Breathing the Aftermath: A Review of Respiratory Health Effects in Diverse Groups Exposed to 9/11 WTC Dust

by
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ABSTRACT

WOLVERTON, CATHERINE VICTORIA MAZO. Breathing the Aftermath: A Review of Respiratory Health Effects in Diverse Groups Exposed to 9/11 WTC Dust (Under the direction of Dr. Jennifer Richmond-Bryant).

The September 11, 2001 terrorist attacks on the World Trade Center (WTC) in New York City resulted in a complex mixture of airborne pollutants that posed significant health risks to various exposed populations. This literature review examines the short-term and long-term respiratory health impacts on residents, passers-by, children, and rescue and recovery workers. A literature search was conducted using Web of Science, PubMed, and the CDC World Trade Center Health Program databases. Twenty-six studies meeting specific eligibility criteria were included in the final analysis. This review focused on general respiratory symptoms, asthma, and sarcoidosis. Findings show general respiratory symptoms were widespread, with passers-by showing the highest prevalence (69.2%), followed by rescue workers (68.9%), residents (65.9%), and children (53%). Asthma prevalence increased over time across all populations, with rescue workers showing an increase from 3.2% (2003-2004) to 18.1% (2015-2016), and children from 5.7% (2003-2004) to 25.5% (2005-2006). Children under 5 years old at the time of the attack showed higher vulnerability to asthma compared to other age groups. Sarcoidosis incidence was elevated among firefighters, with a short-term peak of 54 per 100,000 person-years (2003-2004) and long-term rates of 22-25.5 per 100,000 person-years over 14 years. Webber et al. (2017) reported a standardized incidence ratio of 4.2 (95% CI: 3.1-5.6) for WTC-exposed firefighters compared to unexposed populations in the first five years. Limitations of the reviewed studies include potential recall bias in self-reported data, variations in study methodologies, and challenges in accounting for other environmental or occupational exposures. The persistence of respiratory health issues across different groups and over time highlights the need for continued monitoring and care for affected populations.

DEDICATION

I dedicate this paper to my biggest supporter, my husband, Austin. Thank you for everything you have done for me, not only now but in the past 16 years. You have always encouraged me to be brave and try new things even when they seem hard. I truly appreciate you and all encouragement and assistance you have given me to be able to accomplish this especially after becoming new parents.

BIOGRAPHY

Catherine Wolverton currently resides in Kernersville, North Carolina with her twin daughters and husband. She was born and raised in Queens, New York and is first generation American. Catherine moved to North Carolina at the age of 15.

Catherine completed Bachelor of Art in Biology in 2016. Her focus was on plants and did undergraduate research on developing a photo key of North American Oak Trees under Dr. Bruce Kirchoff. She entered North Carolina State University as a graduate certificate student for the Regulatory Science Certificate. After completion of the certificate, Catherine became a master's student in Environmental Assessment.

Catherine's professional career started as a pharmacy technician for seven years until she decided to pursue a career in agriculture. Catherine began working at Syngenta Crop Protection, LLC, in 2018 as a State Regulatory Specialist. She is currently a Regulatory Specialist focusing on continuous improvement for the North America Regulatory Team.

The master's in environmental Assessment helped Catherin understand the impact of environmental toxicants in water, soil, air in both the short term and long-term effects on humans and the environment. It also helped understand the purpose and implementation of environmental laws and why certain regulations are in place in both the state and federal level. This knowledge will help Catherine in her career in regulatory.

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INTRODUCTION

The terrorist attacks on the World Trade Center (WTC) on September 11, 2001, left a devastating impact on New York City. The collapse of the twin towers created a massive dust cloud, smoke plumes due to smoldering fires, and debris in the air and around Lower Manhattan and the surrounding areas. Lioy et al. (2002) reported within the first 12 hours the predominant sources of pollution included fires and the collapse of the twin towers. Burning jet fuel was also reported to be in the first 12 hours and for the next two days. From day 3 to December 20, 2001, Lioy et al. (2002) reported that the predominant sources of pollution included smoldering fires, resuspension of settled dust and smoke, and removal of debris by trucks and other heavy equipment. The airborne particles that Lioy et al. (2002) reported from September 11, 2001 to December 20, 2001 were generated by combustion (gaseous and particulate), evaporating gases, coarse particle resuspension, and diesel exhaust. Several different populations of people were exposed to the dust cloud and the debris which included residents, children, passersby, and rescue workers.

Lioy et al. (2002) found that the complex mixture of the dust cloud contained a hazardous combination of pulverized concrete and glass, asbestos fibers, heavy metals including lead and mercury, polycyclic aromatic hydrocarbons (PAHs), dioxins and other toxic organic compounds. The dust was characterized to be highly alkaline (pH ranged from 9.2-11.5 depending on the dust sample), contained small particle sizes, and had products of incomplete combustion. Fine particles that were $< 2.5\mu m$ were found in the dust samples which have greater potential to reach the alveoli. Basic particles create potential to cause irritation to the respiratory system. Additional studies have corroborated and expanded these findings.

Another study by Ottenberg et al. (2003) collected 14 samples in the initial days after September 11, 2001. The study focused on Polycyclic aromatic hydrocarbons (PAHs), Polychlorinated biphenyls (PCBs), and selected organochlorine pesticides. The results reported by Ottenberg et al. (2003), were ∑37-PAHs comprised up to 0.039% by mass in six samples, ∑86-PCBs comprised less than 0.001% by mass in three bulk samples, and organochlorine pesticides were found at low concentrations in bulk samples. The study also segregated samples based on size and found that there were significant concentrations in fine particles (< 2.5μm). The study estimates approximately 100-1000 tons of ∑37-PAHs were immediately spread over the localized area after the WTC disaster.

McGee et al. (2003) also collected samples within a half mile at the World Trade Center site and found that the samples primarily consisted of gypsum and calcite. McGee et al. (2003) reported that gypsum and calcite irritate the mucus membranes of the eyes, nose, throat, and upper airways. The study reports that it is likely major acute inhalation hazards are due to the presence of gypsum, calcite and cement or concrete dust components. This study is significant because it identified specific components that could cause an immediate respiratory inflammation found in the WTC dust. McGee et al. (2003) also reports that inhalation of high doses of the dust could potentially cause toxic respiratory effects.

The WTC dust cloud exposure raised immediate concerns about the short-term and long-term health outcomes to the exposed population. This study is important because it identified specific components that could cause an immediate respiratory inflammation found in the WTC dust. The pollutants emitted from the WTC collapse and subsequent fires posed respiratory health risks. Fine PM (<2.5μm) identified by Lioy et al. (2002) and Offenberg et al. (2003) can penetrate deep into the lungs, potentially causing both acute and chronic respiratory issues. The highly alkaline nature of the dust (pH 9.2-11.5) reported by Lioy et al. (2002) can cause immediate irritation to the respiratory system. McGee et al. (2003) highlighted that gypsum and calcite, primary components of the dust, can irritate the mucus membranes of the nose, throat, and upper airways, leading to acute inhalation hazards. The presence of asbestos fibers raises concerns about long-term lung damage. McGee et al. (2003) also reported that inhalation of high doses of the dust could potentially cause toxic respiratory effects. Products of incomplete combustion and diesel exhaust can increase existing respiratory conditions and contribute to the development of asthma or other chronic respiratory diseases (McGee et al., 2003). Exposure to this complex mixture of pollutants has the potential lead to a range of respiratory symptoms, from short-term irritation and coughing to more severe long-term respiratory conditions. This review examines various respiratory health issues that emerged immediately and in the years after 9/11. Health outcomes include general respiratory issues, asthma, and sarcoidosis. The populations reviewed in this article are exposed residents, passers-by, children, and rescue and recovery workers. The goal of this review is to obtain a broader understanding of the short and long-term health outcomes for the different exposed populations because of the WTC dust cloud exposure.

METHODS

The purpose of the search is to identify peer-reviewed studies that have documented the respiratory effects of air pollution from the September 11, 2001 attack on the World Trade Center. This study evaluates literature for health effects on adult residents, rescue workers, passers-by, and children.

Several databases were searched, including Web of Science, PubMed, and the CDC World Trade Center Health Program. For the Web of Science and PubMed databases, the terms included in the search were “September 11, 2001”, “September 11”, “9/11”, “9-11”, “9/11/2001”, “9-11-2001”, “9/11/01”, “9-11-01”, “asthma”, “children”, “air pollution”, “World Trade Center”, and “respiratory”. These searches were conducted with no date filter. In addition, to find studies that looked at long term effects, several searches were done using the terms “sarcoidosis,” “September 11, 2001,” and “respiratory,” along with a date filter of studies published after the year 2010. For the CDC World Trade Center Health Program dashboard, the filters included “Physical Conditions” and “Aerodigestive Disorders” (Table 1). If a study that was saved in a previous search appeared in any search result afterwards, it was noted as a Duplicated Article either from a different source database or different search string. Any duplication of a study within a search was noted as a duplicate article found within the same search.

The following eligibility criteria were developed (Figure 1). The study must either contain original data or have supplemental data generated. The data must represent respiratory health outcomes that were diagnosed or self-reported after September 11, 2001. An example of a study (Wagner, et al., 2005) that did not meet the criteria was the survey asked participants, “Have you ever been diagnosed with asthma?” This does not show that asthma was a health outcome due to the air pollution of the World Trade Center events since someone could have been diagnosed prior to the events and answered yes to this question, violating Hill’s (1965) temporality criterion for timing of the onset of the disease to occur after the exposure. The Wagner et al. (2005) study will not support causality since it shows the disease came before the exposure. The data for the respiratory health outcomes must be analyzed separately from any other non-respiratory outcomes. Additionally, a study needed to present data that could clearly be attributed to the respiratory disease alone. For example, Brackbill et. al (2009) examined the correlation between asthma and PTSD. The data included from this study pertained to asthma or respiratory symptoms separate from PTSD.

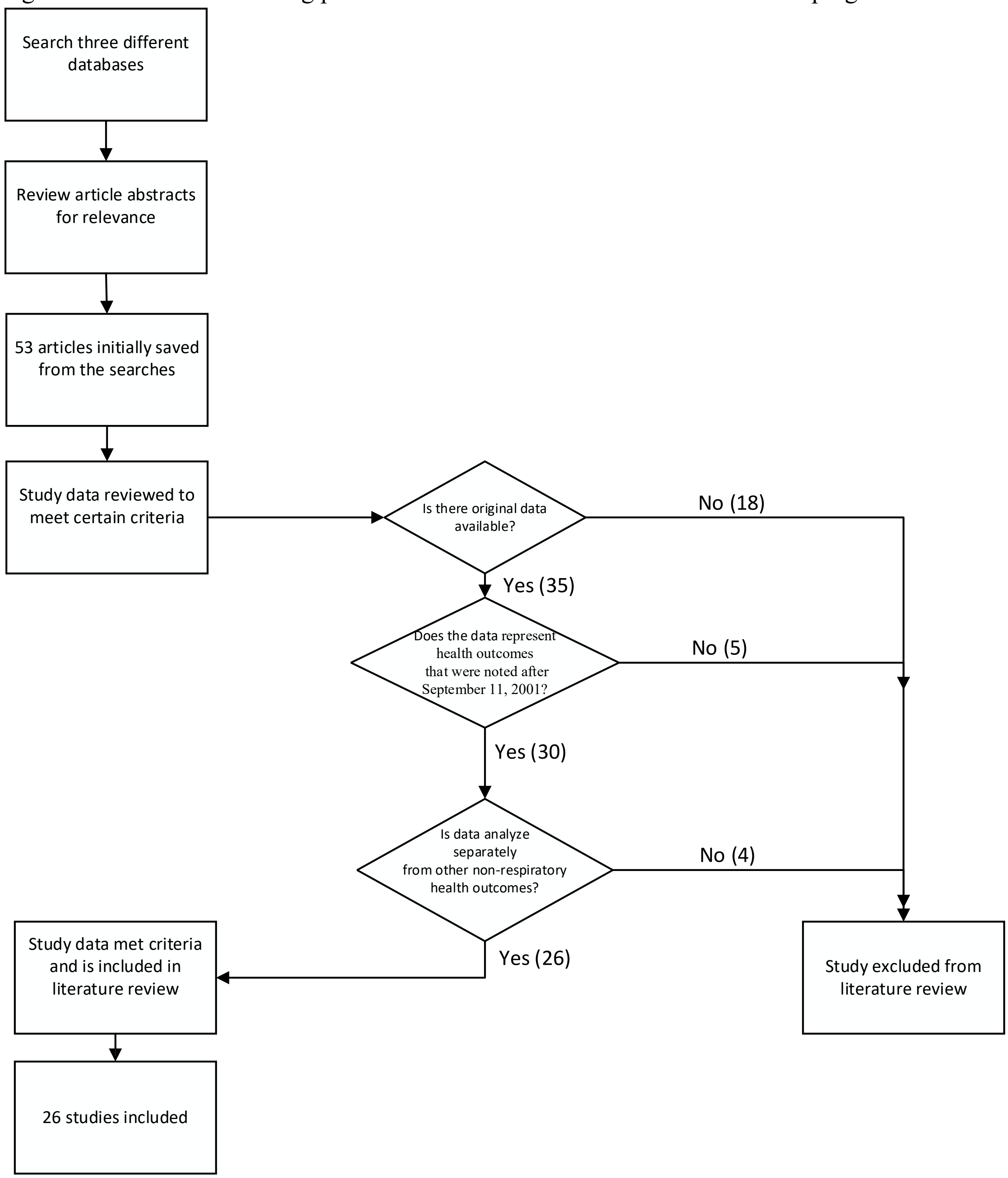
Studies were saved after reading the abstract to make sure they contained data from the World Trade Center event and the respiratory health outcome identified in the search string. Fifty-three articles were saved for further review after confirming eligibility. The majority of studies used the World Trade Center Health Registry data. Other studies used their own survey or data collection.

Table 1. Search results for each string and database

Search Number assigned	Filters	Source Database	Search Results	Saved Articles	Included Articles (passed screening steps)	Duplicated Article either from different source database or different search strings	Duplicated Articles within the same search string
1	**September 11, 2001** (All Fields) and **ast hma** (All Fields)	Web of Science	88	16	9		
2	**September 11, 2001** (All Fields) and **ast hma** (All Fields) and **chi ldren** (All Fields)	Web of Science	32	5	2	5	
3	**September 11, 2001** (All Fields) and **air pollution** (All Fields)	Web of Science	11	2	1	2	
4	**September 11, 2001** (All Fields) and **air quality** (All Fields)	Web of Science	60	3	1	0	

5	**9/11** (Title) and **air quality** (All Fields)	Web of Science	4	1	1	0	
6	**9/11** (Title) and **air pollution** (All Fields)	Web of Science	11	1	1	3	
7	**September 11 2001** (Title) and **air pollution** (All Fields)	Web of Science	11	1	1	3	
8	World Trade Center Health Program: Youth 9/11 Health Effects Library. Conditions filtered by "**Physical Conditions**" and "**Aerodigestive Disorders**"	WTCH https://www.cdc.gov/wtc/ysrdashboard.html	15	8	7	5	
9	(sarcoidosis) AND (world trade center) And year filter for 2010 to Current	PubMed	31	8	6	0	2
10	**September 11 2001** (Topic) and **respiratory** (All Fields)	Web of Science	181	3	2	0	
11	**sarcoidosis (All Fields) AND world trade center (All Fields)** And year filter for 2010 to Current	Web of Science	35	5	4	6 repeated from Pub Med (search #9 from the search results but the 4 articles that are included are new, describe further	

Figure 1. Process for selecting peer-reviewed literature for inclusion in the scoping review.



RESULTS and DISCUSSION

After evaluating the 53 articles and following the inclusion criteria, 26 articles were included in the scoping review. The majority of the studies focused on rescue workers since they were the most exposed population (Figure 2).

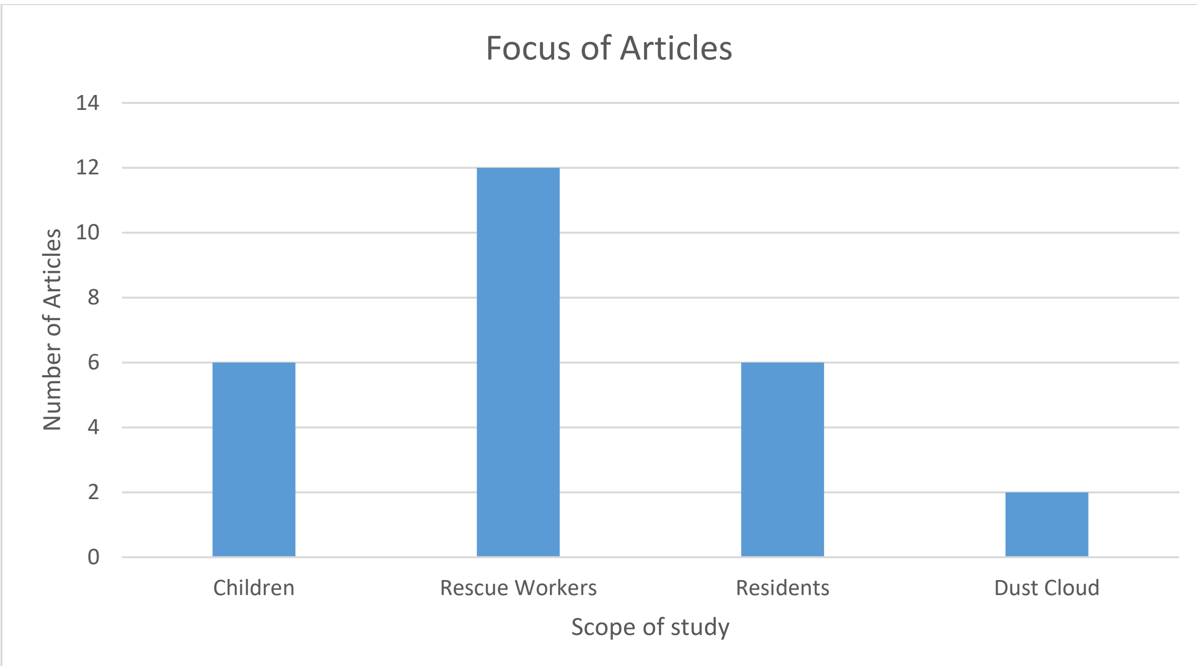


Figure 2. Number of articles by population group in 9/11-related respiratory effects studies.

Each data set was categorized based on the population and the health outcomes. Health outcomes were categorized under generalized respiratory symptoms, asthma, bronchial hyperactivity, and sarcoidosis. The population groupings included rescue workers, adult residents, passers-by, and children (school children and residents). For each data set, the time period and participant count was recorded.

Generalized Respiratory Effects

Table 2. Prevalence of new or worsening generalized respiratory effects for each population across multiple studies.

Generalized Respiratory Effects					
Population	Source	Timeframe	Prevalence (%)	Comparison to Control Population	Notes
Rescue Workers	Farfel et al. (2008)	2003-2004	68.9%	NR	
Residents	Lin et al. (2005)	2001-2002	53.8%	32%	This number is specific to shortness of breath
	Farfel et al. (2008)	2003-2004	65.9%	NR	
Passerby	Farfel et al. (2008)	2003-2004	69.2%	NR	
Children	Farfel et al. (2008)	2003-2004	53%	NR	
	Thomas et al. (2008)	2003-2004	53%	NR	

Adjusted Odds Ratio (AOR) were not reported in these studies

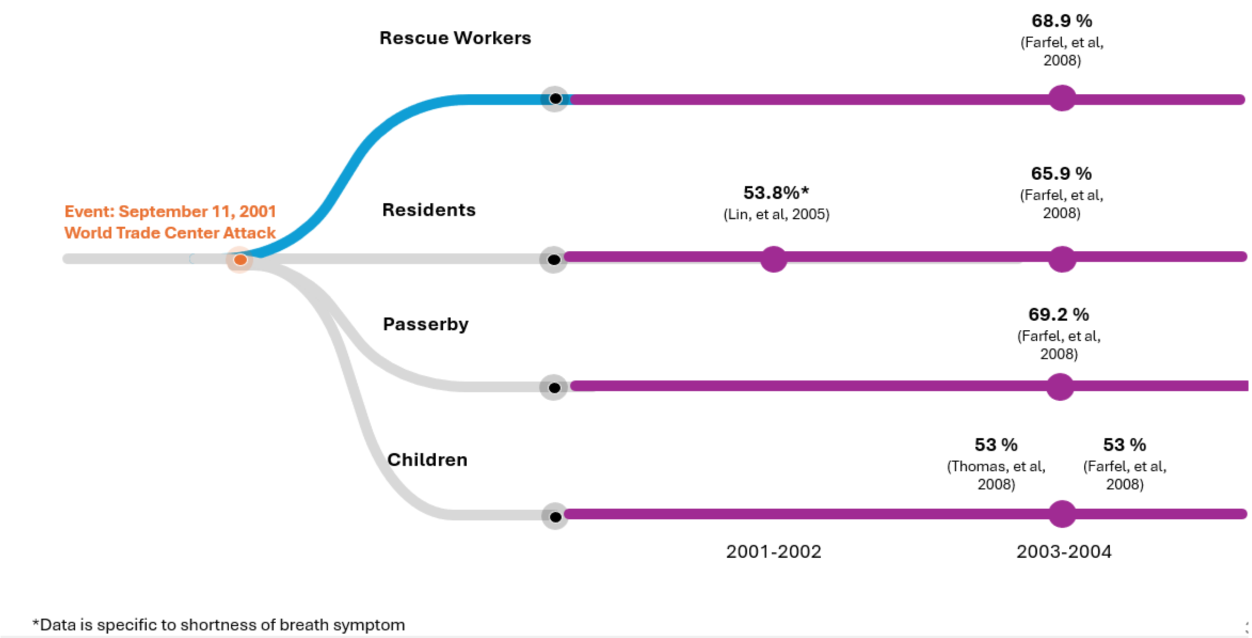


Figure 3. Timeline of generalized respiratory effects prevalence in the different populations after the WTC Attack.

The data show varying prevalence rates for general respiratory symptoms across the different populations exposed to the WTC dust and debris. The highest prevalence rates of respiratory effects are seen by passers-by, who were present during the attack on September 11, 2001, at 69.2% as reported by Farfel et al. (2008) during the 2003-2004 timeframe. Rescue workers were the second most affected population, prevalence rate of 68.9% as reported by Farfel et al. (2008) during the 2003-2004 timeframe. This is due to the exposure of dust and debris at the World Trade Center site and landfills by rescue workers. Residents showed a slightly lower prevalence rate of general respiratory effects at 65.9% (Farfel et al., 2008) during the same timeframe. Children had the lowest prevalence rate of all the groups at 53%, but the prevalence is still high, reported by both Farfel et al. (2008) and Thomas et al. (2008) during the same period. These differences may be due to the duration of exposure and the proximity of the WTC site.

When analyzing the timelines and the proportion of residents experiencing respiratory symptoms, there was a clear increase in respiratory symptoms from the reported studies of Lin et al. (2002) and Farfel et al. (2008). Lin et al (2002) also compared exposed residents to a controlled population that they established in Upper Manhattan more than 9 km from the World Trade Center site. Lin et al. (2002) reported that the control population had a prevalence percentage of shortness of breath at 32% while residents in the affected area had a prevalence of 53.8%. Lin et al. (2002) also documented that the affected residents reported having a prevalence percentage of shortness of breath at 26.1 % prior to September 11, 2001. This comparison shows the significant increase of shortness of breath residents in the affected area had compared to prior to the attack and compared to the control area residents post 9/11.

The prevalence was still high after 2–3 years. The data indicate widespread acute respiratory effects on several vulnerable populations. Respiratory symptoms can likely be short term response to the contaminants in the dust and debris. Farfel et al (2008) supports this conclusion by reporting that significant proportion of residents (32.7%) were still experiencing respiratory symptoms 2 to 3 years after intense dust cloud exposure or home damage.

Asthma

Table 3. Prevalence of newly diagnosed asthma for each population (except children) across multiple studies.

Asthma						
Population	Source	Timeframe	Prevalence (%)	Adjusted Odds Ratio (AOR), Confidence Interval	Comparison to Control Population	Notes
Rescue Workers	Farfel et al. (2008)	2003-2004	3.2	NR	NR	AOR not reported. Only

Not Specified (rescue workers combine).						the prevalence is reported in this study
	Wheeler et al. (2007)	2003-2004	3.6	NR	NR	
	Brackbill et al. (2009)	2006-2007	12.2	2.2 [95% CI, 1.9-2.6]	NR	
	Jordan et al. (2018)	2015-2016	18.1	NR	NR	AOR not reported. Only the prevalence is reported in this study
Other rescue workers	Cone, et al. (2016)	2001-2004	5.4*	NR	NR	*This is the cumulative incidence (95% CI, 4.5-6.6%)
Firefighters	Wheeler et al. (2007)	2003-2004	5.2	1.74 [95% CI, 1.43–2.12]	NR	
Residents	Lin et al. (2005)	2001-2002	18	1.50*[95% CI, 0.69-3.24]	NR	*This study reports a cumulative incidence ratio instead of an AOR
	Farfel et al. (2008)	2003-2004	3.1	NR	NR	AOR not reported. Only the prevalence is reported in this study
	Brackbill et al. (2009)	2006-2007	8.0	1.4 [95% CI, 1.1-1.7]	NR	
	Jordan et al. (2018)	2015-2016	13.2	NR	NR	

Passerby	Farfel et al. (2008)	2003-2004	3.0	NR	NR	AOR not reported. Only the prevalence is reported in this study
	Brackbill et al. (2009)	2006-2007	8.6	NR	NR	
	Jordan et al. (2018)	2015-2016	15.8	NR	NR	AOR not reported. Only the prevalence is reported in this study

NR= Not Reported

Table 4. Prevalence of newly diagnosed asthma for children of different age groups across multiple studies.

Asthma							
Population	Source	Age Group	Timeframe	Prevalence (%)	Adjusted Odds Ratio (AOR), Confidence Interval	Comparison to Control Population	Notes
Children	Farfel et al. (2008)	Overall	2003-2004	5.7	NR	NR	AOR not reported. Only the prevalence is reported in this study
	Thomas et al. (2008)	Overall	2003-2004	5.7	NR	*Reported as asthma prevalence percentage overall instead of newly diagnosed asthma. See discussion below	This study reported age groups based on age at the time of the WTC attack

		Age <5	2003-2004	10.8	4.6 [95% CI, 3.0–7.0]	NR	
		5-11	2003-2004	5.0	2.0 [95% CI, 1.3–3.1]	NR	
		12-17	2003-2004	2.8	1.0 [95% CI, 1.0]	NR	
	Gargano et al. (2017)	Overall	2011-2012	25.5	NR	NR	AOR not reported. Only the prevalence is reported in this study
		Age <2	2011-2012	26.9	NR	NR	
		Age 2-5	2011-2012	21.9	NR	NR	
		Age 5 to 8	2011-2012	28.1	NR	NR	

NR= Not Reported

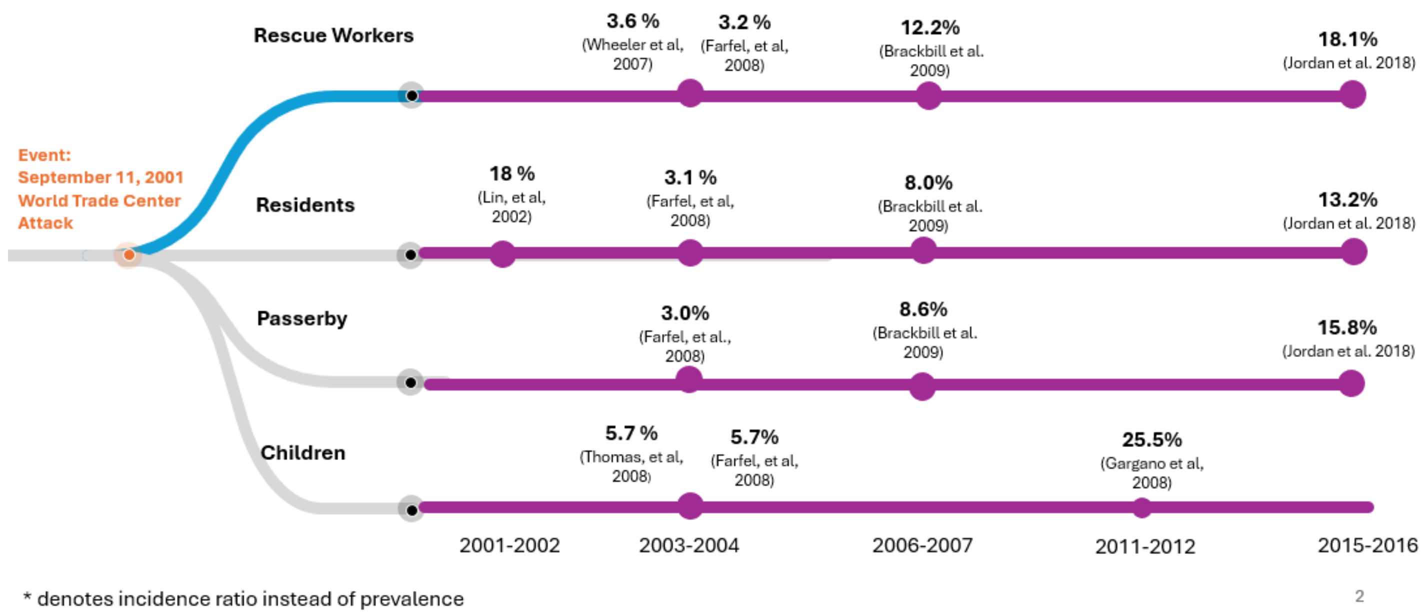


Figure 4. Timeline of asthma prevalence in the different populations after the WTC Attack.

<u>Rescue Workers</u>

Research findings from Farfel et al. (2008) and Brackbill et al. (2009) consistently show the increase of newly diagnosed asthma in rescue workers over time. Rescue workers had the highest risk for asthma compared to other exposed populations because they had the greatest exposure. The elevated risk was likely due to prolonged presence at the site and working directly with debris pile. Also reported by Brackbill et al. (2009), rescue workers who worked on the debris pile had a twofold higher rate of reporting recently diagnosed asthma compared to other groups.

Wheeler et al. (2007) also stated that the population group at greatest risk was workers who arrived on 9/11 and worked more than 90 days. This study's results were consistent with others in that significant risk factors for newly diagnosed asthma included duration of hours worked at the WTC site or barges. This suggests that long term exposure to contaminants resulted in new asthma diagnosis. Wheeler et al. (2007) also reported that newly diagnosed asthma in the three-year timeframe was 12 times higher with WTC rescue workers compared to the general population.

All studies show a pattern of increase in new asthma cases among rescue workers (Table 3). Risk factors for asthma among firefighters were consistent throughout all studies that included dust cloud exposure, working on the WTC debris pile, and time period of working at the WTC site or on barges. The increase of prevalence is shown over time since the new asthma cases rose from 2003-2004 at 3.2% (Farfel et al., 2008), to 2015-2016 at 18.1% (Jordan et al., 2018).

Residents/Office Workers/Passers-by

The data for residents show that the new asthma cases vary among the different groups of residents, passers-by, and office workers in the affected area (Table 3). Several studies consistently reported that residents who did not evacuate the affected area had a higher prevalence of asthma. These groups experienced different levels of exposure to the dust cloud, proximity of the site, and duration of exposure. Even though the groups had varying asthma rates, all the studies show a consistent increase of new asthma cases over time.

Children

There is a pattern of increasing prevalence of asthma diagnosis in children over time (Table 4). Farfel et al. (2008) and Thomas et al. (2008) used WTC Health Registry data and both found an overall prevalence of newly diagnosed asthma among children at 5.7% during 2003-2004. This shows consistency across the analysis of survey data and shows early impact of health effects due to the exposure of dust and debris. Overall, for all age groups, Gargano et al. (2017) reported a prevalence rate of 25.5% for newly diagnosed asthma for 2005-2006.

Thomas et al. (2008) reported a breakdown of the prevalence based on the children’s age group. The study reported that children under 5 years old had the highest prevalence of newly diagnosed asthma at 10.8% compared to the other age groups. A study by Gargano et al. (2017) also reported based on children’s age group for newly physician diagnosed asthma occurring 10 to 11 years after the WTC attack. The study reported from 2011-2012, children under 2 years old at the time of the 9/11 attack had a prevalence of 26.9% of newly diagnosed asthma. A consistent pattern is seen from these studies which shows higher rates in younger age groups compared to older children. This suggests that younger children were more vulnerable to health effects from exposure to the dust cloud. The trend is consistent that the same age group has had a significant increase of asthma over time.

Thomas et al. (2008) also compared age specific asthma prevalence at the time of interview with the 2003 National Health Interview Survey (NHIS) (Center for disease Control and Prevention 2003). The total asthma prevalence reported from children enrolled in the WTC Health Registry was 18.3% (95% CI, 16.8-19.8). This percentage is higher than the asthma percentage reported for all children in the NHIS 2003 survey at 12.4% (95% CI, 11.8-13.0). Thomas et al. (2008) also compared children from the U.S Northeast only that is part of the NHIS 2003 survey. The prevalence of asthma reported from children located in the Northeast was 14.1% (95% CI, 13.5-15.7). When comparing WTC exposed children to all children and children only located in the northeast in the NHIS 2003 survey, the exposed children have a statistically significantly higher asthma reported prevalence. The studies consistently show that children in the exposed area of the WTC had a higher prevalence of asthma compared both to the national average and the Northeast regional average.

Sarcoidosis

Table 5. Incidence rate of sarcoidosis for different populations across multiple studies.

Sarcoidosis					
Population	Source	Timeframe	Incidence rate of cases (per 100,000 persons-years)	Comparison to Unexposed Population	Notes
Firefighters	Crowley et al. (2011)	2001-2007	192**	NR	**Reports Sarcoidosis like granulomatous pulmonary disease
	Crowley et al. (2011)	2003-2004	54**	NR	**Reports Sarcoidosis like granulomatous

					pulmonary disease
	Hena et al. (2019)	2001-2015	22	NR	
	Jordan et al. (2011)	2003-2004	26	NR	
	Webber et al. (2017)	2001-2015	25.5*	10.2 (per 100,000 persons-years) from REP data	*(included EMS)
General population exposed to WTC dust cloud	Jordan et al. (2011)	2003-2004	15	NR	

NR= Not Reported

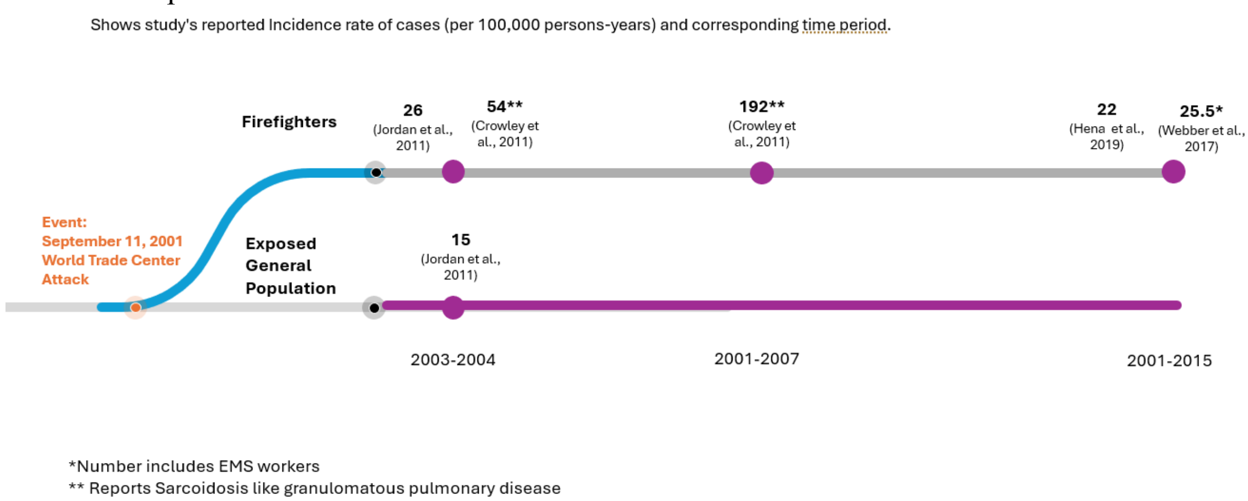


Figure 5. Timeline of sarcoidosis incidence rate in firefighters and the exposed general population after the WTC Attack

Several studies have evaluated the incidence of sarcoidosis in the population exposed to the WTC disaster. The majority of studies focused on firefighters and looked over different timeframes. Short-term studies, such as Crowley et al. (2011), reported the highest incidence rate among firefighters; however, the study only covered the first 6 years after 9/11. Crowley et al. (2011) reported the peak of cases occurred between 2003-2004 at an incidence rate of 54 per 100,000 persons-years. The study also reported that over a six year timeframe the incidence rate was 192 cases per 100,000 persons-years. It needs to be noted that Crowley et al. (2011) gathered sarcoidosis diagnosis by using diagnosis codes, ICD-9, and health records. All other studies used cardiac images, and/or biopsies to confirm sarcoidosis. Building on this, Webber et al. (2017) calculated the standardized incidence ratio (SIR), for the same initial five-year period. The study reported the SIR to be 4.2 (95% CI: 3.1-5.6), indicating the WTC exposed firefighters experienced 4.2 times more cases than the unexposed population within the first five years.

Long-term studies differ in the reported incidence patterns for sarcoidosis among WTC-exposed populations. Webber et al. (2017) reported an incidence rate of 25.5 (95% CI =19.6, 47.2) cases per 100,000 persons-years for firefighters and EMS workers over the entire study timeframe of 14 years. Similarly, Hena et al. (2019) studied sarcoidosis incidence over 14 years and observed an incidence rate of 22 cases per 100,000 persons-years. These long-term rates show decreases over time when compared to short-term incidence rate in the first six years of 192 cases per 100,000 persons-years reported by Crowley et al. (2011). These findings may suggest the risk for sarcoidosis cases that occurred within the first 6 years of the event with rates declining over time.

The consistency among studies suggests an elevated risk of sarcoidosis among first responders of the WTC disaster. The incidence rate for firefighters that was reported by Hena et al. (2019) was 22 cases per 100,000 person-years. Similarly, Jordan et al. (2011) reported 26 cases per 100,000 person-years for firefighters. For overall WTC survey responders, Jordan et al. (2011) reported 15 cases per 100,000 person-years. This finding highlights the increased risk of sarcoidosis for firefighters.

Strong evidence from comparative studies supports these findings. Webber et al. (2017) looked at both firefighters and rescue workers (EMS) combined and compared with unexposed demographically similar population reported by the Rochester Epidemiology Project (REP). REP contains medical records from over 70,000 Olmsted County, MN residents and was established in 1966. Given the geographical location, the study reports the population would likely be unexposed since it is approximately 1300 miles away from New York City. Webber et al. (2017) selected REP data to match the study period of 2003-2013 and the sarcoidosis incidence rates of similar age and sex distribution of the WTC-exposed rescue workers. Webber et al. (2017) reported the age-adjusted incidence of sarcoidosis for the FDNY cohort was 25.5 per 100,000 (95% CI= 19.6, 47.2) versus the REP cohort of 10.2 per 100,000 (95% CI=7.7,12.7). By comparing to an unexposed population, the study provides strong evidence that firefighters and EMS workers who were exposed to the dust cloud on September 11, 2001, had a higher incidence of sarcoidosis compared to the general population. The consistency among studies and the comparison with unexposed populations shows that rescue workers exposed to the WTC dust cloud have a higher risk of sarcoidosis and the risk is even higher within the first five years of the WTC event.

Limitations

Studies that contained self-reporting include potential recall bias, especially for studies that had multiple surveys over time. Participants may have difficulty accurately remembering the timing, duration, and intensity of their exposure or onset of symptoms. They might misreport certain factors which can result in biased data. Many participants may not respond to surveys, which could make the data an inaccurate representation of the entire exposed population.

Some variations of the percentages when comparing studies can be due to different methodologies when analyzing survey data. For example, most studies reported using WTC Health Registry data. Cone et al. (2016), specifically stated that they incorporated diagnoses of reactive airways dysfunction syndrome (RADS) into the cases of asthma. Other studies did not mention this method of analyzing asthma data.

Other environmental or occupational exposures unrelated to 9/11 could contribute to the health outcomes such as asthma and sarcoidosis but may not be fully accounted for in all studies. For example, personal habits of responders, such as smoking, could also contribute to respiratory health impacts. Webber et al. (2017) compared WTC-exposed firefighters and EMS to unexposed population can be seen as a limitation since firefighters in general have a higher risk of sarcoidosis due to the occupational exposure. Other factors potentially contributing to exposures could include pre-existing health conditions, living near a high traffic road, occupational exposure.

Limited pre-9/11 baseline data can make it challenging to definitively confirm all observed cases to WTC dust cloud exposure. Misdiagnosis could have occurred, especially in the days immediately following the attack, when healthcare providers did not yet understand the WTC-related health issues. These limitations highlight the complexity of studying respiratory health impacts of the WTC event and shows the need for continued long term research.

CONCLUSIONS

The literature review of several studies investigating the short- and long-term respiratory health impacts of the World Trade Center (WTC) attack reveals consistent findings. Generalized respiratory effects were widespread. Passers-by had the highest prevalence of general respiratory symptoms, followed by rescue workers. These effects still persisted even after 2 to 3 years following the 9/11 attacks. Asthma prevalence increased over time for each of the vulnerable populations. Rescue workers comprised the highest percentage of newly diagnosed asthma, and the highest risks were for those workers who arrived on 9/11 and worked more than 90 days.

Children under 5 at the time of the attack had more vulnerability to asthma compared to children in other age groups. Sarcoidosis rates among firefighters were reported to be higher than in unexposed groups. The studies showed consistency that the incidence rate was higher within the first 5 to 6 years after the WTC attack.

These results emphasize the persistence of WTC-related respiratory health outcomes across different groups and over time. The persistence of these health outcomes highlights the need to continue health monitoring and care for affected individuals. The general findings in the studies emphasize the importance of continuing monitoring for long term health effects for all populations. Ongoing monitoring and research efforts are crucial to understanding and addressing the long-term health effects of the WTC attack. The research efforts can provide valuable insight for disaster preparedness and response strategies in the future.

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