diabetes.

trimester on September 11, 2001. This association is almost entirely accounted for by the comparison births to mothers living more than 5 miles from the World Trade Center (more than 99% of the study population).

Among births conceived and delivered before September 11, mean gestational age and birth weight were lowest in births with estimated date of conception between September 12, 1999, and December 31, 1999, and highest in those in the third trimester on September 11, 1999 (Table 3). We also found women in their first trimester in September through December 1999 had a higher odds of preterm delivery (adjusted OR 2.27, 95% CI 2.05–2.51) and low birth weight (adjusted OR 1.56, 95% CI 1.40–1.74) com-

pared with women in their third trimester in September 1999.

Sixty-one women (12.6%) screened positive for probable PTSD at the time of interviews. Probable PTSD was not associated with a difference in gestational age of delivery ($P=.3$) but was significantly associated with a difference in birth weight of 169.8 g ($P=.03$; Table 4) in the unadjusted analysis, although this association was borderline nonsignificant when controlling for confounding (152.4 g, $P=.06$). There was an increased odds of preterm delivery (adjusted OR 2.48, 95% CI 1.05–5.84) and low birth weight (adjusted OR 2.49, 95% CI 1.02–6.08) after controlling for confounding in women with a high PTSD score compared with a lower score.



Table 3. Multiple Regression Results for Historical Comparison Births Conceived and Delivered Before September 11, 2001*

Trimester on 9/11/99	Birth Weight			Gestational Age		
	Coefficient	95% CI	P	Coefficient	95% CI	P
Pregnant after 9/11/99 and before 12/31/00	−54.6	−66.0 to −43.0	<.001	−0.5	−0.5 to −0.4	<.001
First trimester	−19.6	−32.0 to −7.2	.002	−0.3	−0.3 to −0.2	<.001
Second trimester	−38.7	−51.2 to −26.1	<.001	−0.3	−0.3 to −0.2	<.001
Third trimester	Referent	Referent	Referent	Referent	Referent	Referent

CI, confidence interval.

* Live births to New York City residents not covered by Medicaid occurring between September 11, 1999, and October 14, 2000, controlling for race and ethnicity, education, maternal employment, foreign born, parity, neonatal sex, maternal medical-related complications, and cesarean delivery.

More than half of the women (297 [59.5%]) reported being caught in the dust cloud on September 11. There was no association between reported dust cloud exposure and either mean birth weight ($P=.2$) or mean gestational age of delivery ($P=.1$). However, births to women who reported dust cloud exposure had a trend toward a higher odds of low birth weight, but this association was not significant when controlling for confounding (adjusted OR 1.70, 95% CI 0.72–4.01).

A high percent of mothers in the Registry reported witnessing a horrific event (312 women [62.5%]). Although there was a higher odds of low birth weight (adjusted OR 2.53, 95% CI 1.08–5.93) in the unadjusted analysis, with confounder adjustment, this association was attenuated and nonsignificant (adjusted OR 1.62, 95% CI 0.67–3.96) as were associations with birth weight, gestational age, and preterm delivery (Table 4).

DISCUSSION

Our results indicate that there was no difference in birth outcomes to pregnant women enrolled in the World Trade Center Health Registry compared with the control population. Although mean gestational age and birth weight varied with trimester on September 11, a similar association was found among births in previous years, consistent with a seasonal effect not related to exposure. Among singleton live births to Registry enrollees, those whose mothers had probable PTSD had higher odds of preterm delivery and low birth weight.

Births to women who were in the Registry and either lived or worked near the World Trade Center site on September 11 or in the subsequent months had a similar distribution of birth weight and gestational age at birth compared with births among women residing more than 5 miles from the World Trade

Table 4. Multiple Regression Results for Maternal September 11-Related Posttraumatic Stress Disorder and Experiences Among World Trade Center Health Registry-Linked Births

Exposure	Number Exposed n (%)	Birth Weight* Coefficient, P (95% CI)	Gestational Age† Coefficient, P (95% CI)	Birth Weight Less Than or Equal to 2,500 g‡ OR, P (95% CI)	Delivery Less Than 37 Weeks§ OR, P (95% CI)
Probable PTSD	61 (12.6)				
Unadjusted		−169.8, .03 (−326.8 to −12.8)	−0.3, .3 (−0.9 to 0.2)	3.13, .003 (1.42–6.89)	2.67, .01 (1.23–5.80)
Adjusted		−152.4, .06 (−312.2 to 7.4)	0.1, .7 (−0.7 to 0.4)	2.49, .04 (1.02–6.08)	2.48, .03 (1.05–5.84)
Dust cloud	297 (59.5)				
Unadjusted		−74.1, .2 (−179.2 to 31.1)	−0.3, .1 (−0.7 to 0.1)	2.40, .03 (1.06–5.40)	1.57, .21 (0.77–3.25)
Adjusted		−26.8, .6 (−131.6 to 78.0)	−0.1, .4 (−0.5 to 0.2)	1.70, .22 (0.72–4.01)	1.29, .52 (0.60–2.78)
Witnessed horrific events	312 (62.5)				
Unadjusted		−74.3, .2 (−180.8 to 32.2)	−0.2, .2 (−0.6 to 0.1)	2.53, .03 (1.08–5.93)	1.58, .21 (0.77–3.25)
Adjusted		−21.2, .7 (−127.3 to 84.9)	0.02, .9 (−0.4 to 0.3)	1.62, .29 (0.67–3.96)	1.25, .58 (0.57–2.72)

CI, confidence interval; OR, odds ratio; PTSD, posttraumatic stress disorder.

* Controlling for race and ethnicity, maternal medical risk factors, participation in Medicaid, and maternal employment.

† Controlling for race and ethnicity, maternal medical risk factors, parity, mode of delivery, and source of information.

‡ Controlling for race and ethnicity, maternal medical risk factors, participation in Medicaid, and mode of delivery.

§ Controlling for race and ethnicity, maternal medical risk factors, mode of delivery, source of information, and maternal education.



Center during the same time period. Our finding differs from prior studies that have shown associations with one or more related outcomes.^{14,16,17} The samples of exposed and comparison births in one of these studies¹⁴ were identified from very different populations and methods and may have had differential selection biases. A second study¹⁷ showed a significant but small effect size, which was not replicated in our study.

Previously, Lederman and colleagues¹⁷ found that mothers who were in their first trimester of pregnancy on September 11, 2001, delivered 3.6 days earlier than mothers who were past the first trimester on that date regardless of location of work or residence in New York City. Our analysis found a similar pattern, but we also showed that this same association exists among births conceived and delivered before September 11, 2001, in relation to pregnancy trimester on September 11, 1999, suggesting the association is not causally related to the World Trade Center attacks that occurred in 2001. One possible explanation of this association is confounding by an association of season and birth weight, possibly mediated by ambient temperature or other environmental variables.^{24,25,28–30} Because season and trimester on a specific date are perfectly confounded, a seasonal bias on our result and those of Lederman et al cannot be excluded.

Women within the Registry varied in their experiences related to the World Trade Center attacks and in associated psychologic stress and physical exposures. Although the number of births linked to women reporting symptoms compatible with PTSD was limited (61, approximately 13% of the total), those births were significantly more likely to be preterm or to be low birth weight. Mean birth weight was also lower in this subgroup, although this effect was marginally nonsignificant in the adjusted analysis. More than half of Registry-linked births were to mothers who reported either being caught in the dust cloud from the World Trade Center attacks or witnessing one or more specified horrific events.²⁵ Crude associations of these experiences with low birth weight and were substantially attenuated and nonsignificant with adjustment for confounders. These inconclusive results are limited by wide CIs indicating limited power to detect an effect as well as some overlap of these experiences with probable PTSD.

Previous data on possible connections of psychologic stress from the events of September 11 and adverse pregnancy outcomes are limited. Engel et al³¹ assessed outcomes of a small cohort of pregnant women (n=52) who completed at least one prenatal

psychologic assessment and observed a marginal association among symptoms of probable posttraumatic stress symptomatology, increased gestational duration, and decreased head circumference. Of this cohort, only four women had probable PTSD.¹⁵

Although there are numerous studies evaluating stress and trauma in pregnancy, less than a handful of studies have evaluated PTSD as a risk factor for adverse perinatal outcomes although PTSD is the third most common psychiatric illness among pregnant women.³² The stress response involves coordination of several systems, but particularly the hypothalamic–pituitary–adrenal axis, which may lead to an increase in cortisol production and cortisol-releasing hormone, which are involved with the cascade that leads to delivery.^{12,33}

Our study was limited, because births outside of New York City to pregnant women enrolled in the World Trade Center Health Registry were not captured. Additionally, the validity of some covariate data from the birth certificates such as maternal health conditions is questionable, thereby limiting the ability to control for potential confounders. Some mothers in comparison neighborhoods may have been present near the World Trade Center on September 11 and eligible for enrollment but did not enroll, which may have introduced some exposure misclassification into our data. However, essentially all women in the Registry would be considered “exposed” to the September 11 attacks using more stringent proximity criteria than used in prior studies, whereas the proportion exposed among controls is almost certainly much lower. Enrollment in the registry raises questions about the representativeness of the study population. It seems most likely that Registry mothers would be more likely to enroll had they had problems with a pregnancy outcome. This would tend to bias the Registry population toward a finding with a higher risk of adverse pregnancy outcomes than a less exposed population, which we did not find. Finally, the interview collecting the PTSD measure occurred 3–4 years after the event and may have not fully captured the complete stress response for the women between the time of September 11 and the birth of their children.

Despite these limitations, the analysis within the Registry showed that there is a higher odds of preterm delivery and low birth weight in women who had the highest level of exposure to stress associated with September 11. Our findings contribute to the growing body of evidence that extreme levels of psychologic stress and PTSD affect pregnancy outcomes.



REFERENCES

- Liyo PJ, Georgopoulos P. The anatomy of the exposures that occurred around the World Trade Center site: 9/11 and beyond. *Ann N Y Acad Sci* 2006;1076:54–79.
- Landrigan PJ, Liyo PJ, Thurston G, Berkowitz G, Chen LC, Chillrud SN, et al. Health and environmental consequences of the World Trade Center disaster. *Environ Health Perspect* 2004;112:731–9.
- Lee BE, Ha EH, Park HS, Kim YJ, Hong YC, Kim H, et al. Exposure to air pollution during different gestational phases contributes to risks of low birth weight. *Hum Reprod* 2003;18:638–43.
- Rich DQ, Demissie K, Lu SE, Kamat L, Wartenberg D, Rhoads GG. Ambient air pollutant concentrations during pregnancy and the risk of fetal growth restriction. *J Epidemiol Community Health* 2009;63:488–96.
- Maisonet M, Correa A, Misra D, Jaakkola JJ. A review of the literature on the effects of ambient air pollution on fetal growth. *Environ Res* 2004;95:106–15.
- Cokkinides VE, Coker AL, Sanderson M, Addy C, Bethea L. Physical violence during pregnancy: maternal complications and birth outcomes. *Obstet Gynecol* 1999;93:661–6.
- Curry MA, Perrin N, Wall E. Effects of abuse on maternal complications and birth weight in adult and adolescent women. *Obstet Gynecol* 1998;92:530–4.
- Glynn LM, Wadhwa PD, Dunkel-Schetter C, Chicx-Demet A, Sandman CA. When stress happens matters: effects of earthquake timing on stress responsivity in pregnancy. *Am J Obstet Gynecol* 2001;184:637–42.
- Smith MV, Rosenheck RA, Cavaleri MA, Howell HB, Poschman K, Yonkers KA. Screening for and detection of depression, panic disorder, and PTSD in public-sector obstetric clinics. *Psychiatr Serv* 2004;55:407–14.
- Xiong X, Harville EW, Mattison DR, Elkind-Hirsch K, Pridjian G, Buekens P. Exposure to Hurricane Katrina, post-traumatic stress disorder and birth outcomes. *Am J Med Sci* 2008;336:111–5.
- Yehuda R, Engel SM, Brand SR, Seckl J, Marcus SM, Berkowitz GS. Transgenerational effects of posttraumatic stress disorder in babies of mothers exposed to the World Trade Center attacks during pregnancy. *J Clin Endocrinol Metab* 2005;90:4115–8.
- Seng JS, Oakley DJ, Sampselle CM, Killion C, Graham-Bermann S, Liberzon I. Posttraumatic stress disorder and pregnancy complications. *Obstet Gynecol* 2001;97:17–22.
- Chang HL, Chang TC, Lin TY, Kuo SS. Psychiatric morbidity and pregnancy outcome in a disaster area of Taiwan 921 earthquake. *Psychiatry Clin Neurosci* 2002;56:139–44.
- Berkowitz GS, Wolff MS, Janevic TM, Holzman IR, Yehuda R, Landrigan PJ. The World Trade Center disaster and intrauterine growth restriction. *JAMA* 2003;290:595–6.
- 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 Epidemiol* 2005;19:334–41.
- 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;22:3013–20.
- Lederman SA, Rauh V, Weiss L, Stein JL, Hoepner LA, Becker M, et al. The effects of the World Trade Center event on birth outcomes among term deliveries at three lower Manhattan hospitals. *Environ Health Perspect* 2004;112:1772–8.
- Rich-Edwards JW, Kleinman KP, Strong EF, Oken E, Gillman MW. Preterm delivery in Boston before and after September 11th, 2001. *Epidemiology* 2005;16:323–7.
- 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;61:715–7.
- Farfel M, DiGrande L, Brackbill R, Prann A, Cone J, Friedman S, et al. An overview of 9/11 experiences and respiratory and mental health conditions among World Trade Center Health Registry enrollees. *J Urban Health* 2008;85:880–909.
- Murphy J, Brackbill RM, Thalji L, Dolan M, Pulliam P, Walker DJ. Measuring and maximizing coverage in the World Trade Center Health Registry. *Stat Med* 2007;26:1688–701.
- Sample Building and Denominator Estimation: World Trade Center Health Registry: RTI International; January 2006. Available at: <http://www.nyc.gov/html/doh/wtc/downloads/pdf/wtc/wtc-building-denominator.pdf>. Retrieved June 29, 2009.
- Spandorfer SD, Grill E, Davis O, Fasouliotis SJ, Rosenwaks Z. September 11th in New York City (NYC): the effect of a catastrophe on IVF outcome in a New York City based program Cornell Medical Center/NY Presbyterian Hospital, New York. *Fertil Steril* 2003;80:51.
- Lee SJ, Steer PJ, Filippi V. Seasonal patterns and preterm birth: a systematic review of the literature and an analysis in a London-based cohort. *BJOG* 2006;113:1280–8.
- Murray LJ, O'Reilly DP, Betts N, Patterson CC, Davey Smith G, Evans AE. Season and outdoor ambient temperature: effects on birth weight. *Obstet Gynecol* 2000;96:689–95.
- Weathers FW, Litz BT, Herman DS, Huska JA, and Keane TM. The PTSD Checklist (PCL): reliability, validity, and diagnostic utility. Paper presented at the Annual Meeting of the International Society for Traumatic Stress Studies, San Antonio, TX, 1993.
- DiGrande L, Perrin MA, Thorpe LE, Thalji L, Murphy J, Wu D, et al. Posttraumatic stress symptoms, PTSD, and risk factors among lower Manhattan residents 2–3 years after the September 11, 2001 terrorist attacks. *J Trauma Stress* 2008;21:264–73.
- Hort KP. Seasonal variation of birthweight in Bangladesh. *Ann Trop Paediatr* 1987;7:66–71.
- Matsuda S, Hiroshige Y, Furuta M, Doi T, Sone T, Kahyo H. Geographic differences in seasonal variation of mean birth weight in Japan. *Hum Biol* 1995;67:641–56.
- Matsuda S, Kahyo H. Geographic differences in seasonality of preterm births in Japan. *Hum Biol* 1998;70:919–35.
- Landrigan PJ, Forman J, Galvez M, Newman B, Engel SM, Chemtob C. Impact of September 11 World Trade Center disaster on children and pregnant women. *Mt Sinai J Med* 2008;75:129–34.
- Loveland Cook CA, Flick LH, Homan S, McSweeney M, Gallagher ME. Posttraumatic stress disorder in pregnancy: prevalence, risk factors and treatment. *Obstet Gynecol* 2004;103:710–7.
- Wadhwa PD, Dunkel-Schetter C, Chicx-DeMet A, Porto M, Sandman CA. Prenatal psychosocial factors and the neuroendocrine axis in human pregnancy. *Psychosom Med* 1996;58:432–46.

