Cancer in Firefighters: Recent Research

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Outline

- Why study firefighters?
- How to conduct EPI Studies
- Recent EPI Studies
  - U.S. firefighters
  - Nordic firefighters
  - Australian firefighters
- Exposure Assesment
- Future research needs

Why study firefighters?

Toxic Exposures

- Many and varied exposures
- Multiple known carcinogens
- Change in 1960's with introduction of synthetic materials
- "Overhaul" phase of fire presents high exposure risk
- SCBA has greatly reduced exposure: use issues
- Multiple routes of entry

Why study firefighters?
Affected Population

Large population at risk:

- 1.1 M U.S. firefighters
  - 31% career firefighters
  - 30,000 fire departments nationwide
- 1.4 million fires per year
  - 0.5 million structure fires
  - ~ 1-5% of time is spent at structure fires (20-100 hrs/yr)

Significant public concern:

- Fire Service (IAFF, IAFC)
- Recommending bodies and advocacy groups (IARC, NLC, and FCSN)
- U.S and State Governments (U.S. Fire Administration, U.S. Congress, Pennsylvania State Legislature)

Existing Research

- 1st Generation (1950s – 2000s): Mostly mortality in single municipal fire departments (see Table 2.1 of IARC Monograph Vol. 98).

- 2nd Generation (2006 - 2010): Systematic reviews and meta-analyses of first generation studies (LeMasters et al., 2006; Guidotti, 2007; IARC, 2010)

- 3rd Generation (2013-present): Pooled studies (U.S. Firefighters, Nordic Firefighters, Australian Firefighters

Meta Analysis, LeMasters et al. (2006)

- Reviewed 32 previous studies
- Classified cancers as either probable, possible, or unlikely related to firefighting
- 4 probable cancers (right panel)
- 8 possible:
  - skin
  - malignant melanoma
  - brain
  - rectum
  - buccal cavity and pharynx
  - stomach
  - colon
  - leukemia

Probable Cancers	**SRE (95% CI)** ***n*=number of studies**
Testes	2.02 (1.30-3.13), *n*=4
Mult. Myeloma	1.53 (1.21-1.94), *n*=10
NHL	1.51 (1.31-1.73), *n*=8
Prostate	1.28 (1.15-1.43), *n*=13

LeMasters GK, Genaidy AM, Succop P, et al. J Occup Environ Med 2006;48:1189–1202.

Lit Review, Guidotti (2007)

- Causality of occupational cancers in firefighters; the weight of evidence.
- Presumption is *justified* for:
  - Genitourinary cancers (bladder, kidney, and testes)
  - Brain
  - Lung cancer in non-smokers
  - NHL
  - Leukemia
  - Myeloma

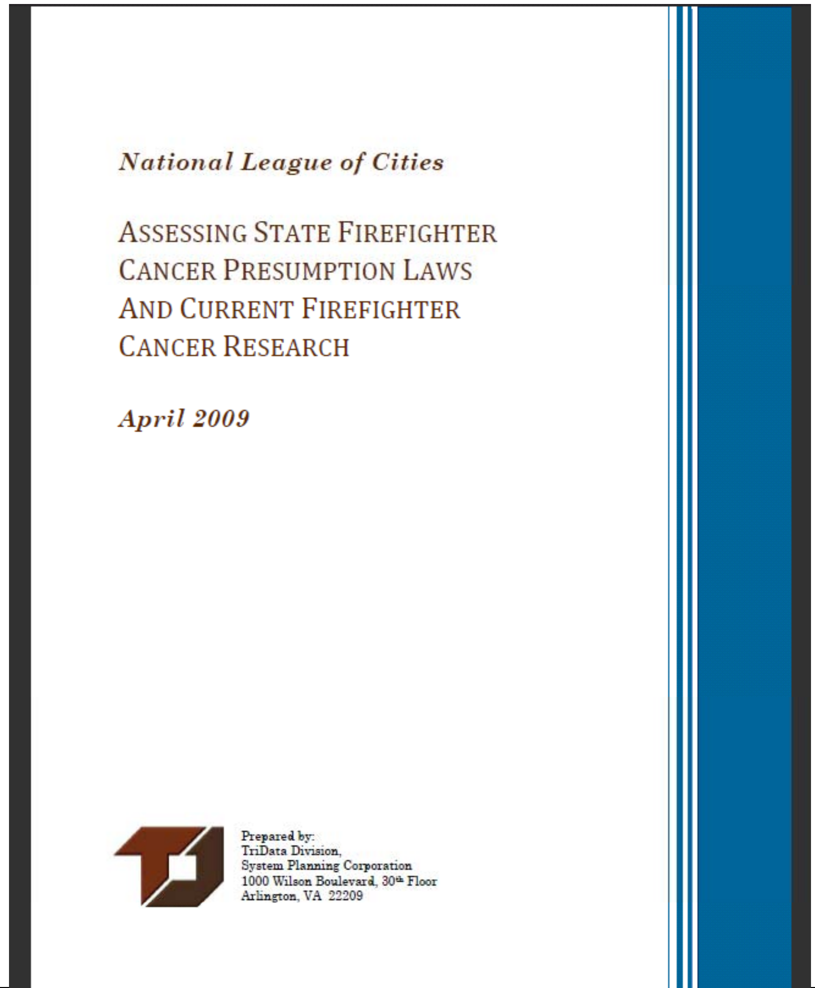
Guidotti, TL, Occup Med 2007;57:466–471

National League of Cities (2009)

The NLC (TriData) Report:

- "…a lack of substantive scientific evidence currently available to confirm or deny linkages between firefighting and an elevated incidence of cancer."

National League of Cities


National League of Cities

ASSESSING STATE FIREFIGHTER CANCER PRESUMPTION LAWS AND CURRENT FIREFIGHTER CANCER RESEARCH

April 2009

Prepared by:
TriData Division,
System Planning Corporation
1000 Wilson Boulevard, 30th Floor
Arlington, VA 22209

Why Study Firefighters?

Gaps in Current Knowledge

- Elevated cancer risk at many different sites but few consistently observed
- IARC reviewed 42 Epi studies and identified 3 potential sites (right panel)
- Studies at best used indirect (poor) measurements of exposure.

Probable Cancers	SRE (95% CI) n=number of studies
Testes	1.47 (1.20-1.80), *n*=6
NHL	1.21 (1.31-1.73), *n*=7
Prostate	1.30 (1.08-1.36), *n*=16

IARC's conclusions "limited evidence in humans for the carcinogenicity of occupational exposure as a fire fighter" (Group 2B, *possibly carcinogenic to humans*)

IARC Monogr Eval Carcinog Risks Hum 2010;98:9-764.

Cancer

- A group of diseases characterized by uncontrolled growth and spread of abnormal cells.
- Multifactorial etiology: genetic, environmental, medical, lifestyle, and chance.
  - 1/3 variation due to environmental and genetic factors
  - 2/3 stochastic effects (Tomasetti and Vogelstein, 2014)
- Risks tend to increase with age. About 77% of all cancers are diagnosed in persons 55 years of age and older.
- Early diagnosis and treatment are vital; identifying persons at increased risk is an important objective of cancer research.

U.S. Cancer Facts

- About 1.7 million new cancer cases each year.
- Men have about a 1 in 2 lifetime risk of developing cancer; for women, the risk is a little more than 1 in 3.
- Cancer accounts for 1 in 4 deaths; 2^{nd} most common cause.
- Direct costs of cancer are about $124 billion per year.
- About 33 million disability days per year; $7.5 billion in lost work productivity.
- Occupational cancer comprises about 4 to 10% of cases.

U.S. Cancer Stats

Cancer	New Cases per 100,000 PYAR	Deaths per 100,000 PYAR	Lifetime Risk (%)	5-year Survival (%)
All Cancer	460.4	173.8	40.4	66.1
Prostate	147.8	22.3	15.0	98.9
Testis	5.6	0.2	0.4	95.3
NHL	19.7	6.3	2.1	69.3
Lung & Bronchus	60.1	48.4	6.9	16.8
Female Breast	124.6	22.2	12.3	89.2
Colorectal	43.7	15.9	4.7	64.7
Leukemia	13.0	7.1	1.4	57.2

Rates based on 2007-2011 cases and deaths.
Lifetime risk based on 2009-2011 data.
5-year survival based on 2004-2010 data.

http://seer.cancer.gov/

SEER Surveillance, Epidemiology, and End Results
Turning Cancer Data Into Discovery

Some definitions

Scientific certainty is seldom attainable; *causality* is based on the *weight of evidence*.

- Causality: relating causes (e.g., smoking habits) to the effects they produce (e.g., lung cancer).
- Association: statistical dependence between two or more quantities (common measures: RR, SMR, and OR). **The presence of a statistical association alone is not "proof" of causality.**
- Probabilistic Causality: the causal factor is neither necessary nor sufficient. **Having cancer (effect) does not imply exposure (cause) and exposures do not always result in cancer.**

What is evidence of causality?

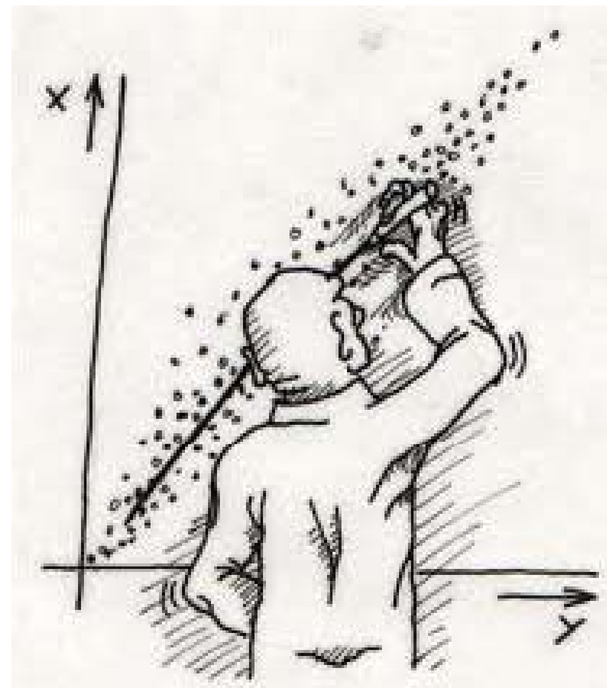
Guideline	Explanation or example
Strength of Association	The larger the association, the more likely the exposure is causing the disease.
Consistency	The association is observed repeatedly in different persons, places, times, and circumstances.
Temporality	The exposure must precede the disease in time.
Biologic Gradient (dose-response)	Persons who have increasingly higher exposure levels have increasingly higher risks of disease.
Plausibility	The relationship does not conflict with current knowledge of natural history and biology of disease.
Experiment	Intervention that lowers exposure should result in less disease

Cancer Epidemiology

Investigates the frequency and distribution of cancers in a defined population to determine causes, discover ways to alleviate them, and to prevent their reoccurrences

Cancer Epi Studies

- Uncover disease etiology
  - Describe cancer in populations over time.
  - Determine whether an agent is carcinogenic
  - Quantify risk per unit exposure.
  - Identify population at risk.
- Mitigation/Prevention
  - Develop preventive measures
  - Assess efficacy of preventive measures



Hierarchy of Epidemiologic studies

Descriptive
- Case report
- Case series
- Survey

Analytic

- **Observational**
  - Cross sectional
  - Longitudinal (e.g. Cohort study)
- **Experimental**
  - Randomized controlled trials

Strength of evidence for causality between a risk factor and outcome

Longitudinal studies

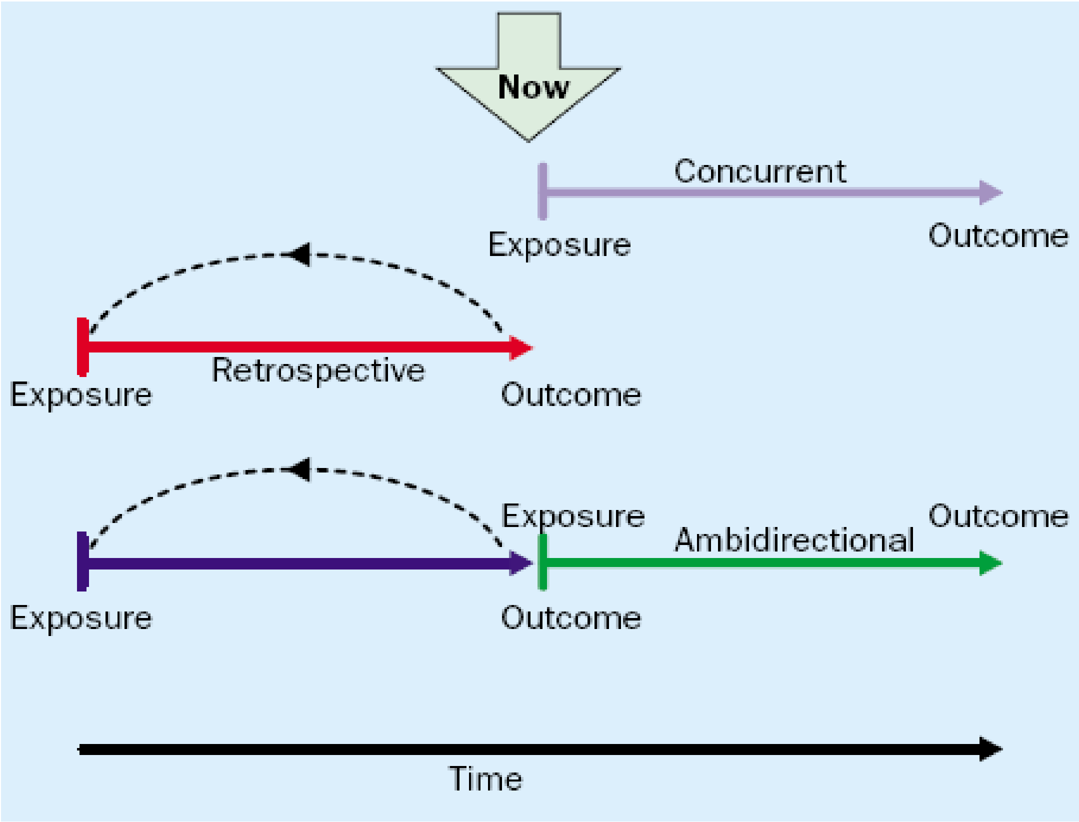


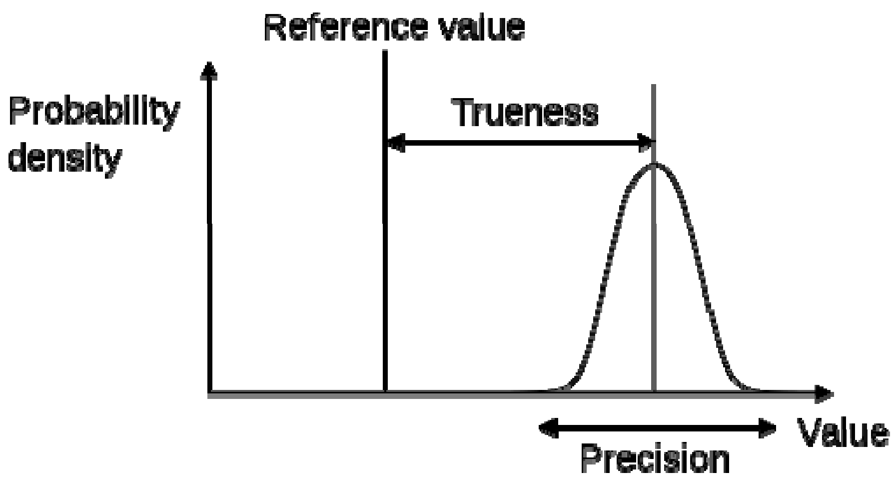
Figure 2: **Schematic diagram of concurrent, retrospective, and ambidirectional cohort studies**

What's needed for a longitudinal (cohort) study?

- Large number of subjects and cases.
- Long length of time for follow-up.
  - Disease latency
  - Modification by age and time since exposure
- Information on exposure
  - Quantity and distribution
- Information on factors that can modify risk
  - Age, sex, race, lifestyle, etc.

Something to Consider

- No study is error-free.
- Small associations are more affected by errors.
- Relative effect measures (RR, HR, SMR, SIR, and OR) < 2.0 are generally considered “weak” or “small”.
- Statistical “significance” does not imply “trueness”.



Narrow confidence intervals imply very high precision but do not guarantee a lack of bias.

Recent Epidemiologic Studies

- NIOSH Firefighter Study (2013)
  - Daniels RD, Kubale TL, Yiin JH et al. Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950-2009). *Occup Environ Med* 2014;71:388-97. doi:10.1136/oemed-2013-101662
- Nordic Firefighter Study (2014)
  - Pukkala E, Martinsen JI, Weiderpass E et al. Cancer incidence among firefighters: 45 years of follow-up in five Nordic countries. *Occup Environ Med* 2014;71:398-404. doi:10.1136/oemed-2013-101803
- Australian Firefighter Study (2014)
  - Final Report Australian Firefighters' Health Study. Monash Centre for Occupational and Environmental Health (MonCOEH), School of Public Health & Preventive Medicine, Department of Epidemiology & Preventive Medicine. December 2014, 175 p.

NIOSH Study

- **<u>Phase I (published):</u>** *Is cancer associated with firefighting?*
  - Recruit study group of career firefighters
  - Determine mortality and cancer incidence among group
  - Compare cancer risk to the general population

OEM

Mortality and cancer incidence in a pooled cohort of US firefighters from San Francisco, Chicago and Philadelphia (1950–2009)

Robert D Daniels, Travis L Kubale, James H Yiin, et al.

Occup Environ Med published online October 14, 2013
doi: 10.1136/oemed-2013-101662

http://www.cdc.gov/niosh/firefighters/ffCancerStudy.html

- **<u>Phase II (submitted):</u>** *Are higher-exposed firefighters more at risk?*
  - Estimate the exposure potential of each study participant
  - Examine the relation between exposure and cancer risk

NIOSH Study Population

	ALL	SFFD	CFD	PFD
Persons	29,993	5,313	15,185	9,495
White	80.8%	80.1%	77.3%	86.9%
male	96.7%	94.3%	96.8%	97.9%
Deaths	12,028 (40%)	2,074	5,944	4,010
Cancer Deaths	3,285 (27%)	578	1,670	1,037
Diagnoses	4,461	855	2,186	1,420

Career firefighters employed for at least one day in fire departments serving San Francisco, Chicago, or Philadelphia, from 1950 through 2009.

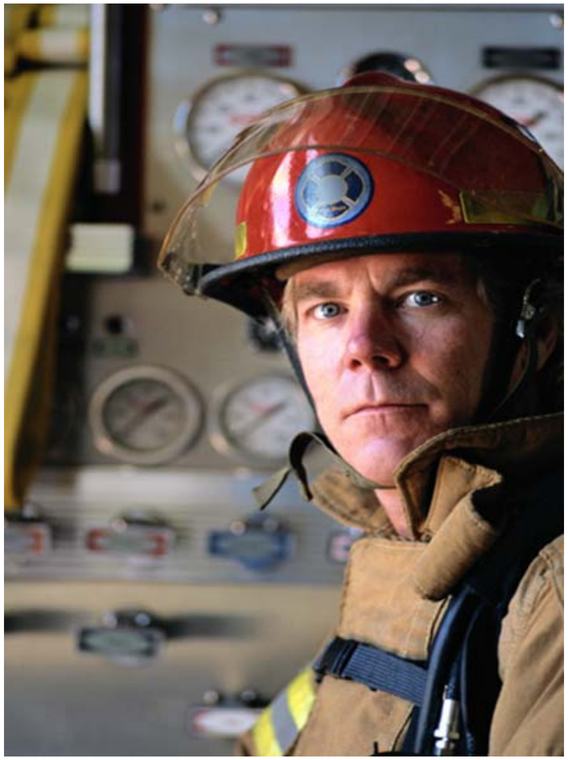
NIOSH External Comparisons: All Causes and All Cancer

Overall mortality was not elevated:

Outcome*	Obs	Mortality SMR (95% CI)
All Causes	12,028	0.99 (0.97 to 1.01)
IHD	3,619	1.01 (0.98 to 1.04)
COPD	367	0.72 (0.65 to 0.80)

However, there was excess cancer:

Risk Measure	Obs	All Cancers
SMR (95% CI)	3,285	1.14 (1.10 to 1.18)
SIR (95% CI)	4,461	1.09 (1.06 to 1.12)



Mortality: 1950-2009; *n*=29,993; 858,938 person-years at risk.
Incidence: 1985-2009; *n*=24,453; 403,152 person-years at risk.

NIOSH External Comparisons: Excess Cancers*

Excess cancer was limited to solid cancers, primarily of the respiratory, digestive, oral, and urinary organs.

		Mortality		Incidence
Outcome	Obs	SMR (95% CI)	Obs	SIR (95% CI)
Esophagus	113	1.39 (1.14 to 1.67)	90	1.62 (1.31 to 2.00)
Intestine	326	1.30 (1.16 to 1.44)	398	1.21 (1.09 to 1.33)
Lung	1046	1.10 (1.04 to 1.17)	716	1.12 (1.04 to 1.21)
Kidney	94	1.29 (1.05 to 1.58)	166	1.27 (1.09 to 1.48)
Oral cavity†	94	1.40 (1.13 to 1.72)	174	1.39 (1.19 to 1.62)
Mesothelioma	12	2.00 (1.03 to 3.49)	35	2.29 (1.60 to 3.19)

*Cancers with statistically significant excesses in mortality and incidence.
†Oral cavity includes lip (excluding skin of the lip), tongue, salivary glands, gum, mouth, pharynx, oropharynx, nasopharynx, and hypopharynx

NIOSH External Comparisons: Minority Firefighters (n=4,657 males, 15.5%)

Outcomes	Obs	Mortality SMR (95% CI)	Obs	Incidence SIR (95% CI)
All causes	453	0.68 (0.62 to 0.74)	NA	NA
All cancers	104	0.80 (0.65 to 0.97)	240	0.92 (0.81 to 1.05)
Prostate	17	1.64 (0.95 to 2.63)	94	1.26 (1.02 to 1.54)
Leukemia	5	1.28 (0.41 to 2.98)	11	1.90 (0.95 to 3.40)

Minority firefighter risks were generally decreased; however, prostate cancer and leukemia appeared elevated.

NIOSH External Comparisons: Women Firefighters (n=991, 3.3%)

		Mortality		Incidence
Outcome	Obs	SMR (95% CI)	Obs	SIR (95% CI)
All causes	26	0.91 (0.59 to 1.33)	NA	NA
All cancers	6	0.74 (0.27 to 1.61)	40	1.24 (0.89 to 1.69)
Breast	<5	1.46 (0.30 to 4.26)	18	1.45 (0.88 to 2.29)
Bladder	<5	33.51 (4.06 to 121.1)	<5	12.53 (3.41 to 32.1)

Bladder cancer was significantly elevated; however, the small sample and the lack of confirmatory results suggest cautious interpretation.

NIOSH External Comparisons: Risk differences by age

Significant age-at-risk differences observed in bladder and prostate cancer incidence:

Outcomes	Age Group	Obs	Incidence SIR (95% CI)
Bladder	All ages	316	1.12 (1.00 to 1.25)
	17-64	97	1.33 (1.08 to 1.62)
Prostate	All ages	1261	1.03 (0.98 to 1.09)
	17-64	426	1.21 (1.10 to 1.33)
	45-59	249	1.45 (1.28 to 1.64)
	45-49	31	2.14 (1.46 to 3.04)

Key findings from external comparisons

- The NIOSH study found excess solid cancers in firefighters:
  - Digestive (colon, esophagus)
  - Genitourinary
    - Kidney
    - Bladder in women and in men at younger ages (<65y)
    - Prostate at younger ages (<65y)
  - Oral sites (mouth, throat, tongue)
  - Respiratory (larynx, lung)
  - Mesothelioma
- The results add to the weight of evidence that firefighters are at risk for a variety of specific cancer outcomes.

NIOSH Study Internal Comparisons

- Estimate exposures for each firefighter:
  - Identify all jobs held and duration
  - Define exposure potentials by job
    - # fire runs (CFD & PFD)
    - # exposed days (All)
    - # fire run-hours (CFD only)
- Compare cancer risks in higher-exposed to lower-exposed by conditional logistic regression.
- Publish exposure-response modeling results (Early 2015).

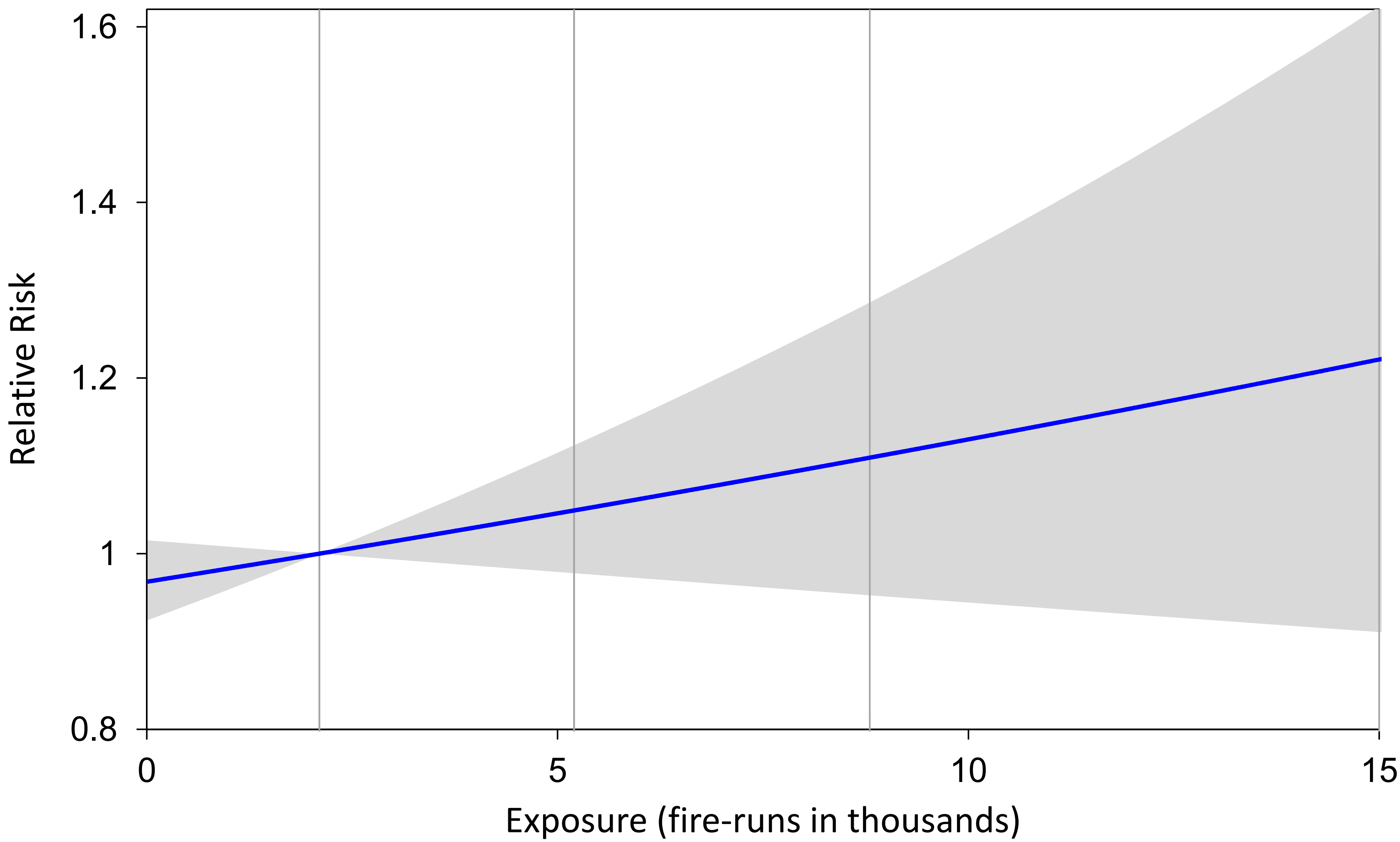
Regression modeling methods

- Eight cancer and four non-cancer endpoints examined
- Three exposure measures: exposed-days, fire-runs, and fire-hours.
- General relative risk models used to calculate hazard ratios comparing 75th- and 25th-percentiles of lagged cumulative exposure.
- Model fits to loglinear, linear, log-quadratic, power, and restricted cubic splines were examined.
- Piecewise constant models were used to examine risk differences by time since exposure, age at exposure, and calendar period.

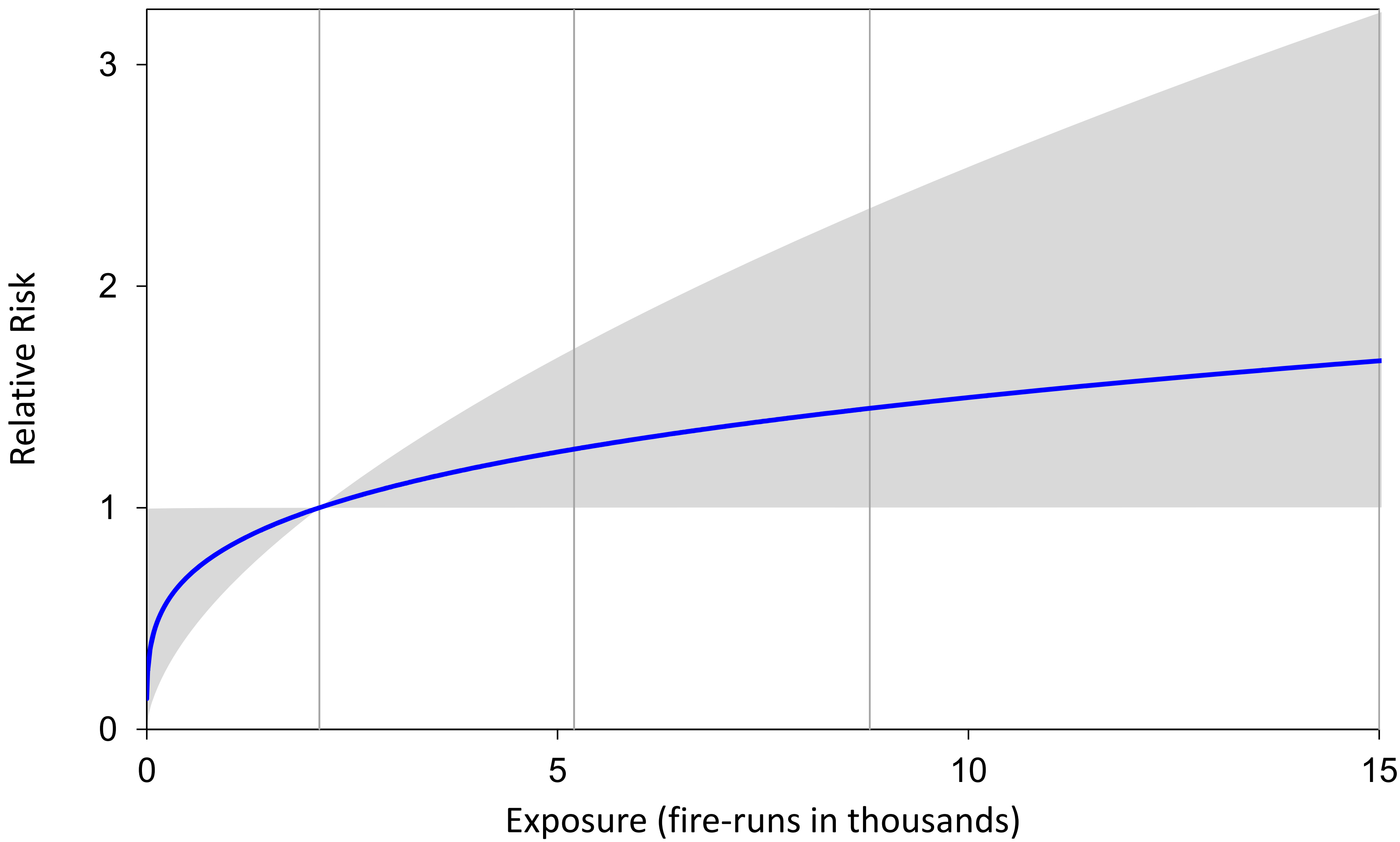
Exposure by cumulative fire runs

Assignment	Job Title	Start Date	End Date	Years at Assignment	Fire Runs
FTS	Firefighter	10/19/1959	12/20/1959	0.17	0
E 60	Firefighter	12/21/1959	10/15/1967	7.82	5730
L 28	Firefighter	10/16/1967	8/26/1973	5.87	3905
FH	Firefighter	8/27/1973	11/30/1973	0.26	0
L 28	Lieutenant	12/1/1973	11/24/1978	4.98	6016
E 77	Lieutenant	11/25/1978	8/20/1983	4.74	2064
				Cumulative Runs = 17715	

Lung cancer dose-response model (Loglinear)
25th percentile is referent (95% CI shown as shaded area)



Leukemia dose-response model (power)
25th-percentile is referent (95% CI shown as shaded area)



Key findings from internal comparisons

- Metrics in order of preference were: 1) run-hours, 2) number of runs, and 3) exposed days. All were improvements to using simple employment duration.
- A positive exposure-response observed for lung cancer mortality and incidence and leukemia mortality, suggesting increased occupational cancer risk.
- A negative exposure-response observed for colorectal and prostate cancers, suggesting a healthy worker survivor effect or possible screening bias.

Strengths

- Large cohort (~30,000 career firefighters) under long observation (~850,000 person-years).
  - Includes firefighters of all races and gender
  - Includes multiple fire departments from the East, Midwest, and West regions
  - Includes both historical and recent firefighting experience (1950-2009)
- Cancer mortality and incidence examined.
- Framework for future studies (e.g. in-depth studies of single outcomes).

Limitations

- Low statistical power (difficulty observing causal effect)
  - Long latency of disease
  - Small effect size (most < 2-fold excess)
- Lacking direct information on exposure
- Few women and minority firefighters
- Estimates could be influenced by other factors:
  - Healthy worker and/or survivor effects
  - Case ascertainment errors
  - Information on other risk factors (e.g., tobacco use, alcohol consumption, diet, obesity) is lacking.

Criticism: National League of Cities

- Not representative of typical exposures
  - "old-line cities where the firefighters would be expected to fight more fires and encounter asbestos and chemicals…"
- Does not identify the strength of association criteria used to evaluate the causal relationships
  - "finds only small to moderate increases in risk…"
- Inconsistent with current knowledge:
  - "numerous cancers already targeted by state presumption statutes do not have a significant excess incidence or mortality…"
- Lack evaluation of "other risk factors"

Nordic Firefighter Study (2014)

- Longitudinal cancer incidence study; part of the Nordic Occupational Cancer (NOCCA) project
- Firefighters selected from five Nordic countries
- Data from census and cancer registries for the period 1961–2005.
- 16,422 male firefighters providing 412,991 person-years.
- External comparisons (SMRs and SIRs)

Pukkala et al. Occup Environ Med. 2014 Feb 6. doi: 10.1136/oemed-2013-101803

Key Findings

- Modest excess risk of all cancers combined.
- Cause specific excess risk was observed for:
  - Prostate cancer and melanoma at ages 30-49,
  - Multiple myeloma, lung adenocarcinoma, and mesothelioma at ages 70+

Pukkala et al. Occup Environ Med. 2014 Feb 6. doi: 10.1136/oemed-2013-101803

NIOSH Study vs. Nordic Study (2014)

Cancer Site	Obs	Daniels et al. (2013) SIR (95% CI)	Obs.	Pukkala et al. (2014) SIR (95% CI)
All cancers	4461	1.09 (1.06 to 1.12)	2536	1.06 (1.02 to 1.11)
Testes	15	0.75 (0.42 to 1.24)	9	0.51 (0.23 to 0.98)
Age group 30-49				
Prostate	36	2.04 (1.43 to 2.82)	12	2.59 (1.34 to 4.52)
Melanoma	11	0.44 (0.22 to 0.79)	37	1.62 (1.14 to 2.23)
Age group 70+				
Non-melanoma skin	NA	NA	75	1.40 (1.10 to 1.76)
Multiple myeloma	24	0.93 (0.60 to 1.39)	24	1.69 (1.08 to 2.51)
Lung	359	1.11 (1.00 to 1.23)	141	1.28 (1.08 to 1.52)
mesothelioma	23	2.44 (1.55 to 3.67)	10	2.59 (1.24 to 4.77)

Pukkala et al. Occup Environ Med. 2014 Feb 6. doi: 10.1136/oemed-2013-101803

Strengths and Limitations

- Strengths:
  - Large cohort from multiple countries
  - Relatively long followup (45 years)
  - Incidence data available (histology)
- Limitations:
  - Lacking direct information on exposure
  - Few women and minority firefighters
  - Estimates could be influenced by other factors (e.g., lifestyle, other employment, etc.)

Australian Firefighters Health Study (December 2014)

- Longitudinal study of firefighters employed at one of eight agencies between 1976-2011
  - Mortality (1980-2011)
  - Cancer incidence (1982-2010)
- Results by full-time (career), part-time, and volunteer firefighters
- External comparisons (SMRs and SIRs)
- Internal comparisons (RMRs, RIRs): employment, incidents

Cohort Definition: firefighters who ever attended fires to undertake firefighting tasks, including prescribed burning, as part of their employment or volunteer membership with participating agencies

http://www.coeh.monash.org/ausfireftr.html

Study population (males only)

	Full-time	Part-time	Volunteer
Firefighters	17394	12663	163159
Avg. age at risk start	34.3	33.1	39.4
Avg. age of alive at end of study	49.4	44.2	48.3
Employed prior to 1986	549	0	73
Deaths	780 (4.5%)	286 (2.3%)	4647 (2.8%)
Cancer deaths	329	124	1900
Cancer cases	1208	485	7057

Final Report Australian Firefighters' Health Study (2014)

Excess cancer incidence

Males:

Cancer Site	Career SIR (95% CI)	Part-time SIR (95% CI)	Volunteer SIR (95% CI)
All cancers	1.08 (1.02 to 1.14)	1.11 (1.01 to 1.21)	0.86 (0.84 to 0.88))
Prostate	1.23 (1.10 to 1.37)	1.51 (1.28 to 1.77)	1.12 (1.08 to 1.16)
Melanoma	1.45 (1.26 to 1.66)	1.43 (1.15 to 1.76)	1.00 (0.93 to 1.06)

Females:

Cancer Site	Career SIR (95% CI)	Part-time SIR (95% CI)	Volunteer SIR (95% CI)
All cancers	0.82 (0.35 to 1.61)	1.38 (0.84 to 2.13)	0.97 (0.91 to 1.03)
Brain	NR	11.75 (2.42 to 34.35)*	1.00 (0.56 to 1.65)
Melanoma	NR	2.10 (0.68 to 4.90	1.25 (1.05 to 1.46)

*Based on only 3 cases

Final Report Australian Firefighters' Health Study (2014)

NIOSH Study vs. Australian Study for career firefighters

Cancer Site	Obs	Daniels et al. (2013) SIR (95% CI)	Obs.	Australian Study (2014) SIR (95% CI)
All cancers	4461	1.09 (1.06 to 1.12)	1208	1.08 (1.02 to 1.14)
Esophagus	90	1.62 (1.31 to 2.00)	12	0.76 (0.39 to 1.33)
Intestine	398	1.21 (1.09 to 1.33)	157	1.09 (0.92 to 1.27)
Lung	716	1.12 (1.04 to 1.21)	86	0.81 (0.65 to 1.00)
Kidney	166	1.27 (1.09 to 1.48)	33	0.97 (0.67 to 1.36)
Oral cavity†	174	1.39 (1.19 to 1.62)	55	0.95 (0.71 to 1.23)
Mesothelioma	35	2.29 (1.60 to 3.19)	11	1.33 (0.66 to 2.37)
Prostate	1261	1.03 (0.98 to 1.09)	357	1.23 (1.10 to 1.37)
Prostate (<65 years)	36	1.21 (1.10 to 1.33)	12	1.24 (1.09 to 1.41)
Melanoma	141	0.87 (0.73 to 1.03)	209	1.45 (1.26 to 1.66)

Final Report Australian Firefighters' Health Study (2014)

Key findings

- Modest overall cancer risk compared to general population.
- Site-specific increased risk of:
  - prostate cancer, (trend with incidents in internal analyses)
  - melanoma,
  - male breast cancer among those employed 20+ years (SIR =3.44; 95%CI: 1.12 to 8.04; *n*=5).
  - brain cancer in women part-time firefighters, but few cases.
- Limited evidence of excess mesothelioma and testicular cancer, but numbers were small.
- Significant trends in urinary and Lymphohematopoetic cancers with years of service.

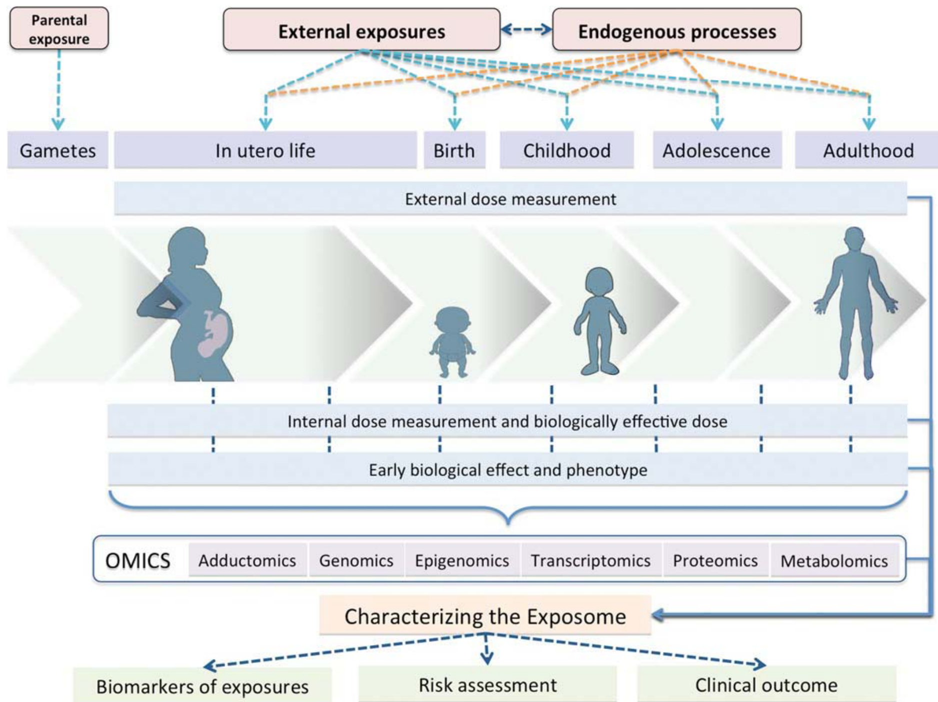
Strengths and Limitations

- Strengths:
  - Large cohort
  - Mortality and cancer incidence
  - Examines health risks in career, part-time, and volunteers
- Limitations:
  - Narrow observation period
    - <5% of the cohort was deceased, few incidence cases
  - Strong healthy worker bias (SMR= 0.67; 95%CI: 0.62 to 0.72)
  - Lacking direct information on exposure
  - Few women and minority firefighters
  - Estimates could be influenced by other factors (e.g., lifestyle, other employment, etc.)

Esposure Assessment Research

Exposome: Characterize Everything!

- Occupational Exposures
- Environmental and lifestyle factors (e.g., chemicals, infectious agents, diet, tobacco, alcohol), and the internal exposures
- Endogenous processes (e.g., metabolism, hormones, inflammation)
- “omic” profiles (e.g., genomics, transcriptomics, epigenomics, etc.)



Environ and Molecular Mutagenesis 54:480-499 (2013)

Occupational exposure: Characterize fire composition

- Most fires: aromatic hydrocarbons, PAHs, nitro-PAHs, aldehydes, cyanides, acids, particulate, oxides of carbon, nitrogen, and sulfur
- Synthetic materials: vinyl chloride, PCBs, plasticizers, phthalates, isocyanates, flame retardants, dioxins and furans
- Inorganics: asbestos, metals
- The unknown?

Fabian et al. (2014) Fire Technol 50, 993-1019)
Alexander and Baxter. J. (2014). Occ Environ Hyg 11 D43-D48
Shaw et al. (2014) Chemosphere Vol. 91(10): 1386-1394

Exposure pathways: dermal absorption

- Neck is vulnerable to exposure (Fent et al., 2014, Baxter et al., 2014)
  - Particles/soot that contact the skin can be absorbed
    - PAHs
    - What else? Nitro-PAHs, dioxins, furans (Shaw et al., 2013; Hsu et al. 2011)?
  - Some vapors can also be absorbed through skin
    - Aromatic hydrocarbons
    - What else? HCN?
- How does the extreme environment affect dermal absorption?
  - Ambient temperatures, skin temperatures, humidity, and sweat
- Transfer of contaminants to skin during doffing and handling gear
  - UL identified various compounds on contaminated gear (e.g., PAHs, phthalates, metals)

Exposure pathways: Inhalation

- Respiratory Protection Use?
  - Overhaul
  - Scene investigation
  - Automobile fires
  - vegetation fires
  - roof ventilation
  - training exercises

Other exposure factors

- Synergistic effects
  - Combine effects of multiple exposures are greater than separate effects
- Intensity vs duration
  - The effects of short duration high intensity exposures compared to long duration low intensity exposures
- Exposure fractionation: time between exposures
- Physical stressors
  - Go from rest (low HR/low BP) to physically demanding work (high HR/high BP/physical stress/heat stress)

Recent Exposure Assessment Research

- Pleil JD, Stiegel MA, Fent KW. Exploratory breath analyses for assessing toxic dermal exposures of firefighters during suppression of structural burns. *J Breath Res* 2014;8:037107.
- Fent KW, Eisenberg J, Snawder J et al. Systemic exposure to PAHs and benzene in firefighters suppressing controlled structure fires. *Ann Occup Hyg* 2014;58:830-45.
- Lacey S, Alexander BM, Baxter CS. Plasticizer contamination of firefighter personal protective clothing - a potential factor in increased health risks in firefighters. *J Occup Environ Hyg* 2014;11:D43-8.
- Baxter CS, Hoffman JD, Knipp MJ et al. Exposure of firefighters to particulates and polycyclic aromatic hydrocarbons. *J Occup Environ Hyg* 2014;11:D85-91.

Future Research Needs

Areas for future EPI research

- Studies to assess causality
  - Strength of association:
    - Increased size and length of followup
    - Account for healthy worker selection and survivor biases
    - Account for important risk factors, such as tobacco use and diet
    - Cause-specific analyes to account for risk dilution from diesease heterogenity. (e.g., examine leukemia subtypes)
  - Investigate dose-response characteristics with improved metrics
    - Complete exposure histories
    - Account for varying employment policies, firefighting tactics, and the use of personal protective equipment.
    - Integrate measurement data when available

Areas for future EPI research

- Studies to identify populations at risk:
  - Assess risk difference by employment type (e.g., career vs volunteer) and fire type (wildland vs structural)
  - Investigate spatial and temporal effect modifiers (i.e., location, age at exposure, time since exposure, calandar period)
  - Examination of cancer risk in minority groups (non-whites and women)
- Studies to assess risk management
  - Intervention studies: Did the mitigation strategy reduce the cancer risk?

Areas for future exposure research

- Characterize exposures to lesser known compounds
  - Nitro-PAHs, flame retardants, plasticizers (DEHP), dioxins/furans
- Elucidate multiple routes and pathways of exposure
  - Inhalation vs. dermal vs. ingestion
  - Downwind of fire, overhaul, post-fire environment, cross contamination
  - Different types of fire and attack methods
- Develop better protection for neck skin and other technological advancements that can reduce exposure
- Study effectiveness of gross decon of PPE

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Questions ?

Exposure

Firefighter exposures:

Groups 1, 2A, and 2B agents have been detected at fires in one or more studies:

11 Group 1 substances:

- e.g., polycyclic aromatic hydrocarbons (PAHs), formaldehyde, benzene, asbestos, diesel exhaust, and arsenic

5 Group 2A substances

18 Group 2B substances

IARC agent classifications:

Group	Description
1	Carcinogenic to humans
2A	Probably carcinogenic to humans
2B	Possibly carcinogenic to humans
3	Not classifiable as to its carcinogenicity to humans
4	Probably not carcinogenic to humans

http://monographs.iarc.fr/ENG/Classification/