Respiratory Health and Lung Function in Children Exposed to the World Trade Center Disaster

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Objectives To compare lung function in a representative sample of World Trade Center (WTC)-exposed children with matched comparisons, and examine relationships with reported exposures.

Study design Study population consisted of 402 participants. Oscillometry, spirometry, and plethysmography were performed on WTC Health Registry (WTCHR) respondents who were ≤8 years of age on September 11, 2001 (n = 180) and a sociodemographically matched group of New York City residents (n = 222). We compared lung function by study arm (WTCHR and comparison group) as well as dust cloud (acute); home dust (subchronic); and other traumatic, nondust exposures.

Results In multivariable models, post-9/11 risk of incident asthma was higher in the WTCHR participants than in the comparison group (OR 1.109, 95% CI 1.021, 1.206; $P = .015$). Comparing by exposure rather than by group, dust cloud (OR 1.223, 95% CI 1.095, 1.365; $P < .001$) and home dust (OR 1.123, 95% CI 1.029, 1.226; $P = .009$) exposures were also associated with a greater risk of incidence of post-9/11 asthma. No differences were identified for lung function measures.

Conclusions Although we cannot exclude an alternative explanation to the null findings, these results may provide some measure of reassurance to exposed children and their families regarding long-term consequences. Further study with bronchodilation and/or methacholine challenge may be needed to identify and further evaluate effects of WTC exposure. Biomarker studies may also be more informative in delineating exposure-outcome relationships. *(J Pediatr 2018;■■:■■-■■).*

Trial registration ClinicalTrials.gov: NCT02068183.

The destruction of the World Trade Center (WTC) on September 11, 2001 resulted in exposure of large populations of individuals, including children, to numerous inhaled toxins. Defined health effects have been predominantly documented in the adult population,[1] but the consequences of a disaster-related exposure during vulnerable developmental years has yet to be clearly defined.[1] In the adult population, studies have shown that WTC dust exposure is associated with declines in spirometry measures including a reduced vital capacity along with a number of other physiological airway abnormalities often localized to the small airways.[2,3] Forced oscillation testing (FOT) demonstrated that adults exposed to the dust had increased small airway resistance, positive response to bronchodilator, and an association with severity and frequency of wheeze.[1-3]

Three studies have examined asthma and/or lung function in children exposed to the disaster, but none examined an unexposed comparison group. Among children participating in the World Trade Center Health Registry (WTCHR), the largest, most representative sample of exposed children, increased asthma prevalence has been documented among children exposed at <5 years of age, and new asthma diagnosis post-September 11 was associated with dust exposure for all age groups.[4] Another study of students living in Chinatown after the attack documented 29% prevalence of abnormal forced expiratory volume in 1 second (FEV_1, <80% predicted normal).[5] Most recently, in a sample of children reporting to a clinic for WTC-related medical care, lower FEV_1 and forced vital capacity (FVC) percent predicted were identified when compared with children who participated in the National Health and Nutrition Examination Survey

BMI	Body mass index
FEV_1	Forced expiratory volume in 1 second
FOT	Forced oscillation technique
FVC	Forced vital capacity
FDR	Frequency dependence of resistance
NHANES	National Health and Nutrition Examination Survey
NYU	New York University
PFAS	Perfluoroalkyl substances
WTC	World Trade Center
WTCHR	World Trade Center Health Registry

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(NHANES) 2007-2010. We also identified an association between dust cloud exposure and abnormal spirometry, low FVC, and obstructive patterns.[6]

Lung function tracks throughout childhood into adult life[7] and that attained early in the third decade is one of the best predictors of chronic obstructive pulmonary disease.[8] An insult during childhood, such as exposure to WTC dust, known to pathologically lead to alveolar destruction,[9] could lead to a critical, yet subclinical loss in lung function and might confer a unique vulnerability to chronic obstructive pulmonary disease. If a subpopulation of WTC-exposed children has such a decrement in lung function, intensified vaccination efforts (for prevention of influenza and pneumococcal illnesses), counseling against smoke exposure, and initiating inhaled steroids might attenuate an accelerated lung function decline.[10]

Based on the above consideration, the present study recruited children from the WTCHR and compared measures of airway function and lung volume obtained by spirometry, plethysmography, and oscillometry with a matched comparison group. Our hypotheses were that lung function would be reduced among WTCHR participants compared with a matched comparison group and WTC-related dust exposures would independently predict lung function outcomes.

Methods

The present study is a comparison of WTCHR children who were ages 0-8 years on the date of the disaster compared with a sociodemographically matched group. We have previously described our study population and recruitment strategy[11] (**Appendix**; available at www.jpeds.com). Briefly, eligibility for the WTCHR was based upon dates of birth on or between September 11, 1993 and September 10, 2001, residence or school attendance south of Canal Street (or presence south of Chambers Street) on September 11, 2001.

Comparisons were not eligible for the WTCHR, and had dates of birth on or between September 11, 1993 and September 10, 2001. In addition to online and web-based recruitment, participants for the comparison group were recruited from general primary care visits at clinics affiliated with the New York University School of Medicine and were excluded if they presented to these clinics for a clinical concern, especially previously diagnosed asthma.

Potential participants that indicated presence of serious lung or heart disease, heart or lung surgery, or an active upper respiratory infection, pregnancy, and inability to follow procedures at the time of their scheduled visit, were also excluded from participation. To maximize comparability between the 2 study populations, we developed a table of the desired frequencies of controls by age (0-2, 3-5, or 6-8 years old on September 11, 2001), sex, race (White, African-American, Asian, other), ethnicity (Hispanic, non-Hispanic), and income (<$25 000, ≥$25 000).

Pulmonary Evaluation Procedures

For comparison with the previous studies, we adjusted questions used in the NHANES pertaining to current and previous diagnosis of asthma[12-14]: (1) Do(es) you (your child) currently have asthma?; (2) Have (Has) you (your child) ever been diagnosed with asthma? If yes - were (was) you (your child) diagnosed before or after September 11, 2001?; (3) Can you write the month and year you were (your child was) first diagnosed with asthma?; (4) In the past 12 months, have you (has your child) had wheezing or whistling in your (his/her) chest? By wheezing or whistling, we mean a high-pitched whistling sound you (your child) makes during breathing. It happens when air moves through tight breathing tubes in your (child's) chest.

We focused on asthma prevalence rather than current asthma prevalence in the present analysis. There were 5 participants in whom there was discordance. All 5 children reported pre-September 11, 2001 asthma, and the parents did not report asthma at all. We used parent response when the child's age on September 11, 2001 was <5 years. Testing also included urine and saliva collection, blood draw, cardiovascular testing, psychosocial stress questionnaires, and medical history and diet questionnaires.

Spirometry, plethysmography, and FOT were performed according to standards outlined by the American Thoracic Society and the European Respiratory Society.[15,16] Each test was performed a minimum of 3 times with the maximum number of trials limited to 5 to avoid participant fatigue. An average of these measures was used. Standard quality assurance procedures including monthly internal staff quality control tests were performed and maintained periodically throughout the study. All pulmonary data were evaluated separately by 2 investigators to ensure reproducibility and reliability of measurements, and exclude possible spurious data.

Spirometry

Spirometry measures included FVC, FEV_1, FEV_1/FVC, and forced expiratory flow over 25%-75% of the vital capacity ($FEF_{25\%-75\%}$; Jaeger Masterscreen Impulse Oscillometry; Carefusion, Yorba Linda, California). NHANES III reference equations[17] were used to determine ethnically/racially appropriate normative values, with statistical analysis applied to percent of predicted values. Because NHANES does not contain Asian norms, Caucasian/White norms were used for Asian participants.

Plethysmography

A Jaeger body box plethysmograph was used to measure functional residual capacity in all subjects. Subjects were instructed so that 4 stable tidal breaths were obtained, followed by 5 pant breaths and a return to normal breathing. Thereafter, subjects were asked to do a maximum exhalation from end tidal volume, a maximum inspiration, and finally return to normal tidal breathing. Total lung capacity and residual volume were derived from the functional residual capacity coupled with the measured inspiratory capacity and expiratory reserve volume.[18] Measurement of residual volume in relation to total lung capacity permitted assessment of air trapping as a further measure of obstructive dysfunction.

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