# Impact of September 11 World Trade Center Disaster on Children and Pregnant Women

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## ABSTRACT

**Background:** Children are uniquely sensitive to toxic exposures in the environment. This sensitivity reflects children's disproportionately heavy exposures coupled with the biologic vulnerability that is a consequence of their passage through the complex transitions of early development.

**Methods and Results:** To assess effects on children's health associated with the attacks on the World Trade Center (WTC) of September 11, 2001, research teams at the Mount Sinai School of Medicine and other academic health centers in New York City launched a series of clinical and epidemiologic studies. Mount Sinai investigators undertook a prospective analysis of pregnancy outcomes in 182 women who were pregnant on September 11, 2001, and who had been either inside or within 0.5 miles of the WTC at the time of the attacks; they found a doubling in incidence of intrauterine growth retardation (IUGR) among infants born to exposed mothers as compared to infants born to unexposed women in northern Manhattan. A Columbia research team examined pregnancy outcomes in 329 women who lived, worked or gave birth in lower Manhattan in the 9 months after September 11; they found that these women gave birth to infants with significantly lower birth weight and shorter length than women living at greater distances from Ground Zero. NYU investigators documented increased numbers of new asthma cases and aggravations of preexisting asthma in children living in lower Manhattan. Mount Sinai mental health researchers documented a significant increase in mental health problems in children who directly witnessed the attacks and subsequent traumatic events; these problems were most severe in children with a past history of psychological trauma. The New York City Department of Health and Mental Hygiene established a WTC Registry that has enrolled over 70,000 persons of all ages in lower Manhattan and will follow the health of these populations to document on a continuing basis the health consequences of September 11. ***Mt Sinai J Med 75:129–134, 2008.*** © *2008 Mount Sinai School of Medicine*

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The terrorist attacks on the World Trade Center (WTC) of September 11, 2001 and the subsequent collapse of the twin towers created an acute environmental disaster of unprecedented magnitude in New York City. The combustion of more than 90,000 L of jet fuel at temperatures above 1,000°C released a dense and intensely toxic atmospheric plume containing soot, metals, volatile organic compounds (VOCs), and hydrochloric acid. The collapse of the buildings pulverized cement, glass, and building contents and generated thousands of tons of particulate matter (PM) composed of cement dust, glass fibers, asbestos, lead, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides, and polychlorinated dioxins and furans.[1–3] These materials dispersed over

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lower Manhattan, Brooklyn and for miles beyond. They entered nearby offices, schools, and residential buildings. Much remained at the site to form Ground Zero, a six-story pile of smoking rubble that burned intermittently for more than 3 months.[4]

Workers at Ground Zero and the public in lower Manhattan, including pregnant workers, infants and children, were exposed to smoke and dust in ambient air, in their communities, in their schools, and in their homes. The release by government authorities of inaccurate and misleading information on air quality in lower Manhattan may have aggravated the health impacts of these airborne exposures by creating a false sense of security that deterred appropriate use of respiratory protection.

In the aftermath of September 11, the National Institute of Environmental Health Sciences (NIEHS) gathered together a consortium of academic research centers in environmental health for the purpose of organizing studies to examine the environmental consequences and human health impacts of the destruction of the WTC. These studies included chemical analyses of the dust that settled at Ground Zero, air monitoring, study of the plumes of smoke and dust released to the atmosphere, and health studies of exposed populations. The populations of greatest concern were workers at Ground Zero, such as police, firefighters, construction workers and building cleaners, and vulnerable populations living, working and attending school in lower Manhattan, especially pregnant women and young children.

## PREGNANCY OUTCOME STUDIES

To investigate health impacts in the vulnerable populations in lower Manhattan, researchers at the Mount Sinai School of Medicine and the Columbia University Center for Children's Health developed conjoint proposals to examine infants born to women who were pregnant on September 11, 2001 and who were either acutely or chronically exposed to smoke and dust from the twin towers. In the Mount Sinai study, the acute exposure group consisted of pregnant women who were actually in the WTC towers or in nearby office buildings at the time of the attacks. The chronic exposure group consisted of women who lived, worked or delivered their babies in the communities of lower Manhattan in the weeks and months after September 11; this group has been followed by researchers from Columbia.

To assess the exposures of these women and their infants to toxic chemicals released into the environment by the destruction of the towers, samples of blood and other biological fluids were taken during pregnancy or at delivery. To further characterize exposures, efforts were made to reconstruct the women's locations in the aftermath of September 11th and then to correlate that information with geocoded data on environmental exposure levels.[5] To assess infants' growth, development and health status, each infant was evaluated at birth and periodically reexamined over the first several years of life. Concomitant psychological examinations of mothers and their babies have also been conducted.

### Mount Sinai Pregnancy Outcome Study

To evaluate whether acute, high-level exposures to environmental toxins on and after September 11, were related to impaired fetal growth or other adverse pregnancy outcomes, researchers from the Mount Sinai School of Medicine established a prospective epidemiologic study of 187 women who were pregnant and either within or near the WTC on or immediately after the attacks; 12 of these women were actually in the towers, and nearly all of the rest were within one-half mile.[6] All of these women were identified through their obstetricians, and they all provided fully informed, written consent to participate in the study.

These highly exposed women experienced no increased frequency of miscarriages and no increases in incidence of either premature or low-birth weight infants. However, a striking finding was that these acutely exposed women experienced a twofold-increased risk of delivering small-for-gestational age (SGA) infants. SGA infants are defined as infants with a birth weight below the 10th percentile for gestational age based on the nomogram by Brenner.[7] This rate of SGA was significantly elevated compared to a population of more than 3,000 women of similar ethnic and socioeconomic background who delivered at Mount Sinai Hospital during the same 9-month time period, and had no direct exposure to dust and smoke from the WTC.

Examination of potential confounders such as marital status, education, pre-pregnancy weight, and pregnancy-induced hypertension did not materially alter the results. No significant difference in the frequency of SGA was observed according to the trimester of pregnancy at the time of the attacks.

This finding of an increased incidence of SGA infants among women acutely exposed suggests that the WTC disaster had a detrimental impact on their pregnancies. The Mount Sinai investigators speculated that women's exposures to smoke and dust from the towers may have contributed to this effect, and they noted that an increased incidence

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of SGA is seen among women who smoke during pregnancy; intrauterine exposure to products of combustion is thought to account for that effect.[6]

In addition to toxic chemical exposures, the destruction of the WTC was a source also of enormous psychological trauma. To assess the potential impact of this psychological trauma on pregnant women and their fetuses, the Mount Sinai investigators undertook mental health assessments of women with singleton pregnancies included in the study described above. A total of 52 women completed at least one psychological assessment prior to delivery. In adjusted multivariable models, both post-traumatic stress symptomatology (PTSS) and moderate depression were associated with longer gestational durations. Further it was found that PTSS was associated with decrements in infant head circumference at birth ($\beta = -0.07$, SE $= 0.03$, $p = 0.01$). The investigators opined that the impact of stress resulting from extreme trauma may be different from that resulting from ordinary life experiences, particularly with respect to cortisol production. The observed decrements in head circumference may influence subsequent risk of neurocognitive development. Long-term follow-up of these infants is needed to evaluate the persistence of these effects.[8]

### Columbia Pregnancy Outcome Study

The Columbia Center for Children's Environmental Health launched a study in December 2001 to examine effects on gestational age, birth size, respiratory health and neurocognitive development of chronic exposure during pregnancy to WTC contaminants. This study was undertaken in a group of 329 women who lived, worked or gave birth in lower Manhattan during the months after September 11.

Of 738 women initially screened for eligibility, 369 women were eligible and gave their consent for participation; 329 contributed at least one blood sample (cord or maternal blood), medical record information, and a complete postpartum interview, all of which were required for full enrollment in the study.[9] All provided fully informed written consent to participate in the study.

The researchers found that the participating women who lived within two miles of the WTC delivered infants with significantly lower weight (−149 g) and reduced length (−0.8 cm) at birth as compared to women who lived at greater distances. Only part of this observed reduction could be accounted for by shortening of duration of gestation. Mothers who were in their first trimester of pregnancy on September 11 delivered infants with statistically significantly shorter gestation duration (−3.6 days) and smaller head circumference (−0.48 cm), compared to women who were in later stages of pregnancy on that date, regardless of the distance of their residences or work sites from the WTC.[10]

Further work in the Columbia Population has documented associations between biomarkers of exposure and proximity to the site and has also found associations between exposure biomarkers and developmental outcomes (http://www.CCCEH.org).

## MOUNT SINAI PEDIATRIC HEALTH STUDY

To examine the behavioral consequences in preschool children of exposure to the WTC attacks, Mount Sinai investigators conducted a retrospective cohort study of children living in lower Manhattan.[11] A total of 116 preschool children directly exposed to the WTC attacks participated in this study. The psychological traumas assessed included seeing people jumping out of the towers, seeing dead bodies, seeing injured people, and witnessing the towers collapsing. Past history of exposure to psychological trauma was also assessed. A child was considered exposed to psychological trauma following September 11, if the child had experienced at least one of the above listed events. The main outcome measure was clinically significant behavioral problems as measured by the Child Behavioral Checklist.

Preschool children exposed to high-intensity WTC attack-related events were found to be at increased risk for sleep problems and for anxious/depressed behavioral symptoms. Children who were directly exposed to high-intensity WTC attack-related events and who had a past history of psychological trauma were especially likely to have clinically significant emotionally reactive, anxious/depressed, and sleep-related behavioral problems.[11]

## MOUNT SINAI PEDIATRIC OUTREACH

Mount Sinai's Pediatric Outreach Program worked extensively after September 11th in lower Manhattan with residents, businesses, schools, churches and community organizations. The goal of this outreach effort was to provide science-based, objective information to parents, pediatricians, government officials and caretakers (i.e. nursery school, day-care and school personnel) about potential environmental threats to children's health. Pediatricians in the program answered questions, formulated plans for clean up and for prevention of further exposures,

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served as an unbiased independent source of analysis, and disseminated information to a wide array of audiences.

The four postal zip codes closest to Ground Zero contain 36 schools serving approximately 19,000 children. Thousands of additional preschoolers reside and/or attend day care and nursery schools in lower Manhattan. The Mount Sinai efforts were aimed at coordinating outreach and education in these schools and nurseries to reduce the very heightened level of anxiety among parents, school officials, area residents and other individuals. Thousands of people were reached through these efforts. The TV interview with Bill Moyers on October 19, 2001 was especially important.

The Pediatric Outreach Program collaborated with the WTC Worker and Volunteer Medical Screening Program at Mount Sinai to provide pediatric environmental consultation to adolescents who had worked at Ground Zero. The Program continues also to answer calls and respond to media reports. After a lull in public focus on the environmental aftermath of September 11, there is now a new wave of concern around the planned demolition of the Deutsche Bank Building and the reconstruction of lower Manhattan. The Program stands ready to respond to calls from members of the community.

To further educate pediatricians about environmental threats to children's health, the Pediatric Outreach Program piloted an educational seminar on November 15, 2004 titled 'The World Trade Center Disaster: Effective Case Management of Environmentally Exposed Children' at the New York Academy of Medicine. The audience consisted of a select group of practitioners and government representatives. The Program utilized the WTC experience as a case study in pediatric environmental exposure to launch a training session focused on efficient evaluation of environmentally exposed children. Topics included a review of the exposures encountered after September 11, Internet and consulting resources available to the practitioner to evaluate environmentally exposed children, and risk communication techniques. The seminar was very well received and the feedback has led to a number of modifications and enhancements.

## NEW YORK UNIVERSITY HEALTH ASSESSMENT OF COMMUNITY RESIDENTS

To assess prevalence of new-onset respiratory symptoms after September 11, 2001 among previously healthy persons in lower Manhattan as well as in residents with preexisting asthma, a team from New York University Medical Center in collaboration with the New York State Department of Health and the New York Academy of Medicine conducted a clinical and epidemiologic survey.[12] Symptoms were assessed by questionnaire, and pulmonary function was evaluated in a subset of the study population by standard screening spirometry.

A total of 2,166 residents of lower Manhattan living within a 1.6-km radius of the WTC were enrolled in this survey and compared with 200 persons living 1.6–8.0 km distant. Spirometry was performed in 52 residents. Preliminary data indicate that previously healthy persons living near Ground Zero had a greater increase in prevalence of respiratory symptoms after September 11 than did more distant residents. These symptoms were predominantly cough, wheeze, and shortness of breath. Symptoms were not associated with abnormal screening spirometry.

Preexisting asthmatic residents in the exposed area also reported a higher prevalence of respiratory symptoms after September 11. They also reported an increased use of asthma medication relative to controls. These findings are consistent with observations in exposed workers and also with findings observed in laboratory animals exposed experimentally to WTC dust.[13]

## NEW YORK CITY DOHMH HEALTH REGISTRY

In 2004, to facilitate continuing follow-up of the populations exposed in the aftermath of September 11, the New York City Department of Health and Mental Hygiene (NYC DOHMH), together with the Center for Disease Control's Agency for Toxic Substances and Disease Registry (ATSDR), established the World Trade Center Health Registry (WTCHR). To establish this Registry, baseline interviews were conducted on more than 71,000 highly affected eligible enrollees.[14–16]

The WTCHR is a vital resource that will enable public health and medical experts to systematically monitor the health of tens of thousands of persons potentially impacted by the September 11, 2001 attacks on the WTC. The WTCHR will make it possible for those who enrolled in the Registry and thousands of others who may have been exposed to receive the information and advice they want and need to make informed decisions about their health. In order for the WTCHR to fulfill its potential as a public health resource, an ongoing effort is

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needed to maintain contact with WTCHR participants and sustain their interest so that they can continue to provide information to the registry and receive feedback on what is learned about the health impact of the September 11 attacks. DOHMH will maintain contact and follow all Registry enrollees for up to 20 years to determine health effects resulting from the environmental and mental health exposure to the attack. It has already documented a two-fold increase in new onset asthma in exposed children[17–18].

## CONCLUSIONS

The data that have emerged from lower Manhattan in the aftermath of September 11 indicate that health effects occurred in vulnerable populations, but that these effects were in general less severe and qualitatively different from the effects observed in the heavily exposed worker populations.

Two major lessons emerge from the WTC experience that should inform preparation and response to future disasters, whether natural or man-made. The first of these lessons is that preparedness is critical. There need to be prepositioned resources in place before the occurrence of a disaster to deal with the inevitable impacts on both the physical health and the mental health of exposed populations, especially vulnerable subgroups. These resources must include human resources–trained personnel and robust organizations–as well as fiscal resources, such as contingency funds in the budgets of CDC, NIH and the Department of Homeland Security that can be rapidly and effectively deployed to qualified organizations in the aftermath of a disaster.

A second lesson is that long-term, continuing follow-up will be needed to fully assess and treat disaster-related health effects. Thus, long-term follow of the infants exposed *in utero*, and follow-up through the World Trade Center Registry of the general population who resided in lower Manhattan in the days and weeks after September 11 will be required to characterize and manage the long-term and delayed consequences of the disaster and thus to chart the full magnitude of the health impact of the attacks on the WTC.

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