A 30-YEAR STUDY OF CANCER INCIDENCE IN FIREFIGHTERS AND POLICE OFFICERS IN NEW JERSEY'S FOUR LARGEST MUNICIPALITIES

By

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Professor Michael Gochfeld

And Approved by

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ABSTRACT OF THE DISSERTATION

30-Year Study of Cancer Incidence in Firefighters and Police Officers in New Jersey's Four Largest Municipalities

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Objectives: To determine if one cohort of paid firefighters and one cohort of paid police officers from the four largest municipalities in New Jersey demonstrated a greater incidence of cancer than the U.S. General Population.

Methods: Four cohorts of paid firefighters and four cohorts of paid police officers, were identified through the NJ Police and Firefighters Retirement System records, (PFRS), and sent to the New Jersey State Cancer Registry for linkage. The information included employment start and end dates, year of birth and death, age at time of diagnosis and ICD-O-3 Diagnostic Code. Standard Incidence Ratios (SIRs) were calculated for each cancer for both cohorts utilizing the Life Table Analysis System (LTAS) developed by the National Institutes of Safety and Health (NIOSH).

Results: The Standardized Incidence Ratios (SIR) for firefighters reflects an excess of eye cancer, 3.80 times greater than the U.S. General Population, SIR = 3.80; (95% CI, 1.53, 7.82). This is a statistically significant excess of Eye Cancer, and when compared to the U.S. General Population, whereas police officers did not demonstrate an excess of Eye Cancer.

Conclusions: The SIR for All Cancers for both firefighters and police officers was below the expected number of cancers demonstrating that New Jersey firefighters and police officers do not have an excess incidence of cancer when compared to the General Population in the United States.

ACKNOWLEDGEMENT

I would like to extend my most sincere thanks to my Advisor, Dr. Michael Gochfeld. It was his constant encouragement and belief in this project that kept me going, even when I was ready to give up. Dr. Gochfeld has been my advisor and mentor since I was in the Master's Degree program at the School of Public Health and was the inspiration for this research project, and for this I am truly grateful.

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DEDICATION

I am dedicating this work to my wife, and best friend, Clarisa, you are and
always will be
my inspiration to reach farther and to do more.

I also wish to thank my children, Nelson, Brian and Sonia, who have always been
an endless source of
encouragement and support through
my entire education. I know I would not have made it
to this point without their sacrifices, and for this
I am eternally grateful.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Firefighters and Police Officers are occupations with inherently dangerous job duties. Firefighters have to work in close proximity to burning materials and battle structural fires, while police officers have to deal with violent crimes and apprehending criminals. Due to the dangerous nature of their jobs: environmental exposure to combustible products, workplace stress, and high risk of acute injuries, firefighters and police officers are at increased risk from line-of-duty injuries; however, it is important to investigate if they are also at risk from the long-term effects of their occupations, such as cancer.

According to Bureau of Labor Statistics approximately 125 firefighters (National Fire Safety, 2015) and 150 police officers were killed in the line of duty in 2015. (National Police Memorial, 2015) The number of firefighters and police officers that are killed each year in the line-of-duty is reflective of the serious nature of the work. The similarities in the numbers of fatalities can be seen in the graph in Figure 1.1.

A number of occupational epidemiologic studies have examined the health outcomes of firefighters. Up to this time, however, only two epidemiologic occupational studies, Demers, et al., (1993) and Feuer and Rosenman (1986) compared cancer incidence in firefighters to police officers. Both studies are discussed in detail in Chapter 2.

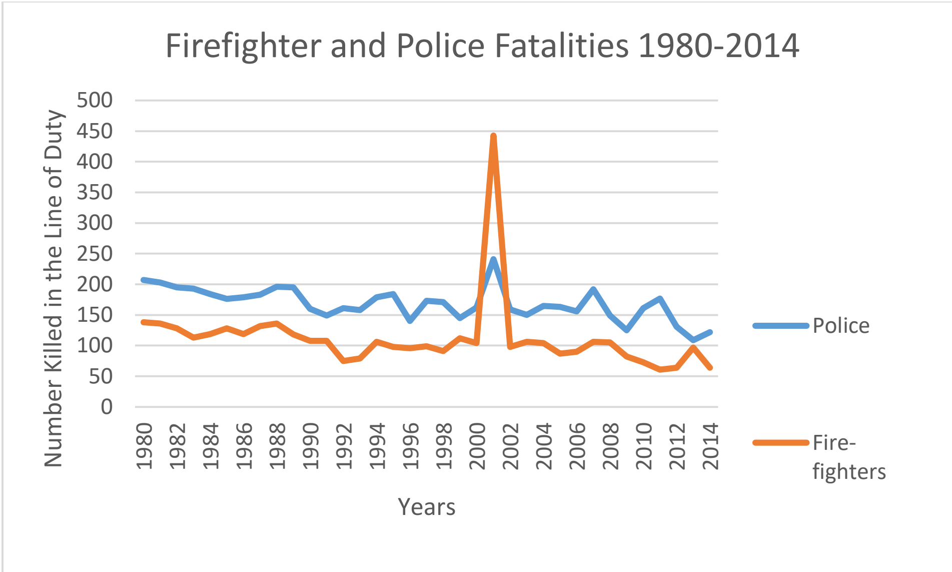

Figure 1.1 Number of firefighter versus police officer fatalities from 1980-2015 across the United States. The large spike in fatalities for both firefighters (n=343) and police officers (n=60) in 2001 was due to the terrorist attacks in New York City and the collapse of the World Trade Center Towers on September 11, 2001. (US Bureau of Labor Statistics, 2015)

This study analyzes the incidence of cancer in both firefighters and police officers in a novel way. It is difficult to obtain the personal identifying information from enough firefighters to conduct a Standardized Incidence Ratio (SIR) study, let alone to collect this information from a cohort of both firefighters and police officers. Many of the cancer incidence studies that have been published have used their state's cancer registries and searched, or data mined, the registry's occupational fields for listings of "firefighter", "fireman" or "firefighting", or "police officer" to identify their cohorts. There are other studies that have identified their cohorts of firefighters from firefighter records from one state or municipality. One study was able to obtain a cohort of firefighters and police officers from the same state; however, they did not conduct a SIR analysis. (Feuer and Rosenman, 1986) None of these studies presented a standardized incidence ratio of a cohort of firefighters and police officers from the same municipalities for comparison, whereby the firefighters from the same fire companies or municipalities were compared to a cohort of police officers from the same municipalities, that would have experienced similar background environmental exposures.

For this study, four cohorts of firefighters, from four of New Jersey's largest cities, Newark, Jersey City, Paterson, and Elizabeth, were compared using cancer incidence data to the General Population of United States. Four cohorts of police officers from the same cities were compared to the US General Population in a similar fashion.

Brandt-Rauf et al., (1988) identified a variety of potential carcinogens, including polycyclic aromatic hydrocarbons (PAHs), arsenic, benzene and formaldehyde in wood smoke from burning buildings. They also noted that asbestos, a commonly used building and plumbing insulation, was found in the smoke and soot of burning buildings. A study by Osinubi, Gochfeld and Kipen, (2000) described the health effects of asbestos exposure to developing mesothelioma.

Two exposure studies of working firefighters in Portugal conducted by Oliveria, et al. (both in 2017) examined the exposure of firefighters to polycyclic aromatic hydrocarbons (PAHs). Her findings demonstrated that firefighters do absorb PAHs and excrete them in their urine. These and other studies are summarized in Chapter 2, provide the rationale to examine health risks to firefighters in more detail. I posed the following questions:

Research Question #1 (RQ#1): Are firefighters in New Jersey at greater risk for cancer than individuals in the General Population in the United States?

Research Question # 2 (RQ#2): Are police officers in New Jersey at greater risk to cancer than individuals in the General Population in the United States?

In order to answer these questions, we can state them in the form of a null hypothesis.

The Null Hypothesis:

H_{O1} = No Difference in Cancer Incidence between Firefighters and the US General Population

H_{O2} = No Difference in Cancer Incidence between Police Officers and the US General Population

1.2 Background

In order to provide additional background information, an attempt was made to compare the number of uniformed personnel working in a municipality to the population of their municipalities, and to identify the number of fires and criminal activity that each municipality had fought for each of the thirty years between 1980 and 2011, as a surrogate for hazardous exposure.

The average number of firefighters and police officers per municipality was assessed through requests from each municipality, and through documents obtained through the Open Public Records Act (OPRA). The number of uniformed personnel by department per year were not uniformly available and were returned with varying degrees of completeness. The average number of uniformed personnel per municipality are listed in Table 1.1.

Table 1.1 Comparison of Municipal Population Levels for Newark, Jersey City, Paterson, and Elizabeth, NJ to the Average Number of Fire Fighters and Police Officer Staffing Levels

Ranking	Municipality	Population	Firefighters	Police Officers
1	Newark	277,140	673 [1980-2014]	1,290 [1980-2014]
2	Jersey City	247,597	795 [2005-2011]	829 [2008-2011]
3	Paterson	146,199	320 [1980- 2013]	411 [2008 to 2015]
4	Elizabeth	124,969	234 [2005-2007]	325 [1980-2013]

Notes: Municipality population numbers were taken from the 2010 U.S. Department of Commerce Decennial Census, the number of firefighters and police officers per municipality are averages across the years in superscript.

The City of Newark, NJ possessed the most publicly accessible and detailed records of firefighting and police activities of the four municipalities studies for the years 1980 through 1996. According to their municipal charter, the city was required to produce an annual report of both firefighting and police activities, which included annual expenses, and the number of uniformed personnel on duty per year. The annual fire department report also provided a detailed history of the number and types of fires fought per year by each of the fire companies had sent personnel to fight fires.

The Newark Municipal Fire and Police Department annual reports for the years 1980 through 1996 were found in the Newark Public Library. The reports were discontinued in 1997, and not produced again until 2015, despite being required by the n, or the resumption of the annual reports. Since the records were kept in the Newark Public Library, they were readily available for review as archived public records.

Each municipality maintained varying degrees of records over the years. The New Jersey Division of Fire Prevention collected data regarding the number of fires from each fire company and maintained the most consistent records regarding the number of fires across the State. In spite of the NJDFP collecting data on the number of fires from each municipality, they also had their lapses in data.

1.2.1 Fire Statistics for New Jersey and the Four Largest Municipalities in NJ

Fire data is reported by each municipality to the New Jersey Department of Community Affairs, New Jersey Division of Fire Safety (NJDFS). As with the municipalities, the NJDFS records were not uniformly complete. The NJDFS was only able to provide fire data as far back as 1996. They could not locate any fire data prior to that year. Fire data for 1996 through 2004 were incomplete, as multiple months were missing from each of the four departments. Fire data reporting is voluntary, and the drop in data may be due to the municipalities not reporting the data for that time period.

It should be noted that not all fires are similar to each other, as fires can vary greatly in terms of scale, nature, and the types of environmental pollutants generated.

Table 1.2 identifies the number of fires reported for each municipality; the type and severity of the fires could not be identified.

Table 1.2 Number of Fires Reported by each Municipality by Year to the New Jersey Division off Fire Safety

Year	Newark*	Jersey City*	Paterson*	Elizabeth*	NJ State Totals
1996	1,967*	2,360	804	1,165	24,106
1997	*	*	*	*	10,370
1998	1,348	1,884	799	153	21,948
1999	781*	*	835	182	16,937
2000	127*	950	1,164	567	14,309
2001	2,029	2,165	914	952	42,454
2002	785*	1,768	577	890	38,299
2003	886*	1,618	529	806	35,451
2004	1,548	1,731	246	729	40,893
2005	1,327	1,724	939	792	47,138
2006	1,434	1,584	904	706	48,739
2007	1,724	1,557	915	769	47,251
2008	1,882	1,389	858	708	44,580
2009	1,193	1,376	871	663	39,271
2010	1,344	1,294	814	697	41,610
2011	1,316	1,167	611	557	36,370
2012	1,085	1,206	720	563	36,063
2013	1,120	1,398	672	495	34,052
2014	1,196	1,528	1,025	601	36,907

* denotes municipalities with missing data for that year.
(Data obtained from an OPRA Request of the New Jersey Division of Fire Safety)

The data from Table 1.2 was utilized to create a graph of the number of fires across the four cities. Since the data prior to 2004 is incomplete and unreliable, the graph was created from 2005 through 2014, and represents an estimate of the number of fires reported in each municipality, and graphically depicts similarities between the size of the departments and the number of fires fought each year.

The missing fire data reflects the difficulty in obtaining accurate exposure data experienced by each fire company.

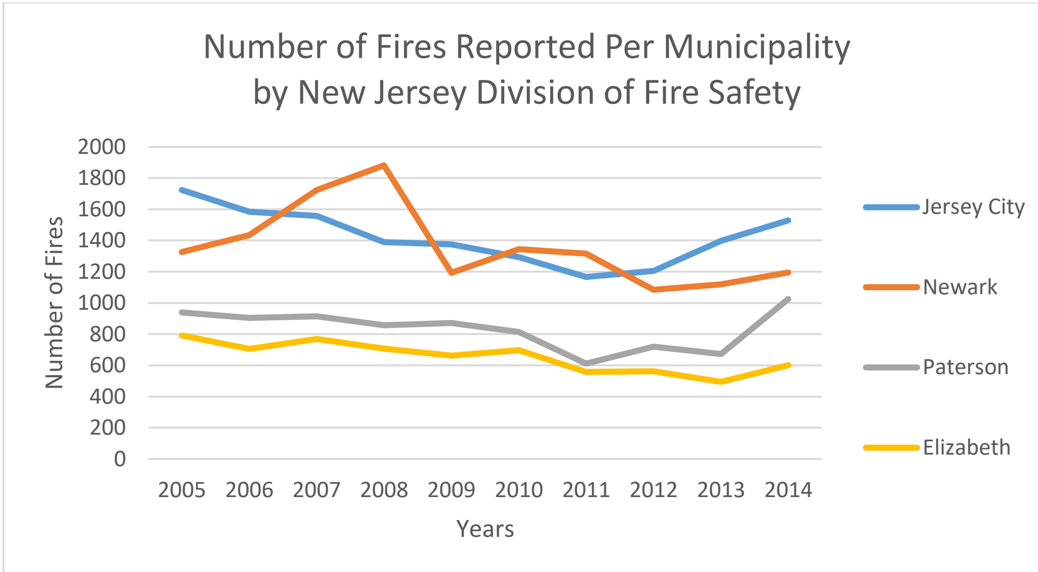

Figure 1.2 Chart of the Number of Fires reported by each municipality starting in 2005 through 2014. Note the drop in the number of Fires in 2009. National Fire Incident Reporting System (NFIRS). According to the N.J. Division of Fire Safety, they could not locate any fire records prior to 1996.

Although there were no consistent and reliable data found from the three municipalities, Jersey City, Paterson and Elizabeth, from 1980 through 2014, the Annual Report for Newark, NJ did contain an annual record of the number of fires to which their departments responded. Figure 1.3 is a depiction of those numbers across the seventeen-year period of 1980 through 1996. It should be noted that there was a large number of fires, averaging well over 7,000 fires per year, between 1980 and 1983, and steadily declining over time, as demonstrated by the overlying trend-line (Dashed Red Line). This represents a 71.7 % decrease in the number of fires. Although there is a decline in the number of fires for the City of Newark, the large number of fires is reflective of an overall high degree of exposure to combustion products received by the Newark firefighters, especially between the years of 1980 and 1990.

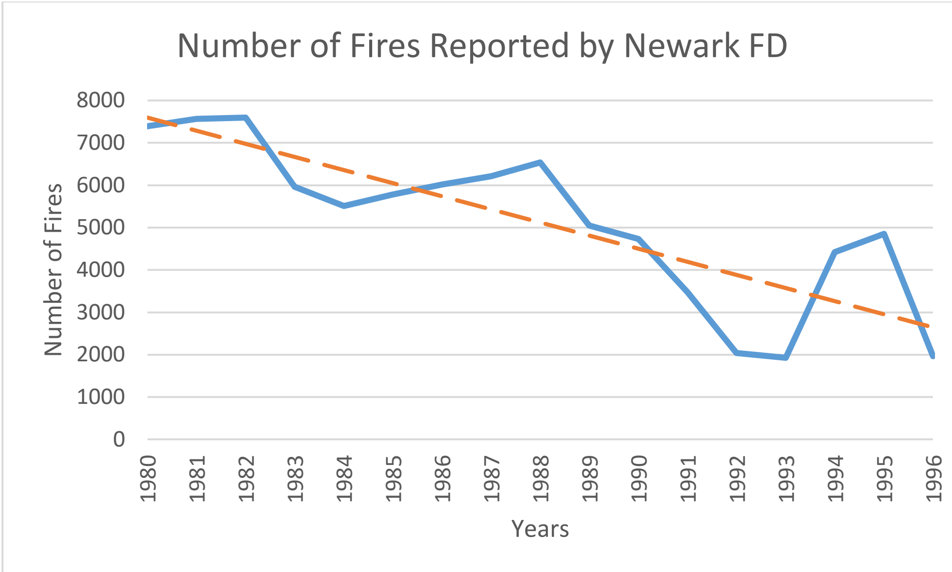

Figure 1.3 Chart of the number of fires reported by Newark, NJ Fire Department in their Annual Reports, 1980-1996. The dashed red line represents a trendline analysis and reflects a decline in the number of fires per year in the City of Newark, NJ.

Newark and Jersey City represent the two largest municipal fire departments and, although incomplete, the annual number of fires reported in each of their municipalities were still larger than the number of fires reported in Elizabeth and Paterson.

Since there were multiple points of municipal data drop-out, the NJ State totals were also incomplete, and should be viewed as an under reporting of the actual numbers of fires fought. The annual numbers of fires reported by the State of New Jersey Division of Fire Safety contained too many deficiencies, such as missing numbers of fires from one or more quarters in each year, to be considered a reliable source of fire statistics between 1996 and 2004 for a true comparison between these municipalities.

A more reliable depiction of fire events can be generated by looking at the number of fires reported between 2005 and 2014. Figure 1.4 depicts the number of fires for the State of New Jersey without any known losses in fire reporting.

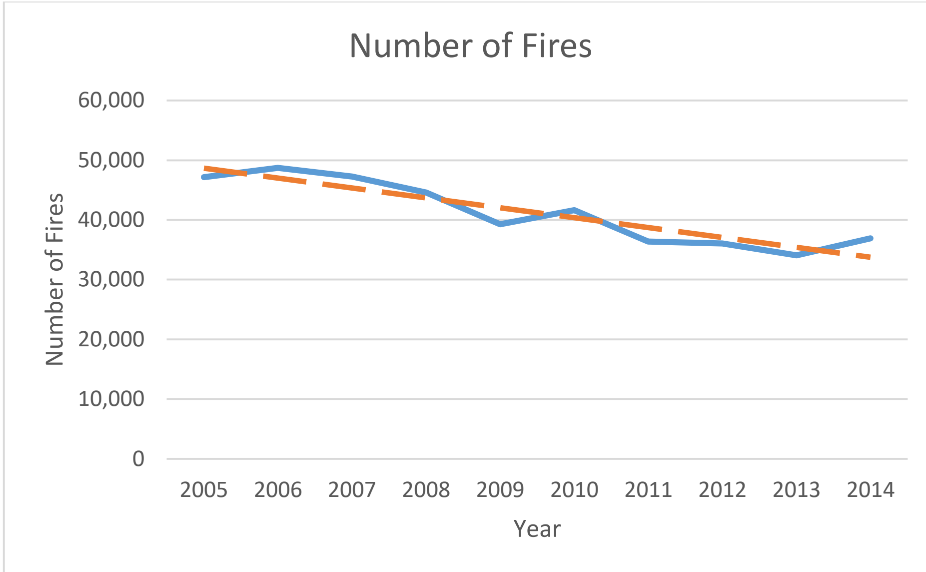

Figure 1.4 Chart of the Total Number of Fires Reported by the New Jersey Division of Fire Safety from 2005 through 2014. These numbers were reported not to have any data losses from each of the four municipalities and are considered a more reliable depiction of fires across New Jersey. The straight segmented red line represents a trend line reflecting a 21.7% decrease in the number of fires statewide.

Due to the lack of reliable data from each of the local municipalities between 1980 and 2010 from the State level, a search of the National Fire Incidence Reporting System (NFIRS) was conducted.

The National Fire Incidence Reporting System was developed in 1974 following a national report on fires entitled “America’s Burning”. Following the release of this report, the U.S. Congress, enacted the Federal Fire Prevention and Control Act of 1974 (P.L. 93-498), which created the National Fire Data Center (NFDC), within the United States Fire Administration (USFA). The USFA was created as a division under the direction of the Federal Emergency Management Agency (FEMA).

The concept behind the NFIRS was to develop a means by which the states could track and identify fires and responses in order to identify trends in firefighting activities and improve firefighter safety. The NFDC was also tasked with assisting the states to develop their own fire reporting and analysis systems in order to provide reliable and accurate data to the NFDC. It should be noted that each state's participation in NFIRS reporting is voluntary. Therefore, approximately 25 % of fires nationwide are not reported, and once again, historical records of firefighter statistics are not entirely accurate.

A recent review of the NFIRS fire reports revealed that there were approximately 1.55 million fires reported nationwide in 2004. The NFIRS data continued through 2013 where the number of fires reported was 1.24 million. This reflected a decreasing trend of 21.6 % over the ten-year period of 2004 through 2013, as demonstrated by the graph obtained from the NFIRS website in Figure 1.5 below.

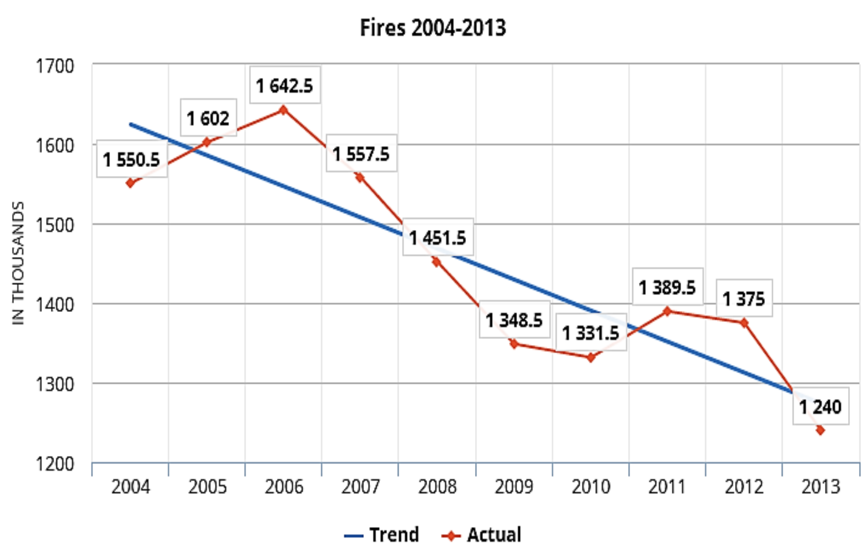

Figure 1.5 National Fire Incidence Reporting System (NFIRS) Data from 2004 through 2013 reflecting a decreasing trend (solid blue line) in the number of fires nationwide. (Source: https://www.usfa.fema.gov/data/statistics/)

Individual NFIRS data at the municipal level could not be accessed for comparison. Therefore, although incomplete, the number of fires reported for each municipality will be a best estimate until the fire companies, state reporting departments, and the National Fire Safety Administration can develop a more detailed method of reporting the actual number of fires in each municipality.

1.2.2 Crime Statistics for New Jersey and the Four Largest Municipalities in NJ

If the number of fires represented the risk to firefighters, then the number of violent and non-violent crimes may represent a risk to police officers. Criminal and police activity are recorded by the New Jersey State Police, as well as by the United States Department of Justice, Federal Bureau of Investigation (FBI). The NJ State Police maintained an accurate and detailed account of violent and non-violent criminal activity across New Jersey and by municipality.

Each of New Jersey's cities reported the number of criminal acts including murder, arson, rape, aggravated assault, burglary, larceny-theft, and motor vehicle theft to the New Jersey State Police. The number of criminal incidents was converted into a rate of criminal activity per 1,000 individuals. Figure 1.6 demonstrates the number of criminal acts reported across the State of New Jersey by the New Jersey State Police.

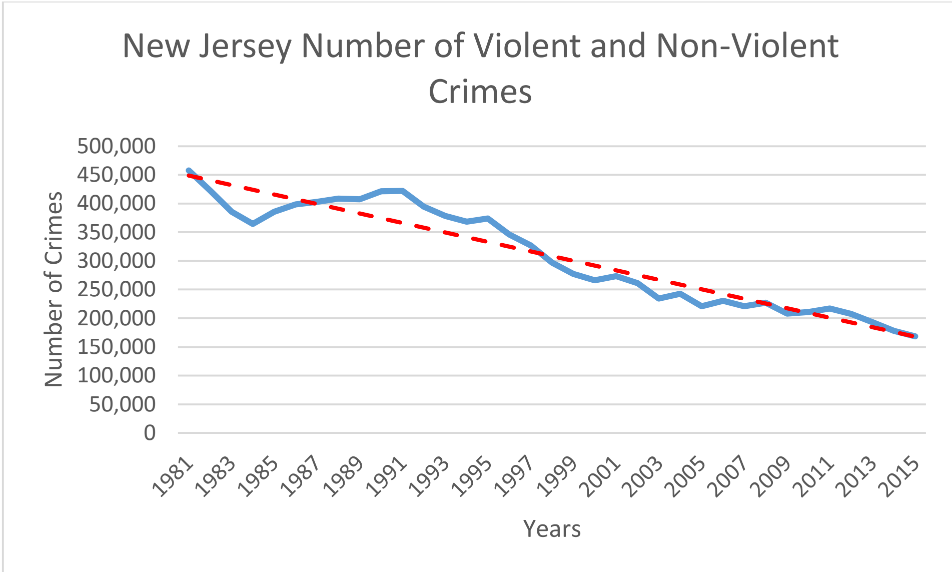

Figure 1.6 State-wide criminal activity from the New Jersey State Police Annual Report of Crime in the Cities, 1981 through 2015. The dashed Red Line is a trend line showing a 36.8% decrease in criminal activity from 1981 through 2015.

Crime statistics are further broken down by each of the four municipalities, Newark, Jersey City, Paterson and Elizabeth, NJ. The number of criminal acts are once again self-reported by each of the New Jersey's municipalities. The New Jersey State Police Records were available back through 1980. Figure 1.7 demonstrates the number of violent and non-violent crimes reported in each city.

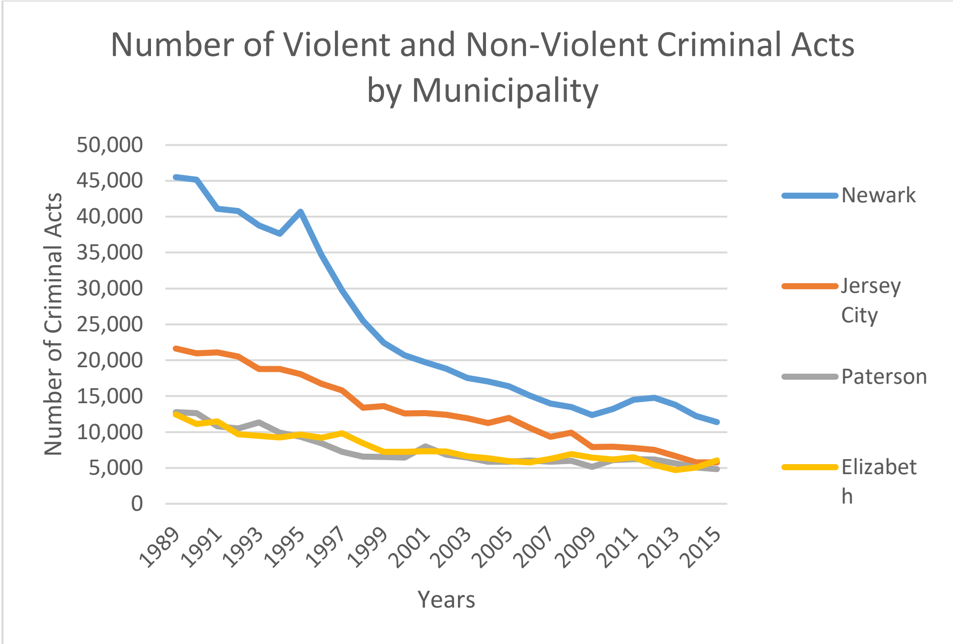

Figure 1.7 Number of criminal acts by municipality from the New Jersey State Police (NJSP) Annual Reports, 1989 through 2015. NJSP records for individual municipalities were only available from 1989 through 2015.

According to the NJSP Report of Crimes in the Cities, the City of Newark, NJ experienced the largest degree of criminal activity of the four municipalities, followed by Jersey City. The degree of criminal activity in Elizabeth and Paterson are virtually identical. The number of criminal acts is relative in number to both the population and the number of officers in their respective police forces. Newark, NJ having the largest population, also has the largest police force and the highest number of criminal acts, followed by each municipality according to their population.

The number of male police officers for each year for each city is depicted in Figure 1.8 and demonstrates the change in the number of police officers in each municipality over time, with Newark, NJ demonstrating the largest reduction in force, followed by Jersey City, NJ. Again, both Paterson and Elizabeth remain relatively constant in their numbers of uniformed officers between 1989 and 2013.

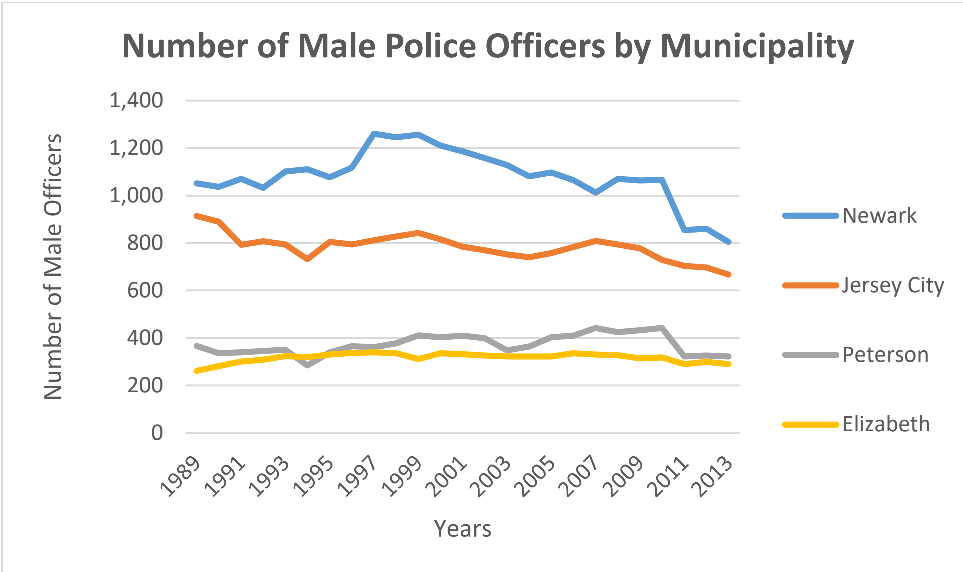

Figure 1.8 Comparison of the number of male police officers from each of the four police departments. Data obtained from the NJ State Police.

Although the number of criminal acts is a representation of the degree of criminal activity in a community, the rate of criminal activity, in this case the number of criminal acts per 1,000 individuals in each municipality is also important. Figure 1.9 reflects the rate of criminal acts in each municipality. Newark and Jersey City have higher crime rates, with the other three municipality's following according to their population numbers. The rate of criminal activity for each municipality is trending downward.

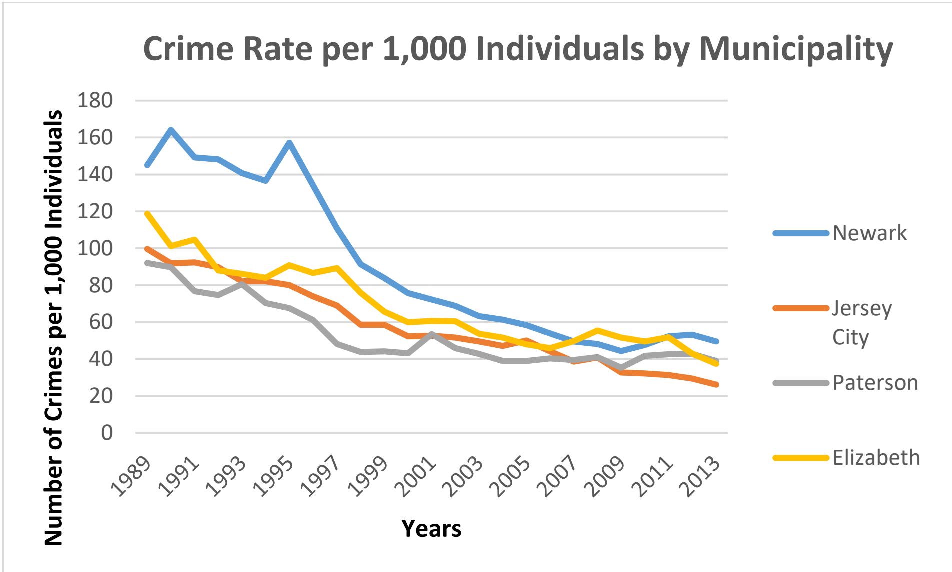

Figure 1.9 Comparison of the crime rates per 1,000 individuals from each of the four municpalites proved by the New Jersey State Police.

1.2.3 Cancer Statistics in New Jersey and the Four Largest Counties in NJ

In order to obtain an additional layer of information to round out the environmental landscape that affected these employees, the number of cancer cases per county, per year, and the rate of cancer per 100,000 individuals per year are also important metrics to consider in occupational epidemiology studies.

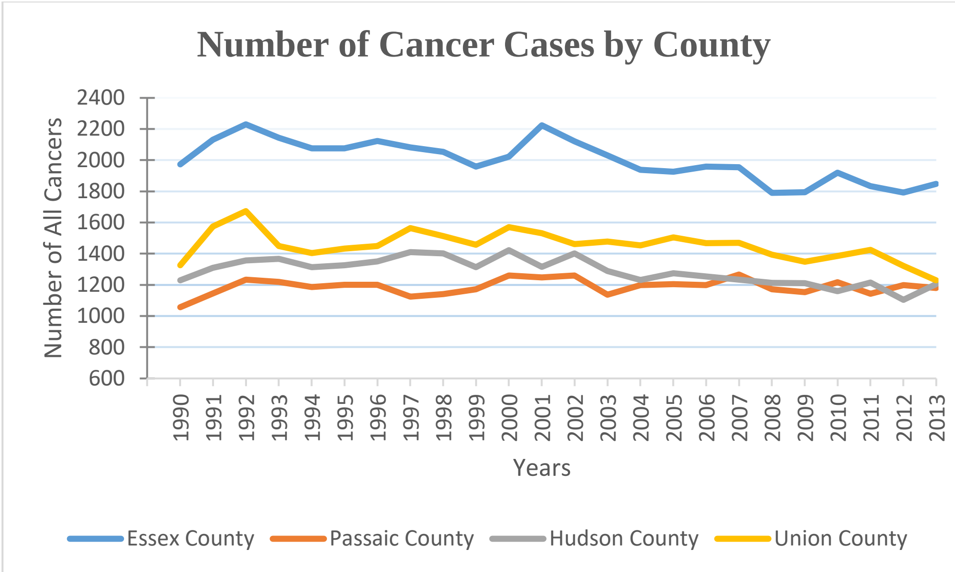

Figure 1.10 Chart of the number of cancer cases per county, (Raw unadjusted counts) with Essex County demonstrating the highest number of cancer cases over a 33-year period. Data obtained from the New Jersey State Cancer Registry.

Figure 1.10 reveals that Essex County has the highest number of cancer cases (not age-adjusted) per year of the four counties, followed by Union County. Given that the population of Essex County is proportionally larger than the other three counties, this finding appears to be consistent with the idea that the larger population area should have a greater number of cancer cases. Surprisingly, this does not hold true for Union County which had the second highest number of cancer cases. If the number of cancer cases were consistent with the size of their populations, then the number of cancers should mirror the population gradients of Essex, Hudson, Passaic and Union Counties. Therefore, it is important to look at the age and population adjusted incidence rates of cancer for each of the four counties as depicted in Figure 1.11.

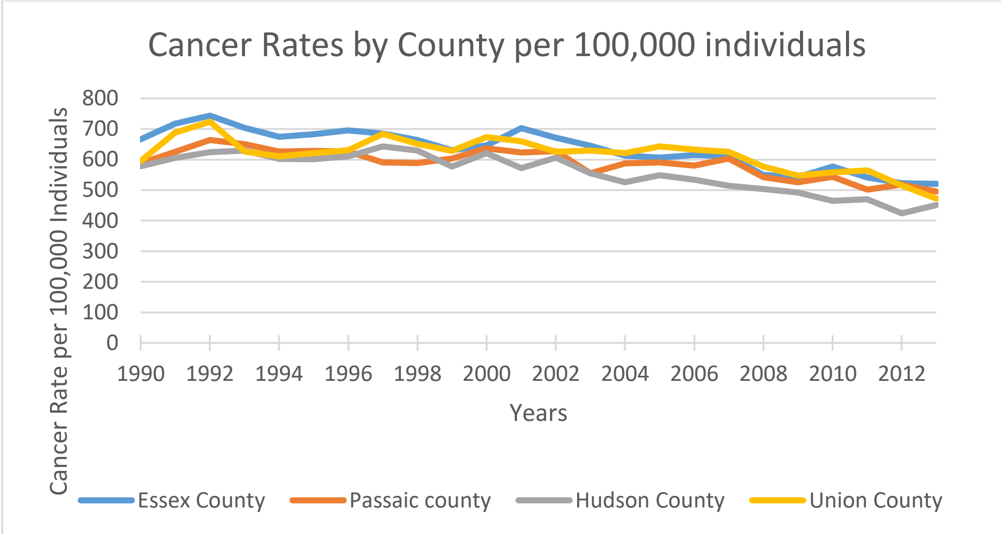

Figure 1.11 Graph of Cancer Rates of Essex, Hudson, Passaic, and Union Counties per 100,000 individual, per year. Data obtained from the NJ State Cancer Registry.

The cancer rate per 100,000 individuals demonstrates that the cancer rates are similar, with just enough difference to make the number of cases appear disimilar due to the differences in population. However, it is clear that the rate of cancer is also higher in Union County, NJ than in either Hudson or Passaic Counties. It is also clear that the rate of cancer in Union County surpasses the rate of the much more industrialized Essex County in 2005 and led the four counties in the rate of cancer from 2005 through 2009.

1.3 Problem Statement

The negative health effects of firefighter exposure to the by-products of burning material, chemical fumes and soot, has long been thought to be a foregone conclusion. Numerous studies on firefighter morbidity and mortality reported that firefighters indeed suffer ill effects over their careers from fighting fires. These studies are discussed at length in Chapter 2.

An initial prediction is that firefighter studies would reflect both similar outcomes and demonstrate a greater incidence of cancers of the respiratory tract due to their repeated occupational inhalation exposure to smoke and soot. However, out of 13 studies reviewed, only one (Hansen, et al., 1990) reported a statistical increase in lung cancer in firefighters. It should also be noted that one study by Daniels et al., identified a statistical increase in mesothelioma. (2013) Mesothelioma, although a pleural cancer and not a respiratory tract cancer, has been linked to inhalation exposure of asbestos fibers. After a careful review of the available literature, and the lack of an extensive number of studies demonstrating respiratory cancers in firefighters, there is a strong inclination to investigate the incidence of cancer in firefighters across a broad range of cancers, and not just lung or respiratory tract cancers.

There are two basic types of occupational epidemiological methodologies used amongst researchers today: case-control studies, whereby a cohort is determined based upon the presence of a disease and compared to a control group of individuals without disease; and cohort studies were a cohort is selected based upon a group's relationship or exposure to a hazard. Case-control studies, can begin by searching (or data mining) death certificates for causes of death or cases. Cohort studies can search the occupational fields of municipal records or cancer registries for specific occupations, such as firefighter or police officer, creating an occupational cohort. Both studies have advantages and limitations primarily with obtaining accurate information regarding exposure and diagnosis of disease. For example, obtaining cancer mortality from death certificates presents reliability issues. A study conducted by Johnson, et al., (2012) found that 94.7% of death certificates correctly reported the correct cancer site for cause of death, however, the accuracy for identifying mortality due to stomach cancer was only 68.1%.

All published firefighter studies have one notable limitation: a lack of identifying an individual's exposure that could account for any one cancer. Instead, the authors conducted data mining searches of death certificates and cancer registries. Only one of the firefighter studies: (Ide, et al., 2014) captured personal medical and social information, such as individual alcohol and tobacco use, as this study was able to review firefighter personnel and medical records. No other firefighter cohort study exists that includes this valuable social information that is so often a confounder of epidemiological studies. Given the significant number of residential, industrial and vehicular fires that professional firefighters encounter during their careers, it is almost impossible to identify a single event as the single cause of a specific cancer. The single, most notable, exception to this rule occurred on September 11, 2001, when a large number of firefighters lost their lives in the structural collapse of the World Trade Center Towers, and were on-site at ground zero for multiple weeks thereafter and were exposed to a veritable "witches brew" (Lioy, 2010) of toxic compounds in the dust during the recovery operations. Multiple exposures, over the course of a career may be just as hazardous to an employee's health as a single exposure.

Many of the previous cancer studies relied on data mining cancer registries or death certificates to identify their study population. Unfortunately, many of these studies relied on databases that lacked information, such as municipality of employment or years employed. Chapter 2 will identify several data-mining studies (Sama, et al., 1990, Ma, et al., 2006, Kang, et al., 2008, and Tsai, et al., 2014) which have limitations in identifying the larger population of an entire firefighter and police officer cohort from the records examined. This current study captured the larger population of exposed employees and was able to overcome these limitations. In the absence of detailed firefighter histories of the number and type of fires fought across an entire career, the present study uses the number of years that each firefighter worked as a surrogate for exposure.

1.4 Objective

This research evaluates four large cohorts of firefighters and four large cohorts of police officers from similar municipalities to identify if there is an excess of cancer incidence in either group.

1.5 Significance of the Proposed Research

This is the first study to obtain recent cohort information regarding firefighters and police officers from the same municipalities, including names, years of birth, the last four numbers of their Social Security numbers, and their exact lengths of service. Obtaining cohorts in this fashion, allowed us to compare similar cohorts, and to calculate an accurate Person Years at Risk (PYAR) for each cohort.

This approach to studying cancer in firefighters and police officers will add to the basic knowledge base of cancer incidence in firefighters and police officers. Increased knowledge in this area may well lead to advances in the prevention and mitigation of cancer in these groups.

Furthermore, this study will benefit the residents of New Jersey, by helping to identify the relative cancer risk in firefighters and police officers, and providing the information necessary to allocate resources, specifically health and pension benefits, where they are needed most.

1.6 Organization of the Dissertation

This dissertation is divided into eight chapters. Chapter 1 describes the basic background information, concerns and current problems, regarding occupational epidemiological studies of firefighters. This introduction also defines the concerns of present day information gathering regarding municipal workers.

Chapter 2 is a comprehensive literature review of previous peer-reviewed articles regarding cancer incidence in fire fighters and police officers.

Chapter 3 contains a meta-analysis of six peer-reviewed journal articles that have not been previously included in other meta-analysis.

Chapter 4 details the study design, methodology for data collection, and the steps taken for study subject protection, including the Institutional Review Board application and New Jersey State Cancer Registry application process. The Statistical Analysis utilized to conduct a Standardized Incidence Ratio study is also discussed here.

Chapter 5 presents the analytical results of the 30-Year Study of Cancer Incidence in Firefighters and Police Officers in New Jersey's Four Largest Municipalities, including the Standardized Incidence Ratios, Relative Risks, summary findings, conclusions and recommendations for future studies. This chapter also discusses the limitations and benefits of this study.

Chapter 6, contains a longevity analysis of the firefighters and police officers. The longevity analysis compares the length of service and dates of retirement and death of each firefighter and police officer, as well as a survivability analysis.

Finally, Chapter 7 presents a summary and conclusion.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Firefighters evoke images of brave young men, and now in many cities women, wearing heavy boots, jackets and breathing equipment running into burning buildings, putting out fires, and saving lives. The job of a firefighter entails a variety of dangers, not only the acute hazards of fighting fires, such as accidents, burns and smoke inhalation, but also the longer term disorders such as cancer and cardiovascular disease. Many of the same images of brave men and women in protective gear, putting their lives in harm's way also apply to police officers.

A comprehensive literature-search of the databases Embase and PubMed was conducted to identify health studies of firefighters and police officers, to provide the necessary background information, the rationale for this study and the recommendations therein. Keywords used in the search included firefighter, police, police officers, standardized incidence rates and ratios, cancer, cancer registries, and multiple combinations thereof. According to the latest National Fire Protection Association Report (Fahy, 2016) of firefighter fatalities, there were 69 on-the-job fatalities in 2015, down from 105 in 2008 and 82 in 2009. The report focuses on the fatal injuries and illnesses that arise as a direct identifiable incident. Numerous papers were identified regarding the chemical make-up and toxicity of fire smoke and the health effects of these contaminants. Papers identified from the data bases, were backtracked through their literature reviews to other papers. In some cases, more than one paper has reported on a single cohort.

This literature review is presented in four sections: exposure studies, mortality studies, cancer incidence studies, and meta-analyses. Firefighting is inherently dangerous, and all-cause morbidity would therefore be increased. However, one study (Kirkeleit et al., 2013) suggests that using the U.S. General Population may cause an underestimation in cancer risk due to a healthy worker effect. The healthy worker effect is a term coined by McMichael in 1976 to describe the impact that workers that maintain a higher level of physical fitness or that do not indulge in social problems such as excessive drinking and/or tobacco use. (McMichael, 1976)

Firefighters would experience a high incidence of respiratory tract exposure to large amounts of smoke and airborne toxic materials from burning materials in residential and commercial buildings, car and truck fires, as well as from brush fires adjacent to railroad lines. The major risk factors for bladder cancer are smoking and chemical exposures. An earlier study (Lenahan, et al. 1999), identified an excess of bladder cancer among firefighters responding to the Chemical Control fire in Elizabeth NJ in 1980. Therefore, in reviewing the literature there was an indication that lung and bladder cancers needed further investigation.

2.2 Exposure Studies of Firefighters and Police Officers

Brandt-Rauf et al., noted that there are a variety of potential carcinogens, including polycyclic aromatic hydrocarbons (PAHs), arsenic, benzene and formaldehyde in wood smoke. They also noted that asbestos is a common building insulation and is sometimes present in the smoke and soot of burning buildings. (Brandt-Rauf, 1988)

Oliveria (2017) examined the occupational exposure to eighteen polycyclic aromatic hydrocarbons (PAHs) in the breathing zone of firefighters in Portugal. The breathing zone was analyzed with personal (for 54 days) and firehouse facility air sampling monitors (for 1 day). Although there were urban fire houses, the firefighters were primarily involved in forest fire containment. Her findings revealed that of the 18 PAHs Acenaphthylene was the most abundant compound found in the breathing zone of the urban firefighters, followed by acenaphthylene, acenapththene, naphthalene, and phenanthrene. Acenaphthylene has been found in multiple combustion products including wood, crude oil, and tobacco smoke.

Oliveria (2017), also analyzed the urine of the same Portuguese firefighters for six urinary monohydroxyl metabolites (OH-PAHs). Individual samples were collected after a normal eight-hour shift (smokers were excluded). Urinalysis results identified 1-hydroxynapthalene and 1-hydroxyacenapthene as the predominant metabolites. Lesser concentrations of benzo[a]pyrene, a biomarker of the carcinogen naphthalene, was also identified in the urine.

2.3 Mortality Studies of Firefighters and Police Officers

Mortality studies have tended to rely on death certificates, or reports of death from hospital records to identify cases. The next group of studies are mortality studies that identified a cohort of firefighters and then searched vital status and death certificates.

An SMR study conducted in 1978 examined the mortality of 5,655 Boston, Massachusetts firefighters, employed for a minimum of three years, between the years 1915 and 1975. (Musk, 1978) This study identified firefighters from actual Boston Fire Department employee records and then searched death certificate records for cause of death.

The study concluded that there did "not appear to be a strong association between occupation and cause-specific mortality". The study reported an SMR = 0.91 for all-cause mortality due to all deaths, when compared to the number of expected male deaths in Massachusetts and the United States, and may represent a healthy worker effect. The SMR for cardiovascular and cancer deaths were both = 0.86. The mortality data from this study relied on death certificates dating back to 1915. These older death certificates may not accurately reflect the true cause of death, as the methods and manner of reporting mortality were not standardized until 1975 when the conventions of the National Center for Health Statistics were implemented. Therefore, death certificate cause of death reporting for most of the first half of the twentieth century should be considered suspect for inaccuracies and under-reporting in the pathological identification of the cause of death, especially cancer. Furthermore, although the authors did have access to personnel records, these records did not include any information regarding smoking history or alcohol use. The study did not calculate Person Years at Risk (PYAR), nor did they include a confidence interval or P-Value. (Musk, 1978)

A Proportionate Mortality Ratio (PMR) study conducted in New Jersey, compared a cohort of firefighters to a cohort of police officers and the New Jersey General Population. (Feuer and Rosenman, 1986) They obtained cause of death data from the New Jersey Police and Firefighters Retirement System (PFRS), for a six-year period, 1974 to 1980. The PFRS is a comprehensive retirement system of salaried police officers and firefighters; volunteer firefighters are not included. Although they analyzed the firefighters and police officers separately, they did not separate them by municipality or county. Comparative cohort mortality data was taken from the National Mortality Database, and the New Jersey State Department of Health. They found a statistically significant increase in the PMR for

Atherosclerotic Heart Disease (ASHD) for both police officers, (PMR = 1.15) and firefighters, (PMR = 1.2). Retired police officers and retired firefighters had PMRs = 0.96 and 0.98, respectively. Firefighters demonstrated an increase in nonmalignant respiratory diseases, (PMR = 1.98), and leukemia, (PMR of 2.76), were statistically increased compared to police officers. One additional component of that study is the distribution of the age of death among the employed and retired firefighters and police officers in New Jersey. The study demonstrated the majority of firefighter and police officer deaths occurred between the ages of 40 and 64 years of age.

A 2013 study of the life expectancy of Buffalo, NY Police Officers found that the life expectancy of police officers was "significantly lower than the U.S. Population". (Violanti, et al., 2013) The mean difference in their life expectancy was 21.9 years; (95% CI = 14.5-29.3). These Buffalo, NY Police Officers were found to have potential years of life lost 21 times larger than that of the U.S. population. Reasonable explanations put forward by Violanti et al. (2013) include workplace stress, (workplace politics and shift differentials), post-traumatic stress, obesity, and environmental stressors other than the inhalation of combustion products.

A cohort of Danish firefighters identified from the National Bureau of Statistics was followed over ten years, 1970 to 1980, and compared to a cohort of civil servants, and salaried employees (Hansen, et al., 1990). Hansen found an excess cancer mortality in persons 30 to 74 years of age, SMR = 173; (95% CI = 104-270). Lung cancer was also elevated with a SMR = 317; (95% CI = 117-691) in the older age group of 60 to 74 years.

Beaumont, et al., (1991) studied cancer and other causes of mortality among 3,066 San Francisco, California firefighters employed for at least one-day between 1940 and 1970.

The authors identified a cohort of firefighters from the San Francisco Fire Department employee records. They then obtained death certificates from the California State Registrar's Office. The investigators carried out a Relative Risk (RR) analysis. Overall, they reported a RR for all causes of death at 0.90; (95% CI = 0.85-0.95). They also reported a RR = 0.95; (95% CI = 0.84 -1.08) for all malignant neoplasms. The category of malignant neoplasms was further broken down to specify the RR for malignancies of the genitourinary system at 0.84; (95% CI = 0.5-1.33). The authors were able to differentiate the genitourinary and digestive cancers, and identified the RR of death due to bladder cancer at 0.57; (95% CI = 0.19-1.35; n= 18), and esophageal cancer at 2.04; (95% CI = 1.05-3.57). If bladder cancer was not listed as a primary cause of death it may have been under-reported resulting in a low relative risk. The authors also reported that death certificates prior to 1968 (No indication of exactly how many there were.) may not have coded the cause of death uniformly, as California did not adapt the International Classification of Diseases (8^{th} Revision) until January 1, 1969.

Demers, et al. (1992) conducted a large mortality study of 4,546 firefighters from three northwestern U.S. cities, Seattle, WA, Tacoma, WA, and Portland, OR. The study looked for mortality and an increased risk of cancer, lung and heart disease, in firefighters employed for at least one year between 1944 and 1979. The investigators calculated SMRs with the United States national mortalities database, and against the mortality rates of police officers from the same three cities. They reviewed 1,162 death certificates (99%). Demers, et al. (1992) concluded that there was no increased risk of cancer to the firefighters. Although all of the firefighters in the study had at least one year of firefighting experience, there is no indication as to actual length of service. The author estimated length of service.

Like many of the above studies, the Demers et al. study was limited, as the authors could not determine any history of smoking or exact years of service as a firefighter prior to the onset of any mortality or morbidity. The risk of overall death (all causes) was lower than expected with an SMR = 0.81; (95% CI = 0.77-0.86); and death from all cancers SMR = 0.95; (95% CI = 0.85-1.07), suggesting a healthy worker effect. Brain cancer, however, reflected a statistically significant two-fold increase in risk with a SMR of 2.09; (95% CI = 1.31-3.17). Lung and bladder cancer mortality rates were 0.96; (95% CI = 0.77-1.17), and 0.23; (95% CI = 0.03-0.83; n= 18) respectively. (Demers, 1992)

A mortality study of 7,789 Philadelphia, PA firefighters looked at mortality from all causes and found a statistically significant excess risk of colon cancer with an SMR of 1.51, (95% CI = 1.18-1.93) and ischemic heart disease with an SMR = 1.09; (95% CI = 1.02-1.16). The study also reflected a non-significant risk in bladder cancer with an SMR = 1.25; (95% CI = 0.77-2.0). (Baris, 2000)

A mortality study of Florida firefighters looked at employed, non-volunteer, firefighters working from 1972 through 1999 (Ma, et al., 2005). They identified their cohort from a professional pre-employment certificating-examination required of all firefighters since 1972. Although the certificating examination is required prior to working as a firefighter, it is not proof that the individual did work as a paid firefighter. Furthermore, the study did not have access to any data as to when their firefighter terminated their employment as a firefighter. Therefore, the authors estimated Person Years at Risk (PYAR) from the date of certification through to a date of death, or the end of the study, December 31, 1999. The study reported an elevation in the SMR in both male breast cancer, SMR = 7.41; (95% CI =

1.99 to 18.96); and an increase in bladder cancer, with an SMR = 1.79; (95% CI = 0.98 to 3.00). (Ma, et al., 2005)

Guidotti (2007) reviewed multiple firefighter studies involving firefighters from Canada, New Zealand and Vermont, USA. He constructed a reporting mechanism whereby he reported the overall preponderance or presumption of certain cancers in firefighters. Although his study was a review, and not a meta-analysis, he concluded that there was a preponderance of evidence supporting the association between firefighting and urinary bladder, kidney, and testicular cancers. (Guidotti, et al., 2007)

Zeig-Owens (2011) followed 9,853 New York City firefighters for seven years following the September 11, 2001 (9/11) terrorist attacks. These firefighters were exposed to the unique, high pH dust and debris of Ground Zero (Lioy, 2010), following the collapse of the World Trade Center (WTC) Towers. These firefighters had been working for at least eighteen months on January 1, 1996, and were followed through to their date of death, first cancer diagnosis or through to the end of the seven-year study period of December 31, 2008. Although the Standardized Incidence Rate (SIR) study was an "Early Assessment" of the firefighters following the 9/11 attacks, it identified a "modest excess of cancer cases in the WTC-exposed cohort". Surprisingly, lung cancer was significantly reduced SIR = 0.28; (95% CI = 0.13 to 0.62). Kidney and bladder cancers had similarly low SIRs for exposed firefighters of 0.86; (95% CI = 0.46 – 1.60), and 1.01; (95% CI = 0.56-1.83), respectively. The authors included only lung cancer diagnosed two years after 9/11. This lag in diagnosis was to allow for cancers an adequate time to develop. (Zeig-Owens, et al., 2011).

Table 2.1 Incidence Studies of Firefighters

Author	Subjects	Period	Observed	Cancer	Ratio	95% CI
Feuer, 1986	901	1974 - 1980	67	Overall	1.15	
			23	Respiratory	0.98	
			2	Genitourinary	1.09	
Hansen, 1990	886			Overall	173	104-270
				Lung	317	117-691
Beaumont, 1991	3,066	1940-1970	236	Overall	0.95	0.84-1.08
			12	Esophagus	2.04	1.05-3.57
			63	Respiratory	0.83	0.64-1.06
			5	Bladder	0.57	0.19-1.35
Demers, 1992	1,162	1944 - 1979	291	Overall	0.95	0.85-1.07
			95	Lung	0.96	0.77-1.17
			2	Bladder	0.23	0.03-0.83
			22	Brain	2.09	1.31-3.17
Baris, 2000	6,477	1935-1986	500	Overall	1.10	1.0-1.20
			64	Colon	1.51	1.18-1.93
			17	Bladder	1.25	0.77-2.0
			162	Lung	1.13	0.97-1.32
			20	NHL	1.41	0.91-2.19
Ma, 2005	Male 34,796	1972 - 1999	403	Overall	0.85	0.77-0.94
			155	Lung	0.93	0.79-1.09
			14	Bladder	1.79	0.98 - 3.00
Ma, 2005	Female 2,017	1972 - 1999	8	Overall	1.03	0.44-2.03
			3	Lung	2.22	0.45-6.49
			0	Bladder	0.0	0.0

2.4 Incidence Studies of Firefighters and Police Officers

Incidence studies rely on obtaining personal identifying information that can be utilized to search cancer registry databases for incident cases of cancer. Table 2.4 summarizes the incident studies described below.

Sama, et al. (1990) queried the Massachusetts Cancer Registry for individuals with "Firefighting" as their self-reported professions, and found 315 Massachusetts firefighters diagnosed with cancer during a four-year period, 1982 through 1986. The study conducted a

Standardized Morbidity Odds Ratio (SMOR), which is similar to an SIR analysis, in that the cancers are identified, and the number of observed cases is divided by the number of expected cases in the reference populations. The author searched the cancer registry by occupational category, rather than identifying a well-defined cohort first, and searching the cancer registry for cancers relating to that cohort. By searching for individuals who self-report their professional status, one risks introducing a reporting bias for those individuals who may have changed professions, or retired from their companies, and were listed in another occupational category, or as retired, and not as a firefighter, or not listed at all. Sama, et al., (1990) confirms that the underreporting of professions was a significant problem, as “Occupational information is available for only approximately 50% of all MCR cases” (Sama et al. 1990). The authors stated “Previous investigations of cancer among firefighters have been limited to mortality data and have yielded inconsistent results.” Individuals listed as male “police officers” were used for a reference population for the comparison group. In spite of a relatively small study population, and an underreporting of the professional category by up to 50%, the author reported finding significant increases in melanoma with a SMOR = 292; (95% CI = 107 to 414), non-Hodgkin’s lymphoma SMOR = 327; (95% CI = 119-898); and bladder cancer, SMOR = 159; (95% CI of 102 to 250). Although this study did identify the incidence of cancer in firefighters, the cancer registry data could not identify firefighters or police officers by company, division or municipality, that would have had similar firefighting experiences. (Sama, 1990)

In a second study, Ma et al. (2006) conducted a SIR investigation of the same cohort of firefighters from his previous 2005 mortality study. In both studies, Ma obtained a cohort of firefighters from the Florida Fire Marshall’s Office, and linked it to the Florida Cancer

Data System (FCDS) to reveal the incidence of cancer. Although the cohort included firefighters certified in 1972, the study focused on cancers reported between 1981 and December 31, 1999, and included 34,796 male and 2,017 female firefighters (413,022 and 18,843 Person Years at Risk, respectively). They compared this cohort to Florida's General Population and again estimated Person Years at Risk. That male firefighters had significantly increased incidence of bladder cancer with an SIR = 1.29; (95% CI = 1.01-1.62); testicular cancer, SIR = 1.60; (95% CI = 1.20-2.09); and thyroid cancer, SIR = 1.77; (95% CI = 1.08-2.73). The study also found that female firefighters had a statistically increased overall rate of cancer, with an SIR = 1.63; (95% CI = 1.22-2.14); cervical cancer, SIR = 5.24; (95% CI = 2.93-8.65); and thyroid cancer with an SIR = 3.97; (95% CI = 1.45-8.65). (Ma, et al., 2006)

In a 2007 Cancer Incidence Study of male Massachusetts firefighters, Kang et al. (2007) utilized a similar approach used by Sama (1990) in her earlier Massachusetts firefighter study. Once again, the author queried the "Occupation" text field of the Massachusetts Cancer Registry for "fireman", "firefighter", "fire lieutenant", "fire chief" or "fire captain" as the listed profession. The cancer registry maintained a listing of 258,964 cancer cases during a study period that extended from 1987 through to 2003. Only 161,778 of these cases had any occupation listed. Since the time of the Sama (1990) study, the listing of profession had only increased from approximately 50% to just 62.5%. The authors conducted a Standardized Morbidity Odds Ratio (SMOR) where they reported a moderate increase in risk in both colon cancer, reported at 1.36; (95% CI = 1.04 – 1.79); and brain cancer SMOR = 1.90; (95% CI = 1.10-3.26). A slightly weaker increase in risk was also found for bladder cancer, which had a reported SMOR = 1.22; (95% CI = 0.89–1.69). Lung cancer did not demonstrate a significant elevation, SMOR = 1.02; (95% CI = 0.79-1.31). (Kang, 2008)

Ide, et, al., (2014), conducted an aged-matched cancer incidence study of Scottish firefighters working during a 20-year period between 1984 and 2005. The author reviewed the medical records of 2,200 firefighters from the second largest firefighting company in the United Kingdom, and compared them to two populations of men, one West of Scotland, and one from Scotland, aged between 20 and 54. The cancer incidence from this group was used as the reference population in denominator, or expected cases, and was not further broken down by individual year of diagnosis. This study is one of the few studies that reviewed actual medical records that included personal histories of smoking and alcohol consumption. Ide reported that the overall annual incidence of cancer was lower in firefighters with an annual cancer incidence of 86.5, as compared to an expected 123.7, p Value < 0.01, cases of cancer in the general Scottish population were found to be lower in fire fighters when compared to the general Scottish population. The study reported the annual incidence rates from melanoma = 13.6 versus 8.1 cases, p Value < 0.01 in the general Scottish population; and kidney cancer = 9.1 versus 4.4 cases in the general Scottish population. Lung cancer showed a lower than expected incidence at 6.8 for the firefighters versus 20.4 for the general Scottish population, p Value < 0.001. (Ide, 2014)

Pukkala, et al. (2014) studied cancer incidence in five Nordic countries, (Sweden, Finland, Norway, Denmark and Iceland). Searching the national census databases of each country, they identified a cohort of 16,422 male firefighters between the ages of 30 and 64. Firefighters entered the study on January 1st of the year after they were identified in a census and were counted until a date of emigration, death, or study termination, which was

December 31, 2003 for Denmark and Norway; December 31, 2004 for Iceland, and December 31, 2005 for Finland and Sweden. The authors estimated Person Years at Risk by how many years each firefighter remained accountable on the census. The study concluded that there was a moderate excess risk of cancer overall, SIR = 1.06; (95% CI = 1.02 to 1.11). As a whole, both lung cancer and bladder cancer did not show any significant increases in risk with an SIR of 0.97; (95% CI = 0.87–1.09), and 1.11; (95% CI = 0.96–1.28), respectively. (Pukkala, et al., 2014)

Table 2.2 Incidence Studies of Firefighters

Author	Subjects	Period	Observed	Cancer	RR	95% CI
Sama, 1990 *	321	1982-1986	321	Melanoma	292	107-414
				NHLǂ	327	119-898
				Bladder	159	102- 250
Ma, 2006	Male 34,796	1981-1999 18,843	970	Overall	0.84	0.79-0.90
			73	Bladder	1.29	1.01-1.62
			54	Testicular	1.60	1.20-2.09
			20	Thyroid	1.77	1.08-2.73
				Lung	0.65	0.54-0.78
Ma, 2006	Female 2,017	1981-1999		Overall	1.63	1.22-2.14
				Bladder	10	0.13-55.60
				Cervical	5.24	2.93-8.65
				Thyroid	3.97	1.45-8.65
Kang, 2008	2,125	1986-2003	200	Colon	1.36	1.04-1.79
			28	Brain	1.90	1.10-3.26
			113	Bladder	1.22	0.89–1.69
Ide, 2014	2,308	1984-2005 2,200	38	Overall	86.5	-290.3-209.7
			4	Kidney	9.1	2.4 to 6.7
			2	Bladder	6.5	2.8-6.4
			6	Melanoma	13.6	13.0 to 8.8
Pukkala, 2014	16,422	1961-2005	2,536	Overall	1.06	1.02 -1.11
			310	Lung	0.97	0.87–0.09
			194	Bladder	1.11	0.96–1.28
			82	NHL	1.04	0.83-1.29
Tsai, 2014	3,996	1988-2007	254	Melanoma	1.8	1.4-2.1
			55	Myeloma	1.4	1.0-1.8
			68	Esophagus	1.6	1.2-2.0
			42	AML	1.4	1.1-2-0
			1,397	Prostate	1.5	1.3-1.7
			87	Brain	1.5	1.2-2.0
			115	Kidney	1.3	1.0-1.6
			98	Bladder	0.94	0.73-1.21
Glass, 2017	17,002	1980-2011	1,208	Overall	1.08	1.02-1.14
			352	Prostate	1.23	1.10-1.37
			209	Melanoma	1.45	1.26-1.66
			23	Bladder	0.85	0.54-1.27

* Reporting professional category 50%
ǂ NHL = non-Hodgkin's lymphoma
1* reporting professional category 62.5%

2.5 Meta-Analysis Studies of Cancer in Fighters and Police Officers

Meta-analysis studies examine previous studies and attempt to increase the statistical power of the studies by combining the results of each individual study together in order to increase the number of individuals examined. The literature search revealed two large meta-analysis studies involving firefighters. Each of the following meta-analysis studies included one or more of the previously mentioned studies.

Most studies of morbidity and mortality of firefighters involve comparisons between a selected group of firefighters and a reference cohort selected from an available database to calculate the Standardized Mortality Ratios (SMRs). These studies have their limitations and potential confounders as there are many assumptions, such as the cohort's history of smoking, alcohol consumption, or exposure to other events that could affect the outcome, differentially in the two groups.

Guidotti et al. (1995) reviewed 22 studies involving firefighters published from 1959 through 1994. They calculated the Standard Mortality Ratios (SMR) in order to estimate the magnitude of risk of cancer and working as a firefighter. An SMR of 200 equaled a 100% increased risk of dying from certain cancers. The authors concluded that there is a weak association between firefighters and lung cancer, with a SMR = 150 for non-smokers. Adding smoking as a cofactor, this association between firefighting and lung cancer becomes negligible. They went on to conclude that there is strong association between firefighters and cancers of the genitourinary tract, including kidney and ureter (SMR of 150), and specifically bladder (SMR of 200). There were no confidence intervals or P-Values reported on their calculations. (Guidotti, 1995)

Haas et al. (2003) identified 17 Standardized Mortality Ratio (SMR) studies of firefighters published between 1959 and 2001. From the list, the authors were able to identify only eight studies that contained enough time-dependent information to investigate morbidity and mortality as a function of length of time as a paid professional firefighter. The study reported, “There was no convincing evidence that employment as a firefighter is associated with increased all-cause, Coronary Artery Disease (CAD), cancer, or respiratory disease mortality.” (Haas et al., 2003)

A meta-analysis conducted by LeMasters et al. (2006) looked at cancer incidence reported across thirty-two separate studies. This work identified and reviewed the majority of significant studies involving firefighters, published from 1959 through 2003. The authors identified six studies that had identified bladder cancer as a possible occupational result of firefighters. LeMasters ranked the cancer incidence as to whether they were “Probable”, “Possible”, or “Unlikely” in relation to their work as firefighters. Their meta-analysis revealed a probable cancer risk for multiple myeloma with a Summary Risk Estimate (SRE) = 1.53, (95% CI = 1.21-1.91), non-Hodgkin’s lymphoma SRE = 1.51; (95% CI = 1.31-1.73), and prostate cancer SRE = 1.28; (95% CI = 1.15-1.43). The study also reported a “possible” association of testicular cancer, SRE = 2.02; (95% Cl = 1.30-3.13). LeMasters, et al., (2006) reported 379 cases of lung cancer across eight of the 32 studies reviewed, with an expected finding of 359 cases; SRE = 1.05; (95% CI = 0.95-1.16), reflecting a possible small risk for lung cancer. (LeMasters, et al., 2006)

In a study conducted by Youakim (2006), a fixed-effects model examined the mortality risk of six cancers, bladder, kidney, colon, brain, leukemia and Non-Hodgkin’s Lymphoma from 13 previously published cohort studies. This study included the cohort from

New Jersey reported by Feuer, and Rosenman, (1986). Youakim reported an increased summary Relative Risk (sumRR) = 1.22; (95% CI = 1.02-1.43) for kidney cancer, and a sumRR of 1.40; (95% CI = 1.20-1.60) for Non-Hodgkin's Lymphoma. He also separated the cohorts into a subcohort of firefighters with 30 or more years of service. This subcohort demonstrated a statistically significant increase in colon cancer with a sumRR of 1.51; (95% CI = 1.05-2.11), kidney cancer a sumRR of 6.25; (95% CI = 1.70-16.00), brain cancer a sumRR = 2.53; (95% CI = 1.27-7.07) and leukemia a sumRR of 2.87; (95% CI = 1.43-5.14). After 40 years of firefighter employment, the sumRR for mortality due to colon cancer rose to 4.71; (95% CI = 2.03-9.27, kidney cancer sumRR of 36.12; (95% CI = 4.03-120.42); and bladder cancer sumRR of 5.7; (95% CI of 1.56-14.63).

A study by the National Institute of Occupational Safety and Health (NIOSH), analyzed cancer incidence in a pooled cohort of 29,993 firefighters from San Francisco, Chicago, and Philadelphia. This study also identified a slight increase in bladder cancer, with a SIR of 1.11; (95% CI = 0.99-1.24) as well as a statistically significant excess of mesothelioma with a SIR of 2.29; (95% CI = 1.60–3.190). (Daniels et al., 2013)

One study conducted by Bigert, (2016) utilized pooled data from Synergy Project, which contained 14 case control studies conducted in Europe, Canada, New Zealand, and China. The SYNERGY project included data on smoking habits. From this database, the author was able to identify 190 cases of lung cancer in firefighters, out of 14,748 cases of lung cancer and 17,543 controls. His conclusions were that there was no evidence of an increased risk for firefighters for lung cancer overall, either with or without a history of smoking with an odds ratio of 0.60 (95% CI = 0.14-2.58) (Never smoked), 0.75 (95% CI = 0.45-1.26) (former smoker); and 1.18 (95% CI = 0.73-1.90) (current smoker).

2.6 Mortality Versus Incidence Studies of Firefighters

Each of the studies noted found increased risk of at least one form of morbidity or mortality in their firefighter cohorts. With the exception of the study by Bigert (2016), the majority of these studies, had one or more limitations. Chief among the limitations was the lack of complete and reliable information regarding the smoking and social habits of the cohorts in question. It should also be noted that none of the studies presented any information regarding prior military service of any of the cohorts. Military service would have to be considered in excess cases of mesothelioma, as many of veterans that served in the U.S. Navy were exposed to asbestos in the engine compartments of ships. Veterans that had served in the Army and Marine Corps during the Vietnam War could have been exposed to defoliants and other carcinogens. All veterans that served during Desert Storm and throughout the middle east were exposed to high levels of environmental toxins from burning oil wells as well as to chemical weapons.

Incidence studies have a greater sensitivity for identifying diseases that are often serious on their own, such as genitourinary cancers, but may not be a cause of death that would reveal itself in a mortality study.

Table 2.3 Mortality Studies

Author	Subjects	Period	Observed	Cancer	RR	95% CI
Sama, 1990 *	321	1982-1986	321	Melanoma NHLǂ Bladder	292 327 159	107-414 119-898 102- 250
Ma, 2006	Male 34,796	1981-1999 18,843 PYAR	970 73 54 20	Overall Bladder Testicular Thyroid Lung	0.84 1.29 1.60 1.77 0.65	0.79-0.90 1.01-1.62 1.20-2.09 1.08-2.73 0.54-0.78
Ma, 2006	Female 2,017	1981-1999		Overall Bladder Cervical Thyroid	1.63 10 5.24 3.97	1.22-2.14 0.13-55.60 2.93-8.65 1.45-8.65
Kang, 2008	2,125	1986-2003	200 28 113	Colon Brain Bladder	1.36 1.90 1.22	1.04-1.79 1.10-3.26 0.89–1.69
Ide, 2014	2,308	1984-2005 2,200	38 4 2 6	Overall Kidney Bladder Melanoma	86.5 9.1 6.5 13.6	-290.3-209.7 2.4 to 6.7 2.8-6.4 13.0 to 8.8
Pukkala 2014	16,422	1961-2005	2,536 310 194 82	Overall Lung Bladder NHL	1.06 0.97 1.11 1.04	1.02 -1.11 0.87–0.09 0.96–1.28 0.83-1.29
Tsai, 2014	3,996	1988-2007	254 55 68 42 1,397 87 115 98	Melanoma Myeloma Esophagus AML Prostate Brain Kidney Bladder	1.8 1.4 1.6 1.4 1.5 1.5 1.3 0.94	1.4-2.1 1.0-1.8 1.2-2.0 1.1-2-0 1.3-1.7 1.2-2.0 1.0-1.6 0.73-1.21
Glass, 2017	17,002	1980-2011		Overall Prostate Melanoma	1.09 1.23 1.45	1.03-1.37 1.10-1.37 1.26-1.66

* Reporting professional category 50%

ǂ NHL = non-Hodgkin's lymphoma

1* reporting professional category 62.5%

Table 2.4 Meta-Analysis Studies

Author	Studies	Cancer	RR	95% CI
LeMasters, 2006	35	Multiple Myeloma	1.53	1.21-1.91
		NHLǂ	1.51	1.31-1.73
		Prostate	1.28	1.15-1.43
		Testicular	2.02	1.30-3.13
		Lung	1.05	0.95-1.16
Youakim, 2006	13	Kidney	1.22	1.02-1.43
		NHL	1.40	1.20-1.60
		Colon	1.51	1.05-2.11
		Kidney	6.25	1.70-16.00
		Brain	2.53	1.27-7.07
Bigert, 2016	14	Lung	1.18	0.73-1.90

CHAPTER 3

A META-ANALYSIS OF CANCER INCIDENCE STUDIES OF FIREFIGHTERS, 2006 – 2016

3.1 Introduction

Firefighting is without a doubt a dangerous profession that anyone could choose to pursue. Fighting fires is inherently dangerous on multiple fronts, as firefighters battle not only the acute physical hazards of bodily injuries from accidents, they must also deal with longer-term diseases such as the possible cancer related to occupational exposures. Brandt-Rauf (1988) demonstrated that firefighters are exposed to a variety of organic and inorganic compounds during the course of firefighting through the use of portable ambient environmental sampling monitors worn by firefighters fighting fires. Compounds such as Carbon Monoxide, Benzene, Hydrogen Cyanide, aldehydes and particulates were found in the breathing zones of these firefighters. (Brandt-Rauf, 1988) In a more recent study by Kales, first responders, including EMS (9%), police officers (27%) and firefighters (20-23%), were found to have elevated blood pressure readings, a marker for cardiovascular disease. (Kales, 2017). Immediate dangers such as vehicular accidents, intense heat, flames, collapsing buildings and explosions are easily accountable. It is the delayed or latent effects from exposure to the gasses and fumes, as well as the stresses of being in harm's way, which are difficult to ascertain.

Fighting fires occurs in stages. The first stage called the knock down phase is the initial battle that firefighters conduct to knock down the fire, keep it from spreading and extinguish the flames. Firefighters are equipped with self-contained breathing apparatus (SCBAs) which provides clean air during overwhelming smoke conditions and are regularly used in heavy smoke conditions. The next phase, or overhaul phase begins once the flames are out. This phase includes the search of the burned structures and the removal of burned debris to make certain that they have extinguished all of the burning embers. During this phase, the amount of smoke is significantly reduced; however, there is still a measurable degree of residual smoke and fumes that contain the byproducts of combustion. (Austin, et al., 2001) Due to the lower amount of smoke at this point, firefighters tend not to wear their SCBA masks and are exposed to the remnant smoke and fumes. (Bolstad-Johnson, et al., 2000). This is considered a period of potentially great exposure to carcinogens such as free-floating asbestos particles, and irritants in smoke, such as arsenic, hydrogen cyanide and soot. (Austin, et al., 2001), and can contribute to carcinogenesis.

3.2 Methods

A computerized literature search was conducted in June of 2017 of the Medline and Embase databases for keywords: police; firefighter(s); cancer incidence; cancer registries and Standardized Incidence Rate/Ratio studies. June, 2017 was the cutoff point for this study. The search identified two peer-reviewed meta-analysis studies (Howe and Burch, 1999, LeMasters et al., 2006). The search also identified seven recent peer reviewed studies on the subject of firefighter mortality and incidence of cancer published between 2006 and 2016. Six of these seven studies were selected based upon their use of a cancer registry to obtain cancer incidence data and the presence of sufficient detail in their results reporting. One study (Ide, 2014) was excluded as the study did not involve a cancer registry, and cancer sites were not identified by SEER or ICD codes.

Since Standardized Mortality Ratio studies rely on the reviews of death certificates they can only return cancers listed as cause of death and lack the high degree of sensitivity that a Standardized Incidence Ratio study can generate in identifying cancer in worker cohorts. The use of a cancer registry was required as registries require histologic confirmation of the diagnosis. Cancer registry data are generally reported using Surveillance Epidemiology and End Results (SEER) Codes or International Classification of Diseases (ICD) codes, increasing the level of accuracy and precision in the cataloging of diseases. All six studies included SEER or ICD-10 coding of their cancer sites. The utilization of SEER and ICD-10 codes greatly reduces variability and discrepancies in cancer site analysis. This meta-analysis study was conducted to bring these individual studies together in order to increase the statistical power of identifying a relationship between firefighting and cancer, and by identifying cancer sites by codes increased the probability that the correct cancer sites were selected.

All six studies utilized a Standardized Incidence Ratio (SIR) method of determining excess cancers. The greatest strength of the SIR method is in its' greater sensitivity in identification of non-terminal cancers that are being diagnosed early, but are not captured on a death certificate, a requirement for a Standardized Mortality Odds ratio (SMOR) study. An SIR study looks at incidence of cancer as reported from a cancer registry, whereas an SMOR study identifies cancers from a death certificate. Both approaches are complex, and both require additional information such as the expected number of cancers from the regional or national populations. The observed numbers of cancers in firefighters at each organ site were divided by the expected numbers of cancers for that site based upon the regional incidence. Unfortunately, not all states maintain a cancer registry, and regional or state specific expected rates are not available in some states. The majority of cancer studies rely on a compilation of the available rates as a U.S. based population.

Six recently published cancer incidence studies in firefighters that have not been previously included in a prior meta-analysis review studies were selected and are identified in Table 3.1.

Table 3.1 Firefighter Studies Selected for Meta-Analysis

Author	Study Size (n)	Cohort Location	Period	Type
Ma (2006)	**34,796**	Florida State-Wide	1981-1999	SIR
Bates (2011)	**3,659**	California State-Wide	1988-2003	SIR
Daniels (2013)	**29,993**	Chicago, Philadelphia & San Francisco	1985-2009	SIR
Pukkala (2014)	**16,422**	5 Nordic Countries	1961-2005	SIR
Tsai (2015)	**3,996**	California State-Wide	1988-2007	SIR
Glass (2017)	**17394**	Australia	1970-2010	SIR

3.3 Statistical Analysis

There are two mathematical models for calculating a meta-analysis, fixed-effects and random-effects models. The fixed-effects model assumes that the selected studies have populations and effect sizes are more homogenous, whereas the random-effects model assumes that effect sizes vary randomly from study to study. The populations and effect sizes in a random-effects model are thought to be more heterogeneous. For this meta-analysis, the six studies were analyzed utilizing a random-effects model, as the fire companies were from different parts of the country, with one study from another country. Therefore, the study populations and results were expected to be more heterogeneous. A separate fixed-effects model meta-analysis was also conducted to identify if there were any differences between a random-effects and a fixed-effects model.

Data, including the point estimate and confidence intervals, from each of the six studies utilized information obtained from a state-based cancer registry. All six studies utilized a Standardized Incidence Ratio (SIR) method for identifying excess cancer in their populations.

The meta-Risk Ratio was calculated utilizing STATA Software (Version 14.2). Since each individual study involved samples of varying sizes, each study was weighted by using the inverse of the Standard error:

$$w = \frac{1}{SE^2}$$

The product of the individual study weights and the point estimate from each study produced the weighted Relative Risk. ("Meta Risk Ratio" is the term utilized by LeMasters, 2006)

$$\text{Meta Risk Ratio} = (RR)(w)$$

Finally, the meta Risk Ratio was calculated for each individual cancer site utilizing the following formula:

$$\text{Meta Risk Ratio} = \frac{\sum (w_v * RR) - [\sum(w * RR)]^2}{\sum w_v}$$

Confidence Intervals (CIs) were calculated using the formula:

$$CI = mRR \pm (1.96 * SE)$$

Heterogeneity was calculated using Stata 14.2. The variance was calculated first using the upper and lower confidence limits, where the lower confidence limit was subtracted from the upper confidence limit, divided by two times the Z score and then squared. The following formula was utilized for calculating variance.

$$variance_i = \left(\frac{\text{CI upper limit } - \text{ CI lower limit}}{2 * Z}\right)^2$$

Heterogeneity is then calculated by multiplying Sigma by 1 over the variance multiplied by difference in the pooled effect and the effect squared.

$$Q = \sigma_i \left\{ \left(\frac{1}{variancei}\right) * \left(effect_i - effect_{pooled}\right)^2 \right\}$$

3.4 Results

The fixed-effects analysis of the six fire fighter studies failed to identify any excess cancer overall; however, an excess of prostate cancer, with a mRR of 1.11 (95% Confidence Interval of 1.07, 1.15). was identified. The random-effects meta-analysis identified a slight excess meta-relative risk for Esophageal Cancer, mRR of 1.2; (95% Confidence Interval of 1.04, 1.36) and prostate cancer, with a mRR of 1.11 (95% Confidence Interval of 1.07, 1.15). The results from the LeMasters' study (2006) are also presented in Table 3.2 for comparison.

Table 3.2 Results of the Random Effects Meta-Analysis Studies Compared to LeMasters' Study

Meta-Analysis Cancer Site	Current mRR	Meta-Analysis 95% CI		LeMasters (2006) mRR	95% CI
Lung	0.96	0.91	1.01	1.03	(0.97-1.08)
Esophagus	**1.20**	**1.04**	**1.36**	1.16	(0.86-1.57)
Stomach	0.93	0.82	1.03	1.22	(1.04-1.44)
Bladder	1.03	0.90	1.16	1.2	(0.97-1.48)
Kidney	1.07	0.97	1.17	1.07	(0.78-1.46)
Testicular	1.09	0.92	1.27	**2.02**	**(1.30-3.13)**
Brain	0.97	0.85	1.10	**1.32**	**(1.12-1.54)**
Prostate	**1.11**	**1.07**	**1.14**	**1.28**	**(1.15-1.43)**
NHL	1.04	0.95	1.13	**1.51**	**(1.31-1.73)**
Myeloma*	0.97	0.82	1.13	Not	Done

*Only 5 studies reported multiple myeloma

LeMasters included publications from 1978 through 2001, with study periods ranging from 1925 through 1997 and were separated into incidence and mortality studies. The studies included above were from Incidence studies only.

Table 3.3 Meta-Analysis Comparing Fixed-Effects Model to LeMasters' Study to Random-Effects Model

	Fixed Effects Model		LeMasters (2006)		Random Effects Model	
Cancer Site	**mRR**	**95% CI**	**mRR**	**95% CI**	**mRR**	**95% CI**
All Sites*	**1.05***	**(1.02 - 1.06)**	Not	Done	1.01	(0.91 - 1.12)
Esophagus	**1.2**	**(1.04 - 1.36)**	1.16	(0.86 - 1.57)	1.18	(0.82 - 1.53)
Stomach	0.93	(0.82 - 1.03)	**1.22**	**(1.04 - 1.44)**	0.90	(0.71 - 1.08)
Lung	0.97	(0.91 - 1.01)	1.03	(0.97 - 1.08)	0.93	(0.79 - 1.08)
Prostate	**1.11**	**(1.07 - 1.14)**	**1.28**	**(1.15 - 1.43)**	**1.17**	**(1.07 - 1.27)**
Testicular	1.1	(0.92 - 1.27)	**2.02**	**(1.30 - 3.13)**	1.14	(0.76 - 1.52)
Kidney	1.08	(0.97 - 1.17)	1.07	(0.78 - 1.46)	1.06	(0.91 - 1.21)
Bladder	1.03	(0.96 - 1.10)	1.2	(0.97 - 1.48)	1.03	(0.90 - 1.16)
Brain	0.98	(0.85 - 1.10)	**1.32**	**(1.12 - 1.54)**	1.00	(0.74 - 1.27)
NHL	1.05	(0.95 - 1.13)	**1.51**	**(1.31 - 1.73)**	1.04	(0.95 - 1.13)
Myeloma*	0.98	(0.82 - 1.13)	Not	Done	1.03	(0.79 - 1.27)

(*Only 4 Studies were included; **Only 5 Studies were included)

Individual study results can be depicted graphically on a Forest Chart. Forest Charts place each study on a single line. The point estimates were placed relative to the number one, with the confidence intervals on either side. When the confidence intervals are greater than one, we can assume that there is a statistical significance to the point estimate. Therefore, there is a high degree of confidence that esophageal cancer is associated with firefighting. A forest plot of the results is depicted in the Figure 3.1

3.5 Analysis for Publication Bias

During the course of scientific research, epidemiologic studies were conducted on various cohorts, however, these cohorts were sometimes not large enough to wield the statistical power necessary to draw a valid conclusion. Therefore, a system was developed in order to draw a group of smaller studies together in a meta-analysis in order to increase the statistical power for the identification of harmful effects. Meta-analytic studies review the published, peer-reviewed, studies and bring as many of them together in order increase the statistical power of their observations. Unfortunately, there are several types of bias that creep into any scientific study, and in the case of meta-analytical studies, publication bias is the most dangerous. (Rothstein, 2005)

The process for conducting a meta-analysis begins with a thorough review of the literature and the identification of peer-reviewed journal articles of your cohort of interest. Due to the nature of peer-reviewed journal publications, not all studies that have been conducted may have been published. Studies that do not show a statistically positive or negative effect, supporting a clear conclusion, may never get published and would never find their way into a meta-analysis. The lack of a contrasting argument may lead to a furtherance of an incorrect conclusion, just as the inclusion of multiple negative results when included in one large study with a positive result. Therefore, a series of tests, was conducted to measure the impact of each study on the overall conclusions that are drawn from the meta-analysis.

One of the methods to check for publication bias was suggested by Eggers (1994) was to create a Funnel Plot. A funnel plot is a scatter plot of the Log Odds Ratios of each study on the horizontal (X) Axis versus a Log of the Standard Error of the Odds Ratio on the Vertical (Y) Axis.

In addition to the funnel plot, the Standard error and Coefficient can be calculated to determine the appropriateness and the weight of each of the studies. A Funnel Plot was created for each of the cancers identified, depicting the influence of each of the studies. The larger the influence that each study had on the study the higher they were on the chart. The odds ratio is depicted as the solid line; the dashed lines represent the 95% confidence intervals.

The calculations for the Egger's Test produces an intercept from zero. The greater the deviation of the intercept from zero, the more pronounced the asymmetry will appear. The calculation also includes a *p*-value of the intercept. When the *p*-value of the intercept is 0.1 or smaller, the asymmetry of the funnel plot is considered to be statistically significant.

The Appendix contains the Forest Plots and Tests for Heterogeneity for the meta-analysis using the Random-Effects Model.

3.6 Limitations

Meta-analysis studies, like many other studies, have inherent limitations that can affect the outcomes and interpretation. Having a well-defined set of inclusion and exclusion criteria, are essential to every study. Including a study in a meta-analysis that does not have well-designed study parameters can weaken the meta-analysis. Other critical components such as study start and end dates, can also influence the outcome of the original studies, and subsequently place a proportional influence on the meta-analysis as it did on the original study.

Meta-analysis studies are designed to take studies with small populations and combine them in order to increase the power and statistical significance. Conducting meta-analysis using studies conducted under dissimilar methodologies and populations may not reveal risks that are endemic to one specific population, but dilute the risks and mask the true risks facing each population.

Although the meta-analysis is designed to combine smaller studies into one larger study in the hopes of increasing the statistical power, and therefore, increasing the ability to find correlations, there are limits. A meta-analysis can only be as good as the studies included in the analysis. Including studies that are themselves statistically inaccurate may lead to a cascade of inaccuracies when amplified through a meta-analysis. The failure of studies to be published that do not support or refute other studies, i.e. publication bias may interfere with the true results and hence, render inaccurate conclusions.

Furthermore, confounders include the environmental conditions experienced by the various fire departments throughout the country. The six studies included firefighters from California, Washington State, Illinois, Pennsylvania and Florida. Each fire company would have experienced widely variable environmental exposures from the different building materials encountered. Social activities, such as smoking and excessive alcoholic consumption, may also have a confounding effect.

3.7 Conclusions

This study looked at six recently published journal articles, all six were Standardized Incidence Ratio Studies of cancer in firefighters. The results of this meta-analysis demonstrated that firefighters have a slight statistically increased excess of prostate cancer and Non-Hodgkin's Lymphoma (NHL).

The majority of the studies include firefighters from an entire state, either California, Florida, or Massachusetts. Two studies, Daniels, (2013) included firefighters from three states, but of importance, from three geographically diverse urban areas, and Glass (2015) included firefighters from another country, Australia. Firefighters from one state may each face similar environmental exposures, and even similar smoke and soot exposures from fires, due to the predominant building materials common to their countries, states and even municipalities. Therefore, although firefighters from one area to another may demonstrate excess cancers of one type or another due to their local exposures, combining them into a meta-analysis may actually dilute the excess to a point where it cannot be identified. Additional studies will need to be conducted whereby we can follow individual local cohorts of firefighters across longer periods of time.

CHAPTER 4

METHODOLOGY

4.1 Introduction

There are several methods available to researchers and epidemiologists to evaluate morbidity and mortality in workers. Calculating the Standardized Incidence Ratio (SIR) is one such method and an excellent method for identifying incidence of diseases, such as cancer, in specific workplace cohorts. Standardized Incidence Ratios take the observed number of cases in a cohort and compare them to expected number of cases in the same population. In occupational epidemiological research, the observed number of cases in a given cohort are divide it by the number of cases in which that cohort resides. The current research identified one cohort of firefighters and one of police officers from each of the four largest municipalities in New Jersey and calculated the standardized incidence ratio by dividing the observed cases by the expected number of cases of the U.S. General Population. This chapter will present the methods regarding study design, IRB approval, study subject protection, identifying and obtaining cohort information, and the transfer of data between New Jersey's Division of Pensions and Benefits (NJDP&B) to the New Jersey State Cancer Registry (NJSCR) for linkage and identification of cancer cases.

4.2 Study Sites

Data analysis was conducted at the Rutgers University, School of Public Health, Department of Environmental and Occupational Health, Piscataway, NJ; the Rutgers University Environmental and Occupational Health Sciences Institute (EOHSI), Piscataway, NJ; and the New Jersey Cancer Registry (NJSCR), New Brunswick, NJ.

4.3 Sample Size Justification

This is an occupational epidemiology surveillance study of municipal firefighters and police officers employed in Newark, Jersey City, Paterson and Elizabeth, NJ. The number of firefighters and police officers that met the inclusion and exclusion criteria determined the actual size of the study population.

4.4 Study Subject Protection and Institutional Review Board (IRB) Oversight

The Rutgers University Institutional Review Board (IRB), New Brunswick, NJ provided study subject protection and protocol oversight.

All studies involving the use of the NJ State Cancer Registry must submit their protocols to the NJSCR Scientific Review Board (SRB) for review and approval prior to submission to the Rutgers University IRB. The NJSCR SRB reviewed and approved this study in October of 2014.

The Protocol was then submitted for review in November of 2014 to the Rutgers University IRB, and received expedited approval in February of 2015. The IRB study number is Pro20140000746. The Protocol, Version 2, was submitted for continuing review in November of 2015. The Rutgers University IRB granted a one-year continuation of their approval in February of 2016, and again in February of 2017.

4.5 Informed Consent Procedures

The analysis involved data analysis and no contact or identification of individual subjects. Neither obtaining informed consent, nor using an Informed Consent Form (ICF), was required for the firefighters or police officers. The Rutgers University Institutional Review

Board (IRB) granted a waiver of the requirement for obtaining informed consent as per the Code of Federal Regulations 45 CFR 46.116(d), as the following four conditions were met:

(a) the research involved no more than minimal risk to the subjects;

(b) the waiver did not adversely affect the rights and welfare of the subjects;

(c) the research could not practicably be carried out without the waiver; and

(d) the subjects will be provided with additional pertinent information after participation

Furthermore, it would not be practical to obtain an informed consent on these study subjects since this is an occupational epidemiology study involving large numbers of municipal firefighters and police officers exposed to chemical fumes and hazards. It would not be in the best public health interests of those exposed or at-risk individuals to include only those individuals for which we can identify vital status, location and/or their current employer and obtain an informed consent.

4.6 Study Subject Selection and Enrollment

The fire companies and police departments from the four largest municipalities in New Jersey were chosen as they had large numbers of professional public safety workers.

Police officers from each of the firefighter cohort's respective municipalities were also selected in order to conduct a separate SIR analysis to examine if police officers in the same cities, that have experiences in similar historic environmental conditions for similar amounts of time, but limited exposures to fire byproducts of fumes and soot, would exhibit similar incidences of cancer.

4.7 Inclusion Criteria

This study population was defined as those municipal firefighters and police officers that were employed as paid municipal firefighters or police officers in Newark, Jersey City, Paterson and Elizabeth, NJ, working for at least one month, between April 1, 1980 and March 31, 2011.

A request was made of the New Jersey Division of Pensions and Benefits (NJDP&B) for a listing of all firefighters and police officers that were working for at least one month between April 1, 1980 and March 31, 2011, regardless of hire or retirement date.

NJDP&B could not identify any individual by Race; and unless an individual was diagnosed with cancer and linked in the New Jersey State Cancer Registry, Race could not be identified as a variable. Consequently, African-American male employees were included in the analysis along with white males and all males of other Races.

The data listing obtained from the NJP&B also identified the municipality of employment. The municipality identification allowed us to separate the master listing into eight cohorts two from each municipality.

4.8 Exclusion Criteria

This study did not include subjects under the age of 18, as 18 is the minimum age to become a firefighter or police officer in New Jersey. Volunteer firefighters, and volunteer police officers, were not included in this study.

Female employees were excluded from the analysis as there were too few women to provide a statistical significance to the analysis, and could confound the analysis.

The New Jersey Division of Pensions and Benefits provided a listing of employees that were employed during this time, but did not know if any of them had a diagnosis of cancer. When the NJSCR identified produced the linkage, there were a number of employees that were employed during the 30-year study period, but had a diagnosis of cancer prior to their employment start dates, n = 11, (0.06%) and were completely excluded. Employees that started their employment after the end of the inclusion period March 31, 2011, (n= 573, 6.9%) were similarly excluded from the study. None of the above excluded individuals had their diagnosis or PYAR included in the analysis.

4.9 The New Jersey State Cancer Registry

New Jersey State Cancer Registry (NJSCR) is operated by the New Jersey Department of Health, Cancer Epidemiology Services in conjunction with the New Jersey State Cancer Center of the Rutgers University Biomedical and Health Sciences.

Since October of 1979, the NJSCR has received notification of any diagnosis of cancer in New Jersey, and maintains a computerized database of diagnosed neoplastic conditions. Any individual diagnosed with cancer in New Jersey since 1979 would find their name, date of birth, Social Security number, type of cancer and date of diagnosis on file with this Registry. The Registry also attempts to follow these individuals, even when they relocate out of state, to record additional diagnosis of cancer occur after relocation.

For this study, the New Jersey State Cancer Registry ran a probabilistic search between our list of firefighters and police officers and their database. Probabilistic searches use more than one piece of an individual's information (names, birth dates and last four numbers of the social security number) to match an individual's identity to the Cancer

Registry's list. This results in a high degree of certainty that the individual from the cohort is the individual diagnosed with cancer.

Officials from the New Jersey Division of Pensions and Benefits supervised and directed the collection of the data from their official personnel records and the submission of the encrypted files to the NJSCR.

The Linkages from the NJSCR were provided to the School of Public Health (SPH) in a de-identified fashion. The NJSCR created unique study subject identifying numbers, generated at random, to identify each study subject cancer while still providing important information such as age at diagnosis and length of time in service before diagnosis for each cancer. No individual subject's personal identity was revealed with respect to their respective cancer diagnosis.

The data set from the NJDP&B included last name, first name, middle initial, the last four numbers of the social security number, and gender as depicted in Column A of Table 4.3. The information from NJDP&B was reviewed by the NJSCR and a linkage of the names to cancer diagnosis was made based upon the information in Column B of Table 4.3 for possible errors, such as returning two or more different individuals with similar names. They then created an analytic file for SPH investigators which included the information in Column C of Table 4.3

The NJSCR reported cancer incidence information utilizing the International Classification of Diseases for Oncology, Revision 3 (ICD-O-3) codes. These codes, published by the World Health Organization, provide a uniform numerical system for physicians and cancer registries to accurately describe each specific cancer diagnosis utilizing four categories, primary site; cellular histology; behavior, and sequence. The

NIOSH LTAS reference population data was written using ICD-O-10 codes, which presents the four ICD-O-3 categories in a single three and sometimes a four-digit number. The NJSCR data was converted from the ICD-O-3 format to the ICD-O-10 format in order for the LTAS program to match the cases to the reference population.

Table 4.1 Concordance Table Listing Variables Supplied by the NJDP&B and NJSCR

NJDP&B Provided Data	NJSCR Matched	NJSCR Provided for Analysis
First Name	First Name	
Middle Initial	Middle Initial	
Last Name	Last Name	
SSN (last 4)	SSN (last 4)	
Gender	Gender	Gender
Department (Fire/Pol)		Department (Fire/Pol)
Municipality		Municipality
Enrollment date		Enrollment Date
Withdraw/retire date		Withdraw/Retire Date
		Year of Death
		Year of Birth
		Primary Cancer Site
		Date of Diagnosis
		Histologic Type
		Behavior Code
		Cancer Sequence
		Age at Diagnosis
		County Residence at Dx
		Vital Status (Dead or Alive)
		Last Contact Date
		State of Death
		Race
		Randomized/Unique Subject ID

4.10 Statistical Analysis

The analysis of the firefighter and police officer cohorts was carried out utilizing a Standardized Incidence Ratio (SIR) method as defined by Breslow and Day (1987). Calculations were conducted using the computer system Life Table Analysis (LTAS) provided by National Institutes for Occupational Safety and Health (NIOSH) and the Centers for Disease Control and Prevention (CDC). The expected number of cancers for the U.S. General Population was also provided by NIOSH.

The first step in calculating the SIR is the calculation of the Person Years at Risk.

4.11 Person Years at Risk (PYAR)

In conducting a Standardized Incidence Study, conducted over an extended period of time, individual study subjects will enter and leave the study population at different times. (Subjects enter the study when they begin employment, leave when they develop a cancer, die from other causes, or become lost to follow-up.) In order to account for the time that these individuals spend in the exposed pool, a weight needs to be calculated and added to the number of observed and expected cases. This weight compensates for those individuals that spend less time at risk than others that are in the study for longer periods and is known as the Person Years at Risk (PYAR). Similarly, the expected number of cases in the reference population also has to be weighted as these individuals also move through time and are diagnosed at different times. The PYAR should not be confused as a surrogate measure for exposure, all firefighters are considered exposed.

The NJSCR started collecting individual cancer incidence data beginning on October 1, 1979. Prior to this date there were no data available on individual cancer cases in New Jersey. Since the observable cancer cases did not exist before 1979, the start date for calculating the PYAR in the firefighter cohort started in 1979, which is the year that the first cancer cases were identified in the police cohort. The first cancer case for firefighters was identified in 1981; therefore, the PYAR for firefighters was calculated beginning in January of 1981. All police officers hired after 1979 had their PYAR start date set to their date of enrollment into the New Jersey Pension Program.

The start date of the PYAR was calculated from one of two start dates; for those employees that were employed prior to October 1, 1979, the PYAR was calculated from January 1, 1981 for firefighters and January 1, 1979 for police officers. For those employees that started working after these dates, the date of enrollment in to the NJ Pension Plan, was used as the start date for the PYAR. The PYAR was calculated through to the date of the first diagnosis of a malignancy, or the date of last observation, or death, whichever came first. The PYAR for second and subsequent diagnosis was calculated from the date of the first diagnosis through to the diagnosis of the second cancer. The PYAR for the third diagnosis was calculated from the date of the second diagnosis to the date of the third, and so on for the fourth diagnosis.

Study data was transferred from the New Jersey Division of Pensions and Benefits in March of 2016. The study end date, Date of Last Observation (DLO) was set to December 31, 2015. All employees that were not diagnosed with cancer or identified as deceased had a date of last observation (DLO) assigned as December 31, 2015. All employees identified as alive on the Date of Last Observation had their PYAR calculated out from their eligibility date to the DLO.

At its basic, the SIR is the number of observed events divided by the number of expected events as described below.

$$\text{SIR} = \frac{\text{Observed}}{\text{Expected}}$$

An SIR is calculated by dividing the observed events by the expected. The number of observed and expected events need to be standardized using the same weight, in this case, the Person Years at Risk (PYAR). Each cohort will be divided into strata of five-year age groups by year across their lifetimes, and i is used as the index for the strata, with A_i as the number of observed cancer incidence in that stratum, and T_i the Person Years At Risk in that stratum. For each cohort, the Standardized Rate is calculated using the following formula:

$$\mathrm{SR}_{\mathrm{cohort}} = \frac{\sum_i T_i \frac{A_i}{T_i}}{\sum_i T_i}$$

* obtained from the LTAS Manual

The Standardized Incidence Rates for the reference population is calculated by also utilizing the PYAR as Ti, and introducing a new value, R, set to the cancer incidence rate of the reference population, and is expressed as:

$$\mathrm{SR}_{\mathrm{ref}} = \frac{\sum_i T_i R_i}{\sum_i T_i}$$

* obtained from the LTAS Manual

$$\mathrm{SMR} = \frac{\mathrm{SR}_{\mathrm{cohort}}}{\mathrm{SR}_{\mathrm{ref}}} = \frac{\sum_i A_i}{\sum T_i R_i} = \frac{D}{E}$$

* obtained from the LTAS Manual

The Standardized Incidence Ratio was conducted utilizing the LTAS program by NIOSH/CDC. Since the program was initially designed to calculate standardized Mortality Rates (SMRs), an adaption to calculate the SIR was made, replacing observed and expected deaths with observed and expected incidence of cancer. This method had been utilized previously by Daniels in 2013. The resulting formula remains the same, except that SMR is replaced with SIR as noted below:

$$\boxed{\text{SIR}} = \frac{\text{SR}_{\text{cohort}}}{\text{SR}_{\text{ref}}} = \frac{\sum_i A_i}{\sum_i T_i R_i} = \frac{D}{E}$$

* obtained from the LTAS Manual

The confidence intervals are then calculated using the Standardized Rate Ratio (SRR) in the formula below:

$$CI(\text{SRR}_{\text{b vs a}}) = exp\left(ln(\text{SRR}_{\text{b vs a}}) \pm Z_{\alpha/2}\sqrt{var[ln(\text{SRR}_{\text{b vs a}})]}\right)$$

* obtained from the LTAS Manual

4.12 Data Collection and Records Retention

All the data file transfers between the NJDP&B and the NJSCR were accomplished via a secure encrypted method. Personally identifiable information, such as names, dates of birth and the last four numbers of the social security numbers were used by authorized New Jersey Division of Pensions and Benefits, and New Jersey State Cancer Registry staff. NJDP&B has regular access to this information in the course of their regular daily operations. NJSCR was given the minimum personally identifiable information in order to search their data base and identify cancer cases.

The data file will only be used for this specific research project and the data linkages will be destroyed immediately after the study is completed, according to NJSCR protocols.

The results of the data linkages and analysis are discussed in detail in Chapters 5.

CHAPTER 5

A 30-YEAR STUDY OF CANCER INCIDENCE IN FIREFIGHTERS AND POLICE OFFICERS FROM NEW JERSEY'S FOUR LARGEST MUNICIPALITIES

5.1 Introduction

Multiple cancer incidence studies have identified elevated cancer rates among firefighters (Ma, 2006; Ide, 2014; Pukkala, 2014; and Glass, 2017). There are almost no cancer incidence studies of police officers, except for Feuer and Rosenman, 1986. Feuer and Rosenman (1986) examined the Standardized Mortality Ratio (SMR) of New Jersey firefighters and police officers for a six-year period, 1974 to 1980 and did not identify any increase in cancer incidence in either firefighters or police officers.

The Standardized Incidence Ratio (SIR) is one method of determining cancer incidence among a given population. Once a cohort is identified, and the number of cancer cases are enumerated, that number can be compared to a local or national reference base for an accurate depiction of the cancer incidence. The SIR method relies heavily on three key time points. First, the method requires the year of diagnosis for each subject, as the incidence of cancer changes over time. The age of the subject at the time of diagnosis is a second requirement, as the analysis is age adjusted, and requires the age of the subject at diagnosis in order to age-adjust the analysis. Finally, the analysis requires the amount of time, in person years, that each subject is exposed to the environmental hazard in question. Fore firefighters and police officers, the amount of time that they spend on the job will count as their time of exposure.

SIRs are not well adapted to compare cancer incidence between two or more cohorts, as the studies are weighted based upon the age distribution and year of diagnosis of cancer in the cohorts. (Rothman, 1986). For this study, the SIR was calculated separately for each cohort. An odds ratio between the two cohorts was not conducted.

5.2 Methods

Although most firefighters in the smaller towns in New Jersey are volunteers, the larger cities have paid, professional companies, and all are enrolled in the New Jersey Division of Pension and Benefits, New Jersey State Pension System.

A listing of 9,618 firefighters and police officers with unique personal identifiers, but without a race identifier, was forwarded directly from the New Jersey Division of Pensions and Benefits to the New Jersey State Cancer Registry. The New Jersey State Cancer Registry linked this list to their data base and identified 1,660 cases of primary-site malignant neoplasm, including cancer in situ, solid and non-solid tumors, as well as multiple cancers in some individuals. The remaining 8,288 persons had no matches, or no known diagnosis of cancer.

The NJSCR reported cancer incidence information utilizing the International Classification of Diseases for Oncology, Revision 3 (ICD-O-3) codes. These codes, published by the World Health Organization, provide a uniform numerical system for physicians and cancer registries to accurately describe each specific cancer diagnosis utilizing four categories, primary site; cellular histology; behavior, and sequence. The NIOSH LTAS reference population data was written using ICD-O-10 codes, which presents the four ICD-O-3 categories in a single three and sometimes a four-digit number. The NJSCR data was converted from the ICD-O-3 format to the ICD-O-10 format in order for the LTAS program to match the cases to the reference population.

Table 5.1 Listing of Variables Supplied by the NJDP&B and NJSCR

NJDP&B Provided	NJSCR Matched	NJSCR Provided for Analysis
First Name	First Name	
Middle Initial	Middle Initial	
Last Name	Last Name	
SSN (last 4)	SSN (last 4)	
Gender	Gender	Gender
Department (Fire/Pol)		Department (Fire/Pol)
Municipality		Municipality
Enrollment date		Enrollment Date
Withdraw/retire date		Withdraw/Retire Date
		Year of Death
		Year of Birth
		Primary Cancer Site
		Date of Diagnosis
		Histologic Type
		Behavior Code
		Cancer Sequence
		Age at Diagnosis
		County Residence at Diagnosis
		Vital Status (Dead or Alive)
		Last Contact Date
		State of Death
		Race
		Randomized/Unique Subject ID

5.2 Study Subject Protection

This study was approved by the Rutgers University IRB. No persons other than the employees from the NJDP&B and the NJSCR had access to personal identifiers.

5.2.1 Inclusions and Exclusion Criteria

Cancer has different incidence rates based upon such variables as gender, race and ethnicity. 765 of the cancer cases were in firefighters and 895 were in police officers.

Race and Ethnicity

139 of the 1,660 (8.4%) reported cancers were in African-American employees. (n =139, n = 28 firefighters; n = 111 police officers). Race and ethnicity is not a variable that could be provided by NJDP&B. Race and ethnicity information could only be provided by the NJSCR as this information is collected by the registry.) Therefore, since race and ethnicity information was not available for the non-cancerous cases, race and ethnicity was not used as a variable for the analysis; the Standardized Incidence Ratio was conducted on males, all races and all ethnicities

Gender

There were too few female firefighters and police officers to analyze separately, this study focused on male employees only. 17 female study subjects were removed from the 1,660 overall number of cancers reported, and did not contribute any person Years at risk.

Excluded Cases

Ten cases of cancer (6 firefighters and 4 police officers) were diagnosed prior to the date of employment and six cases (2 firefighters and 4 police officers) were duplicate cancers, same subject, diagnosis and date of diagnosis, and were also excluded. The individuals themselves, as well as the corresponding Person Years At Risk, were excluded from the analysis. Once the excluded cases were eliminated a total of 1,633 (n = 1,633) cases were left for evaluation; 758 cases in the firefighter cohort and 875 cases in the police officer cohort.

Table 5.2 Number of Subjects Failing to Meet Inclusion Criteria

Exclusion	**Fire Fighters**	**Police Officers**	**Totals**
Female Employees	21	480	501
Predate & Out of Window	339	205	540
Total Excluded	**364**	**685**	**1,049**

5.2.2 Breakdown of Employees without Cancer

The New Jersey State Cancer Registry identified a total of 8,828 employees with no reported records of cancer: 3,355 firefighters and 4,448 police officers. 485 (6%) female employees (21 firefighters and 464 police officers) were excluded from this analysis.

From this listing the employee start dates were reviewed for inclusion criteria. 570 employees (336 firefighters and 234 police officers) were included in the listing that were employed after April 1, 2011 and were excluded, leaving 3,019 firefighters and 4,247 police officers in the final non-cancer population. The number of excluded employees is presented in Table 5.2. A flow chart of the exclusion process is presented in Figure 5.1.

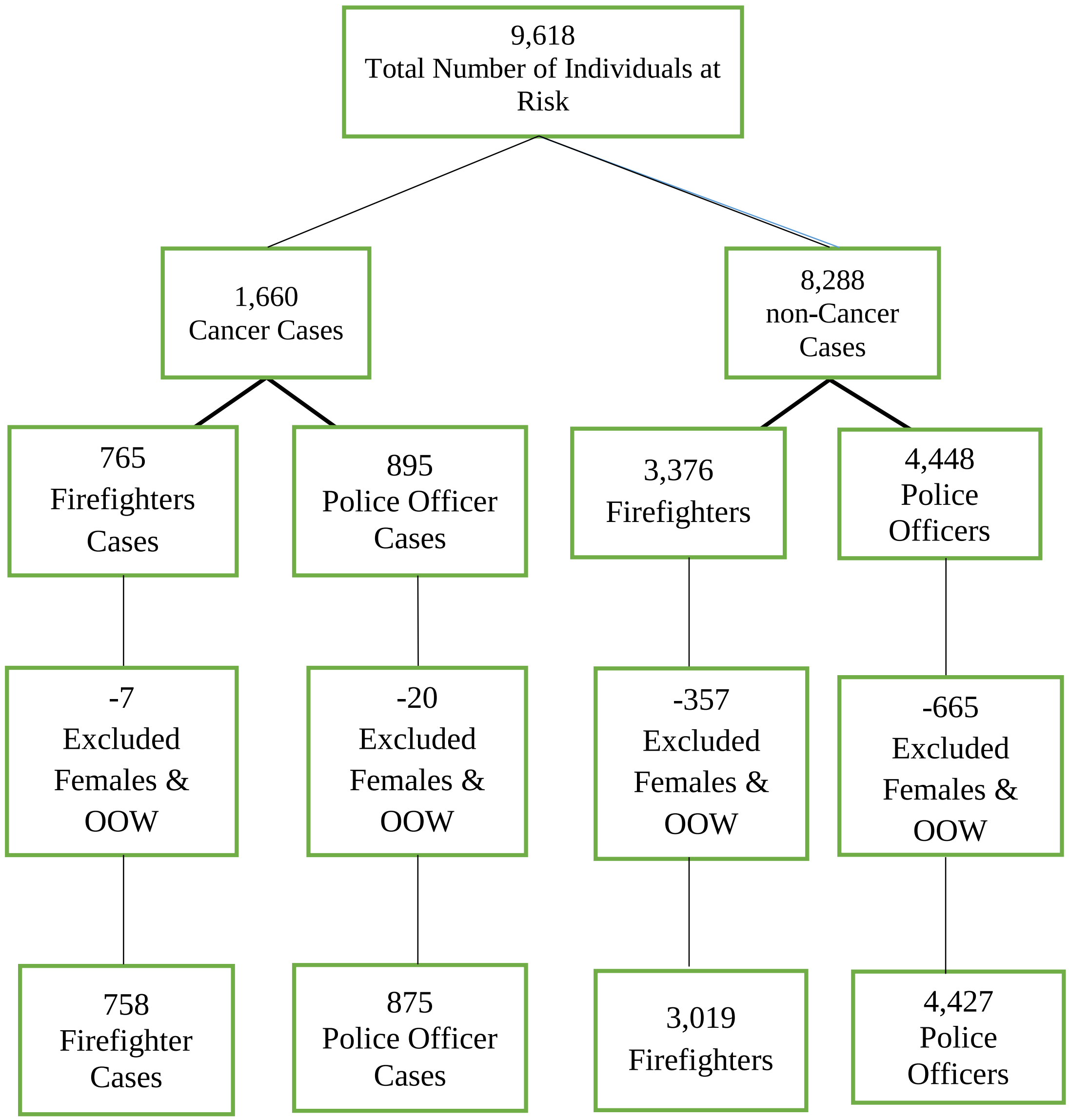

Figure 5.1 Study Population: Flow chart representing the breakdown of the Total Population N= 9,618 as per the inclusion and exclusion criteria. OOW= Out of Window.

5.3 Statistical Analysis

The analysis of the firefighter and police officer cohorts was carried out utilizing a Standardized Incidence Ratio (SIR) method as defined by Breslow and Day (1987). Calculations were conducted using the computer system Life Table Analysis (LTAS) provided by National Institutes for Occupational Safety and Health (NIOSH) and the Centers for Disease Control and Prevention (CDC) as demonstrated by Daniels, et al. (2013).

5.3.1 Persons Years at Risk (PYAR)

This Standardized Incidence Study was conducted over an extended period of time, individual study subjects entered and left the study at different times. (Subjects enter the study when they began employment, leave when they develop a cancer, die from other causes, or become lost to follow-up.) In order to account for the time that these individuals are considered exposed, i.e., are from the start of their employment until the end of the study period, a weight was added to the number of observed and expected cases. This weight compensated for those individuals that spend less time at risk than others that are in the study for longer periods, this weight is known as the Person Years at Risk (PYAR). Similarly, the expected number of cases in the reference population also has to be weighted as these individuals also move through time and are diagnosed at different times. The PYAR should not be confused as a measure for a specific length of time on the job, as all firefighters and police officers are considered exposed.

Cancer registries have a start date from which they began collecting cancer data, and is known as the Date of Ascertainment. The Date of Ascertainment for the NJ State Cancer Registry, the date they started collecting individual cancer incidence data, was October 1, 1979. Prior to this date there were no data available on individual cancer cases in New Jersey. Since the observable cancer cases did not exist before 1979, the calculation for the PYAR was not started until 1979, more accurately, until the year that the first cancer cases were identified for cohort. The first cancer case for firefighters was identified in 1981, and for police officers 1979; therefore, the PYAR was calculated from January 1, 1981 for firefighters, and January 1, 1979, for police officers, hired before 1979.

All employees hired after 1979 had their PYAR start date set to their date of enrollment into the New Jersey Pension Program, which was used as the first date for the PYAR. Only employees that were enrolled into the New Jersey State Pension Plan prior to March 31, 2011 were enrolled into this study

The end point of the PYAR was calculated from one of the two start dates; for those employees that were employed prior to October 1, 1979, the PYAR was calculated from January 1, 1980 for firefighters and January 1, 1979 for police officers. For those employees that started working after these dates, the date of enrollment in to the NJ Pension Plan, was used as the start date for the PYAR. The PYAR was calculated through to the date of the last employment, date of first diagnosis of a malignancy, or the date of last observation, or death, whichever came first. The PYAR for second and subsequent diagnosis was calculated from the date of the first diagnosis through to the diagnosis of the second cancer. The PYAR for the third diagnosis was calculated from the date of the second diagnosis to the date of the third, and so on for the fourth diagnosis.

Study data was transferred from the New Jersey Division of Pensions and Benefits in March of 2016. The study end date, Date of Last Observation was set to December 31, 2015. All employees that were not diagnosed with cancer or identified as deceased had a date of last observation (DLO) assigned as December 31, 2015. All employees identified as alive on the Date of Last Observation had their PYAR calculated out from their eligibility date to the DLO.

The start date for each employee was then subtracted from the end date of each employee (n = 8,600) providing a PYAR for each cohort. The PYAR was found to be 97,295 person-years for firefighters and 139,159 person-years for police officers, for a combined total of 236,454 person-years. The results are depicted in Table 5.3.

Table 5.3 Person Years At Risk (PYAR)

Cohort	Start Date	First Diagnosis	PYAR
Fire Fighters	1/1/1981	1/20/1981	97,295
Police Officers	1/1/1979	3/19/1979	139,159
Total			**236,454**

At its' basic, the SIR is the number of observed events divided by the number of expected events as described below.

$$\text{SIR} = \frac{\text{Observed}}{\text{Expected}}$$

In order to calculate an SIR, and to account for the change in cancer incidence over time, it is not sufficient to simply divide the observed events by the expected. The number of observed and expected events need to be standardized using the same weight, in this case, the Person Years at Risk (PYAR). The PYAR will be calculated for each cohort and utilized as a weight in order to standardize the rates. Each cohort will be divided into strata of five-year age groups across their lifetimes, and is used as the index for the strata, with A_i as the number of observed cancer incident cases in that stratum, and T_i the Person Years At Risk in that stratum. For each cohort, the Standardized Rate is calculated using the following formula:

$$\mathrm{SR}_{\mathrm{cohort}} = \frac{\sum_i T_i \frac{A_i}{T_i}}{\sum_i T_i}$$

* obtained from the LTAS Manual

The Standardized Incidence Rates for the reference population is calculated by also utilizing the PYAR as Ti, and introducing a new value, R, set to the cancer incidence rate of the reference population, and is expressed as:

$$\mathrm{SR}_{\mathrm{ref}} = \frac{\sum_i T_i R_i}{\sum_i T_i}$$

* obtained from the LTAS Manual

Once the standardized rates are set, the SIR is calculated utilizing the following:

$$\mathrm{SMR} = \frac{\mathrm{SR}_{\mathrm{cohort}}}{\mathrm{SR}_{\mathrm{ref}}} = \frac{\sum_i A_i}{\sum T_i R_i} = \frac{D}{E}$$

* obtained from the LTAS Manual

The Standardized Incidence Ratio was conducted utilizing the LTAS program by NIOSH/CDC. Since the program was initially designed to calculate standardized Mortality Rates (SMRs), an adaption to calculate the SIR was made, replacing observed and expected deaths with observed and expected incidence of cancer. This method had been utilized previously by Daniels (2013). The resulting formula remains the same, except that SMR is replaced with SIR as noted below:

$$\boxed{\text{SIR}} = \frac{\text{SR}_{\text{cohort}}}{\text{SR}_{\text{ref}}} = \frac{\sum_i A_i}{\sum_i T_i R_i} = \frac{D}{E}$$

* obtained from the LTAS Manual

The confidence intervals are then calculated using the Standardized Rate Ratio (SRR) in the formula below:

$$CI(\text{SRR}_{\text{b vs a}}) = exp\left(ln(\text{SRR}_{\text{b vs a}}) \pm Z_{\alpha/2}\sqrt{var[ln(\text{SRR}_{\text{b vs a}})]}\right)$$

* obtained from the LTAS Manual

The reference rate data for the U.S General Population was obtained from the National Institutes of Safety and Health (NIOSH).

5.4 Results

The study examined 8,600 employees, 3,630 firefighters and 4,970 police officers. After exclusions described above, 611 firefighters and 723 police officers were diagnosed with at least one malignant cancer. There were 3,019 firefighters and 4,247 police officers with no diagnosis of any cancer.

The calculation of the Person Years at Risk was conducted utilizing the LTAS system. The start dates were based on the date of the first reported cancer for that cohort and are depicted in Table 5.4.

The final number of cancer cases returned by LTAS was 723 firefighters and 832 police officers. There were 139 employees with more than one cancer, multiple primaries, and not metastatic disease. Each individual was considered only once, but each cancer contributed to the site-specific SIR.

The Standardized Incidence Ratios for firefighters was calculated utilizing the LTAS computer system. For firefighters, the total number of observed cancers was 723 over an expected number of 1,003.91; this yielded an overall SIR for All Cancers of 0.72; (95% Confidence Interval of 0.67, 0.77). For police officers, the total number of observed cancers was 832 over an expected number of 1,088.14; this yielded an overall SIR for All Cancers of 0.76; (95% Confidence Interval of 0.71, 0.82).

The LTAS system returned an SIR for 44 different types of cancers in firefighters and 46 in police officers. The Standardized Incidence Ratios can be found in Table 5.4 for firefighters and 5.5 for police officers.

In order to further protect the identities of study subjects, specific cancers with fewer than five cancers identified were not reported.

Table 5.4 Cancers Diagnosed in Firefighters

Cancer Site	Observed	Expected	SIR	95% CI Lower	Upper
All Causes (41 Base)	723	1,003.9	0.72 **	0.67	0.77
Buccal & Pharynx	19	32.8	0.58 *	0.35	0.90
Lip	<5				
Tongue	<5				
Other Buccal	8	9.9	0.81	0.35	1.59
Pharynx	6	10.7	0.56	0.20	1.21
Colorectal	71	106.2	0.67 **	0.52	0.84
Large Intestine	44	72.4	0.61 **	0.44	0.82
Rectum	27	33.7	0.80	0.53	1.16
Digestive & Peritoneum Excluding Colorectal	61	81.3	0.75 *	0.57	0.96
Esophagus	<5				
Stomach	21	18.6	1.12	0.70	1.72
Small Intestine	<5				
& Gall Bladder	12	17.7	0.68	0.35	1.18
Pancreas	19	23.2	0.82	0.49	1.28
Peritoneum, & Other Unspecified	<5				
Respiratory & Intra-Thoracic Organs	119	180.2	0.66 **	0.55	0.79
Larynx	13	15.1	0.86	0.46	1.46
Trachea, Bronchus, Lung	105	162.4	0.65 **	0.53	0.78
Other Respiratory	<5				
Breast (Male)	<5				
Male Genital Organs	203	288.8	0.70 **	0.61	0.81
Prostate	198	278.8	0.71 **	0.61	0.82
Testes	<5				
Other Male Genital	<5				
Urinary	104	105.6	0.98	0.80	1.19
Kidney	32	33.9	0.94	0.64	1.33
Bladder & Other Urinary	72	71.7	1.00	0.79	1.27
Endocrine	5				
Thyroid	5				
Other Solid Tumors	60	79.1	0.76 *	0.58	0.98
Melanoma (Skin)	35	46.5	0.75	0.52	1.05
Melanoma ***in situ***	16				
Mesothelioma	6	3.9	1.55	0.57	3.37
Connective	6	5.5	1.10	0.40	2.39
Brain & Other Nervous	6	14.3	0.42 *	0.15	0.91
Eye	7	1.81	3.80 **	1.53	7.82
Lymphatic & Hematopoietic	71	95.24	0.75 *	0.58	0.94
Hodgkin's Disease	<5				
Non-Hodgkin's Lymphoma (NHL)	33	43.66	0.76	0.52	1.06
Multiple Myeloma	6	11.98	0.50	0.18	1.09
Leukemia	20	26.34	0.76	0.46	1.17
Other Lympho-Hematopoietic	9	8.044	1.12	0.51	2.12
Ill-Specified & Residual	9	24.28	0.37 **	0.17	0.70

* Two-Sided P <0.05 ** Two-Sided P < 0.01

Table 5.5 Cancers Diagnosed in Police Officers

Cancer Site	**Observed**	**Expected**	**SIR**	**95% CI Lower Upper**
All Causes (41 Base)	832	1076.94	0.77 **	0.72 - 0.83
Buccal & Pharynx	15	37.25	0.40 **	0.23 - 0.66
Colorectal	104	111.42	0.93	0.76 - 1.13
Large Intestine	68	74.97	0.91	0.70 - 1.15
Rectum	36	36.45	0.99	0.69 - 1.37
Digestive Peritoneum excluding Colorectal	68	89.69	0.76 *	0.59 - 0.96
Respiratory & Intrathoracic Organs	134	189.30	0.71 **	0.59 - 0.84
Larynx	13	16.58	0.78	0.42 - 1.34
Trachea, Bronchus, Lung	116	169.85	0.68 **	0.56 - 0.82
Other Respiratory	5	2.79	1.79	0.58 - 4.18
Male Genital Organs	254	314.27	0.81 **	0.71 - 0.91
Prostate	246	302.79	0.81 **	0.71 - 0.92
Urinary	102	109.32	0.93	0.76 - 1.13
Kidney	36	37.86	0.95	0.67 - 1.32
Bladder & Other	66	71.46	0.92	0.71 - 1.18
Other Solid Cancers	49	87.29	0.56 **	0.42 - 0.74
Melanoma	25	51.15	0.49 **	0.32 0.72
Melanoma ***in situ***	19			
Mesothelioma	<5	3.77	0.8	0.16 - 2.33
Connective Tissue	8	5.97	1.34	0.58 - 2.64
Brain & Other Nervous System	10	15.77	0.63	0.30 - 1.17
Eye	<5			
Lymphatic & Hematopoietic	81	101.22	0.80 *	0.64 - 0.99
Hodgkin's disease	5	5.62	0.89	0.29 - 2.08
Non-Hodgkin's Lymphoma (NHL)	37	47.48	0.78	0.55 - 1.07
Multiple Myeloma	8	12.93	0.62	0.27 - 1.22
Leukemia	20	27.12	0.74	0.45 - 1.14
Other Lympho-Hematopoietic	11	8.07	1.36	0.68 - 2.44
Ill-specified & Residual	17	25.03	0.68	0.40 - 1.09

* Two-Sided P <0.05 ** Two-Sided P < 0.01

The number of cancer cases diagnosed by year in firefighters and police officers is presented in Table 5.6.

Table 5.6 Number of Cancer Cases Diagnosed by Year

Year of Diagnosis	Fire Fighters	Percent	Police Officers	Percent
1979	0	0	4	0.48
1980	0	0	4	0.48
1981	2	0.28	2	0.24
1982	3	0.41	2	0.24
1983	6	0.83	6	0.72
1984	6	0.83	9	1.08
1985	6	0.83	6	0.72
1986	10	1.38	8	0.96
1987	16	2.21	12	1.44
1988	13	1.8	19	2.27
1989	15	2.07	19	2.27
1990	12	1.66	12	1.42
1991	20	2.77	25	3
1992	18	2.49	19	2.28
1993	29	4.01	19	2.28
1994	20	2.77	25	3
1995	25	3.46	27	3.24
1996	30	4.15	26	3.12
1997	30	4.15	32	4.08
1998	22	3.04	36	4.32
1999	19	2.63	34	4.08
2000	23	3.18	29	3.48
2001	31	4.29	27	3.24
2002	27	3.73	44	5.28
2003	33	4.56	36	4.3
2004	38	5.26	44	5.28
2005	31	4.29	27	3.24
2006	29	4.01	40	4.8
2007	29	4.01	31	3.7
2008	23	3.18	38	4.56
2009	27	3.73	30	3.6
2010	28	3.87	24	2.88
2011	48	6.65	43	5.16
2012	26	3.6	34	4.08
2013	28	3.87	39	4.68
Totals	**723**	**100**	**832**	**100**

Cancer *in situ*

Cancer *in situ* is a grouping of abnormal cells. There is discussion as to whether these cells should even be considered neoplastic or if it is the earliest stage in which a cancer is identified. There were 16 cases of melanoma ***in situ*** in firefighters and 19 in police officers. The LTAS system does not allow for the incorporation of melanoma ***in-situ*** cases to be analyzed, and these cases were eliminated. The predominant cancer ***in situ*** was melanoma. The number of melanoma cases had to be reduced from 41 to 35 in firefighters, and from 44 to 25 in police officers. Firefighters also had 5 cases of cancer ***in situ*** of the colon, whereas police officers had 8 cases.

Multiple Cancers

The list of linked cancers from the New Jersey State Cancer Registry identified 1,600 cases of cancer, 758 in firefighters and 875 in police officers. The majority of malignant cases, 489 in firefighters and 582 in police officers, were primary single incidence of cancers. 110 firefighters and 116 police officers had two or more cases of cancer subsequent to their first diagnosis.

Table 5.7 Frequency Count of Individual Employees with Multiple Cancers

Number of Cancers	Fire Fighter Frequency	Cumulative Frequency	Police Officer Frequency	Cumulative Frequency
0	3031	3031	4272	4272
1	489	3520	582	4853
2	96	3616	100	4953
3	14	3630	14	4968
4	0	3630	2	4970

Location of Reported Deaths

The information provided by the New Jersey Division of Pensions and Benefits identified the State where the employee was reported to have died. There were 825 reported deaths.

Out of the 825 reported employee deaths in the linked cohort, 406 (49%) were firefighters and 429 (51%) were police officers. From these cohorts 363 (89 %) firefighters and 368 (86 %) police officers died in New Jersey. The location of death for 17 (4 %) firefighters and 12 (3 %) police officers were listed in other states, such as Arizona, California and Florida. The location of death for 26 (6 %) firefighters and 39 (9 %) police officers were listed as unknown.

Table 5.8 lists a breakdown of in-state and out-of-state deaths.

Table 5.9 Listing Reported State of Death Location

State of Death	**FF**	**PO**	**Total**
Alaska	1	0	1
Arizona	2	1	3
California	1	0	1
Florida	7	5	12
MA	1	0	1
NC	2	0	2
NE	0	1	1
NJ	363	368	731
NY	0	3	3
PA	2	1	3
TX	0	1	1
VA	1	0	1
Unknown	26	39	65
Total	**406**	**419**	**825**

5.5 Discussion

This study had several strengths, primarily a robust data set provided by the New Jersey Division of Pensions and Benefits. This data set included employee names, birth dates as well as employee start dates as early as the late 1940's. This allowed for a reasonable assurance that all of the employees in the inclusion period were captured and provided sufficient information for a probabilistic search. By the New Jersey State Cancer Registry. Furthermore, the data supplied by the NJP&B contained a large number of firefighters and police officers, allowing for suitable sample size.

The NJSCR was the second strong point of this study as they were able to use the information provided by the NJDP&B to conduct the linkages with a high probability of accuracy.

One limitation of this study was due to selection bias. Initial discussions with the fire and police departments indicated that the majority of personnel records would be paper based records, and that employee records earlier than 1980 could be unreliable. Using unreliable employee records could have resulted in lost subjects and inaccurate evaluations of the person years at risk (PYAR). Since the date of ascertainment for the NJ State Cancer Registry was in 1979, an employee inclusion date of April, 1980 through March 2011 was selected, with the idea that the employee records would be accurate. (The last employee enrolled was in December, 2010.) Once the employee records were obtained, we discovered that the employee records were accurate back to 1947. Unfortunately, by that time we already had made agreements with the NJDP&B, and only those employees employed between 1980 and 2011 were selected.

It was determined that the mean number of years between the enrollment as a firefighter, or police officer, and the time of the first diagnosis, was 39.3 years for firefighters and 37.17 years for police officers. Therefore, it would be appropriate to go back to the earliest enrollment date available of 1947, and include all firefighters and police officers working in New Jersey since that time. This would allow enough time for any potential cancers in firefighters and police officers to be diagnosed and to have had a cancer registry to capture the corresponding cancers. For those individuals enrolled in 1947, looking at an average of 38 years, the majority of cancers would be diagnosed around 1985 and later. Looking at Figure 5.2 we can see the distribution of the cases diagnosed by years after enrollment, with the greater number of diagnosed cases coming at approximately 38 years.

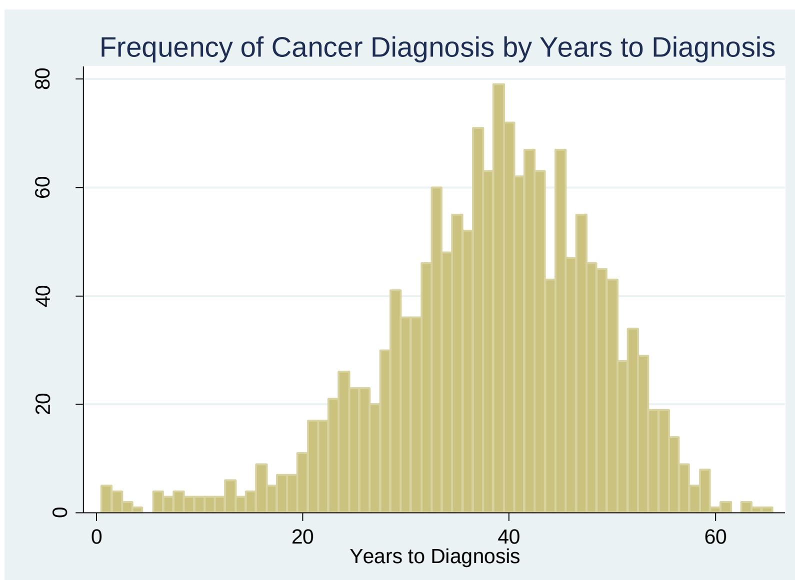

Figure 5.2 is a Histogram of the number of individuals, All Employees, All Cases (n=1,633) diagnosed with cancer by the number of years from their date of enrollment.

Another limitation is the potential loss to follow-up of study subjects to retirement in other states. 11% of the study subjects were noted to have died in other states. At this time there is no central clearing house or central or National cancer registry to submit names or cohorts of subjects in order to look for cancer incidence in every state at once. This is not only a potential limitation for this study, where the subjects may have moved or retired to other states, but for human clinical studies, or for military personnel that may have experienced an exposure to equipment or materiel on a vessel or aircraft, or in a combat theatre.

Cancer registries are not linked to one another and patients that relocate to another state may be lost to follow-up, and not have an initial or subsequent cancer reported to the state where the subject has lived. Generally, cancer registries do not report cancer incidence back to an employee’s home state registry, unless there is an established connection, such as when the employee is already diagnosed with a cancer and then relocates.

The ability to obtain linkages from a single central or National cancer registry would have been of great value as an individual can be followed for a lifetime no matter where they relocate. This can be of great advantage to military personnel as well, as their experiences can be linked to specific theaters of operation far from a home state, and the soldier or sailor can be followed no matter where they may settle.

The inability to identify race as a variable for all subjects was another limitation. The Standardized Incidence Ratio had to be calculated using “males, all races” for the reference population. This can have an effect on certain cancers as certain cancers are more prevalent in certain races. Prostate cancer, for example, will affect 1 in 6 African-American men (18.2%) as compared to 1 in 8 non-Hispanic White men (13.3%). Bladder cancer will affect 1 in 54 African-Americans (1.9%) compared to 1 in 23 non-Hispanic White men (4.4%). (American Cancer Society, Facts and Figures for African–Americans, 2016-2018) Therefore, having Race information and separating out the races would have provided a more accurate SIR for certain cancers. Conversely, including the African-American males allowed for a higher number of study subjects to be included in the SIR, slightly increasing the power of the study.

Finally, at the time of this analysis, we did not have the incidence reference rate data for any of the ***in-situ*** cancers for the LTAS system. The inability to analyze cancer ***in situ*** may have skewed the data on melanoma, colon and rectal cancers, the three highest ***in-situ*** cases excluded from analysis.

5.6 Conclusions

The SIR for All Cancers for both firefighters and police officers was below the expected number of cancers demonstrating that New Jersey firefighters and police officers do not have an excess of cancer than the General Population in the United States. Firefighters and police officers have to pass very rigorous physical fitness tests in order to qualify for their jobs, and begin employment, on average, at 26 years of age. These characteristics are examples of a healthy worker, and the healthy worker effect, which may explain why these individuals exhibit a lower number of cancers than the general population.

The results of the Standardized Incidence Ratios (SIR) for firefighters reflects an excess of eye cancer of 3.80 times than the U.S. General Population, (95% CI, 1.53, 7.82). This is a statistically significant excess of Eye Cancer, and when compared to the U.S. General Population. Police officers did not demonstrate an excess of Eye Cancer.

CHAPTER 6

LONGEVITY ANALYSIS OF FIREFIGHTERS AND POLICE OFFICERS IN NEW JERSEY'S FOUR LARGEST MUNICIPALITIES

6.1 Introduction

Firefighting and police work are two professions where each firefighter and police officer face extraordinary hazards and multiple occupational stresses. There have been multiple studies looking at the acute health hazards of each profession from criminal assault to motor vehicle accidents to the injuries that occur from fighting a fire. This study examines the probability of firefighters and police officers surviving to age 100; and comparing them to each other.

This study utilized a Kaplan-Meier Estimator, a non-parametric statistical method, to measure the survival time in each cohort. The Kaplan-Meier Estimator (KME) has demonstrated exceptional usefulness for measuring safety and efficacy of drug treatments by comparing survival times between investigational drugs and placebos (or comparator drugs). The KME is also useful in determining the probability of survival for given cohorts in occupational exposures.

There are few studies evaluating the life expectancy of police officers, one study (Violanti, 2013) demonstrated that the life expectancy of Buffalo, NY police officers was significantly lower than the U.S. General Population. With a mean loss of life expectancy of 21.9 years, (95% CI: 14.5, 29.3).

Life Expectancy (LE), the time that one can be statistically expected to live, has been calculated over time in several different formats. The overall LE is the mean of the age at death. This number has been calculated from empirical data, primarily death certificates, and has been utilized as a surrogate for the health of a population. Life Expectancy is also an important metric for several agencies providing social services such as the Social Security Administration and the Internal Revenue Service to calculate the funds necessary for retirement and benefits planning. One of the most commonly used metric is Life Expectancy from age 65. Life Expectancy changes over one's lifetime. At birth, we are expected to live a certain number of years; however, as we reach certain ages that number changes as those that die at earlier ages are no longer counted in calculating longevity. Therefore, when examining only those individuals living to age 65, we see that they have a better chance of living to age 70 than if they were combined with everyone that was born in their same birth year.

This study looked at the probability of survival in a cohort of firefighters and one of police officers and compared their probability of survival to each other. The analysis also included the age of hire, retirement, death, and the length of time that each employee remained On-The-Job (OTJ) and how their cohorts compared to one another.

6.2 Methods

De-identified employment records from the New Jersey Division of Pensions and Benefits for the fire and police departments of the four largest municipalities in New Jersey were forwarded to the New Jersey State Cancer Registry (NJSCR) for linkage to the New Jersey State Cancer Registry's database of reported cancers.

The NJSCR provided the linkage information, i.e., the number of cancers and specific information regarding each cancer, including the type and date of diagnosis and age of the employee at the time of diagnosis. The NJSCR also provided the year of birth and death, as well as the year of enrollment and retirement for each employee.

This study analyzed an initial cohort of 7,027, male firefighter and police officer retirees, all races, working for at least one month between 1980 and 2010, with 2,601 being deceased and eligible for inclusion in a probability of survival calculation. Each of these individuals were a paid municipal firefighter or police officer from one of New Jersey's four largest municipalities, Newark, Jersey City, Paterson or Elizabeth, NJ. All 2,601 employees were born between 1914 and 1970, and had died between 1983 and 2016.

An analysis was conducted using year of birth, year of hire, year of retirement, year of diagnosis, and year of death for each cohort. The employee's age at death was calculated from this information. These dates were also used to calculate average ages of hire, retirement and length of time in service. The average longevity from time of retirement to time of death, and years from diagnosis to time of death was also calculated for each cohort and compared to each other. The age of death was utilized to calculate the Probability of Survival.

6.3 Statistical Analysis

The data was analyzed using a Kaplan-Meier Estimator, a non-parametric statistical method for measuring survival time in cohorts. The survival data for the U.S. General Population is maintained by the Centers for Disease Control (CDC) and was obtained from their 2011 Annual Report.

The Kaplan-Meier Estimator, ŝ (t), is calculated by:

$$\widehat{S}(t) = \prod_{i:\ t_i \le t} \left(1 - \frac{d_i}{n_i}\right),$$

with d_i the *number of events* and n_i the total *individuals at risk* at time *i*.

*From the Stata Manual

The KME for both the firefighters and police officers were created using actual dates of death as the event **(d_i)** and the age at the time of death was used as the time to survival ***(t)***.

A Log-rank Test was used to compare the survival distribution between firefighters and police officers. The Log-rank test is a non-parametric test used extensively for testing the survivability distribution between cohorts taking investigational and placebo (or comparator) drugs in clinical drug trials. The Log-rank test produces a Chi Square and a *p-Value* to determine the significance of the relationship between the two curves.

The Log-rank Test was applied to the comparison curves between firefighters and police officers. The Kaplan-Meier Estimate, graphs, and log-rank tests were conducted using STATA 14.2.

6.4 Results

This study looked at 2,593 deceased employees, 1,184 firefighters and 1,409 police officers working in the four largest municipalities in New Jersey. The mean age of retirement was 53.78 for all employees, 55.3 for firefighters and 52.69 for police officers. The mean years on the job was 28.03 for firefighters and 25.76 for police officers. The Probability of Survival, using the Kaplan-Meier Estimation, showed that police officers have a decreased probability of survival compared to firefighters ($p = 0.05$) Table 6.1 presents the results of the firefighter Probability of Survival calculations.

Table 6.1 Firefighter Probability of Survival Table To Age 100 (n= 1,184)

Age Interval	Fire- fighters	Deaths	Probability of Survival	Standard Error	[95% Conf. Int.]	
24-29	1184	1	0.99	0.0008	0.99	0.99
30-39	1183	8	0.99	0.002	0.98	0.99
40-49	1175	29	0.96	0.005	0.95	0.97
50-59	1146	94	0.88	0.009	0.86	0.90
60-69	1052	295	0.63	0.014	0.61	0.66
70-79	757	412	0.29	0.013	0.26	0.31
80-89	345	300	0.03	0.005	0.02	0.05
90-100	45	45	0	.	.	.

Table 6.2 contains the results of a probability of survival calculations for police officers, conducted utilizing the same method.

Table 6.2 Police Officer Probability of Survival Table to Age 100 (n = 1,409)

Age Interval	Police Officers	Deaths	Probability of Survival	Standard Error	[95% Conf. Int.]	
24-29	1409	3	0.99	0.001	0.99	0.99
30-39	1406	15	0.98	0.003	0.97	0.99
40-49	1391	35	0.96	0.005	0.95	0.97
50-59	1356	141	0.86	0.009	0.84	0.87
60-69	1215	381	0.59	0.013	0.56	0.61
70-79	834	524	0.22	0.011	0.19	0.24
80-89	310	280	0.02	0.003	0.01	0.02
90-100	30	30	0	.	.	.

A comparison between firefighters and police officer probability of survival is presented n Table 6.3.

Table 6.3 Comparison between firefighter and police officer probability of survival

Age Interval	Firefighter Probability of Survival	[95% CI]		Police Officer Probability of Survival	[95% CI]	
24-29	0.99	0.99	0.99	0.99	0.99	0.99
30-39	0.98	0.97	0.99	0.99	0.98	0.99
40-49	0.96	0.95	0.97	0.96	0.95	0.97
50-59	0.86	0.84	0.87	0.88	0.86	0.90
60-69	0.59	0.56	0.61	0.63	0.61	0.66
70-79	0.22	0.19	0.24	0.29	0.26	0.31
80-89	0.02	0.01	0.02	0.03	0.02	0.05
90-100	0	.	.	0	.	.

The results of the Kaplan-Meier Curves for firefighters and police officers are depicted in Figure 6.1. The curves are statistically similar between the ages of 24 and 60. After the age of 60, however, the curves begin to diverge, with police officers showing a decrease in their probability of survival.

The Log-rank Test was conducted on the cohorts as a single entity, and again after separating the two cohorts into eight separate age strata, 24-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80-89 and 90-99. By stratifying the ages in each cohort, we can determine if the probability of survival was age dependent and at what ages were statistically significant.

Figure 6.1 reflects the Kaplan-Meier Curve without confidence intervals, while Figure 6.2 presents the Kaplan-Meier Curve with 95% CIs.

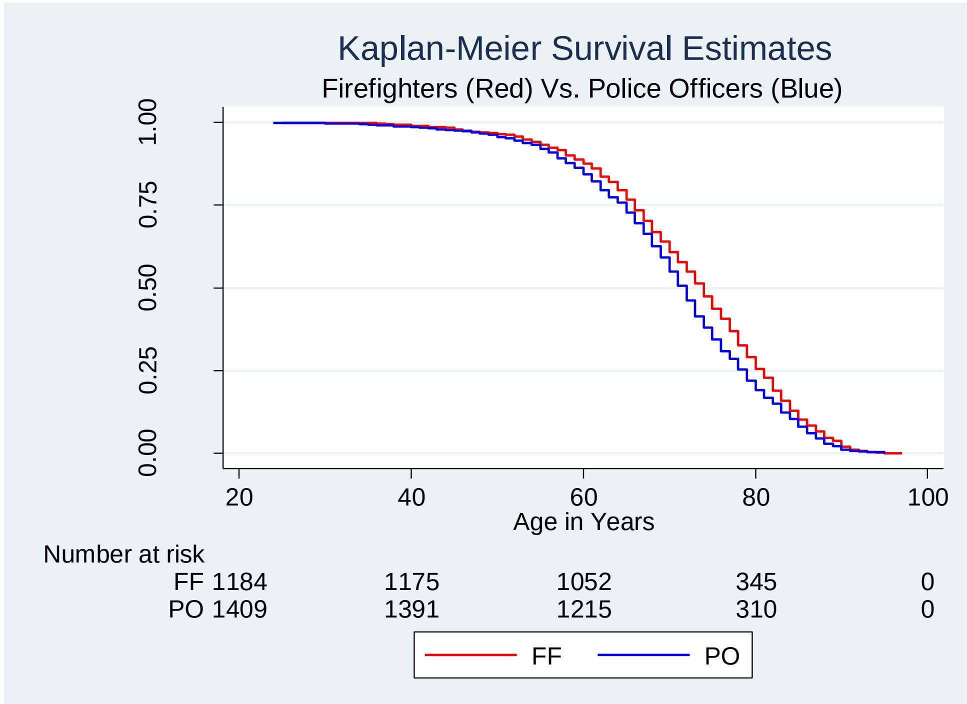

Figure 6.1 Kaplan-Meier Survival Estimate Curve, Firefighters (Red) Vs. Police Officers (Blue)

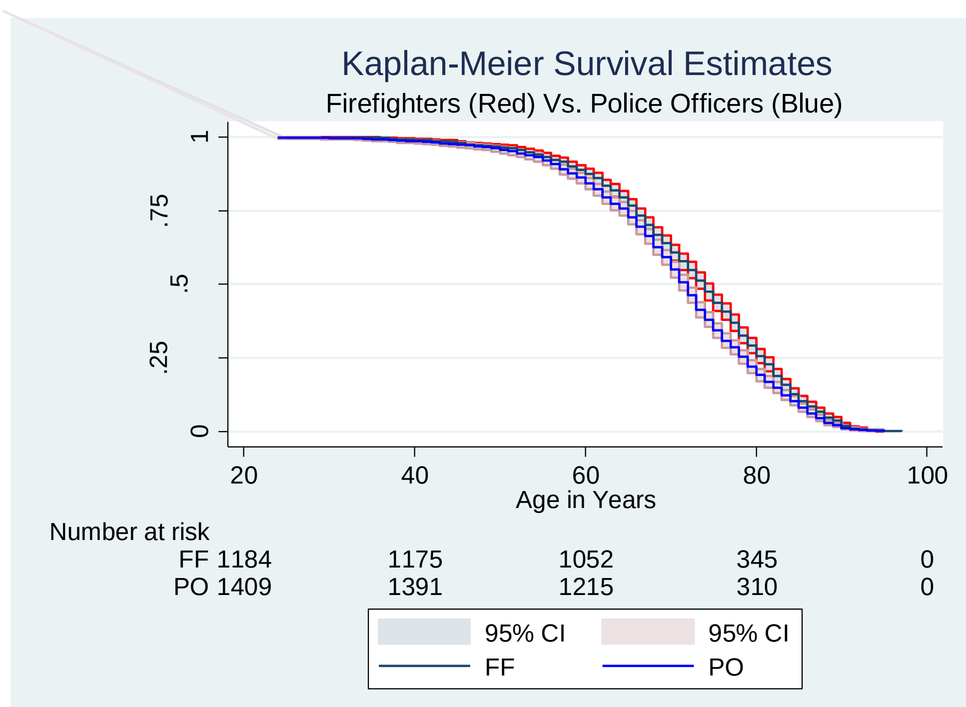

Figure 6.2 Kaplan-Meier Survival Estimate Curve for Firefighters Vs. Police Officers

In order to visualize the differences between the firefighters and police officers at specific age groups, the variables were stratified into the following 10-year brackets:

Age Group # 1	24 to 29 years
Age Group # 2	30 to 39 years
Age Group # 3	40 to 49 years
Age Group # 4`	50 to 59 years
Age Group # 5	60 to 69 years
Age Group # 6	70 to 79 years
Age Group # 7	80 to 89 years
Age Group # 8	90 to 100 years

An additional Kaplan-Meier curve was generated using the 8 10-year age brackets described above, and is depicted in Figure 6.3 below:

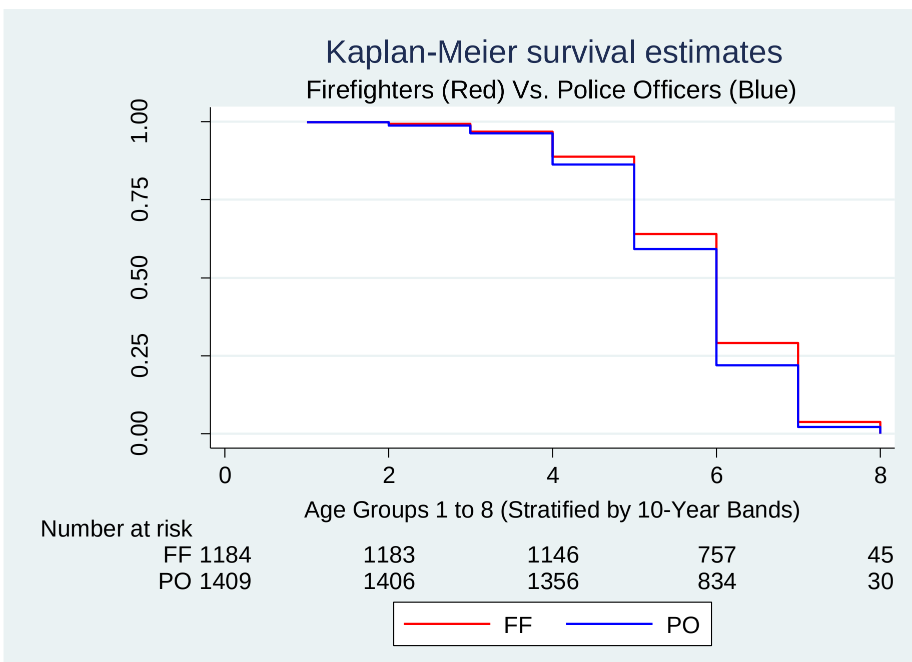

Figure 6.3 Kaplan-Meier Survival Estimate for Firefighters Vs. Police Officers stratified by 10-Year age brackets.

The greatest separation between the probability of survival between the firefighters and police officers occurs at Age Group # 6 (70-79 years of age) where police officers have a 7% lower probability of survival that firefighters for this same age group.

The calculations for the Log-rank test for equality of survivor functions and their respective ***p-Values*** are provided below:

A Stratified Log-Rank Test for Equality of Survivor Functions was conducted to calculate the ***p-Value***.

Age Groups 1 through 5 did not demonstrate a p=Value < 0.05, whereas only one of the Age Groups, Age Group 6 (70-79 years of age), demonstrated a ***p-Value*** < 0.05, with a ***p-Value*** = 0.0067.

1. Age Group 24-29

Cohort	Events Observed	Events Expected
FF	1	0.58
PO	3	3.42
Total	4	4.00

chi2(1) = 0.42
Pr>chi2 = 0.5151

2. Age Group 30-39

Cohort	Events Observed	Events Expected
FF	8	8.97
PO	15	14.03
Total	23	23.00

chi2(1) = 0.27
Pr>chi2 = 0.6029

3. Age Group 40-49

Cohort	Events Observed	Events Expected
FF	29	25.52
PO	35	38.48
Total	64	64.00

chi2(1) = 1.12
Pr>chi2 = 0.2890

4. Age Group 50-59

Cohort	Events Observed	Events Expected
FF	94	95.10
PO	141	139.90
Total	235	235.00

chi2(1) = 0.03
Pr>chi2 = 0.8569

5. Age Group 60-69

Cohort	Events Observed	Events Expected
FF	295	294.68
PO	381	381.32
Total	676	676.00

chi2(1) = 0.00
Pr>chi2 = 0.9764

6. Age Group 70-79

Cohort	Events Observed	Events Expected
FF	412	446.86
PO	524	489.14
Total	936	936.00

chi2(1) = 7.34
Pr>chi2 = 0.0067

7. Age Group 80-89

Cohort	Events Observed	Events Expected
FF	300	291.10
PO	280	288.90
Total	580	580.00

chi2(1) = 0.76
Pr>chi2 = 0.3834

8. Age Group 90-100

Cohort	Events Observed	Events Expected
FF	45	42.79
PO	30	32.21
Total	75	75.00

chi2(1) = 0.49
Pr>chi2 = 0.4852

Total Cohort

Cohort	Events Observed	Events Expected(*)
FF	1184	1205.60
PO	1409	1387.40
Total	2593	2593.00

(*) sum over calculations within All Age Groups

chi2(1) = 1.05
Pr>chi2 = 0.3060

Longevity in the workforce

A cohort of 7,027 employees, 3,018 firefighters (1,183 deceased) and 4,009 police officers (1,401 deceased), born between 1914-1970, were analyzed for the mean age of starting their professional careers, mean age of retirement, and the number of years employed in their respective professions.

Firefighters and police officers entered the workforce at approximately the same age, with police officers more likely to enter the workforce earlier than firefighters by one year.

Table 6.4 Mean and Median Age of Hire

Cohort	Mean	Median (p50)	Minimum	Maximum	Range
FF	27.26	27	18	55	37
PO	26.92	26	17	59	42
Total	**27.06**	**26**	**17**	**59**	**42**

Firefighters remained in the workforce, or on the job (OTJ), for approximately 2.5 years longer than their police officer counterparts.

Table 6.5 Number of Years On The Job

Cohort	Mean	Median (p50)	Minimum	Maximum	Range
FF	28.03	28	1	45	45
PO	25.76	26	1	43	43
Total	26.71	27	1	45	45

Looking at the mean age of retirement, firefighters and police officers retired from the workforce at approximately the same age, with police officers more likely to retire from the workforce slightly earlier than firefighters, again, by one year.

Table 6. 6 Mean Age at Retirement

Cohort	Mean	Median (p50)	Minimum	Maximum	Range
FF	55.3	56	25	69	44
PO	52.69	53	24	72	48
Total	53.78	54	24	72	48

6.5 Limitations

The first limitation of this study was the lack of Racial information across the entire cohort. The New Jersey State Cancer Registry was able to identify Race as a variable as it is a required data field when reporting cancer in New Jersey. Race, and Ethnicity, are important pieces of information in determining longevity and incidence of disease as life expectancies and diseases have different rates for different Races and Ethnicities. The NJ Division of Pensions and Benefits could not provide the Race or Ethnicity of each study subject for the larger cohort of unmatched employees, which may have skewed the longevity analysis depending upon the number study subjects of one Race.

Furthermore, although the data set contained unique de-identified cohort identifiers, there may be a possibility that an unknown number of employees had transferred from one municipality to another or between fire and police departments. An additional analysis of the original cohort should be considered in order to identify if any police officer had transferred to a fire company or vice versa.

The data set contained numerous police officers that were enrolled into the program after the age of 38. Police departments in New Jersey require that an officer join the police force at or before the age of 38. Since there are a number of officers that have enrolled in the retirement program at ages 38 to 59 years, the enrollment date of these officers must be a result of interdepartmental transfers or promotions from within their departments.

The probability of survival estimate compares the probability of survival of a cohort of firefighters and police officers to a hypothetical cohort of similar sizes utilizing the probability of survival rates from the CDC's 2011 U.S. General Population Report. The probability of survival varies over time as the life expectancy of the general population changes over time. Therefore, the probability of survival for the U.S. General population may not be a suitable comparison for the firefighter and police officer curves, and a direct standardization may be needed to compare the curves.

6.6 Conclusions

There is little difference between the overall probability of survival between firefighters and police officers (***p-value*** = 0.306). Although there is little difference between the probability of survival overall, there is a slight separation between the probabilities of survival after age 60 (***p-value*** = 0.976) which becomes statistically significant between the ages of 70 and 79 (***p-value*** = 0.006) when compared to firefighters.

There is no clear explanation for the decrease in the probability of survival, except that firefighters and police officers work in professions where they encounter greater environmental, physical and emotional stressors than in other occupations. Firefighters and police officers reflect a better probability of survival than the general population between ages 24 and 39, possibly due to a healthy worker effect and the fact there are a number of other professions that are more hazardous than firefighting or law enforcement.

There is little difference between firefighters and police officers with respect to the ages that they start working, remain on the job, and retire from their respective professions. Police officers, however, start and retire slightly earlier than firefighters and remain on the job for slightly less time than firefighters. This may be due to the emotional strain of police work, whereby police officers are facing stressors on an almost daily basis, whereas firefighters face their highest degree of physical and emotional stress battling a fires, which occur less frequently.

CHAPTER 7

CONCLUSION

The initial intent of this study was to investigate the incidence of cancer in firefighters in New Jersey's four largest municipalities. The study design evolved to also investigate the incidence of cancer in police officers in those same four municipalities in order to compare two cohorts that would have experienced different occupational exposures, but similar environmental exposures.

A literature review of cancer incidence studies of firefighters revealed that the majority of studies did not identify an overall increase of all cancers in firefighters. Cancer incidence studies for police officers were very sparse and of the few studies available, there were no indications that police officers experienced an overall increase in all cancers.

Depending upon the study, certain cancers, such as prostate cancer and melanoma, were found in excess in firefighters. The majority of the studies include firefighters from a single state, (e.g., California, Florida, Massachusetts) or a single municipality, such as Chicago or Philadelphia. These studies reflect that firefighters from one area to another may demonstrate excess cancers of one type or another due to their local occupational or environmental exposures.

The results of this study identified an excess of eye cancer of 3.80 times the normal rate for firefighters, SIR = 3.80; (95% CI, 1.53, 7.82) The Standardized Incidence Ratio (SIR) for eye cancer in firefighters is statistically significant when compared to the U.S. General Population. Police officers from the same municipalities did not demonstrate any excess in eye cancer.

The SIR for overall all-cancer incidence for firefighters and police officers was below the expected number of cancers demonstrating that overall, firefighters and police officers, do not have an excess of cancer when compared to the General Population in the United States.

Except for eye cancer, these results demonstrated that there is little difference in overall and individual cancer incidence between firefighters and police officers. An analysis of the firefighter and police officer demographics, with respect to the ages that they start working, remain on the job, and retire from their respective professions, similarly demonstrate little differences. Police officers, however, start and retire slightly earlier than firefighters and remain on the job for slightly less time than firefighters.

The life expectancy table between firefighters and police officers reflect that police office experience a slight decrease in the probability in life expectancy between ages 70 and 79, when compared to the firefighters from similar municipalities.

Additional studies will need to be conducted whereby we can follow individual local cohorts of firefighters and police officers across longer periods of time.

APPENDIX

This Appendix contains the Forest Plots and Tests for Heterogeneity for the meta-analysis using the Random-Effects Model for each individual cancer from the studies reviewed in Chapter 3.

A.1 Forest Plots and Tests for Heterogeneity for All Cancers

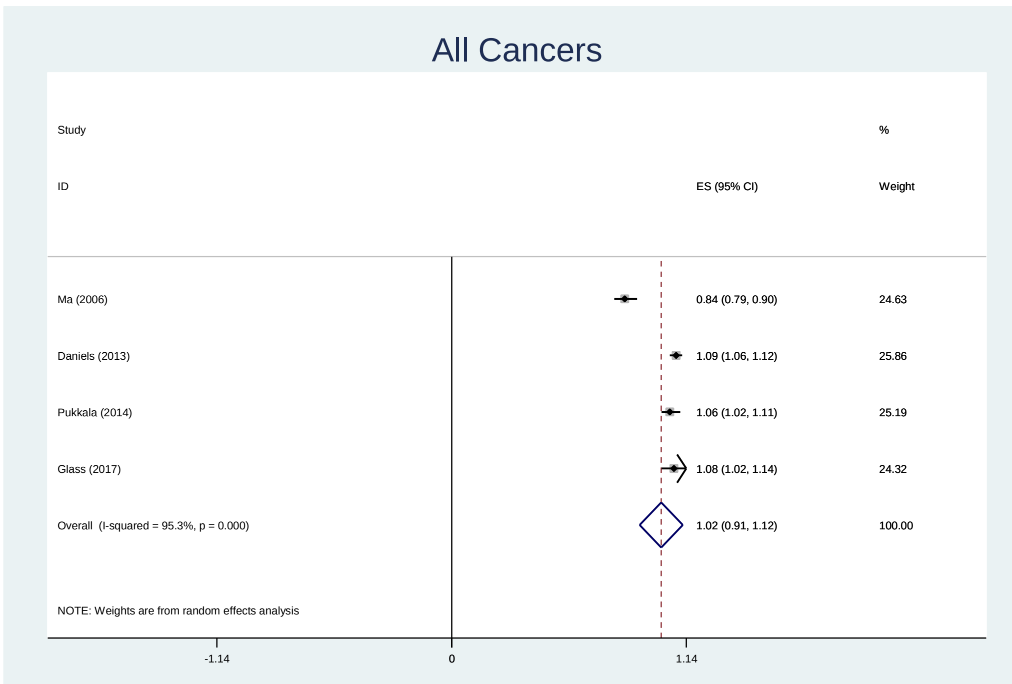

Figure A.1 Stata Output Forest Plot of Meta-analysis for All Cancers demonstrating the overall point estimate for the meta-analysis.

Table A.1.1 Stata Output for the Pooled Estimate for All Cancers

Study	ES	[95% CI]	% Weight
Ma (2006)	0.84	0.79 - 0.90	24.63
Daniels (2013)	1.09	1.06 - 1.12	25.86
Pukkala (2014)	1.06	1.02 - 1.11	25.19
Glass (2017)	1.08	1.02 - 1.14	24.32
Pooled Estimate	**1.01**	**0.91 - 1.12**	**100.00**

Table A.1.2 Stata Output, tests for Heterogeneity, All Cancers.

Tests for Heterogeneity
Heterogeneity chi-squared = 63.74 (d.f. = 3) p = 0.000
I-squared (variation in ES attributable to heterogeneity) = 95.3%
Estimate of between-study variance Tau-squared = 0.0108
Test of ES=0: z= 19.05 p = 0.000

A.2 Forest Plots and Tests for Heterogeneity for Esophageal Cancer

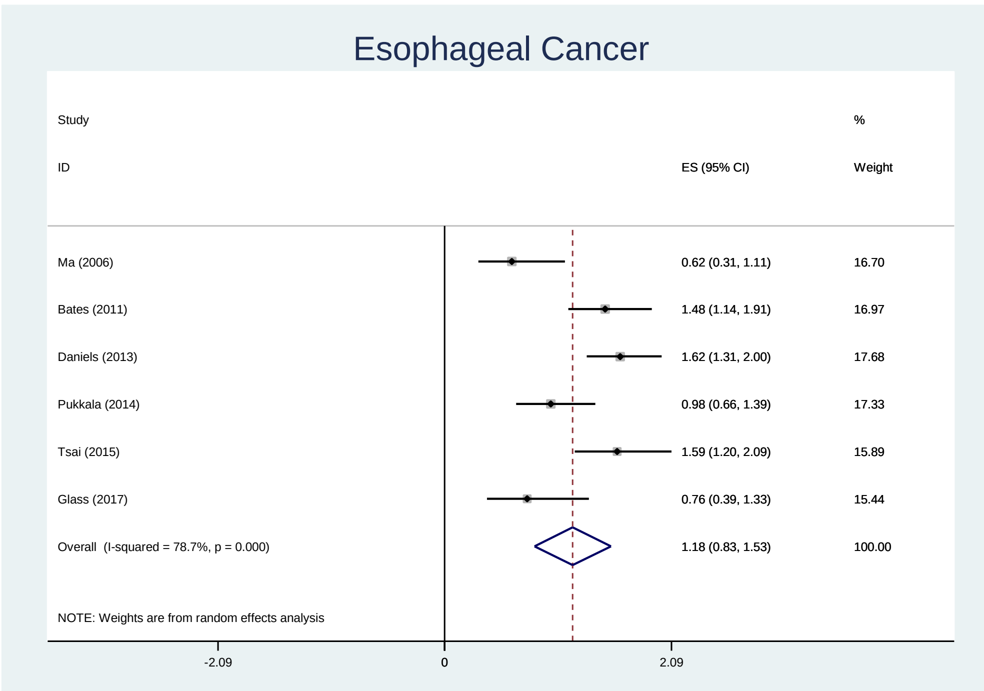

Figure A.2 Stata Output Forest Plot for **Esophageal Cancer** demonstrating the overall point estimate for the meta-analysis.

Table A.2.1 Stata Output for the Pooled Estimate for **Esophageal Cancer**

Study	**ES**	**[95% CI]**	**% Weight**
Ma (2006)	0.62	0.31 - 1.11	16.70
Bates (2011)	1.48	1.14 - 1.91	16.97
Daniels (2013)	1.62	1.31 - 2.00	17.68
Pukkala (2014)	0.98	0.66 - 1.39	17.33
Tsai (2015)	1.59	1.20 - 2.09	15.89
Glass (2017)	0.76	0.39 - 1.33	15.44
Pooled Estimate	**1.18**	**0.82 - 1.53**	**100.00**

Table A.2.2 Stata Output for the Test of Heterogeneity for **Esophageal Cancer**.

Tests for Heterogeneity
Heterogeneity chi-squared = 23.51 (d.f. = 5) p = 0.000
I-squared (variation in ES attributable to heterogeneity) = 78.7%
Estimate of between-study variance Tau-squared = 0.1516
Test of ES=0 : z= 6.57 p = 0.000

A.3 Forest Plots and Tests for Heterogeneity for Stomach Cancer

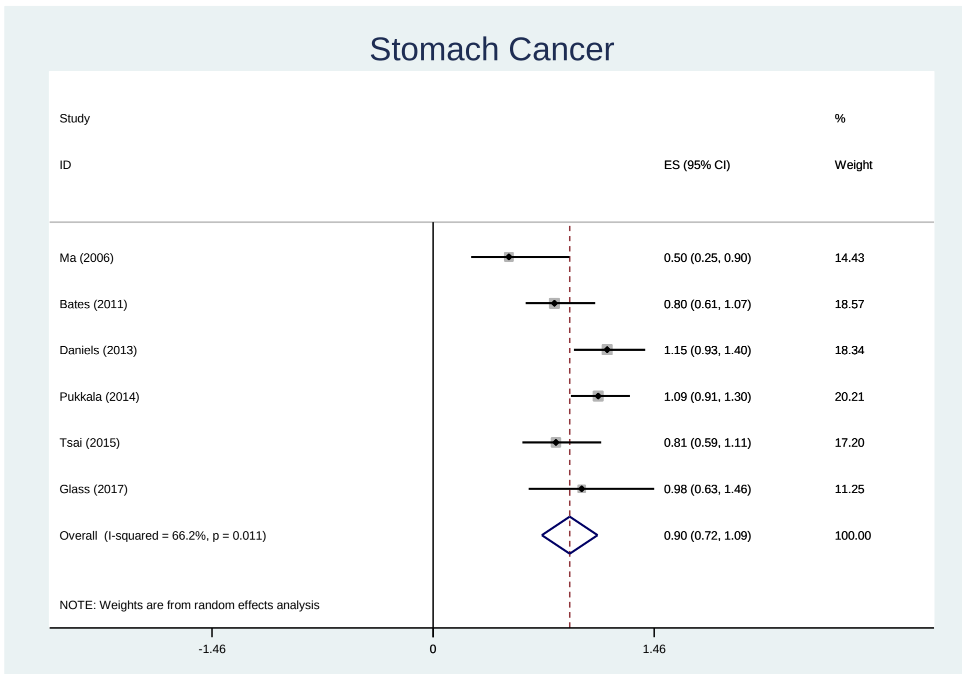

Figure A.3 Stata Output Forest Plot for **Stomach Cancer** demonstrating the overall point estimate for the meta-analysis.

Table A.3 Stata Output for the Pooled Estimate for **Stomach Cancer**

Study	**ES**	**[95% CI]**	**% Weight**
Ma (2006)	0.50	0.25 - 0.90	14.43
Bates (2011)	0.80	0.61 - 1.07	18.57
Daniels (2013)	1.15	0.93 - 1.40	18.34
Pukkala (2014)	1.09	0.91 - 1.30	20.21
Tsai (2015)	0.81	0.59 - 1.11	17.20
Glass (2017)	0.98	0.63 - 1.46	11.25
Pooled Estimate	**0.90**	**0.71 - 1.086**	**100.00**

Table 3.3.1 Stata Output for the Test of Heterogeneity for **Stomach Cancer**

Tests for Heterogeneity
Heterogeneity chi-squared = 14.78 (d.f. = 5) p = 0.011
I-squared (variation in ES attributable to heterogeneity) = 66.2%
Estimate of between-study variance Tau-squared = 0.0340
Test of ES=0 : z= 9.58 p = 0.000

A.4 Forest Plots and Tests for Heterogeneity for Lung Cancer

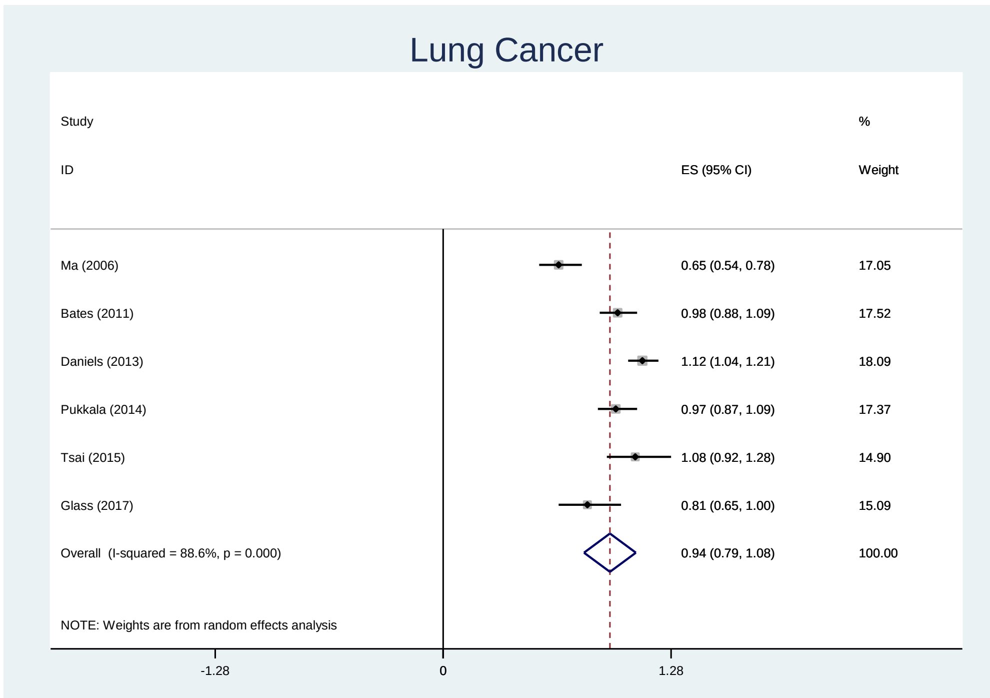

Figure A.4 Stata Output Forest Plot for **Lung Cancer** demonstrating the overall point estimate for the meta-analysis.

Table A.4 Stata Output for the Pooled Estimate for **Lung Cancer**

Study	**ES**	**[95% CI]**	**% Weight**
Ma (2006)	0.65	0.54 - 0.78	17.05
Bates (2011)	0.98	0.88 - 1.09	17.52
Daniels (2013)	1.12	1.04 - 1.21	18.09
Pukkala (2014)	0.97	0.87 - 1.09	17.37
Tsai (2015)	1.08	0.92 - 1.28	14.90
Glass (2017)	0.81	0.65 - 1.00	15.09
Pooled Estimate	**0.93**	**0.79 - 1.08**	**100.00**

Table A.4.1 Stata Output for the Test of Heterogeneity for **Lung Cancer**

Tests for Heterogeneity
Heterogeneity chi-squared = 43.91 (d.f. = 5) p = 0.000
I-squared (variation in ES attributable to heterogeneity) = 88.6%
Estimate of between-study variance Tau-squared = 0.0287
Test of ES=0 : z= 12.58 p = 0.000

A.5 Forest Plots and Tests for Heterogeneity for Prostate Cancer

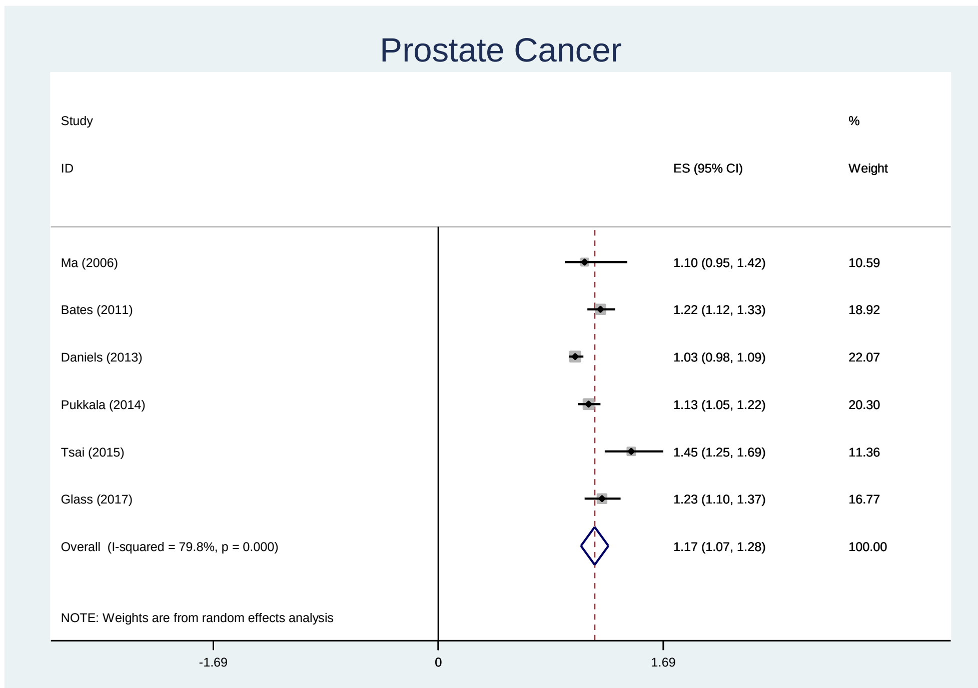

Figure A.5 Stata Output Forest Plot for Prostate Cancer demonstrating the overall point estimate for the meta-analysis.

Table A.5.1 Stata Output for the Pooled Estimate for **Prostate Cancer**.

Study	**ES**	**[95% CI]**	**% Weight**
Ma (2006)	1.10	0.95 - 1.42	10.59
Bates (2011)	1.22	1.12 - 1.33	18.92
Daniels (2013)	1.03	0.98 - 1.09	22.07
Pukkala (2014)	1.13	1.05 - 1.22	20.30
Tsai (2015)	1.45	1.25 - 1.69	11.36
Glass (2017)	1.23	1.10 - 1.37	16.77
Pooled Estimate	**1.17**	**1.07 - 1.27**	**100.00**

Table A.5.2 Stata Output for the Test of Heterogeneity for **Prostate Cancer**.

Tests for Heterogeneity
Heterogeneity chi-squared = 24.77 (d.f. = 5) p = 0.000
I-squared (variation in ES attributable to heterogeneity) = 79.8%
Estimate of between-study variance Tau-squared = 0.0117
Test of ES=0 : z= 22.34 p = 0.000

A.6 Forest Plots and Tests for Heterogeneity for Testicular Cancer

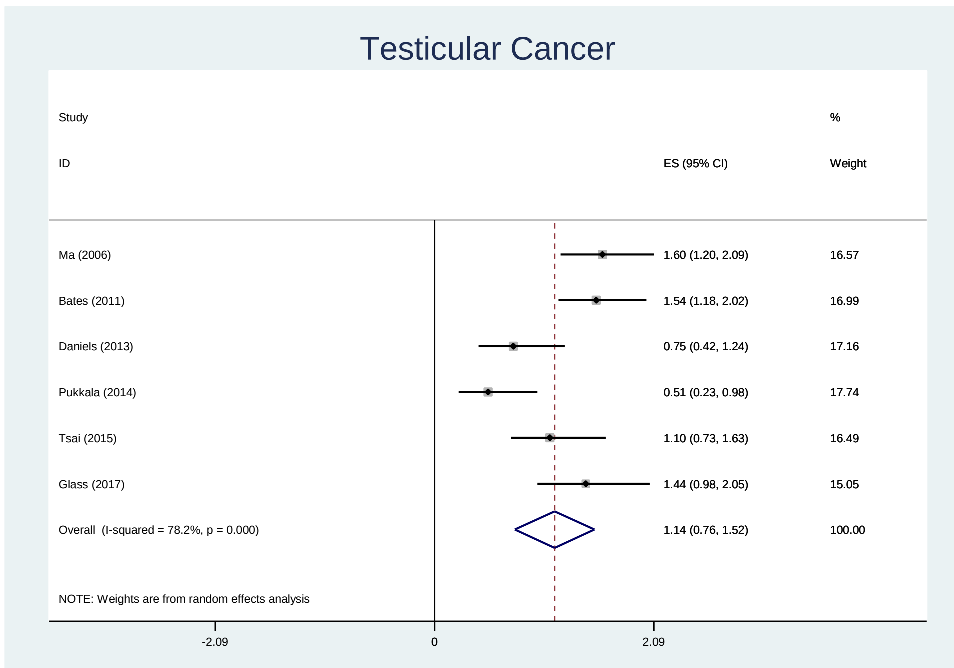

Figure A.6 Stata Output Forest Plot for **Testicular Cancer** demonstrating the overall point estimate for the meta-.

Table A.6.1 Stata Output for the Pooled Estimate for **Testicular Cancer**

Study	ES	[95% CI]	% Weight
Ma (2006)	1.60	1.20 - 2.09	16.57
Bates (2011)	1.54	1.18 - 2.02	16.99
Daniels (2013)	0.75	0.42 - 1.24	17.16
Pukkala (2014)	0.51	0.23 - 0.98	17.74
Tsai (2015)	1.10	0.73 - 1.63	16.49
Glass (2017)	1.44	0.98 - 2.05	15.05
Pooled Estimate	**1.14**	**0.76 - 1.52**	**100.00**

Table A.6.2 Stata Output for the Test of Heterogeneity for **Testicular Cancer**

Tests for Heterogeneity
Heterogeneity chi-squared = 22.93 (d.f. = 5) p = 0.000
I-squared (variation in ES attributable to heterogeneity) = 78.2%
Estimate of between-study variance Tau-squared = 0.1753
Test of ES=0 : z = 5.90 p = 0.000

A.7 Forest Plots and Tests for Heterogeneity for Kidney Cancer

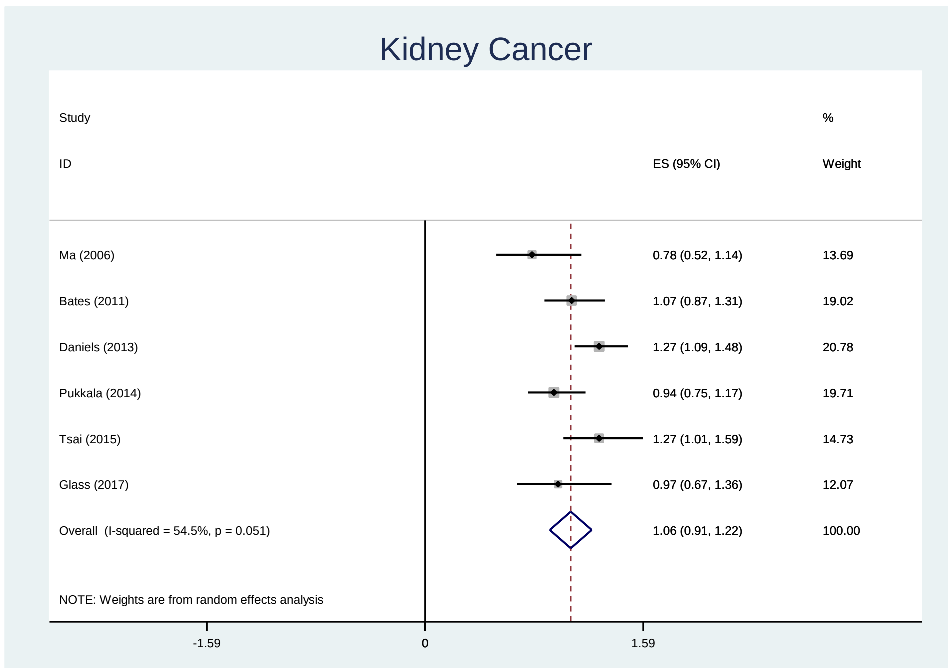

Figure A.7 Stata Output Forest Plot for **Kidney Cancer** demonstrating the overall point estimate for the meta-analysis.

Table A.7.1 Stata Output for the Pooled Estimate for **Kidney Cancer**

Study	**ES**	**[95% CI]**	**% Weight**
Ma (2006)	0.78	0.52 - 1.14	13.69
Bates (2011)	1.07	0.87 - 1.31	19.02
Daniels (2013)	1.27	1.09 - 1.48	20.78
Pukkala (2014)	0.94	0.75 - 1.17	19.71
Tsai (2015)	1.27	1.01 - 1.59	14.73
Glass (2017)	0.97	0.67 - 1.36	12.07
Pooled Estimate	**1.06**	**0.91 - 1.21**	**100.00**

Table A.7.2 Stata Output for the Test of Heterogeneity for **Kidney Cancer**

Tests for Heterogeneity
Heterogeneity chi-squared = 11.00 (d.f. = 5) p = 0.051
I-squared (variation in ES attributable to heterogeneity) = 54.5%
Estimate of between-study variance Tau-squared = 0.0193
Test of ES=0 : z= 13.65 p = 0.000

A.8 Forest Plots and Tests for Heterogeneity for Bladder Cancer

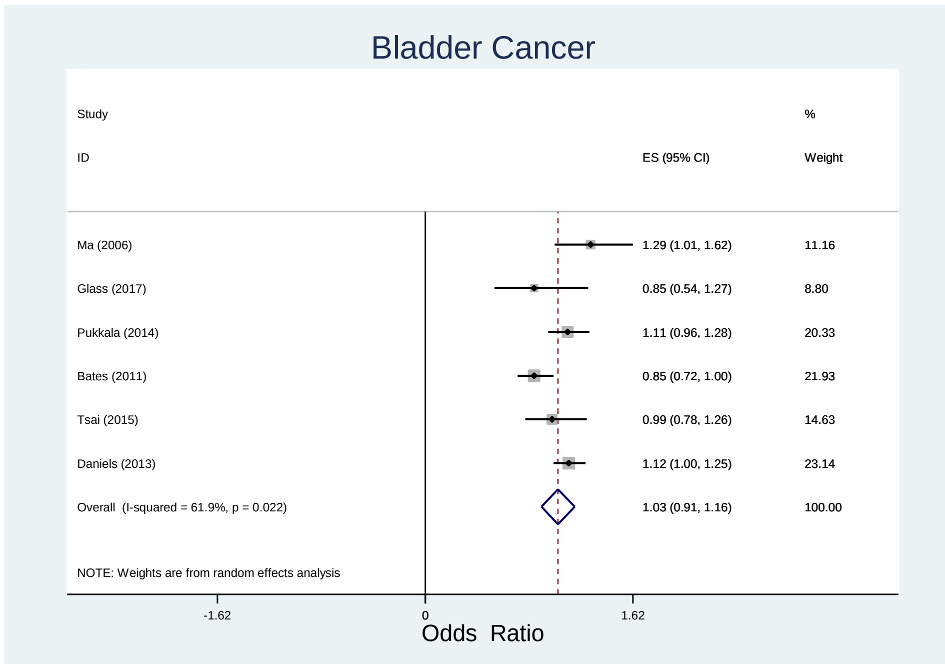

Figure A.8 Stata Output Forest Plot of Meta-analysis for **Bladder Cancer** demonstrating the overall point estimate for the meta-.

Table A.8.1 Stata Output for the Pooled Estimate for **Bladder Cancer**

Study	ES	[95% CI]	% Weight
Ma (2006)	1.60	1.20 - 2.09	16.57
Bates (2011)	1.54	1.18 - 2.02	16.99
Daniels (2013)	0.75	0.42 - 1.24	17.16
Pukkala (2014)	0.51	0.23 - 0.98	17.74
Tsai (2015)	1.10	0.73 - 1.63	16.49
Glass (2017)	1.44	0.98 - 2.05	15.05
Pooled Estimate	**1.14**	**0.76 - 1.52**	**100.00**

Table A.8.2 Stata Output for the Test of Heterogeneity for **Bladder Cancer**

Tests for Heterogeneity
Heterogeneity chi-squared = 22.93 (d.f. = 5) p = 0.000
I-squared (variation in ES attributable to heterogeneity) = 78.2%
Estimate of between-study variance Tau-squared = 0.1753
Test of ES=0 : z = 5.90 p = 0.000

A.9 Forest Plots and Tests for Heterogeneity for Brain Cancer

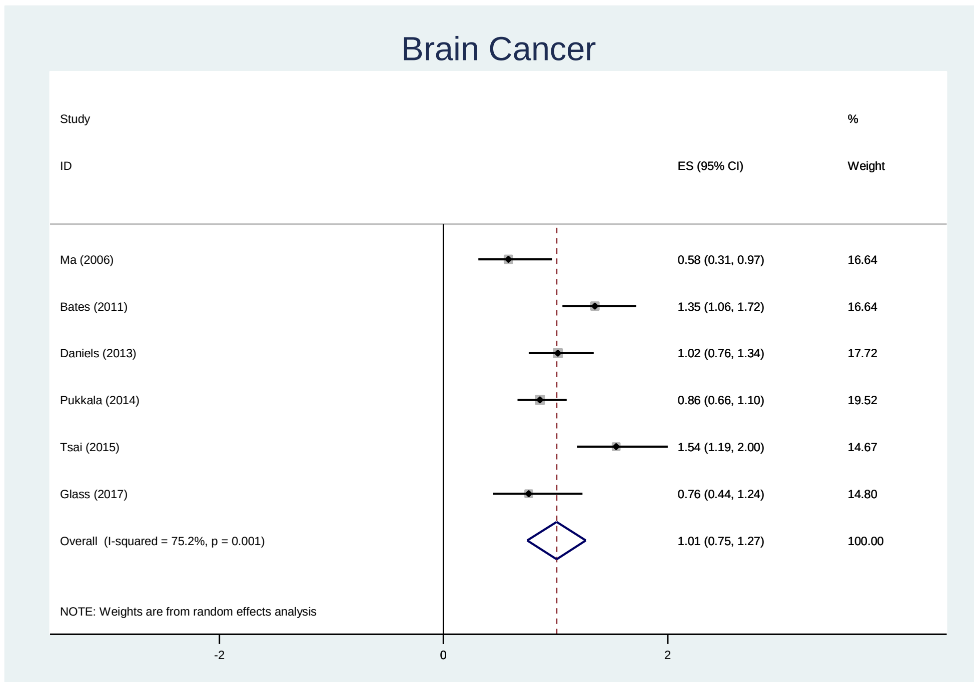

Figure A.9 Stata Output Forest Plot for **Brain Cancer** demonstrating the overall point estimate for the meta-analysis.

Table A.9.1 Stata Output for the Pooled Estimate for **Brain Cancer**.

Study	ES	[95% CI]	% Weight
Ma (2006)	0.58	0.31 - 0.97	16.64
Bates (2011)	1.35	1.06 - 1.72	16.64
Daniels (2013)	1.02	0.76 - 1.34	17.72
Pukkala (2014)	0.86	0.66 - 1.10	19.52
Tsai (2015)	1.54	1.19 - 2.00	14.67
Glass (2017)	0.76	0.44 - 1.24	14.80
Pooled Estimate	**1.00**	**0.74 - 1.27**	**100.00**

Table A.9.2 Stata Output for the Test of Heterogeneity for **Brain Cancer**.

Tests for Heterogeneity
Heterogeneity chi-squared = 20.19 (d.f. = 5) p = 0.001
I-squared (variation in ES attributable to heterogeneity) = 75.2%
Estimate of between-study variance Tau-squared = 0.0785
Test of ES = 0 z= 7.56 p = 0.000

A.10 Forest Plots and Tests for Heterogeneity for Non-Hodgkin's Lymphoma (NHL)

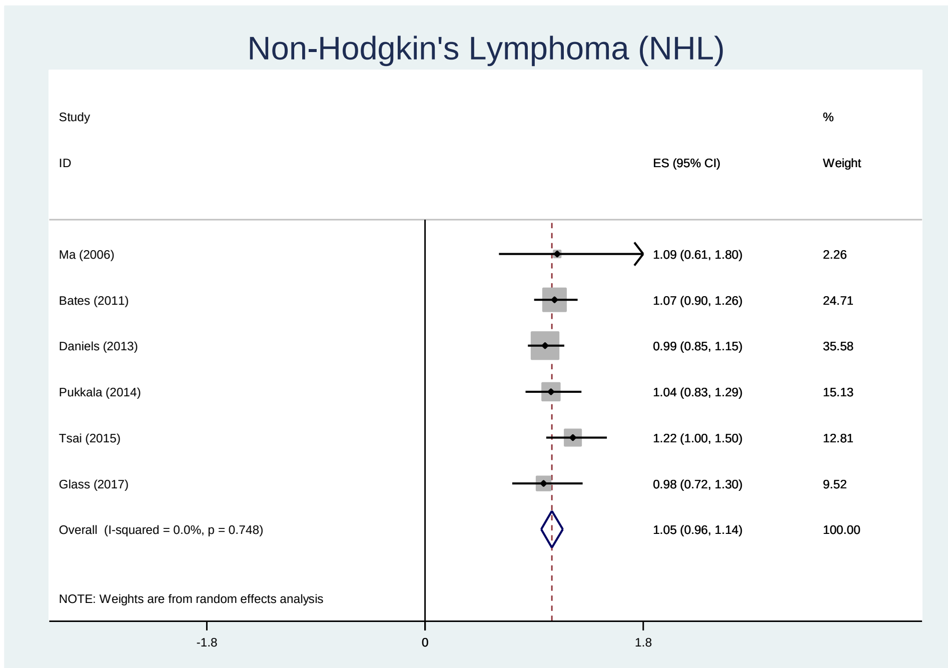

Figure A.10 Stata Output Forest Plot for **Non-Hodgkin's Lymphoma** (NHL) demonstrating the overall point estimate for the meta-analysis.

Table A.10.1 Stata Output for the Pooled Estimate for NHL.

Study	ES	[95% CI]	% Weight
Ma (2006)	1.09	0.61 - 1.80	2.26
Bates (2011)	1.07	0.90 - 1.26	24.71
Daniels (2013)	0.99	0.85 - 1.15	35.58
Pukkala (2014)	1.04	0.83 - 1.29	15.13
Tsai (2015)	1.22	1.00 - 1.50	12.81
Glass (2017)	0.98	0.72 - 1.30	9.52
Pooled Estimate	**1.04**	**0.95 - 1.13**	**100.00**

Table A.10.2 Stata Output for the Test of Heterogeneity for NHL.

Tests for Heterogeneity
Q = Heterogeneity chi-squared = 2.69 (d.f. = 5); p = 0.748
I-squared = 0.0%
Test of ES=0: z= 22.96; p = 0.000

A.11 Forest Plots and Tests for Heterogeneity for Multiple Myeloma

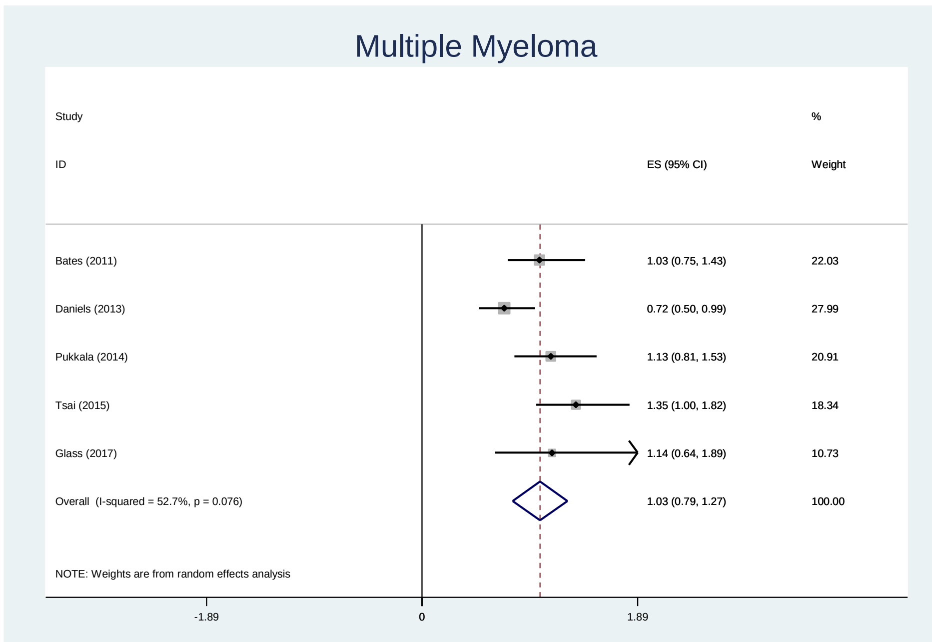

Figure A.11 Stata Output Forest Plot for **Multiple Myeloma** demonstrating the overall point estimate for the meta-analysis.

Table A.11.1 Stata Output for the Pooled Estimate for **Multiple Myeloma**.

Study	ES	[95% CI]	% Weight
Bates (2011)	1.03	0.75 - 1.43	22.03
Daniels (2013)	0.72	0.50 - 0.99	27.99
Pukkala (2014)	1.13	0.81 - 1.53	20.91
Tsai (2015)	1.35	1.00 - 1.82	18.34
Glass (2017)	1.14	0.64 - 1.89	10.73
Pooled Estimate	**1.03**	**0.79 - 1.27**	**100.00**

Table A.11.2 Stata Output for the Test of Heterogeneity for **Multiple Myeloma**.

Tests for Heterogeneity
Heterogeneity chi-squared = 8.45 (d.f. = 4) p = 0.076
I-squared (variation in ES attributable to heterogeneity) = 52.7%
Estimate of between-study variance Tau-squared = 0.0379
Test of ES=0 : z= 8.45 p = 0.000

A.12 Funnel and Egger's Plots and Begg's evaluation for publishing bias for All Cancers

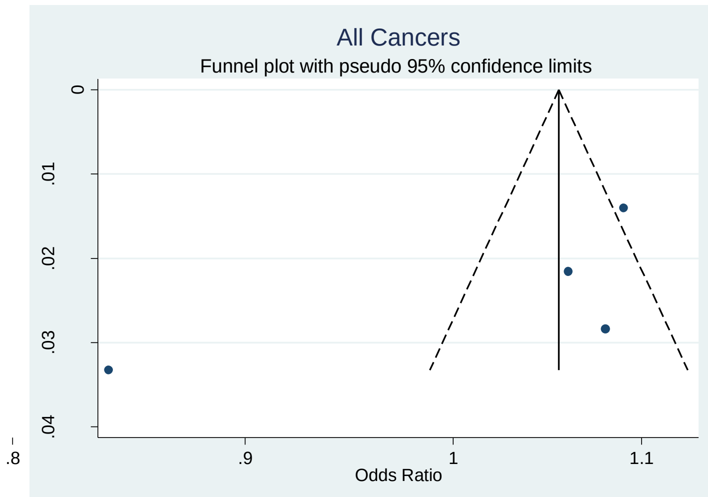

Figure A.12.1 Funnel Plot for Publication Bias for All Cancer Studies

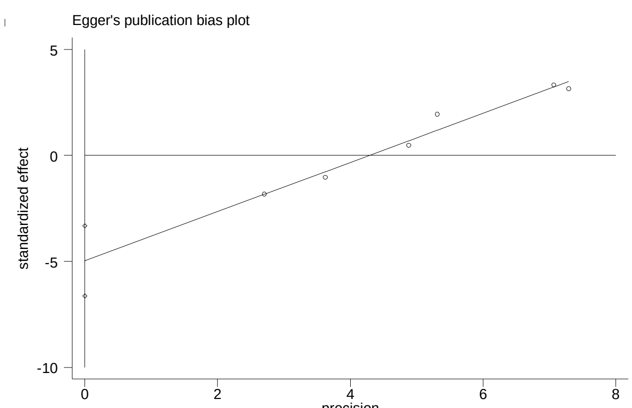

Figure A.12.2 Egger's Plot for Publication Bias for All Cancer Studies

Table A.12.1 Stata Results for Begg's Test for All Cancers

Adj. Kendall's Score (P-Q) = -13	Standard. Deviation of Score = 5.32
Number of Studies = 6	
z = -2.44	z = 2.25 (continuity corrected)
Pr > | z | = 0.015	Pr > | z | = 0.024 (continuity corrected)

Table A.12.2 Stata Results for Egger's Test for All Cancers

Standard Eff	Coef.	Std. Err.	t	P>t	[95% CI]
slope	1.161	1098986	10.57	0.000	0.856, 1.466
bias -	4.974	5944172	-8.37	0.001	-6.624, -3.323

A.13 Funnel and Egger's Plots and Begg's evaluation for publishing bias for Esophageal Cancer

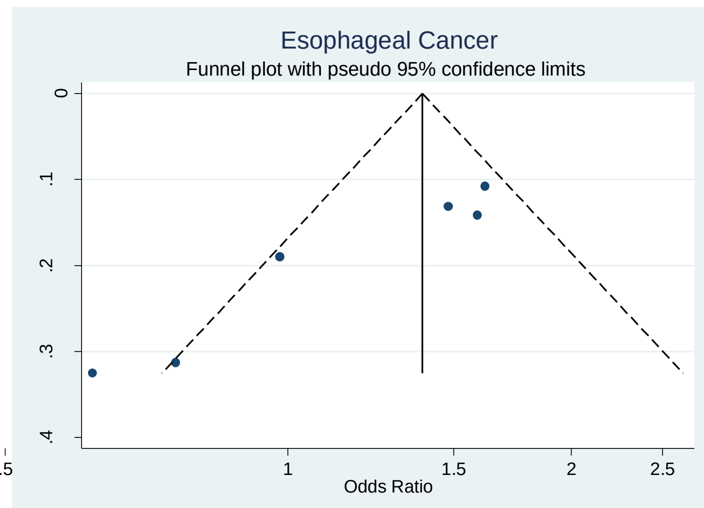

Figure A.13.1 Funnel Plot for Publication Bias for Esophageal Cancer Studies

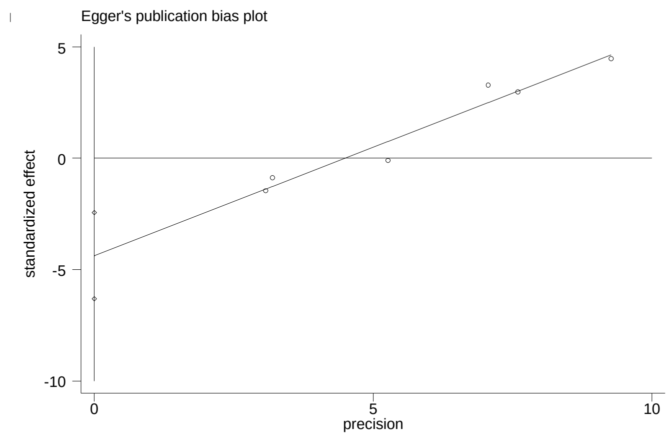

Figure A.13.2 Egger's Plot for Publication Bias for Esophageal Cancer Studies

Table A.13.1 Stata Results for Begg's Test for Esophageal Cancer Studies

Adj. Kendall's Score (P-Q) = -13	Std. Dev. of Score = 5.32
Number of Studies = 6	
z = -2.44	z = 2.25 (continuity corrected)
Pr > | z | = 0.015	Pr > | z | = 0.024 (continuity corrected)

Table A.13.2 Stata Results for Egger's Test for Esophageal Cancer Studies

Standard Eff		Coef.	Std. Err.		t	P>t	[95% CI]	
slope	.	972	.11		8.83	0.001	.66	1.27
bias	-	4.37	.69	-	6.26	0.003	-6.30	-2.43

A.14 Funnel and Egger's Plots, an evaluation for publishing bias for Stomach Cancer

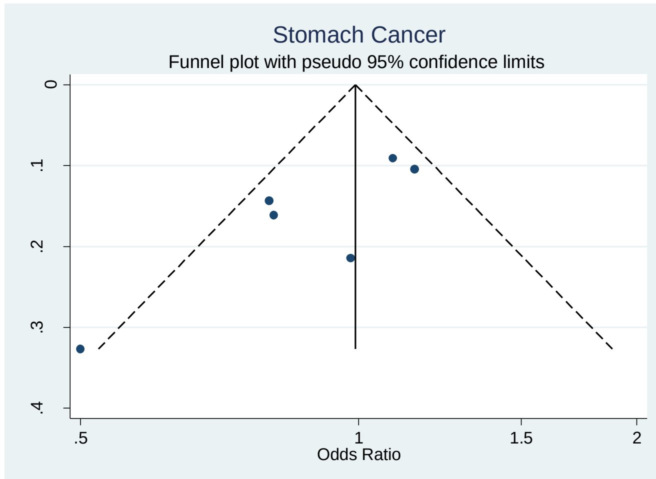

Figure A.14.1 Funnel Plot for Publication Bias for **Stomach Cancer** Studies

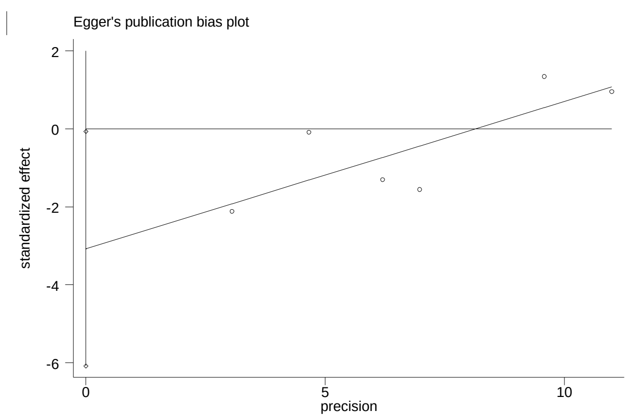

Figure A.14.2 Egger's Plot for Publication Bias for **Stomach Cancer** Studies.

Table A.14.1 Results for Begg's Test for Stomach Cancer Studies

Adj. Kendall's Score (P-Q) = -7	Std. Dev. of Score = 5.32
Number of Studies = 6	
z = -1.32	z = 1.13 (continuity corrected)
Pr > | z | = 0.188	Pr > | z | = 0.260 (continuity corrected)

Table A.14.2 Results for Egger's Test for **Stomach Cancer** Studies

Standard Eff	Coef.	Std. Err.	t	P>t	[95% CI]
slope	.377	.14	2.59	0.061	-.027, .78
bias	-3.08	1.08	-2.84	0.047	-6.07, -.06

A.15 Funnel and Egger's Plots, an evaluation for publishing bias for Lung Cancer

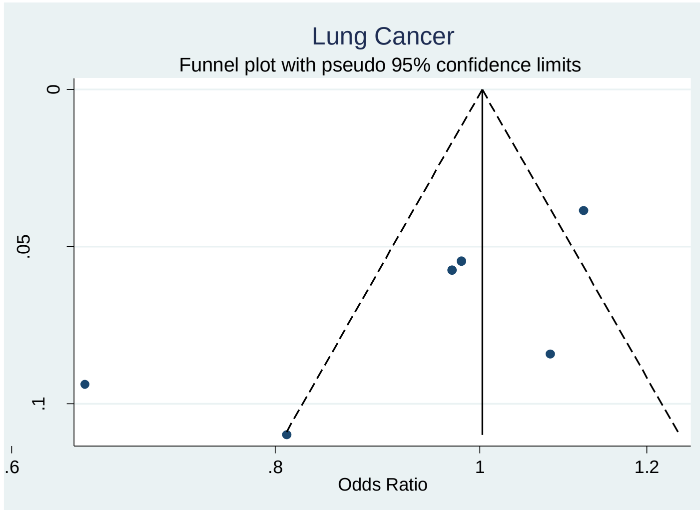

Figure A.15.1 Funnel Plot for Publication Bias for **Lung Cancer** Studies.

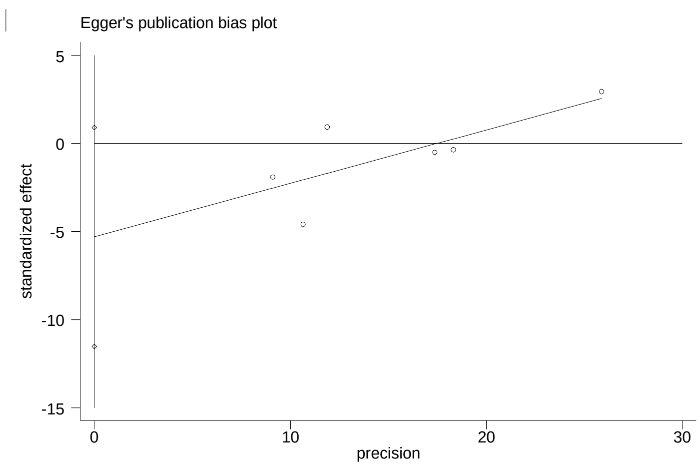

Figure A.15.2 Egger's Plot for Publication Bias for **Lung Cancer** Studies.

Table A.15.1 Stata Results for Begg's Test for **Lung Cancer** Studies

Adj. Kendall's Score (P-Q) = -9	Std. Dev. of Score = 5.32	
Number of Studies = 6	z = -1.69	= 1.50 (continuity corrected)
Pr > | z | = 0.091	Pr > | z | = 0.133 (continuity corrected)	

Table A.15.2 Stata Results for Egger's Test for **Lung Cancer** Studies

Std_Eff	Coef.	Std. Err.	t	P>t	[95% CI]	
Slope	.30	.13	2.25	0.088	-.07	.67
Bias	-5.30	2.23	-2.37	0.077	-11.51	.90

A.16 Funnel and Egger's Plots, an evaluation for publishing bias for Prostate Cancer

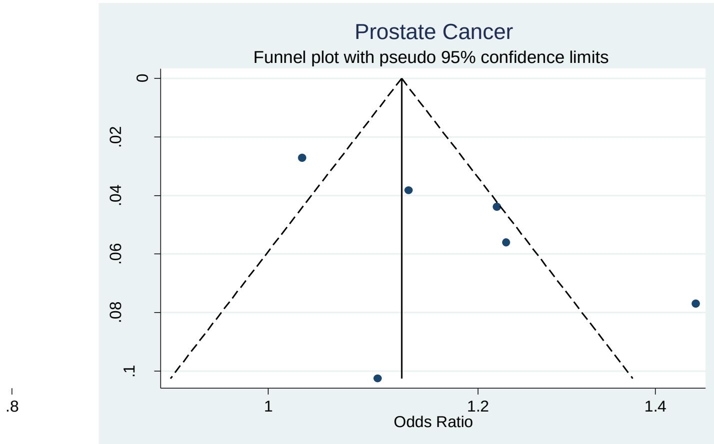

Figure A.16.1 Funnel Plot for Publication Bias for **Prostate Cancer** Studies.

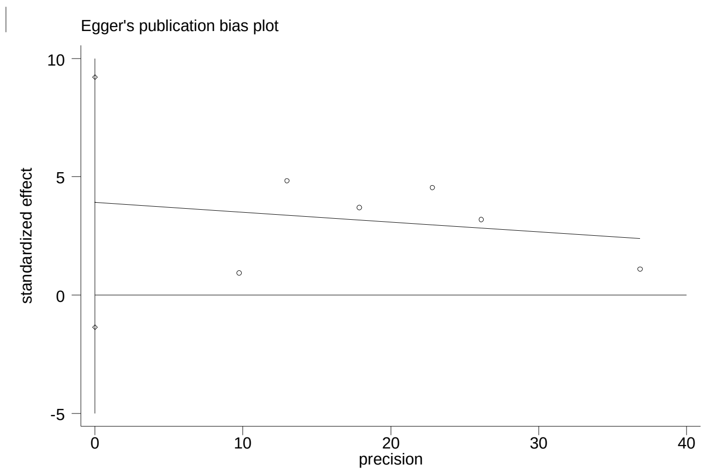

Figure A.16.2 Egger's Plot for Publication Bias for **Prostate Cancer** Studies.

Table A.16.1 Stata Results for Begg's Test for **Prostate Cancer** Studies

Adj. Kendall's Score (P-Q) = 5	Std. Dev. of Score = 5.32
Number of Studies = 6	
z = 0.94	z = 0.75 (continuity corrected)
Pr > | z | = 0.348	Pr > | z | = 0.452 (continuity corrected)

Table A.16.2 Stata Results for Egger's Test for **Prostate Cancer** Studies

Standard Eff		Coef.	Std. Err.	t	p>t	[95% CI]	
slope	-.04	.08	-0.50	0.642		-.27	.18
bias	3.92	1.90	2.06	0.108		-1.36	9.21

A.17 Funnel and Egger's Plots, an evaluation for publishing bias for Testicular Cancer

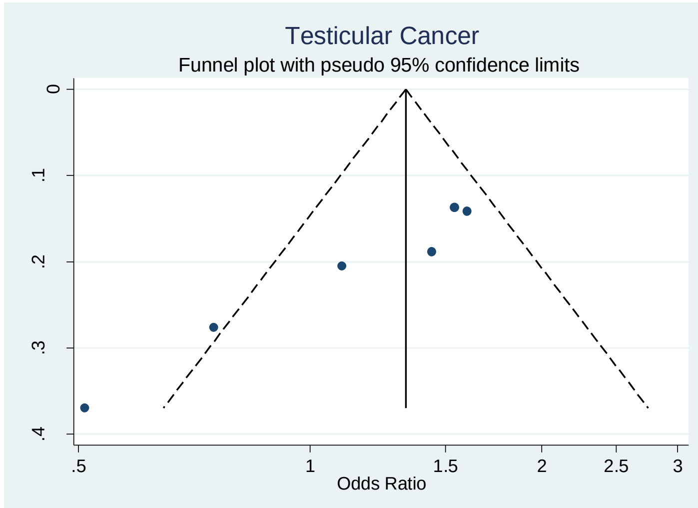

Figure A.17.1 Funnel Plot for Publication Bias for **Testicular Cancer** Studies.

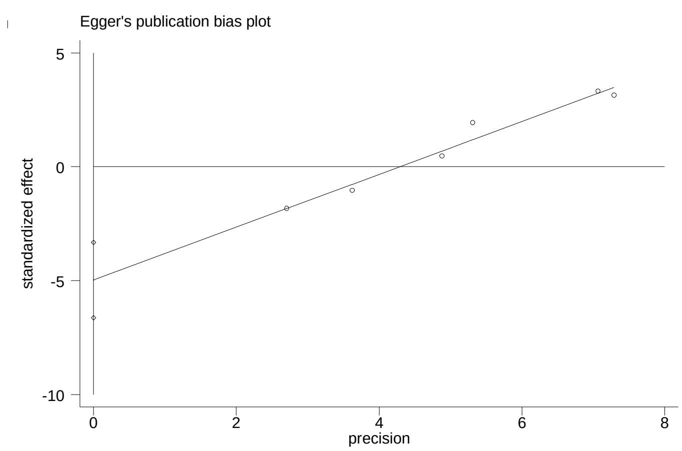

Figure A.17.2 Egger's Plot for Publication Bias for **Testicular Cancer** Studies.

Table A.17.1 Stata Results for Begg's Test for **Testicular Cancer** Studies

adj. Kendall's Score (P-Q) = -13	Std. Dev. of Score = 5.32
Number of Studies = 6	
z = -2.44	z = 2.25 (continuity corrected)
Pr > | z | = 0.015	Pr > | z | = 0.024 (continuity corrected)

Table A.17.2 Stata Results for Egger's Test for **Testicular Cancer** Studies

Std_Eff	Coef.	Std. Err.	t	P>t	[95% CI]	
slope	1.16	.10	10.57	0.000	.85	1.46
bias	-4.97	.59	-8.37	0.001	-6.62	-3.32

A.18 Funnel and Egger's Plots, an evaluation for publishing bias for Kidney Cancer

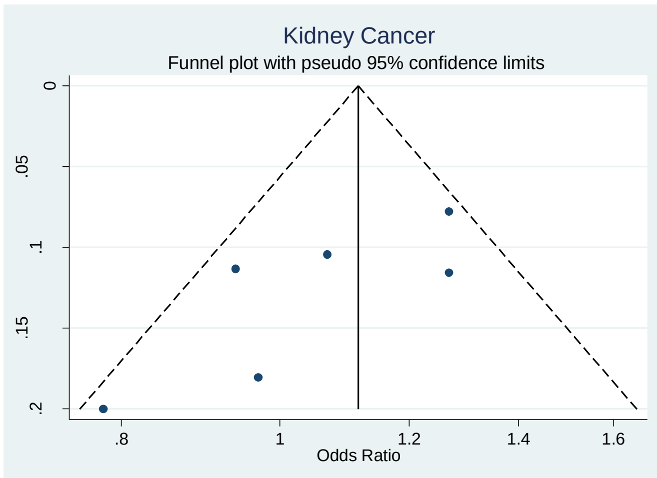

Figure A.18.1 Funnel Plot for Publication Bias for **Kidney Cancer** Studies

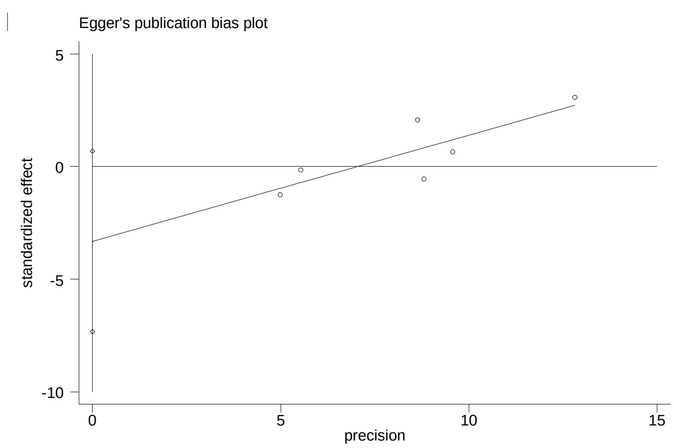

Figure A.18.2 Egger's Plot for Publication Bias for **Kidney Cancer** Studies

Table A.18.1 Stata Results for Begg's Test for **Kidney Cancer** Studies

Adj. Kendall's Score (P-Q) = -9	Std. Dev. of Score = 5.32
Number of Studies = 6	
z = -1.69	z = 1.50 (continuity corrected)
Pr > | z | = 0.091	Pr > | z | = 0.133 (continuity corrected)

Table A.18.2 Stata Results for Egger's Test for **Kidney Cancer** Studies

Stnd Effct	Coef	Std. Err.	t	P>t	[95% CI]	
slope	.47	1642271	2.87	0.046	.015	.92
bias	-3.31	1.44	-2.30	0.083	-7.32	.68

A.19 Funnel and Egger's Plots, an evaluation for publishing bias for Bladder Cancer

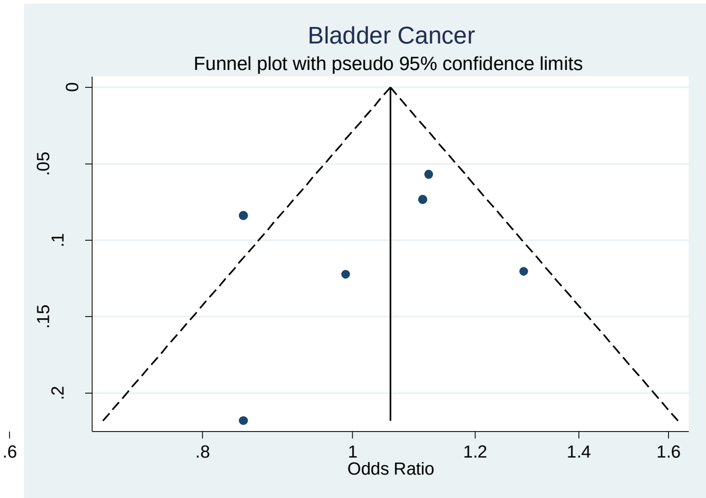

Figure A.19.1 Funnel Plot for Publication Bias for **Bladder Cancer** Studies.

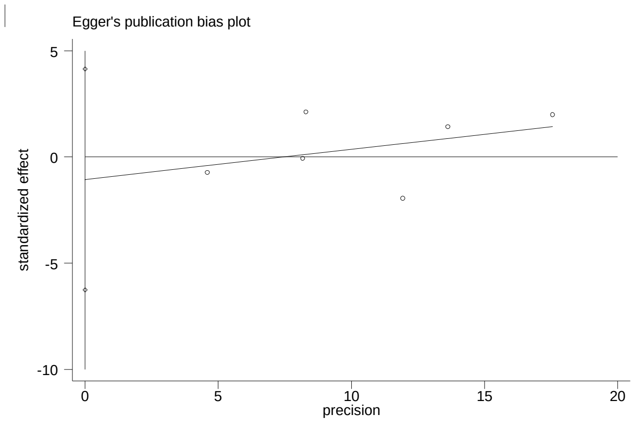

Figure A.19.2 Egger's Plot for Publication Bias for **Bladder Cancer** Studies.

Table A.19.1 Stata Results for Begg's Test for **Bladder Cancer** Studies

Adj. Kendall's Score (P-Q) = -5	Std. Dev. of Score = 5.32
Number of Studies = 6	
z = -0.94	z = 0.75 (continuity corrected)
Pr > | z | = 0.348	Pr > | z | = 0.452(continuity corrected)

Table A.19.2 Stata Results for Egger's Test for **Bladder Cancer** Studies

Std Eff	Coef.	Std. Err.	t	P>t	[95% CI]	
Slope	.14	.16	0.87	0.43	-.31	.59
bias	-1.05	1.87	-0.56	0.60	-6.26	4.14

A.20 Funnel and Egger's Plots, an evaluation for publishing bias for Brain Cancer

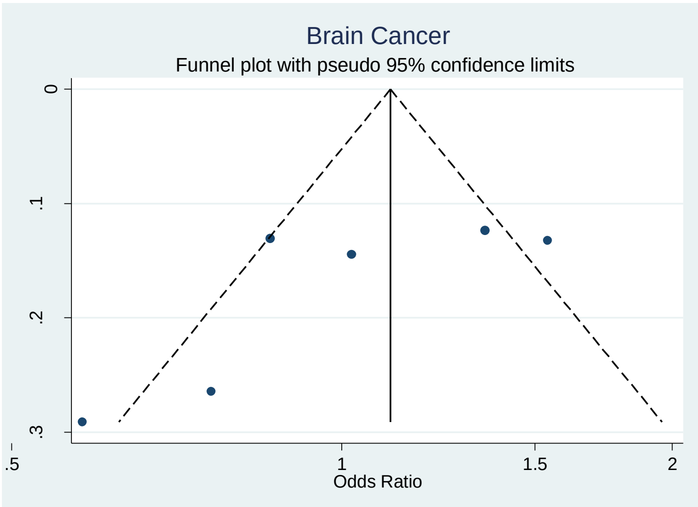

Figure A.20.1 Funnel Plot for Publication Bias for **Brain Cancer** Studies

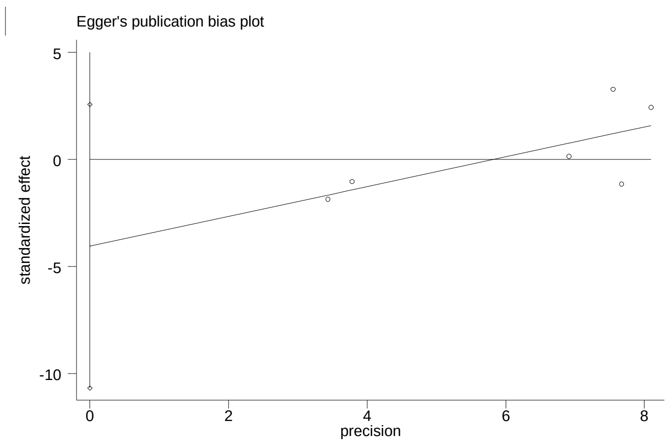

Figure A.20.2 Egger's Plot for Publication Bias for **Brain Cancer** Studies

Table A.20.1 Stata Results for Begg's Test for **Brain Cancer** Studies

adj. Kendall's Score (P-Q) = -7	Std. Dev. of Score = 5.32
Number of Studies = 6	
z = -1.32	z = 1.13 (continuity corrected)
Pr > |z| = 0.188	Pr > |z| = 0.260 (continuity corrected)

Table A.20.2 Stata Results for Egger's Test for **Brain Cancer** Studies

Std_Eff	Coef	Std. Err.	t	P>|t|	[95% CI]
Slope	.69	.365	1.91	0.129	-.31 1.70997
bias	-4.05	2.38	-1.70	0.164	-10.66, 2.56

A.21 Funnel and Egger's Plots, an evaluation for publishing bias for NHL

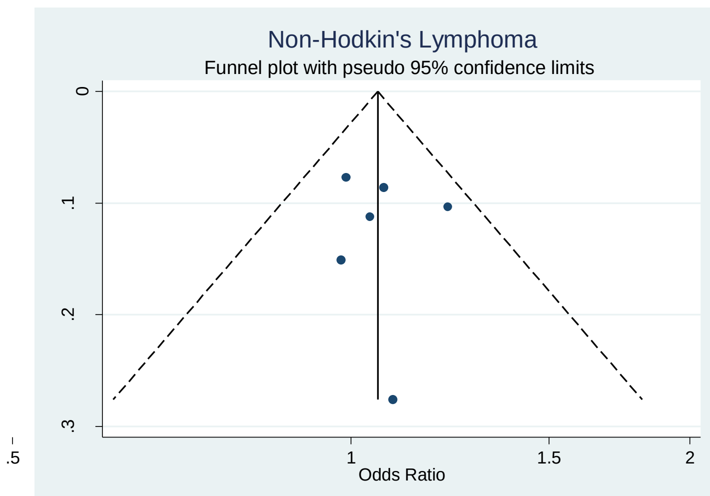

Figure A.21.1 Funnel Plot for Publication Bias for **NHL** Studies

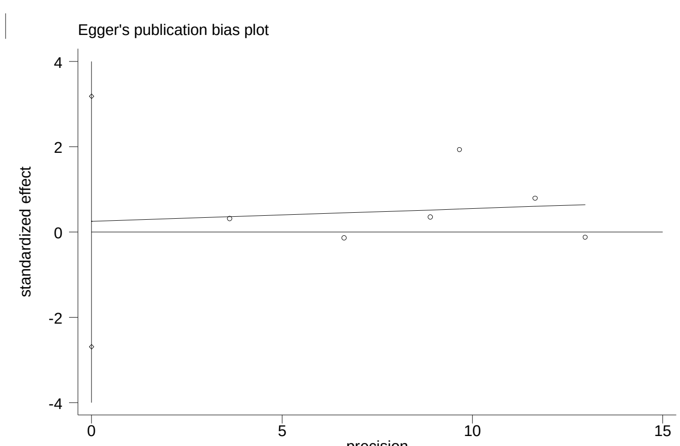

Figure A.21.2 Egger's Plot for Publication Bias for **NHL** Studies.

Table A.21.1 Stata Results for Begg's Test for **NHL** Studies

Adj. Kendall's Score (P-Q) = 1	Std. Dev. of Score = 5.32
Number of Studies = 6	
z = 0.19	z = 0.00 (continuity corrected)
Pr > | z | = 0.851	Pr > | z | = 1.000 (continuity corrected)

Table A.21.2 Stata Results for Egger's Test for **NHL** Studies

Standard Eff	Coef.	Std. Err.	t	P>t	[95% CI]	
slope	.03	.11	0.27	0.80	-.28	.34
bias	.24	1.06	0.23	0.82	-2.69	3.1

A.22 Funnel and Egger's Plots, an evaluation for publishing bias for Multiple Myeloma

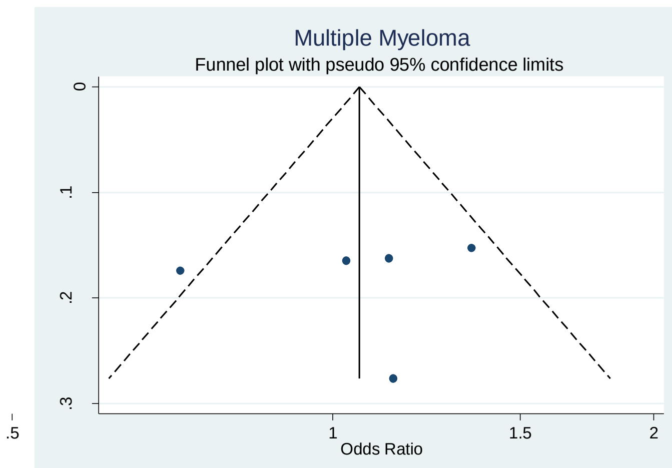

Figure A.22.1 Funnel Plot for Publication Bias for **Multiple Myeloma** Studies

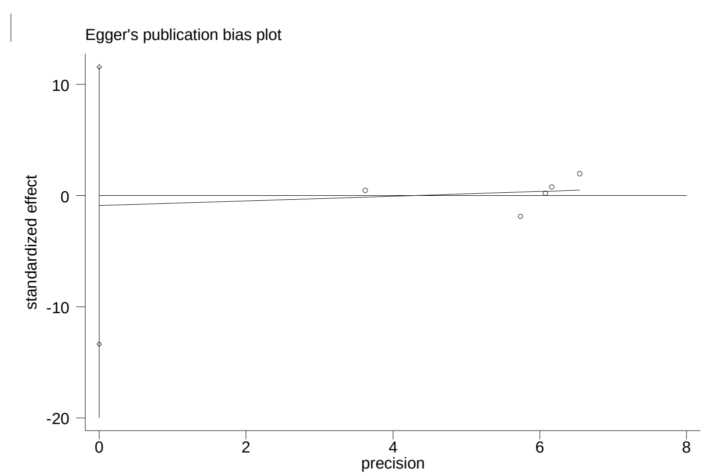

Figure A.22.2 Egger's Plot for Publication Bias for **Multiple Myeloma** Studies

Table A.22.1 Stata Results for Begg's Test for **Multiple Myeloma** Studies

Adj. Kendall's Score (P-Q) = -6	Std. Dev. of Score = 4.08
Number of Studies = 5	
z = -1.47	z = 1.22 (continuity corrected)
Pr > | z | = 0.142	Pr > | z | = 0.221 (continuity corrected)

Table A.22.2 Stata Results for Egger's Test for **Multiple Myeloma** Studies

Stnd Eff	Coef.	Std. Err.	t	P>t	[95% CI]	
slope	.20	.68	0.31	0.78	-1.97	2.38
bias	-.88	3.91	-0.22	0.83	-13.35	11.59

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