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Ten-year cancer incidence in rescue/recovery workers and civilian survivors exposed to the September 11, 2001 terrorist attacks on the World Trade Center

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Background

- Collapse of WTC towers produced known & suspected carcinogens
    - Asbestos, silica, PAHs (polycyclic aromatic hydrocarbons), benzene, heavy metals (eg, cadmium, lead), PCBs (polychlorinated biphenyls)
- Previous WTCHR cancer study (2007-2008)
    - Excess prostate, thyroid cancers and multiple myeloma among rescue/recovery workers
- Previous studies from 2 other responder cohorts (~2008)
    - Excess prostate and thyroid cancers in FDNY cohort
    - Excess thyroid cancer in Mount Sinai cohort

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Objectives

- Continue assessing possible excess cancer among WTCHR enrollees with three additional years of follow-up data
    - Does increased incidence of 3 cancers persist in workers?
    - Are there other cancers more than expected?
    - Is there a dose-response trend?

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Methods (1)

Study sample (N=60,339)

- Enrollees who were residents of 11 states selected for cancer linkage (representing 91% of cohort)
- At risk for 1st primary cancer in the beginning of 2007
- Enrollees with known age and race/ethnicity

Cancer cases

- Identified via linkage to NYS (majority) & 10 other state cancer registries through 12/31/2011
- Reportable to Cancer Registry - 1st primary invasive cancer or in situ bladder cancer

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Methods (2) - WTC Exposure

Workers (Rescue/recovery workers) **(Continuous Score)**	**Survivors** (Residents, area workers, passersby, staff/students) **(Ordered Categories 1-4)**
1. Dust cloud exposure on 9/11 2. Being south of Chambers Street between 1st plane impact and noon 3. Date of arrival at the WTC site 4. Duration of work at the WTC site 5. Date or time period working on the piles	1. Dust cloud exposure on 9/11 2. Evacuated home for residents 3. Returned to work for area workers 4. Present in school on 9/11 for staff/students

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Distribution of WTC Exposure

Workers, N= 24,863

Quartile	% Workers
1 (low)	25.1
2	25.7
3	24.3
4 (high)	25.0
Continuous	
Log transformed	

Survivors, N= 35,476

Ordinal	% Survivors
1 (low)	7.2
2	42.6
3	38.2
4 (high)	12.0
Trend (1 – 4)	

Note: 693 workers and 288 survivors had missing values of exposure

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Methods (3) - Data Analysis

- External comparison – Standardized Incidence Ratio (SIR)
- Internal comparison – Cox proportional hazards model
  - Separately for workers and survivors
  - Cancers diagnosed between 2007 and 2011

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External Comparison - SIR

- Comparison to external population
  - Standardized Incidence Ratio (SIR): observed/expected
  - Expected cases - Apply the cancer incidence rate of the reference (**NYS**) population to our study population by strata (i.e., age, sex, race/ethnicity, and study periods)
  - All cancer sites combined and 24 site-specific cancers

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Internal comparisons – Cox proportional hazards modeling

- Compares cancer incidence among those highly exposed to those less exposed, using Cox Proportional Hazards model
- WTC exposures
  - Excluded unknown WTC exposure (693 workers and 288 survivors)
- Cancers with significant SIRs, and bladder cancers were examined
- Adjusted for socio-demographic characteristics, enrollment source, smoking, and history of medical conditions

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Results - Characteristics at enrollment

	Workers (N=24,863)	Survivors (N=35,476)
Median age at enrollment	42 years	42 years
Male	80%	47%
NH-White	71%	58%
Smoking		
Current	18%	14%
Former	27%	24%
NYS Residents	73%	75%

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SIR Results

All cancer sites combined

Workers (N=24,863)			Survivors (N=35,467)		
# Observed	SIR	(95% CI)	# Observed	SIR	(95% CI)
685	1.11	(1.03-1.20)	992	1.08	(1.02-1.15)

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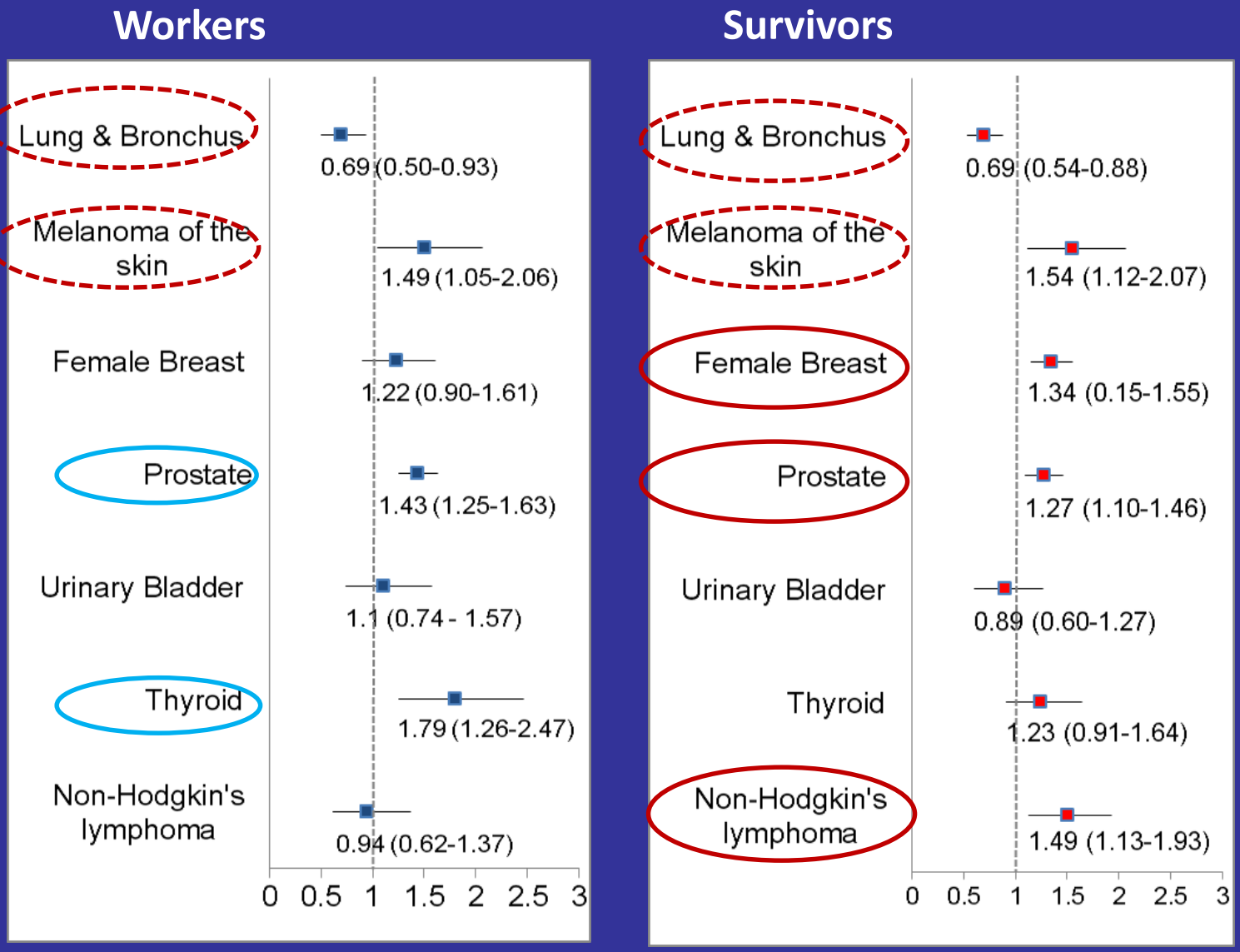
SIR Results – Site-specific cancers



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Results – Cox Proportional Hazards Modeling in Workers

Urinary bladder cancer

WTC exposure scores	# Cancer	Adjusted HR	95% CI
Quartile 1	0	NA	
Quartile 2	10	REF.	
Quartile 3	10	1.21	0.50-2.94
Quartile 4	7	0.87	0.31-2.44
Continuous		1.03	0.995-1.05
Log transformed		2.18	1.10-4.34

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Results – Cox Proportional Hazards Modeling in Survivors

Skin Melanoma

WTC exposure level	# Cancer	Adjusted HR	95% CI
1 (Low)	2	ref	
2	13	1.51	0.34-6.77
3	20	2.66	0.60-11.72
4 (High)	7	3.28	0.66-16.28
Trend (1-4)		1.53	1.04-2.23

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Limitations

- Relatively short follow-up time and small number of cases
- Potential bias due to increased screening for cancer
- Unknown family history of cancer, pre- and post-9/11 occupational/ environmental exposures other than WTC
- WTC exposure matrices may introduce potential measurement misclassification bias

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Summary and Discussion

- Prostate and thyroid cancers remained elevated in workers
  - Subject to surveillance bias
  - No radiation documented in WTC site
- New findings from external comparison
  - All cancer sites combined and skin melanoma in both groups
  - Prostate, female breast cancers and non-Hodgkin's lymphoma in survivors
- New findings from internal comparison
  - Bladder cancer in workers
  - Skin melanoma in survivors

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Future Plans

- Continue on-going cancer surveillance
  - Re-assess the need to expand cancer linkage to more states
  - Assess cancer burden
  - Examine cancer screening practices

- A 4-year joint cancer study of 3 responder cohorts
  - Funded by NIOSH
  - Responders from WTCHR, FDNY, and Mt. Sinai cohorts
  - Purposes: de-duplicated cohort, increase sample size & follow-up time (through 2014)
  - Study aims: incidence, latency and survival of cancer

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11 State Cancer Registries
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Persistent Hearing Problems among World Trade Center Health Registry Rescue and Recovery Workers, 2001 – 2007

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NIOSH NORA Conference June 21, 2017
Preliminary Data
Please do not cite or quote

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Hearing Loss among Adults

- Third-most common chronic physical condition after hypertension and arthritis
- 11% of working population has hearing difficulty
  - 24% caused by occupational exposures
- 8% of working population has tinnitus
- 4% with hearing difficulty and tinnitus

Hearing Loss Associated With

- Cognitive function
- Mental health
- Social isolation
- Balance and walking

- $242 million a year spent on worker's compensation for hearing loss disability

Occupational Hearing Loss

- Noise
- Chemicals
  - Organic solvents (styrene, tricholoroethylene)
  - Metals (mercury, lead, trimethyltin)
- Vibration
- Extreme heat

Relevance to WTC Population

- Hearing problems an emerging concern
- Early Wave 1 analysis
  - Dust cloud associated with hearing problems
  - OR 1.7 (95% CI 1.4 – 2.0)
- Hearing problems raised as community concern

Study Question

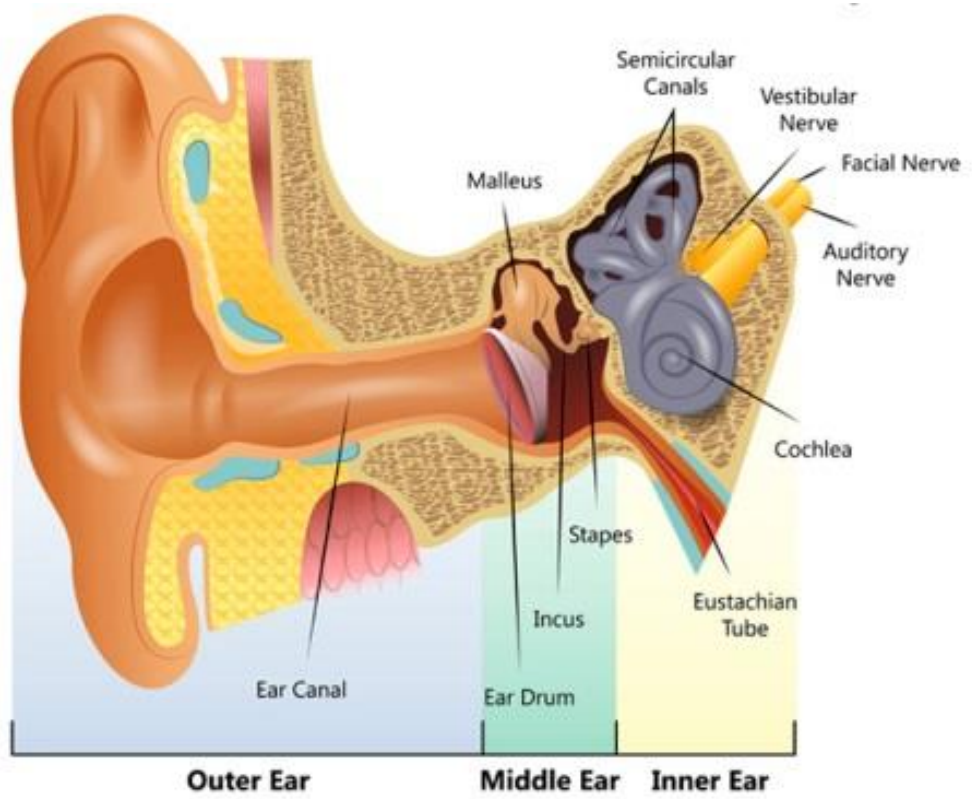
Is there an association between WTC-related exposures and self-reported, persistent, post-9/11 hearing problems among WTC Health Registry rescue and recovery workers?

Expected Study Impact

- Respond to community health concerns
- Preliminary data for in-depth study using objective measures of hearing loss

Ear Anatomy

- Outer
  - Pinna
  - Ear canal
- Middle
  - Ear drum
  - Ossicles (malleus, incus, stapes)
- Inner
  - Cochlea
  - Auditory nerve
  - Brain



https://www.hearinglink.org/your-hearing/how-the-ear-works/

Normal Hearing

- Sound waves enter ear canal and vibrate ear drum
- Vibration moves middle ear's tiny chain of bones
- Last bone in chain "knocks" on cochlea's membrane window and makes fluid and hair cells move
- Fluid movement triggers response in auditory nerve

Hearing Problems

Conductive

- Middle ear problem
  - Ear drum
  - Ossicles
- Relevant risk factors
  - Head trauma
  - Perforated ear drum

Sensorineural

- Inner ear problem
  - Hair cells in cochlea
  - Neural pathways
- Relevant risk factors
  - Head trauma
  - Loud noise
  - Ototoxic chemicals

Study Population

- Rescue recovery workers
- Completed Wave 1 and Wave 2
- No reported pre-9/11 hearing problems
- N=19,602

Outcome:
Persistent Hearing Problem

Wave 1
2003 – 2004

Wave 2
2006 – 2007

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Exposure Measures

- Environmental hazard score
  - Quartiles
- Lost hearing in dust cloud on 9/11
  - Not in dust cloud
  - In dust cloud, able to hear
  - In dust cloud, not able to hear
- Head injury on 9/11
  - “Concussion, head injury, knocked out by being hit on head”

Environmental Hazard Score

- Developed through modified Delphi process
- Experts scored five component measures by intensity of environmental exposure
  - Location on 9/11
  - Dust cloud
  - Arrival date
  - Work duration
  - Time periods worked
- Components summed to create total score
- WTC site only (n= 15,959)

Covariates

- Age, Wave 2
- Sex
- Race/ethnicity
- Education
- Smoking history, Wave 2
- Sinus/headache symptoms, Wave 1 and 2
- Chronic disease, ever diagnosis
  - Hypertension, heart disease, angina, heart attack, other heart conditions, or diabetes

Analytic Plan

- Separate logistic regression for each exposure
- Fully adjusted models
- Supplemental analysis: Models excluding workers reporting sinus/headache symptoms at Wave 1 and 2

Table 1: Frequency of Persistent Hearing Loss

Characteristic (n=16,684)	No Persistent Hearing loss (%)	Yes, Persistent Hearing Loss (%)
Gender		
Male	12,358 (97.9)	324 (2.5)
Female	3,813 (98.7)	49 (1.3)
Sinus Symptoms, Waves 1&2		
No	10,301 (98.8)	123 (1.2)
Yes	5,753 (95.9)	246 (4.1)
Lost Hearing in Dust Cloud		
Not in dust cloud	9,811 (98.6)	140 (1.4)
In dust cloud, able to hear	5,206 (97.5)	132 (2.5)
In dust cloud, not able to hear	971 (91.9)	86 (8.1)
Headache Symptoms		
No	14,393 (98.4)	229 (1.6)
Yes	1,652 (92.3)	137 (7.7)

Table 1 (continued)

Characteristic	No Persistent Hearing loss (%)	Yes, Persistent Hearing Loss (%)
Smoking History, Wave 2		
Never	9,018 (98.0)	186 (2.0)
Former	4,851 (97.6)	119 (2.4)
Current	2,322 (97.2)	66 (2.8)
PTSD Symptoms at W1&W2		
No	14,363 (98.5)	221 (1.5)
Yes	1,229 (90.6)	127 (9.4)
Occupational Noise		
Low	1,294 (98.1)	25 (1.9)
High	7,002 (96.7)	235 (3.3)

Table 2: Adjusted Models*

Exposure	Odds Ratio (95% Confidence Interval)
Environmental Hazard Score	
Quartile 1 (lowest)	1.0
Quartile 2	1.6 (1.0, 2.6)
Quartile 3	2.2 (1.3, 4.6)
Quartile 4 (highest)	3.5 (2.2, 5.7)
Lost Hearing in Dust Cloud	
Not in dust cloud	1.0
In dust cloud, able to hear	1.0 (0.8, 1.4)
In dust cloud, not able to hear	2.9 (2.1, 4.0)

*Adjusted for survey mode at W2, age at W2, age squared, sex, race/ethnicity, education, smoking at W2, sinus/headache symptoms, chronic disease history

What Do Exposures Represent?

- Dust and debris
  - Ototoxic chemicals
- Proximity to disaster
  - Chemicals
  - Noise
- Work at WTC site
  - Occupational hearing loss

Conclusion

- Strong association between WTC-based exposures and self-reported hearing problems among rescue/recovery workers
  - Dose-response association
  - Consistent magnitude across exposure metrics
- Does not appear due solely to sinusitis
- Limited by self-reported hearing measure

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Next Steps

- Ongoing analyses on workers
- Expanding analyses to community members
- Collaborative study with FDNY using audiometric surveillance records

Collaborators

- NYC DOHMH
  - Cheryl Stein, PhD
  - James Cone, MD, MPH
  - Liza Friedman, MPH
  - Nicole Romeo
- University of Miami
  - David Lee, PhD

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Maintenance and Extension of a Cohort of Career Firefighters as a Non-WTC Exposed Comparison for the FDNY Firefighter Cohort

Mayris Webber, PI

Rachel Zeig-Owens, Jennifer Yip,

Charles Hall, David Prezant & the FDNY Research Team

September 11, 2001

The terrorist attack on the World Trade Center and its consequent collapses killed 2,800 persons, including 343 FDNY rescue/recovery workers.

~ 16,000 FDNY rescue workers participated in the rescue/recovery effort, which started immediately and continued for 10 months.

1,600 FDNY firefighters and EMS workers were present when the buildings came down and 6,600 were there by the end of day 1.

Review of WTC Exposures

The exposure mix (partial list):

- Pulverized cement, gypsum
- Pulverized glass
- Asbestos
- Silica
- Fibrous glass
- Heavy metals
- Volatile organic compounds
- Organic products of the combustion of 100,000 L of jet fuel (PAHs, etc)

WTC Exposures

- The collapses caused a massive dust cloud which resulted in a “pile” that reached 50 feet high
- Fires burned through December, 2001; diesel exposure during rebuilding efforts
- Psychological stressors: long work shifts, fear for personal safety and exposure to bodies and body parts

World Trade Center Exposure

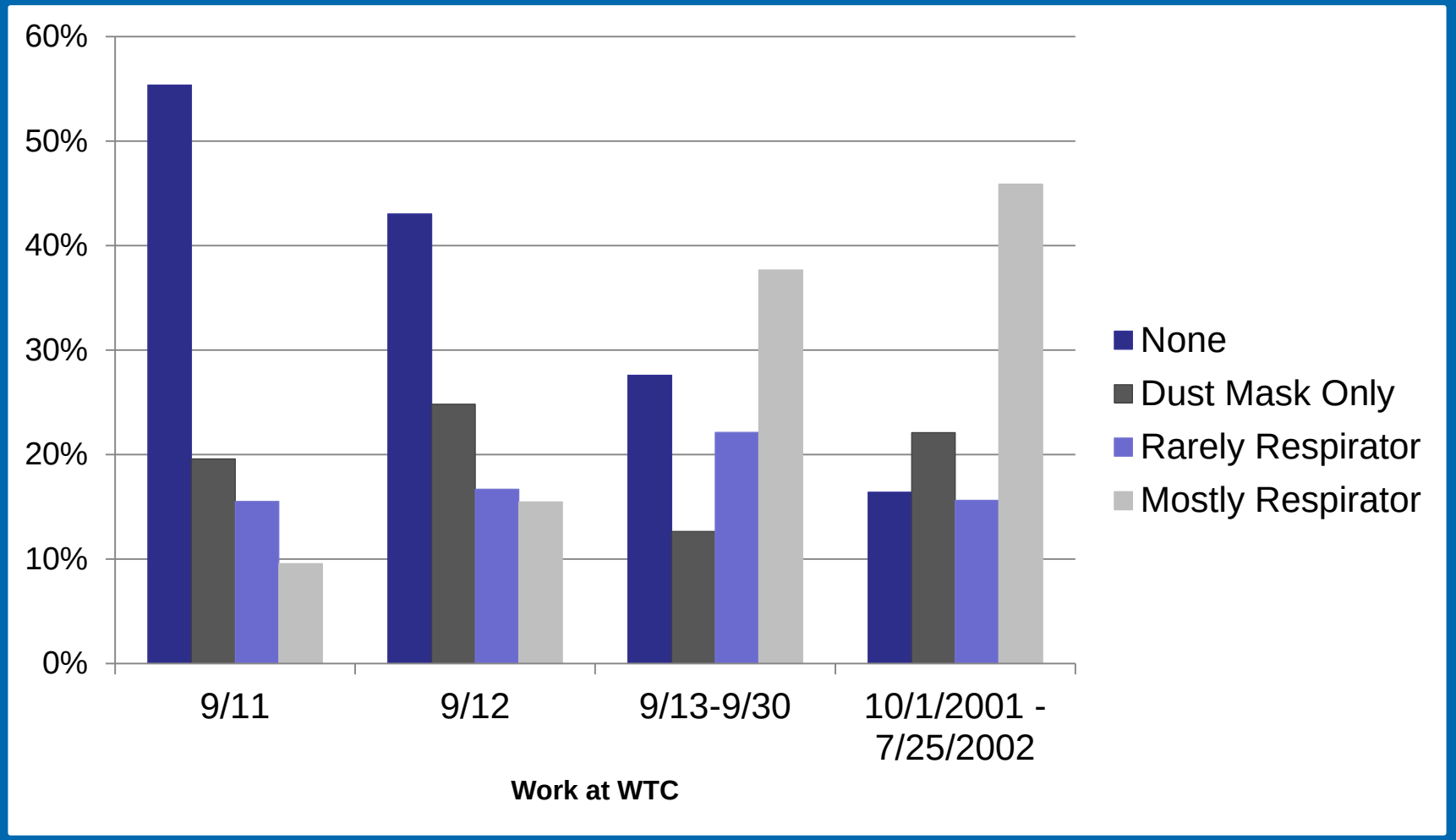
- Nearly all FDNY firefighters and EMS arrived at WTC site within the first 48 hours

	Firefighters		EMS workers		Total	
	N	%	N	%	N	%
Total	13206	100	2440	100	15646	100
WTC arrival group						
Arrival on the morning of 9/11	1814	13.7	459	18.8	2273	14.5
Arrival during the afternoon of 9/11	6100	46.2	721	29.6	6821	43.6
Arrival on 9/12/2001	2441	18.5	293	12	2734	17.5
Arrival any day between 9/13/2001 and 9/24/2001	2045	15.5	604	24.8	2649	16.9
Arrival after 9/24/2001	266	2.0	215	8.8	481	3.1
Undefined Exposure	535	4.1	148	6.1	683	4.4
Duration – months at the WTC Median [IQR range]	3 [1-5]		2[1-5]		2[1-5]	

Exposure

- In the first post-9/11 days
  - rescue/recovery workers suffered exposure to unprecedented volume of aerosolized dust
  - protective respirator/mask use was poor
  - majority of workers developed acute cough
  - a substantial fraction showed upper and lower respiratory tract symptoms.

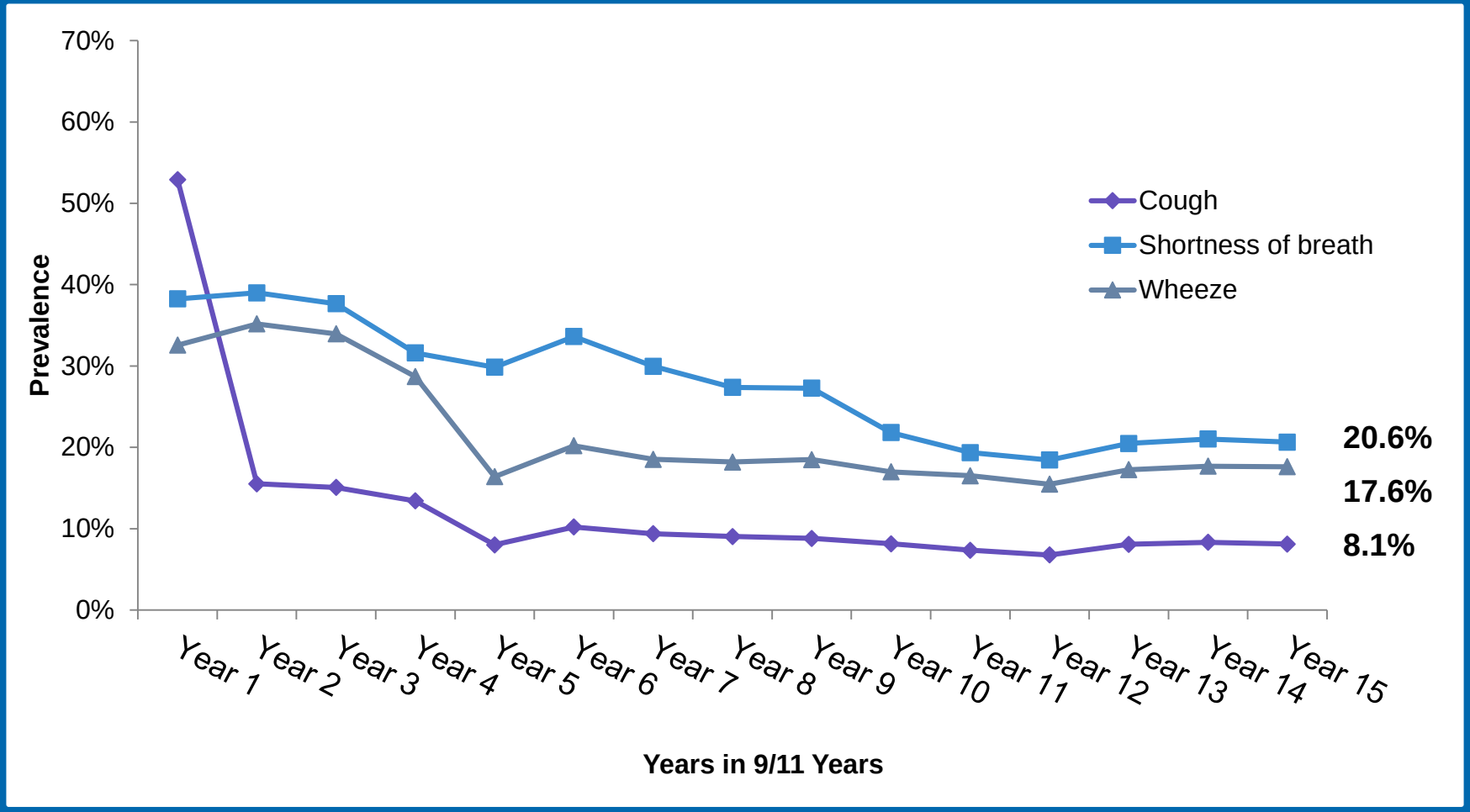
Respirator/Mask Use on 9/11



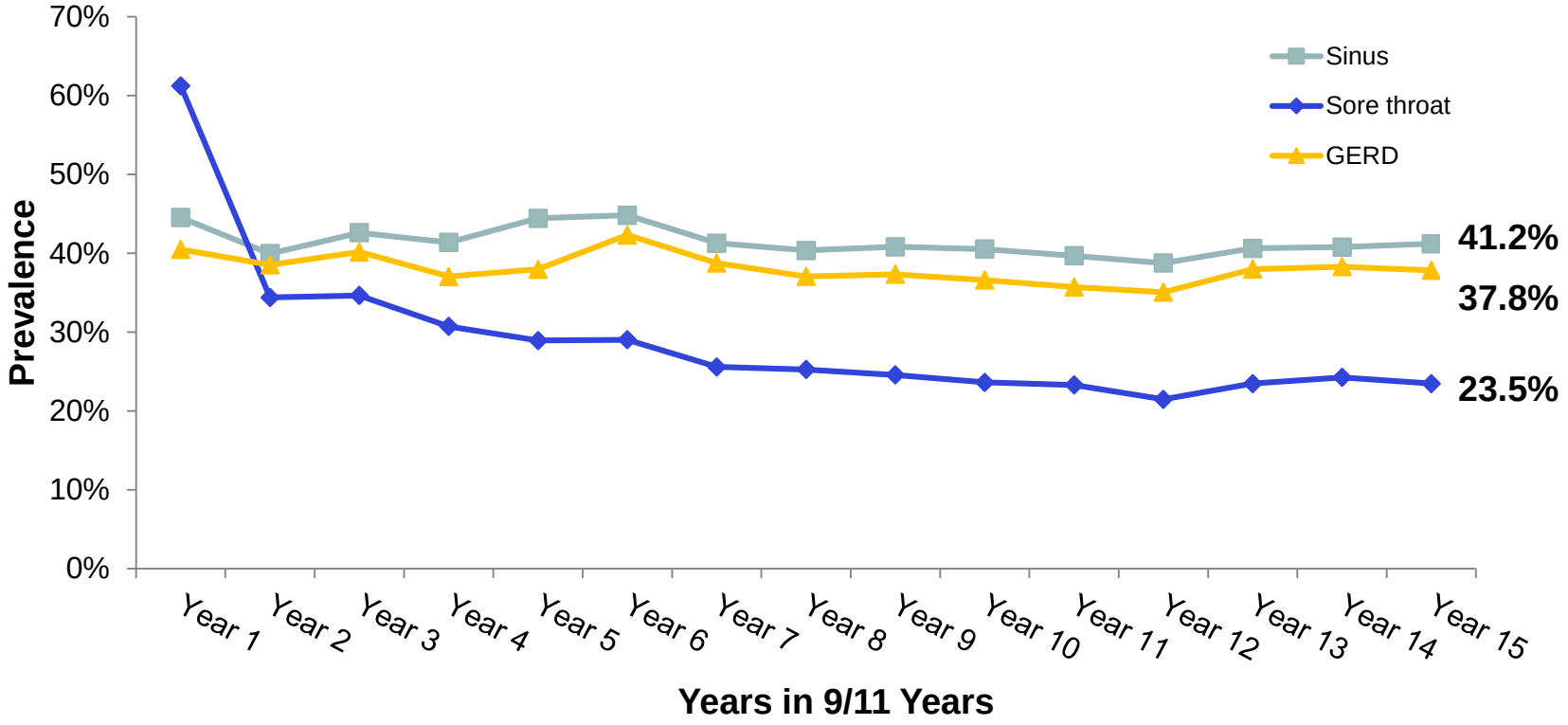
FDNY Occupational Health Service Medical Monitoring Protocol

- Since 1997, FDNY has performed health evaluations every 12-18 months
- Physical evaluations include: spirometry, chest x-rays (every 2 years), blood tests. CT scans are available, if indicated
- Since 9/11, evaluations also include self-administered, computer-based, physical and mental health questionnaires.

Lower Respiratory Symptoms Over Time



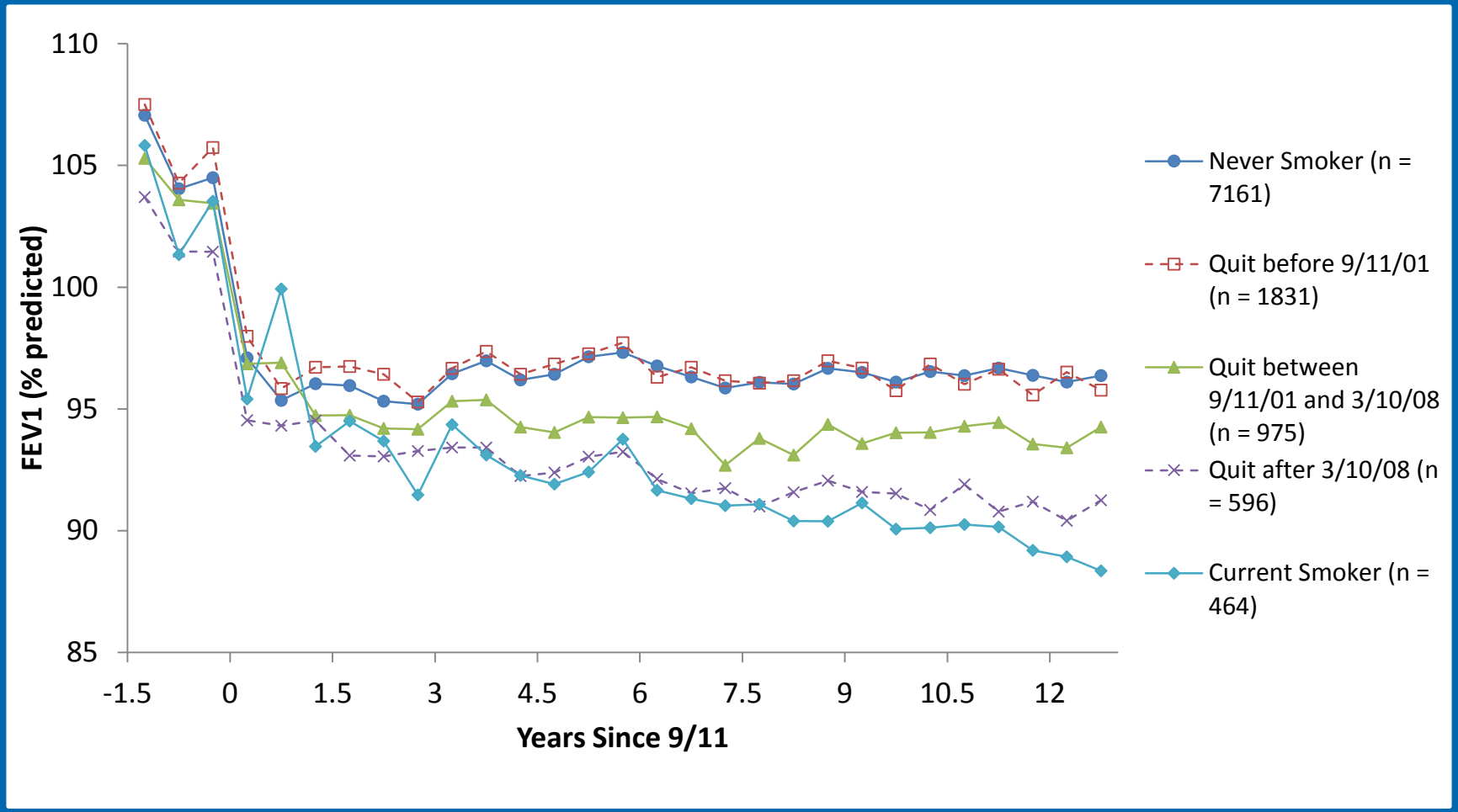
Upper Respiratory Symptoms Over Time



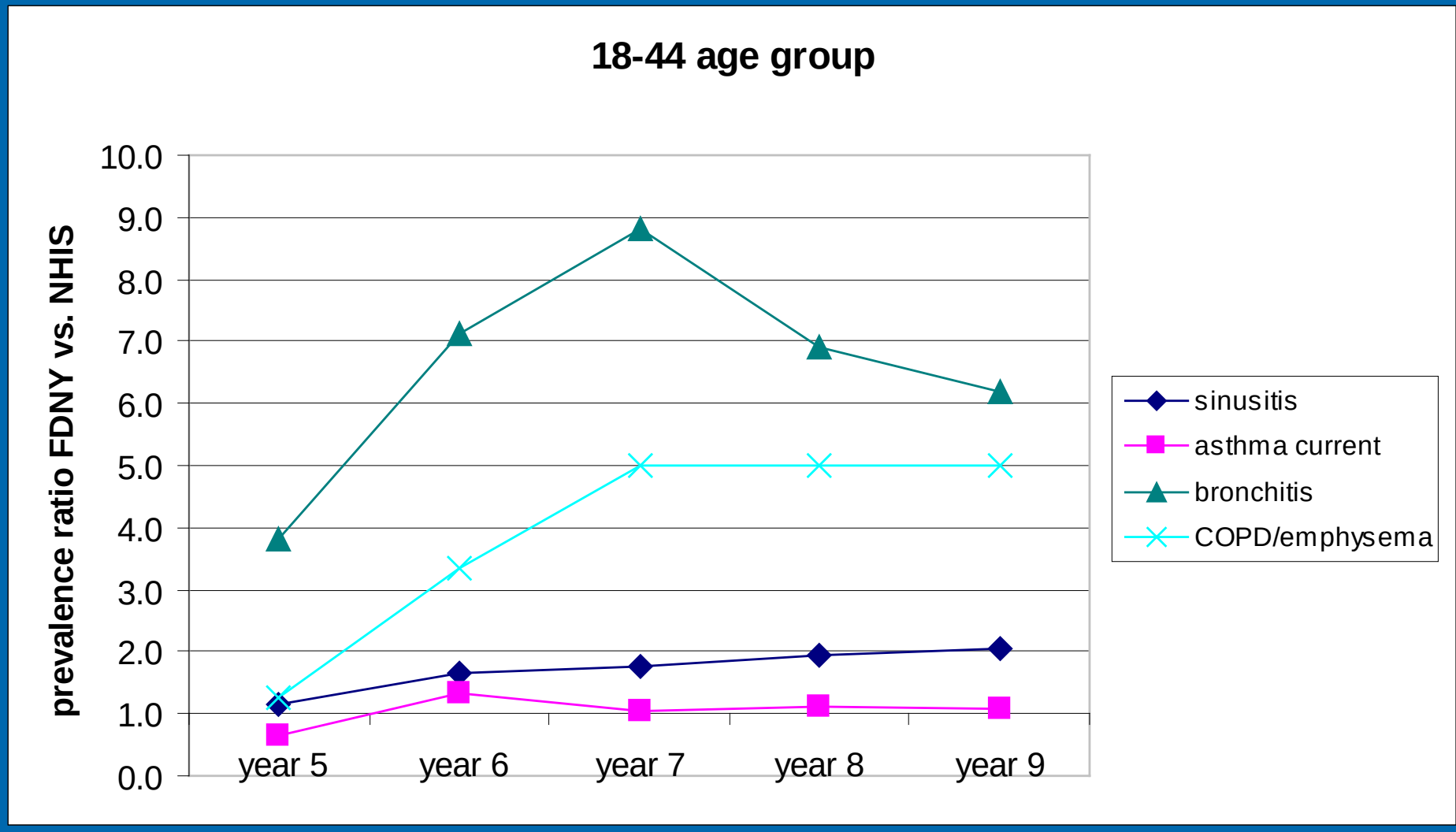
Pulmonary Function

- Spirometry - Non-invasive test which measures the amount of air that can be inhaled and exhaled and how fast.
- FEV_1 – the volume of air that can be forcibly expired in the first second after a maximum inspiration.

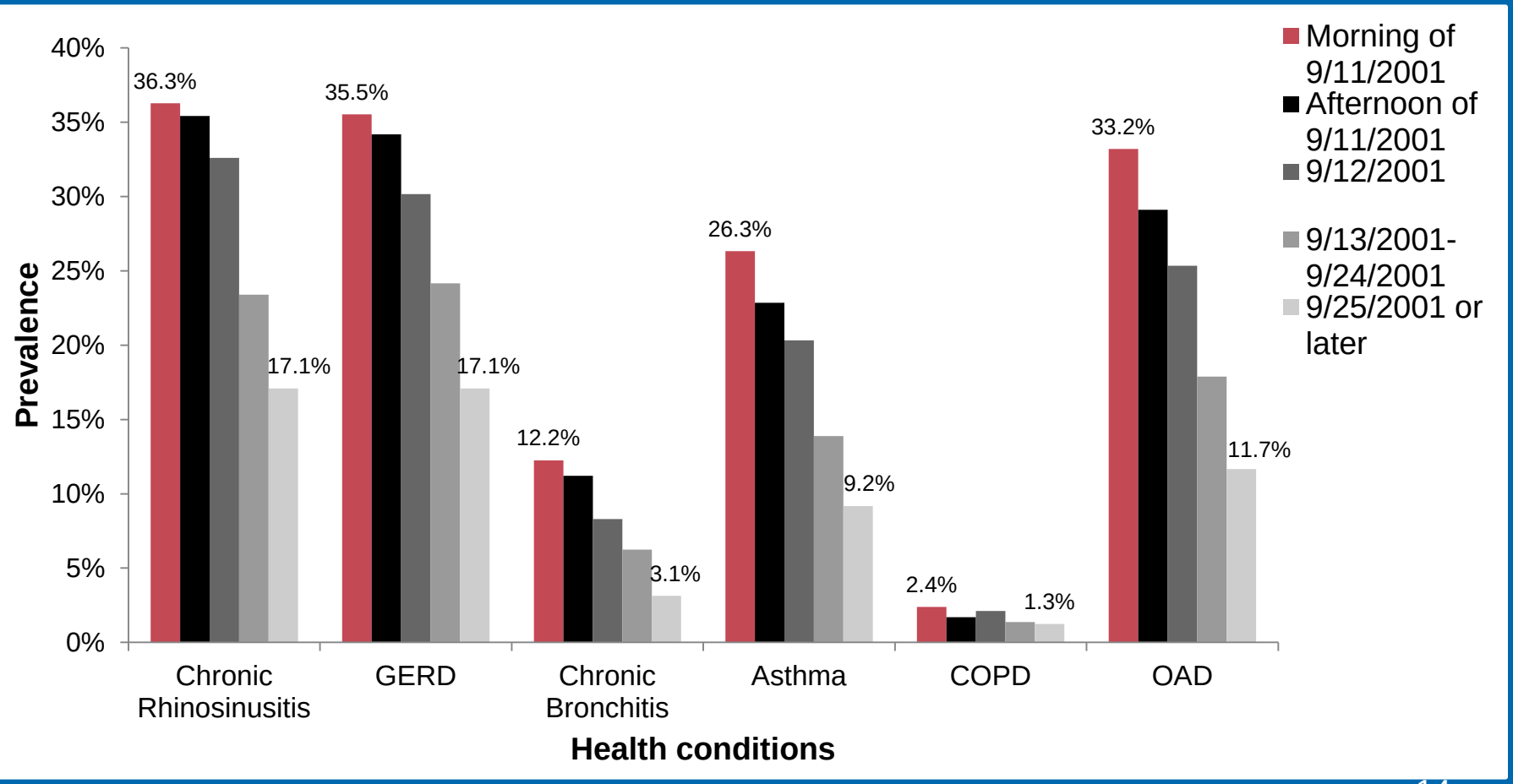
Pulmonary Function over Time in Firefighters – Impact of Cigarette Smoking and Cessation



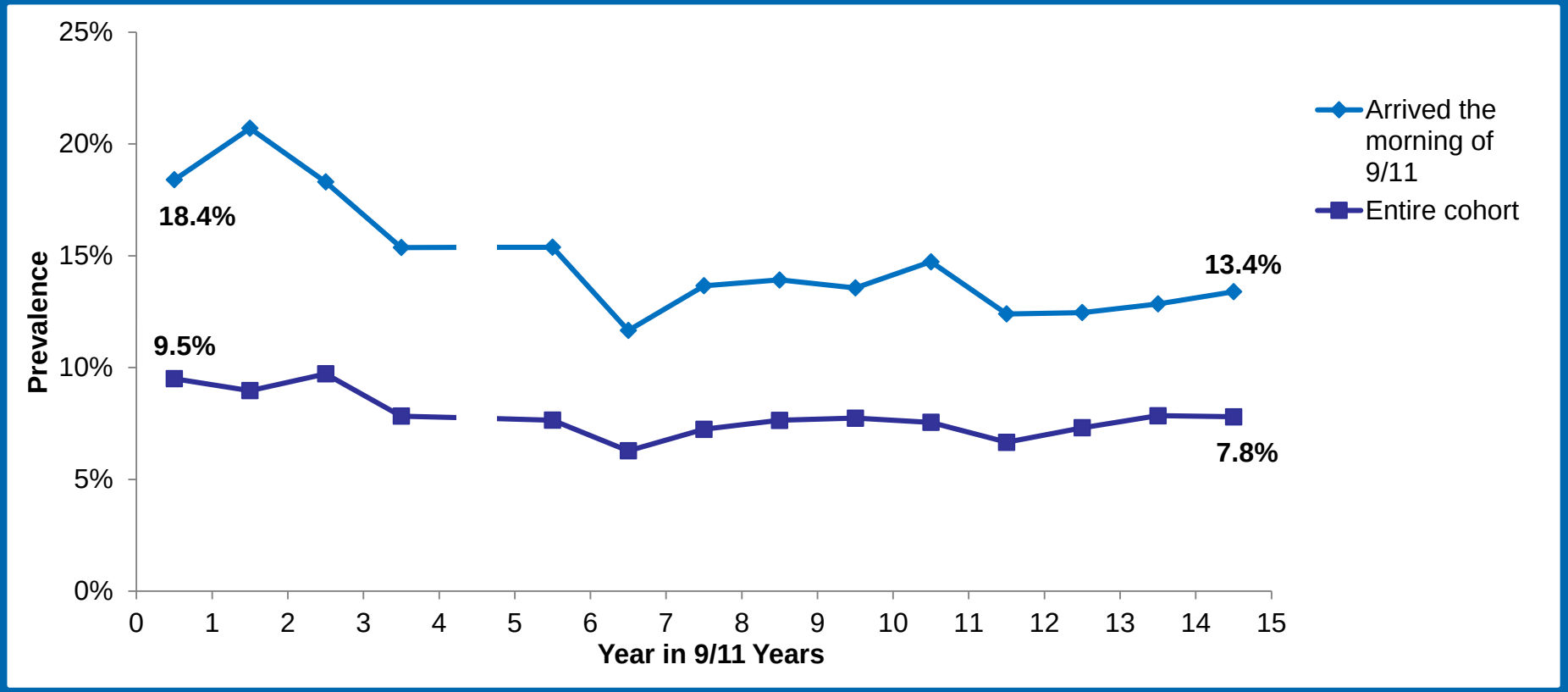
Ratios of reported respiratory diagnoses 2005-2010: FDNY vs. NHIS white males ages 18-44 years



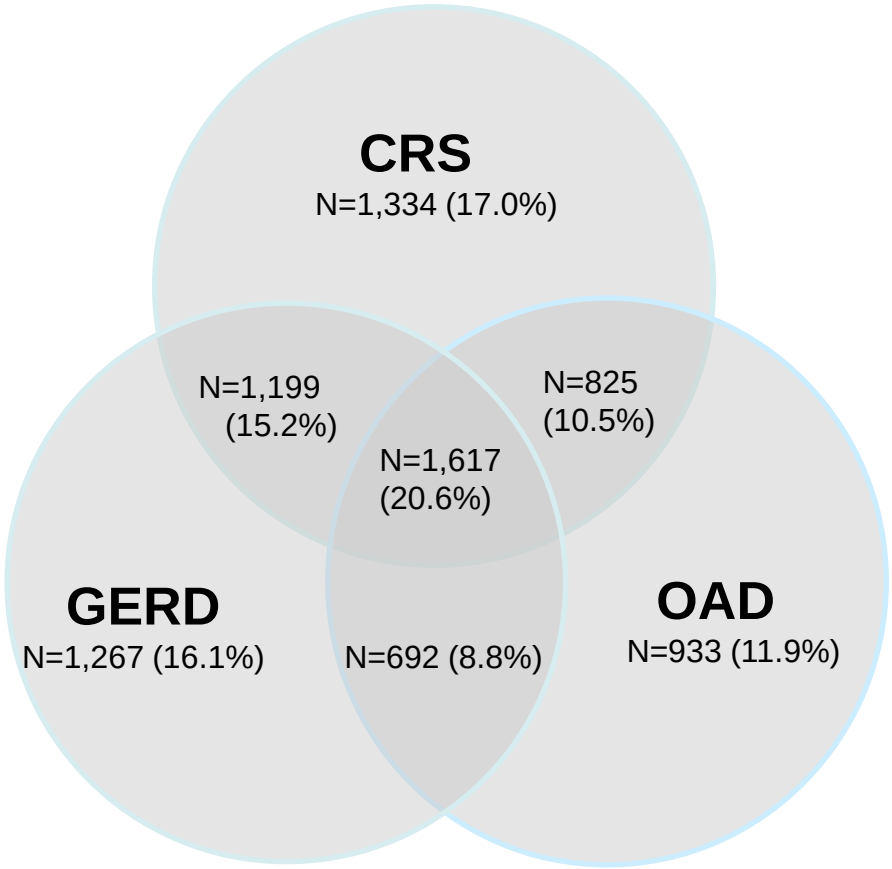
Respiratory Diagnoses by WTC Arrival Time (2001 – 2016)



Prevalence of probable PTSD by 9/11 year

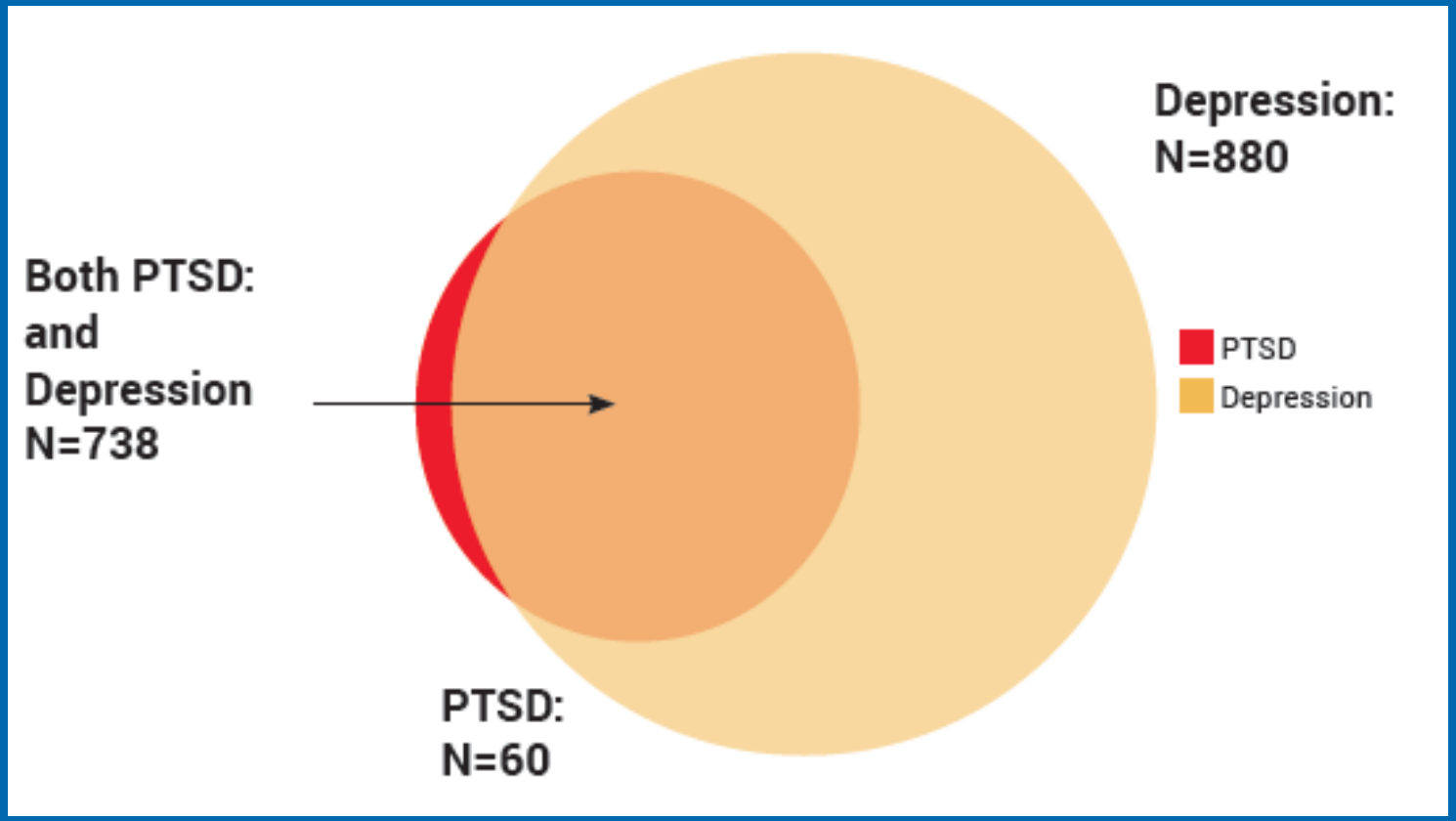


Comorbidity of Respiratory Diagnoses



Total Chronic Rhinosinusitis(CRS): 4,975
Total Gastroesophogael Reflux Disease (GERD): 4,775
Total Obstructive Airways Disease (OAD): 4,067

PTSD and Depression Comorbidity in 2015



Summary of Exposure Effects to Date

- Persistent respiratory symptoms with persistent pulmonary function deficits and more respiratory diagnoses than expected based on similar men in the population.
- Persistent PTSD symptoms (~7%), highly prevalent depressive symptoms (~20%), and a lot of overlap within mental health and between mental and physical health conditions
- Respiratory diagnoses show dose-response gradient.

New NIOSH Cooperative Agreement Background (9/2016-9/2021)

- Hundreds of studies report “higher than expected” disease rates in WTC-exposed workers.
- State tumor registries provide reasonable, if imperfect, comparison cancer rates.
- “Expected” rates for other chronic conditions are unavailable.
- The most critical question remains:

  to what extent are apparent disease and symptom excesses associated with WTC-exposure?

More Background

- New project includes an already assembled comparison cohort of non-WTC-exposed firefighters (FF).
- Comparison group comprised Pooled Cohort of ~30,000 FF established (NIOSH) to study cancer and mortality (1950-2009).
- Professional FF from 3 cities represented: San Francisco, Chicago, and Philadelphia.
- Ref: Daniels RD; *Occup Environ Med* 2014

Cancer Results from 3-City Non-WTC Exposed FF 1950-2009

- All cause mortality was at expectation (SMR=0.99).
- Slight increase in cancer mortality (SMR=1.1; 95% CI 1.1 -1.2).
- Slight increase in cancer incidence (SIR=1.1; 95% CI 1.09-1.12).
- Mesothelioma increase (SMR=2.0)
- Cancer comparison used SEER rates
- Follow up ended 2009

- Ref: Daniels RD; *Occup Environ Med* 2014
- .

Cancer Results from first post-9/11 FDNY Study

- Compared with the general male population in the standardized incidence ratios (SIRs) of the cancer incidence in WTC-exposed firefighters was 1.10 (95% CI 0.98–1.25).

- Ref Zeig-Owens; *Lancet* September 2011.

Cancer Results from FDNY vs. FF Comparison Cohort (through 2009)

- No difference relative rates (RR) all Ca combined (RR=0.96; 95%CI 0.8-1.1)
- Thyroid ca elevated FDNY RR=3.82. After controlling for surveillance bias, rates was attenuated, but still elevated.
- Prostate ca elevated FDNY from 2005-2009 to RR=1.38
- Longer follow-up time needed
- Ref: Moir W *AJIM* 2016 59:722-730.

Why support a FF comparison group?

- Lack of good population-based comparisons except for cancer (e.g., the SEER), mortality (NDI), and some diagnoses (Rochester Epidemiology Project and NHIS).
- FDNY FF healthy workers. Non-FDNY firefighters have similar pre-hire health requirements.
- Firefighting associated with health risks due to potential inhalation and contact exposures, which may confound relationship between WTC exposure and outcomes.
- We can use non-WTC-exposed cohort for incidence estimates of adult onset conditions (like asthma in workers), currently lacking.

Aim 1

- **Aim 1: Determine whether firefighters in the FDNY FF Cohort have higher cancer incidence rates than firefighters in the FF Comparison Cohort.**

Aim 1 Population and Analyses

We intend to re-match and extend original non-WTC-exposed comparison cohort of ~30,000 urban FF to many state registries.

- Relative rates (RR) will be estimated for all cancers combined for the post-9/11 period (9/11/01 – 9/10/2014), comparing FDNY FF Cohort incidence rates to FF Comparison Cohort cancer incidence rates during same time period.
- RRs will permit us to estimate differences between the cohorts, and to assess whether post-9/11 differences can be attributable to WTC exposure.
- Problem: Smoking and other potential covariates of cancer are currently available only for the FDNY FF Cohort. Aim 2 seeks to collect this and other relevant data (alcohol use) from surviving participants of the FF Comparison Cohort.

Aims 2 and 3

- **Aim 2: Establish a subgroup of firefighters from the original FF Comparison Cohort for lifelong follow-up.**
  - This cohort will be selected by comparability to the FDNY FF Cohort in: age on 9/11, years of firefighter service, sex and race/ethnicity for ongoing follow-up every 2 years.
  - RTI International will provide staff for contact tracing and set up the web portal for survey administration.

- **Aim 3: Compare the post-9/11 prevalence and incidence (self-reported) of physical and mental health symptoms and diagnosed conditions in the FDNY FF Cohort and the FF Comparison Cohort.**
  - Obtain survey data via completion of biannual surveys.
  - Ascertain baseline prevalence of common chronic conditions (e.g., asthma, GERD) in both cohorts.
  - Follow up by comparing the annual incidence of these conditions over time.

Populations

- For Aims 2 & 3: **FF Comparison Cohort** composed of survivors of the original 30,000, estimated at ~<15,000.
- RTI has been contracted to contact survivors and enroll – we estimate 7,000-8,000.
- After enrollment, each participant will complete a web-based survey or phone survey.

Chronic Disease Rates

- Survey data will be obtained from FF Comparison Cohort participants the via completion of biannual surveys.
- FDNY firefighters currently complete similar surveys during their routine medical monitoring visits.
- We will also ascertain the baseline prevalence of common chronic conditions (e.g., asthma, GERD, PTSD) in both cohorts.
- Subsequent analyses will compare the *self-reported* annual incidence of new symptoms or new diagnoses over time.

Take Home Points

The new study will permit us to control for the association between firefighting and cancer, allowing us to focus on a WTC effect.

Similarly, it will mitigate the healthy worker effect.

Disaster Lessons Learned

- Whenever possible, obtain pre-disaster health baselines including pulmonary function and mental health screening of rescue/recovery workers
- Protect workers by training and education BEFORE disaster
- Enforce strict worker protection rules including respiratory protection (N95, P-100, SCBA) at the disaster site, especially after initial rescue effort
- Register all workers (electronic id cards) to know # exposed, dates and duration of exposure.
- Integrate Monitoring, Treatment and Research into post disaster programs from the start.