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OCCUPATIONAL MORTALITY AMONG PROFESSIONAL FIREFIGHTERS.

The University of Oklahoma, Ph.D., 1974
Health Sciences, public health

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THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

OCCUPATIONAL MORTALITY AMONG PROFESSIONAL FIREFIGHTERS

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

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Oklahoma City, Oklahoma

1974

OCCUPATIONAL MORTALITY AMONG PROFESSIONAL FIREFIGHTERS

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ACKNOWLEDGMENTS

The writer extends his sincerest gratitude to the committee and departmental chairmen, Dr. Carl A. Nau and Dr. Raymond A. Mill, Department of Environmental Health. To Dr. Nau for his continuing counsel, support and friendship in this and all other graduate efforts. To Dr. Mill whose guidance and assistance strengthened the course of this endeavor.

The writer further expresses his appreciation to other members of the Graduate Faculty Advisory Committee, Dr. Robert N. Thompson, Department of Environmental Health, Dr. Edwin W. Mumma, Department of Management, Dr. Alan S. Grubb and Dr. Wilson D. Steen, Department of Family Practice and Community Health whose constructive influence played a central role in the completion of this effort.

Special thanks are offered to Dr. Charles Lawrence, Department of Environmental Health, Dr. Katherine Sohler and Dr. Donald Parker, Department of Biostatistics and Epidemiology, whose suggestions were most valuable.

Particular acknowledgment is made to Messrs. James Minx, Whalen Simpson and Thomas Riddle of the International Association of Firefighters Local 1524, Chief Byron Hollander of the Oklahoma City Fire Department, Mr. Bill Liebegott of the Oklahoma State Firefighters Association, and Mr. Ray Long, City Clerk for their willing cooperation

and support.

I am greatly indebted to members of the Local 1524 Womens Auxiliary, Ms. Anna Lee Whitaker, Ms. Betty Ayers, Ms. Kathy Hamilton, Ms. Barbara Davis and especially Ms. Skoshi Sellers for their valuable efforts in providing records for this investigation.

To members of the Oklahoma State Health Department, Messrs. Donald Ransom, Charles Abbott, Ms. Irene Silberg and Mr. Roger Pirrong, my thanks for their most important contribution in the provision of vital records.

The assistance and approval of financial support by Mr. Leroy G. Martin of the U.S. Public Health Service during the writer's assignment with this agency is gratefully acknowledged.

Recognition and appreciation is extended to the Veterans Administration and U.S. Public Health Service (Occupational Factors in Health, General Purpose Traineeship Grant #C1209400) whose financial support permitted the pursuit of an advanced graduate degree.

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OCCUPATIONAL MORTALITY AMONG PROFESSIONAL FIREFIGHTERS

CHAPTER I

INTRODUCTION

The development of professional fire services in the United States has been accompanied by specific health outcomes among its workers. The 855,000 firefighters in this country (189,000 full time, 666,000 volunteers), who were responsible for extinguishing $2.3 billion dollars in losses in 1972, have been cited as having the highest on-the-job death rate of any occupation in this country [1-5]. Clinical, experimental, and actuarial reports have also identified certain disability and mortality risks incurred by this sector of the working population.

Although the decline of the relative mortality ratio among insured firemen, from 134 to 120 per cent, has been consistent with mortality decreases in many occupations [6], the Severity Rate, indicating days of disability per million man hours of work, has reached nearly one and a half times the average of all industries. Death and permanent disability figures have risen to 3.53 per million man hours, the highest of all municipal employees and comparable to the hazards of mining [7]. Wise [8] noted the American Society of Actuaries' finding regarding the inordinate risk of accidental death among insured firemen -

specifically, this group experienced more than twice the number of accidental deaths per 100,000 exposed (i.e., 12.4) when compared to all insured occupied men. Burnap [9] also made an interesting observation in 1970, when he compared the rate of 92 deaths/100,000 firefighters to 18 deaths/100,000 for general industry. The recent "Annual Death and Injury Survey", released by the International Association of Firefighters [10] for the 10-year period through 1972, illustrates the magnitude of occupationally related problems with injuries, occupational diseases, and deaths showing appreciable increases.

Dangers in the firefighting profession have been clearly demonstrated to pose a variety of potential health hazards to the individual worker [3-47]. Exposures sustained by the firefighter include inhalation hazards from toxic gases, particulate fractions and other pyrolysis products [48], temperature extremes, traumatic physical injury [12], and unusual physical and mental stress [16, 25] over which he exerts little or no control [23]. The tasks he assumes and environment in which he labors are inherently demanding, typically unpredictable [25], and favorable to the evolution of untoward health effects.

In addition to the above dangers, management policies affecting occupational loading or "manning" may also have health implications for the firefighter [11, 25]. Taking Oklahoma City as an example and correcting for land area expansion through annexation, an appreciable decrease in the distribution of firefighters - from ten per square mile to one per square mile in the last 40 years - has probably increased the total service burden for this group with definite health consequences as a result.

There has been some attention directed toward the examination and resolution of health-related problems besetting the firefighter; however, most research has been of an ad-hoc and superficial nature [3-5, 25]. Of the estimated $105 million dedicated to fire research as reported by the National Commission on Fire Prevention and Control [11], none was allocated to examining health hazards surrounding the fire service. The data that have been collected exhibit little uniformity [25] and have only been subjected to limited statistical analyses [4]. Perhaps more importantly, most of the findings that have been compiled arose from inquiries by the industry itself or insurance studies. From an epidemiological standpoint, the conducting of independent investigations has been rare. The correlation between insurance company and epidemiological data is not known.

Questions surrounding the health status of all service workers, with special reference to firefighters, should gain increasing prominence as this population grows. It has been projected that this occupational category will undergo a 27.9 per cent increase by 1975 (1968 base) [49]. Problems may also be predicted to become more acute as the exposed population increases [50]. Fortunately, increasing interest by the fire service in the safety and health area has been and continues to be shared by management [51] and government [14]. This concern seems to have extended beyond the safety area to occupationally related disease and has apparently become an important factor in union-management negotiations [51].

The fire service has been charged with responsibility for protecting life and property, often with considerable sacrifice among its

members. As one of society's most hazardous professions, firefighting has been only recently acknowledged to pose significant short and long term risks to its workers. Although legislative interest in occupational safety and health has produced statutory protections, firefighters have unfortunately been excluded [52] and have continued to be a seriously understudied population.

Life threatening risks through a variety of occupational exposures have been an inherent and traditional element of the firefighting profession. To assure that this essential community service continues to be performed effectively and that health and safety risks endured by this population will be properly controlled, definitive epidemiological and clinical inquiries need to be undertaken.

CHAPTER II

LITERATURE REVIEW

The occupational setting in which the firefighter has performed provides exposures not comparable in number or intensity to other industrial populations [30]. These stresses have stemmed from exposures on the fireground, as a result of the equipment he has used [11] and tactics he has practiced. Further, the environmental factors affecting community health such as air pollution and climate, have similary impacted on the firefighter's health status.

The physical condition of the firefighter has also played a central role in his adjustment and response to occupational stress. It has not been without concern that many practicing firefighters have been identified as being medically unfit for service because of cardiovascular considerations and visual acuity [53]. Some fire departments, however, demonstrating low disability rates have attributed a high degree of physical fitness as a principal reason for their health status [15, 22-24, 54]. It has not been known whether the criteria used in the various determinations of firefighter health status have been comparable.

Recognizing that the firefighter has endured a full range of environmental hazards with various systemic sequelae, it is appropriate to briefly review the nature of these stresses and origins of occupational diseases before considering their ultimate effect and the subject of

this inquiry, mortality.

Temperature

An examination of firefighter equipment and protective clothing has given a clear indication of the conditions under which firefighters have operated. With individuals laboring under superheated conditions, carrying heavy breathing apparatus with a limited air supply, wearing heat-conducting helmets and insufficiently ventilated turnout coats, the firefighter has been significantly handicapped before entering a conflagration [11].

The firefighter must work in extremely cold temperatures as well, which has further complicated the demands placed on the respiratory, cardiovascular, and nervous systems [25, 55]. Research has been conducted on problems associated with both upper and lower temperature extremes but more studies have related to evaluating stress effects from hot environments. Recognizing that man functions efficiently only within a narrow body temperature range, performance of the firefighter has been directly related to fluctuations in his core temperature [56]. Considering that atmospheric, chemical, electrical, mechanical and nuclear sources of heat energy may singly or in combination impact upon the firefighter, stress management in this area has become particularly important [57].

Notwithstanding the structural dangers and explosion hazards created by temperature extremes, the firefighter has faced physiological risks ranging from minor injury to death. Absolute effects of temperature extremes include heat syncope, prostration, cramps, exhaustion, dehydration, respiratory edema, burns, and pneumonia, bronchitis,

frostbite, coryza and "immersion foot" [11, 25, 55, 57]. Temperature limitations without protective clothing apply to atmospheres exceeding 120°F. to 130°F. or below 30°F.

Reich [12] has described systemic sequelae from exposure to temperature extremes. He identified hyalinosis of the heart with muscular hypertrophy, fibrinous pericarditis and fibrin deposits within the heart as probable physiological outcomes from exposure to lower temperatures. Continuous cold exposure has also experimentally produced hypertension, nephrosclerosis, cardiac hypertrophy, and cardiovascular hyalinosis.

Exposure to high temperatures has been cited as being indirectly responsible for increased absorption of chemical substances. Elevations in heart and respiratory rates have placed additional burdens on the individual firefighter [12, 15, 57]. Systemic disturbances have been recorded from heat flowing through the surface of the body. Generalized cutaneous exposure to hot air and radiant heat has been associated with cutaneous injury and acute circulatory collapse [58].

Kloetzel [59] investigated the relationship between hypertension and prolonged exposure to heat in another occupational group with findings supporting a definite relationship between the levels of blood pressure and years of exposure to high environmental temperatures.

There have been some different interpretations concerning the long term pulmonary effects from fires. Pittman [60] indicated, after clinical and roentgenological studies, that no persisting or secondary pulmonary disease resulted from injuries sustained in the Cocoanut Grove Fire. Similarly, an examination of effects from inhaled heat on the

air passages and lungs demonstrated that the original temperature of heated air would have to be high enough to produce instantaneous burning of the skin and upper respiratory mucosa before there was sufficient residual heat to cause pulmonary injury [61]. Thomas [48] has also substantiated this. Skolnick [32, 34] however, has indirectly associated heat effects in firefighters with tuberculosis and pneumonia.

Extreme temperatures resulting in burns may effect certain cardiovascular changes; there has been consideration of serous myocarditis as being characteristic of burns and panarteritis at a site distant from the injured area [12].

The firefighter has also received exposure to temperature extremes from the ambient environment. Studies substantiating relationships between weather and mortality are not to be discounted in evaluating this population's occupational setting and health status [62, 63].

Chemical

The area of chemical stress includes agents in the physical form of liquids, vapors, gases, dusts, fumes, fogs, foams, mists, aerosols and smoke. Members of the fire service have faced exposure to a variety of elements and compounds in one or more of the above states. The actual risks to their health have arisen from exposure through skin absorption, ingestion, and/or inhalation. As a route of entry the latter has assumed special significance since absorption of toxic materials occurs at a greater rate than skin absorption or ingestion [56]. Aviado [64] has grouped chemical inhalation responses into four areas - the airways, bronchial blood vessels, pulmonary blood vessels, and the heart and systemic vessels.

The considerable literature on smoke inhalation per se, indicated that it be treated separately. As a hazard, it has been reported with significant frequency among firefighters [22]. Ausbie [5] has contended that "the health effects associated with smoke inhalation by certain population groups have been recognized for many years" while other authors have stated that the syndrome of smoke inhalation is a subject about which little has been known [65]. According to Thomas [66], there has been some overstatement of smoke inhalation's prevalence. He has remarked that smoke inhalation does not account for a high percentage of firefighter injuries and deaths but that it is "...the most common single cause of injury to firefighters" [48]. Conversely, Zikria [65] believes it to be a problem grossly underestimated in magnitude.

It has been calculated that smoke inhalation accounts for about 80 per cent of the injuries with approximately 13 per cent requiring hospitalization [55]. To avoid prejudging the significance of smoke inhalation, some investigators have suggested that all persons exposed to smoke inhalation, notwithstanding the apparent effects or lack thereof, should undergo arterial blood gas analysis to determine the extent of hypoxemia and to provide a physiologic basis for treatment of acidosis if present [20]. Physiologic responses which have been somewhat more visible than alterations in blood chemistry have also been discussed. Certain respiratory disorders (pulmonary emphysema, pulmonary fibrosis, pulmonary atelectasis, bronchiectasis) have been linked by Skolnick [35-37] to smoke exposures sustained by the professional firefighter. Thomas [48, 66] has also detailed some of the more classic pulmonary irritants and their pathologic effects on the respiratory system.

Apart from smoke's potential effect on sensory, motor and metabolic function, the National Commission on Fire Prevention and Control has listed a more obvious occupational hazard - blocking the visibility of exits [11].

From a chemical standpoint, smoke is a suspension of small particles in hot air and gases, it contains droplets as well as dry particles less than 0.1 micron in size. These carbon particles have certain combustion products adsorbed to their surfaces [58]. The gaseous and particulate fractions act jointly to occupy confined areas and deplete atmospheric oxygen. This condition creates hypoxia in the firefighter with resulting increases in blood pressure and other vasomotor phenomena. Hypoxia and emotional stimuli also act synergistically in the production of morphologic changes. Physiologically, inhalation of fire gases has reportedly caused interference with oxidation-reduction processes in the body cells; with severe oxygen-want, symptoms of hemorrhage and edema have been found in the lungs. Cardiac infarction has reportedly been precipitated among those with heart disease [12]. These facts are especially important since heart disease (myocarditis, valvulitis, endo- and pericarditis, coronary occlusion or thrombosis and aoritis) has been reported to be the most frequently occurring occupational disease among firefighters [15, 26]. Of the pulmonary disorders, pneumonia has been perhaps most common of the acute diseases resulting in firefighter death and disability [34] while tuberculosis has been the second most commonly occurring chronic disease [31].

The process of combustion frequently yields an abundance of gaseous products with a toxic nature. Various authors have elaborated

the principal pulmonary irritants and toxic gases from fires [12, 21, 55, 57, 65-68]. The gases formed and their relative toxicity are a function of the burning material's chemical composition, the amount of oxygen available for combustion, and the temperature [61]. Gases pose greater danger than most particulate fractions of combustion since the nose, mouth, and throat can not effectively filter them and respiratory protective devices may leak or are not used [69, 70]. Research areas concerning the chemistry and toxicity of pyrolysis products have not been adequately investigated [48, 64, 71] but it has been recognized that fatalities from the inhalation of hot fire gases are far more common than all other causes combined [57].

Gases such as carbon monoxide (CO), carbon dioxide, hydrogen sulfide, hydrogen cyanide, phosgene, and various aldehydes have acted to chemically intoxicate the firefighter by producing a stress or poisoning reaction [12, 21, 66]. Gases typically appear in combinations but there has been a lack of scientific agreement concerning their synergistic action. Reich [12] and others [11] have stated the hazard of two or more gases is greater than the sum of the hazards of each while others have reported that the synergistic effects of toxic products are simply not known [72]. Gaume [73] however, in examining an individual's time to incapacitation in a fire has revealed experimentally that triple gas exposures actually showed a progressive increase in an individual's time of useful function (TUF) as the contaminant mixture became more complex.

Ironically, firefighters must also contend with toxic pyrolysis products from certain fire extinguishing agents. Harmful effects from

many of these such as carbon dioxide, carbon tetrachloride, ethylene glycol, certain Freons, methylene choloride, and the halogenated hydrocarbons have received considerable attention [57, 74, 75]. It has been stated that the combustion gases given off by the fire are much more hazardous than any extinguishing agent currently in use but there is some experimental evidence to the contrary [76]. Comstock [77] found vapors from certain agents to be quite lethal; he demonstrated increased mortality with the halogenated hydrocarbons being tested and also found associations of slow extinguishing to higher mortality. In other experimental investigations, analysis of toxic pyrolysis products evidenced sublethal concentrations but showed relatively high CO levels [72]. Resolution of these experimental disparities will probably be achieved when expertise has been developed in the area of fire gas replication.

CO, one of the most notorious of the fire gases, is always present and has posed a formidable acute and chronic inhalation hazard to the professional firefighter. Its chemical action in binding hemoglobin has been well known experimentally and clinically; its relationship to certain cardiovascular pathologies in firefighters has also been firmly substantiated [26, 29]. Earlier work by Gordon and Rogers [78] described the significance of CO on firefighter health and safety. Fortunately, its influence can be controlled by proper use of respiratory protective devices. Its occupational health importance should not be underestimated however as a recent study again demonstrated the major cause of death among victims without body burns to be CO poisoning [79].

CO has been demonstrated to exert untoward health effects in non-occupational settings as well. Hexter [80] showed a significant

association between community CO concentration and mortality. This agent has continued to be among the foremost of the fire gases to be reckoned with by members of the fire service.

Other experimental demonstrations of the chemical hazards faced by firefighters have been recorded in the recent literature. Hill and others [18] analyzed certain fire gases by mass spectroscopy and gas chromotography with results suggesting potential hazards for the firefighter.

Agents like nitrogen dioxide, which have also played an important role in air pollution, occur on the firegrounds. Although the long term health effects from low level chronic exposure are not known, nitrogen dioxide has posed special dangers for firefighters [17].

In addition to the extrinsic sources of chemical exposure, it should be noted that cigarette smoking among firefighters has been associated with respiratory disease and decreased lung function. Sidor and Peters [23] stated that "cigarette smoking showed greater effects than any of the firefighter occupational exposures, severe, and stressful though these may be."

There are over a half million chemical compounds in use today and discussing the full range of fire gases and their physiologic properties extends beyond the scope of this review. It should be recognized however, that opportunities for exposure are manifold and can result from thermal decomposition of materials used in construction, industrial processing, household solvents, fumigants, pesticides, paints, wood products, petroleum products, plastics and refrigerants [48, 65, 67].

Trauma

The hazards of trauma have been interpreted differently by various workmen's compensation authorities [81]. For purposes of this review, trauma will be considered as "an injury or wound brought about by an outside force" [56].

The hostile environment in which firefighters must work has been partly responsible for a large risk of trauma [23]. In a series of articles by Skolnick, the causal connection between trauma, the formation of active musculoskeletal tuberculosis [42] and active pulmonary tuberculosis [33] were discussed. Although the evolution of such disease is usually remote from the trauma incident, the relationship seems clear. Schwartz [82] has discussed the association between chemical trauma and the development of malignant tumors. This area has received much scientific scrutiny but the relationships are not as well defined. The risk of pathologies in this category has probably been reduced in firefighters because exposure to oncogenic agents has typically not been continuous and has been effectively attenuated by use of proper personal protective equipment and safety consciousness.

The firefighter also has exposure to blasts, concussion, blows to the head, and foreign objects or infections in the ear. In the case of blasts, the firefighter could incur "blast hypertension" as well as some form of acoustic trauma. The risk of such trauma seems high in this group and although there are clinical descriptions, no studies of this problem as it relates to firefighters were found.

In an earlier discussion of firefighting and heart disease it was indicated that extensive traumatic injury and shock have been

associated with numerous cardiovascular phenomena including a decrease in arterial blood pressure and stroke volume. Capillary damage and petechiae are changes which have been seen in all organs; actual myocardial degeneration may also occur. In patients dying of traumatic shock, fatty degeneration of heart muscle fibers has been recorded. Nonfatal trauma and shock from exposure to electrically charged wires, a frequent risk among firefighters, may also effect cardiovascular changes [12]. As in the other trauma categories, the long term implications of extensive trauma as it relates to firefighter mortality have not been investigated.

Given the exposure of firefighters to trauma, studies concerning the incidence of physical injury have been needed. Other than some crude tabulation efforts, a review of the literature uncovered no definitive mortality or morbidity investigations in this area.

Ergonomics

The interdisciplinary area of ergonomics embraces almost all other forms of stress. This section will only briefly mention the occupational hazards not specifically covered earlier.

Considering the firefighter to be the monitoring link of a man-machine environment system, his behavioral and physical operating characteristics have assumed importance in the operation of sophisticated fire fighting equipment. Task stresses as described by the National Safety Council have posed inordinate demands on the firefighter. Regrettably, the nature of the task has not been particularly amenable to design modifications. Design engineers and safety professionals generally have excluded the participation of man in particularly

stressful tasks. Since in many tasks there has been no real relief from mechanical systems, it has been these tasks that the firefighter must perform in the routine course of his duties [56].

Sakai and others [16] have elaborated the effects of work pressure on the firefighter. They noted that continuous mental tension was unexpectedly severe and that insufficient attention was paid to nutrition. The appearance of cardiovascular pathologies was seen as directly related to the firefighter's occupational milieu. Results published by Barnard [83] have also affirmed cardiologic effects from sudden strenuous exercise. Similarly, documented case histories have identified extrinsic stresses experienced by members of the fire service as precipitating the formation of coronary heart disease. It has also been stated that unusual stresses and strains are probably, as a group, the chief factor in the development of coronary thrombosis [27, 30].

General Environmental Stress

Statistical evidence has been generated to support correlations between non-occupational mortality and variables such as sulfur dioxide [84], air pollution [85], urbanization [86], climate [87], or socio-economic status [88]. Such factors have been difficult to adjust for but studies of occupational mortality may be benefited by considering their impact on any population under study concurrent with the occupational stresses earlier reviewed. None of the mortality studies or equations reviewed however, presented any strong valuation of multiple stressors, occupational or otherwise.

Occupational Stress Effects

Direct physiological measurement of the previously described occupational factors has often revealed certain systemic effects on the individual worker. These may, however, also be translated into meaningful epidemiological language through the use of mortality statistics. This method has allowed the detection of associations between environment and specified causes of death which have provided important clues to the etiology of fatal disease [89] as well as its incidence and occurrence [90].

Puffer [91] and Gaffey [51] have stated that it has been mortality statistics that must first be turned to in assessing the health of any occupational group. The merits of using such data have been earlier elaborated by Guralnick [24], Gaffey [51], Enterline [92] and Robertson [93]. The compilation of mortality statistics has allowed examination of inter-group differences, direct comparison of occupational factors, satisfaction of medico-legal requirements apart from occupational factors and, as a biometric method, has allowed a wholly unbiased approach since the event has been reliably recorded and the cause has been consistently registered. Some of these factors have been alluded to in an earlier section.

Fluctuations in some mortality rates have been found to be less pronounced across time and more obvious in the group differences as to risk of death [88]. Where traditional studies formerly empahsized historical patterns, interest in the existence of mortality differentials among population subgroups such as occupational classes is now found. Part of this new direction in the use of mortality statistics results from an increased capacity to control influences which affect

death [94]).

With mortality data being such an accessible measure of a population's health, they can be expected to provide gross descriptions of occupational disease occurrence indicating health problems which justify further investigations. Findings derived in this manner can serve in the modification and improvement of the work setting or health care system to satisfy the needs of the study population [93].

Enterline [95] has remarked of people pursuing a specific occupation at a particular place and time, that as a population they are especially unique. This statement is consistent with observations made by the World Health Organization [96]. In a technical report, they indicated that

> Mortality hazards associated with an occupation may stem from many aspects of the particular employment. They may arise from the work itself, from the regions in which it is pursued, or from the socio-economic concomitants. In some cases, occupational selection or drift may account for the fact that an occupation that recruits substantially from those disabled by chronic illness may show a high mortality from chronic disabling disease.

This last observation has been extremely relevant to fire departments with high disability rates from individuals with pre-existing conditions or who become physically unfit [16, 53].

Methods of studying occupational mortality have ranged from the use of occupational indices such as crude or specific death rates, standardized, comparative or proportionate mortality ratios [89] to other independent measures such as infant death rate which have correlated with decisions about social class [50].

Occupational Mortality

The gathering and analysis effort regarding mortality statistics

in the United States has not been comparable to the experienced and more elaborate system in England and Wales begun in the 1800's. Many of the methods and statistical routines in the United States, however, have seen their origins in those used by the Registrar-General.

The first third of this century was addressed to establishing a registration system encompassing the entire United States. Plans had been made during this time to initiate a study of occupational mortality but were never realized. The published information concerning occupation and mortality was reported to have first appeared in the Bureau of the Census records of 1890 [92]. Subsequent occupational data not officially published until 1950 had been primarily limited to simple enumeration [97]. Doric [98] however, has offered a thorough description and review of studies concerning occupational mortality. This work has also identified certain statistical caveats which researchers in this area should be sensitive to.

The principal uses for occupational mortality statistics have been previously discussed. Additionally, a review of the epidemiological and occupational health literature has demonstrated frequent application of these data to the detection of new hazards and the monitoring of current control measures. In this connection, a large number of occupational mortality studies have been reported in recent years. Although firefighters have been excluded, there have been studies of workers in the newspaper, shipyard, gas, coal,chromate, asbestos, metallurgical, steel, potash, cotton, uranium, and machine shop industries [59, 99-109]. It has been especially noteworthy when, in comparison to firefighting, all these mortality studies have been directed toward industrial

categories of apparently lower risk.

Firefighter Health Statistics

Detailed information on firefighter mortality has not been readily available although the International Association of Firefighters and National Safety Council [1] have been tabulating accidental deaths. It has been this conspicuous absence of routine collection schemes for morbidity and mortality statistics that has been consistently identified by fire officials as a principal weakness in determining the health and safety status of the firefighter [4, 15, 110-112]. Although several industrial groups have enjoyed regular data collection on their accident, disability and mortality experience, similar indices have not been routinely compiled for the firefighter by the Bureaus of the Census or Labor Statistics, National Center for Health Statistics, or International Labour Office of the World Health Organization [113, 114]. Additionally, as public employees, firefighters have been excluded from provisions of the Occupational Safety and Health Act including this type of record-keeping [52]. The annual statistics published on deaths resulting from fire have represented only a crude compilation of all fatalities with no discrete data for the professional firefighter.

In spite of these deficiencies in the data, it has been generally accepted that many diseases or disabilities associated with occupational exposure can eventually be anticipated to express themselves through excess cause-specific mortality [15, 51]. Given this epidemiological sequence and the fact that risks and hazards faced by the firefighter have been only partially recognized [38], some assumptions concerning mortality outcomes may be made when the more frequent occupational

diseases of firefighters are reviewed.

Studies which have disclosed the stressful character of the work conditions [16] and substandard health status of firefighters [53] have been consistent with the more common firefighter pathologies described in the literature. In a lengthy series of articles, Skolnick [26-37, 40-42] described through case histories representative disorders suffered by the firefighting profession. The preponderance of cardiovascular and pulmonary diseases has been repeatedly identified as being responsible for the bulk of deaths and disability among this population's members. All of these associations were described in the first section of this dissertation except for a case concerning a neurologic disease - one which was rare and of questionable significance [26-37, 40-42].

Other epidemiologic inquiries which have concerned themselves with the measurement of ill health, have also supported certain correlations between the firefighters occupational exposure and his health status [5, 12, 13, 15, 22, 23, 115-117] but some variables, particularly smoking, have been cited as being more important than certain occupational factors. Clinical investigations of various firefighting populations have typically revealed normal values and physiological tolerances, to be deviant from those of other populations. The extent of all disorders, however, has not been readily disclosed since the development of certain physiological abnormalities has often been remote from the time of first exposure. Clear cause-effect relationships have been difficult to establish in these cases.

Some legal conclusions concerning firefighter health and safety have also been made in various localities. A number of jurisdictions

have held and affirmed certain causal relationships between firefighter death and disability and his work environment. Such decisions have underscored the important need for health and safety management and continuing research in the area [39, 43-46, 118].

Firefighter Mortality

In the United States data on occupational mortality among firefighters have been found in death certificates, decennial census returns, life insurance records and industrial personnel records. Enterline [92] and Puffer [91] elaborated in detail the historical course of data collection in the area of occupational mortality, some of which concern the fire service. The relative strengths of the various sources have also been considered. In both of these reviews it is clear that the authors were in agreement with Dublin and Vane [119] who demonstrated that industrial policyholders had higher mortality and shorter longevity than other workers - a category which includes firefighters. They also pointed out that the differences were, in fact, due to effects of specific occupations even though other variables had played an important part.

Recognizing the firefighter as a service worker [24] to be in a relatively high risk group, a review of those mortality studies including the firefighting population will illustrate current epidemiological thinking concerning this group.

Table 1 in APPENDIX A has been constructed to chronologically illustrate the principal data gathering efforts concerning firefighter mortality. This compilation accurately reflects the character of the studies, sources of information, general findings and orientation of

the investigator(s). A number of these studies were also cited by Mastromatteo [15] whose work represented one of the few independent investigations with a structured epidemiological approach and offered a comprehensive review as of that time.

An examination of this summary demonstrates some important features concerning the historical course of mortality inquiries. As MacMahon [131] has stated, the greatest body of information relating to occupational disease has been derived from the analyses of the Registrar-General for England and Wales. This agency has collected and published mortality information on firefighters since 1938 [15, 91]. In comparison, the lack of meaningful occupational mortality statistics for this country has been repeatedly mentioned by various authorities as a central weakness in the ability to identify risks and conditions facing the American worker [15, 97, 110, 132]. To a certain extent this has been remedied for certain groups by recordkeeping requirements of the Williams-Steiger Act of 1970. Officials directly concerned with firefighter health and safety have recognized the existing data to be fragmented, epidemiologically incomplete and without statistical strength [4, 110].

Inspection of Table 1 readily discloses that 1950 was the only year providing mortality data by occupation and industry for the entire United States; it was also a singular effort from the standpoint of analyzing mortality among occupational groups based on death certificates and census information - the most extensive study population available [133]. In contrast, fully 40 per cent of the mortality studies concerning firefighters were conducted by the insurance industry which relied

on either ordinary life insurance policies for data by occupation or group life insurance policies for information by industry wherein both cases the study population was select. Hoel [134] indicated that the usual actuarial methods have not been concerned as much with individual diseases (i.e., general health) as with the construction of life tables and general mortality rates. Relying on commercially motivated studies, particularly where the investigator has a fiduciary relationship with his subject, also has raised concern about investigator motivation which may be reflected in design or orientation of the inquiry. A redeeming feature of the life insurance findings has been that they have frequently shown a favorable correspondence between the identification of hazards and reduction of accident rates [92]. It should also be noted that these studies, as others, have not demonstrated sensitivity to important variables such as changing work weeks, improved work conditions, safety practices and equipment and medical advances in diagnosis and treatment areas. Additionally, full and part time firefighters have not been identified. Without addressing variables which affect the firefighter, it has been difficult to demonstrate what factors explain decreased or increased mortality.

Recognizing that findings from different sources have frequently been at variance, it should be understood that various epidemiological designs incorporated different orientations. A number of the studies cited had not standardized for age, discriminated racial characteristics, firmly identified retired personnel, or adjusted for educational or socioeconomic status. The high accident rate was one distinct trend however where agreement was universal, regarding it as a

principal cause of death.

With only 10 per cent of the studies comprising independent epidemiological efforts, additional investigations with stronger statistical controls should produce credible and needed data for assessing the health status of this population.

CHAPTER III

PURPOSE AND SCOPE

The data on firefighter mortality have suggested significant elevations in the death rate for this group as a result of occupationally related exposures. General mortality information on this population however, has been identified as being abjectly inadequate. Further, findings among various investigators have not been completely consistent. As mortality statistics have been the principal biometric method for comparing occupational health indices [92] and for measurement of a population's health [91, 93], the application of such methods as a definitive approach for the finer examination and determination of the firefighters' mortality experience is certainly indicated.

The specific purpose of this study was to accurately identify the total at risk population, retrospectively generate vital information, compare the health status of the firefighters with that of the general population and examine the relationship between duration of employment and longevity. Evaluation of these relationships and examination of cause of death trends should lead to the identification of occupational risks and facilitate recommendations for the development of control regimens [89-91, 93].

CHAPTER IV

METHODS

Experimental Design

Since the purpose of this study was to determine and evaluate the health status of a specific occupational group and to relate this to the occupational hazards faced by this group, the experimental protocol was initiated by determining the study population's mortality experience followed by the derivation and comparison of observed and expected death rates [95]. The experimental design included collection of extensive vital information on a complete population of decedents, most of whom had appreciable tenure in the firefighting profession. Inspection and statistical analysis of death events yielded determinations of their mortality experience. These trends were examined in order to identify certain risks experienced by this group and to develop indicated measures to control them, the latter being the ultimate goal of this investigation.

Tracing and follow-up methodologies outlined by Redmond et al. [135] and Lloyd [136] were particularly pertinent in this inquiry. The direction of this work was sensitive to common assumptions and biases which limit analysis and distort the age variable often encountered in this area. Recognizing that the greatest source of bias is frequently the identification of the study group, special care was exercised in

defining the population at risk.

Study Population

The study population was comprised of members in a metropolitan fire department. This group was an ethnically mixed, predominantly white, all male firefighting force which operated as a professional, full-time department in the urban setting of Oklahoma City.

The population included all occupational categories having firefighting experience, all ranks and all classes of employment - i.e., active, retired and separated. The active group represented 20,354 of unadjusted person-years of risk for the 1930-1973 period. Personnel in the separated population numbered 556 while the pensioned group included 322 men.

Procedures

This inquiry, a prospective study done in retrospect, followed that described by Lloyd and Ciocco [136] - a working population with sufficient history was identified so latent effects could be observed and large numbers could be examined. Total deaths and causes of death for the study population were retrospectively observed for the period 1922 to 1974. Examination of this group's work history from 1900 to 1974 permitted additional assessment of their effective working life.

The total at-risk population was examined which included firefighters on active, service-retired, disability-retired, resigned, dismissed and leave of absence statuses. A single definition of occupation was employed which permitted observations on deaths occurring after employment within the fire service had ceased but which could be

reasonably related to some environmental factor in that occupation [137].

The total active and pensioned populations under observation were ascertained from annual personnel registers submitted to the State Insurance Commission and maintained by the State Fire Fighter's Association and from an accounting roster of the Firemen's Relief and Pension Fund. Active firefighters who separated through resignation, dismissal, transfer or leave of absence were followed by first identifying their status on available personnel records. Their vital status was initially verified by searching the known decedent and the living re-employed population. Providing their death was not already recorded among this group, their vital status was traced within the state through the Public Health Statistics Division of the State Health Department. This effort disclosed additional deaths amounting to slightly more than 10 per cent of the separated population. The search methodology, the "Russell Soundex System" lessened the chance of overlooking a decedent due to spelling, transcription or other recording errors. Each year subsequent to the year of termination was examined for possible death registration of firefighters formerly employed with the department under study. Fire department membership rosters in earlier years, which listed employees separated by year, displayed a number of partial or incomplete names, i.e., full surnames with initials only. These records were cross checked with available city personnel and financial records which evidenced similar entries. Because common surnames with first and middle name initials frequently had multiple recordings in state vital records, their tracing and retrieval was infeasible. Many of the decedents who were traced had been classified by their occupation at death and not the

usual occupation. A number of occupational designations were altogether absent. Positive identification of these individuals was therefore compromised. (Irregular and inaccurate entry practices of occupation have been one of the typical deficiencies associated with death registration) [24, 91, 97, 132, 138, 139].

When a formerly employed individual who met the criteria for inclusion was determined to have died and was positively identified, necessary information was collected from the sources described in the following section.

The reconstruction of the entire population's mortality experience required abstracting data from several state, professional, and local sources, viz: the State Department of Labor, State Health Department (Vital Statistics and Public Health Statistics Division), State Insurance Commission, State Industrial Court, State Fire Marshal, Oklahoma State Fire Fighters Association, City Personnel Office, City Clerk's Office (custodian of pension records), City Auditor's Office (source of employee financial records), and the personnel record section of the department under study which variously included medical histories, legal records, employment application forms, newspaper accounts, promotion histories, personal investigation documents and official correspondence. The information gathered on each decedent included year of birth, year of death, years of first and last exposure, rank at first and last exposure, length of service, principal and underlying causes of death, income at retirement and/or death, marital status at beginning and end of service, race, number of children, county of death and employment status at death (active, retired with or without disability, resigned,

dismissed, transferred, leave of absence). These data were cross-matched and verified on each decedent with entries that were duplicated on other records.

The general epidemiologic criteria outlined by Holland [140] and tracing methodology of Redmond et al. [135] provided helpful guidelines in identifying useful sources of demographic information. The tracing design described to follow active and pensioned members was comprehensive in scope. The number of deaths observed in this subgroup was known to be wholly representative and complete.

Procedures followed in the assessment of beta-naphthylamine and asbestos worker mortality also had application in this study [136]. In this connection, it was determined that examination of this group's experience should begin from the optimum point of observation, the time of entering the fire service. This rationale was applied universally. With respect to terminated personnel, mortality has been demonstrated to either occur subsequent to and/or be consequent from exposure in occupations other than the usual occupation. The likelihood of a distribution of different causes of death for those separating from the fire service may have acted to influence the proportionate mortality in the entire population [135, 136]. However, this inquiry recognized the importance of observing total mortality which included personnel with shorter tenures in the fire service, a great majority of whom voluntarily separated and represent the force of self-selection stated in the hypothesis of this study. Subsequent occupational exposures experienced by this population may have been dissimilar in nature to firefighting and probably did not approximate its severity. This phase of the study

reduced the bias of observation toward the non-mobile and older groups of workers since slight differences in active and separated populations have been significant when there was exclusive reliance on death rates in the stable group. Additionally, this bias has been shown to increase over time [135].

The derivation of observed and expected death rates required collection of all active and pensioned members' ages by year. In determining this distribution the membership rosters for each year were first alphabetically reconstructed; each active and pensioned firefighter was then traced individually. Gross figures were initially calculated from annual personnel registers submitted to the State Insurance Commission and from a financial accounting roster of the Firemen's Relief and Pension Fund. In years where the total population remained constant, adjustments were made for changes in the age grouping by attrition and addition of the subject population. Each year's distribution was typically corrected for personnel additions (employments and re-employments), resignations, dismissals, transfers, leaves of absence, retirements, active deaths and pension deaths.

Substantial fragmentation of data through recording gaps or destruction of records restricted this restoration effort. Moreover, the available records did not provide information to allow identification of individuals in support positions who were therefore unexposed. Mortality figures are therefore somewhat understated.

Partial application of Mastromatteo's [118] data was used as a statistical alternative to ascertain the estimated age distribution for the years 1930 to 1951. These percentages were used to allocate the

original study population by year into 10-year age groups. This approach also minimized the effect of error in age since intragroup errors are somewhat counterbalancing [141].

Firefighting populations are known to "represent a highly standardized occupational group with long tenures of position and low levels of labor turnover before retirement" [142]. This fact supported the author's contention that there was no substantial variation between these two populations' age compositions or other demographic features of their constituencies. Identical entrance ages and general requirements, similar retirement practices, similar probabilities of management policies being affected by the same professional association and similar membership trends due to political and economic influences also favored the selection of a statistical distribution in lieu of unavailable data.

Ethnic variability within the study population observed during inspection and retrieval of earlier records was considerable. Fluctuations in this area were regarded to be at least as great as the expected differences between the two populations.

The tracing of personnel in the later years was complete; however, some clerical weaknesses were disclosed in the entry of personnel actions. Incomplete removal of all terminated personnel on the active rosters expanded the total population figures. Since this error was apparently random, a correction factor was developed to normalize the inflated age distribution. The percentage of personnel actually recorded in each category was initially computed; the excess population was then determined and reduced by the same proportion to yield the true total. This procedure was identical to one followed by Henderson and Enterline

[107] for unrecorded causes of death. As they pointed out, it is not known whether any bias is introduced by this method. The derivation of expected deaths required the selection of a standard population. Age-specific death rates for white males in the State of Oklahoma were calculated. Mortality information was abstracted from annual volumes of Mortality Statistics and Vital Statistics of the United States by residence (de jure) while population information was retrieved from decennial and intercensal Department of Commerce documents in the United States Regional Depository. The selection of this population for comparative purposes is known to act as an understating influence in the determination of the study group's mortality.

Mutually exclusive cause of death groupings were developed to provide an accurate and homogeneous classification scheme for causes prevalent in the firefighting profession. The causes of death for 90 per cent of all decedents, obtained from a search of State Health Department vital records and from pension files for out-of-state deaths, were grouped according to selected classifications excerpted from the Eighth Revision of the International Classification of Diseases and Causes of Death. The category used for accidental deaths does not discriminate among those occurring domestically, publicly, or occupationally. Table 8 in the appendix illustrates the proportionate cause of death distribution by age group, occupational status and study period categories.

To render the decedent population comparable in terms of their actual exposure, management policies governing the length of the working year in person-hour units were obtained for the period 1900 to 1974.

Since the observed population had undergone eight changes in working hours since its establishment as a full-time department, each decedent's work history was adjusted to provide person-year exposure figures in 1974 years. The calculation and use of this denominator was instrumental in reducing inherent comparison errors of the worker's occupational burden where different employee cohorts by period have experienced different lengths of actual exposure due to temporal changes in the work schedule.

Data from the Oklahoma City and Norfolk,Virginia Fire Departments were gathered on the distribution of firefighters per capita and per square mile, the number of total fire calls per capita and per square mile and the ratio of firefighters to fire incidents. Historical information on the fire prevention component of the Oklahoma City Fire Department was similarly collected to possibly explain the trend or frequency of fires in the Oklahoma City area. The prevalence of fire incidents has been associated with the relative occupational stresses endured by the firefighter. These data were utilized for more qualitative assessments of the study population's occupational loading.

The anlaysis of this population's mortality experience concerned itself with the interpretation of various parametric indices based principally on magnitude, frequency and occurrence of mortality events. Less relevant to the health community but applicable to economic concerns were the mention of labor force measurements involving occupational mortality. These indirect expressions relate primarily to the length of working life [143].

The analyses of these data accounted for such variables as age, duration of exposure, length of service, cause of death and employment

status at death.

Proportionate mortality rates (P.M.R.) the number of deaths ascribed to a particular disease expressed as a proportion of all deaths [144], were calculated to identify period prevalence among selected causes of death. Standardized Mortality Ratios (S.M.R.'s) (ratio of actual mortality to mortality that would be expected if the age-race-sex-specific rates for the standard population were to apply), were employed as an age-independent index to facilitate comparisons of the study population's mortality experience [96, 120, 145]. It was derived through the use of the indirect method.

Observed death rates for all causes and observed cause-specific death rates for cardiovascular-renal disease among the study population were compared with those expected according to age-race-sex-cause-specific mortality rates by residence in the State of Oklahoma for four time periods using exact midpoint rates. These rates were obtained by using the actual number of deaths in the State of Oklahoma and actual population totals except from one earlier year which was derived by linear interpolation of decennial figures in the United States Census.

The population at risk was determined by computing the unadjusted person-years of risk in each of the age groups 20-29, 30-39, 40-49, 50-59, 60-69 and 70-. The expected numbers of deaths were derived by applying the above described rates for the years 1935, 1946, 1957 and 1968 to the accumulated person years in each age group during the years 1930-1940, 1941-1951, 1952-1962 and 1963-1973. Statistical analysis of deaths from all causes was performed by applying a chi-square goodness-of-fit test for the binomial distribution in each time period and for

each age-specific sub-group of the study population [89]. The mortality patterns for cardiovascular-renal deaths were also tested for significance. Because the firefighter population under study was fairly sizeable and the mortality rate small, the number of deaths was assumed to be a Poisson variable [146]. In this analysis the ratio of the observed Poisson variable, for each age-specific group in each time period, to the expected number was calculated. This proportion, the S.M.R., was tested at the .05 probability level.

Observed deaths were corrected to exclude fire service personnel in non-exposed or support categories (e.g., administrative, clerical, dispatcher, electrician, mechanic). Individuals in these categories constituted only 7 per cent of the total department membership and omission of their experience comprised less than 1 per cent of the observed population. No individual in an exposure category was lost from observation or analysis since all information collected was applicable in at least one presentation scheme.

For purposes of this analysis, individuals in separated or leave of absence categories whose deaths were not entered on state vital statistics records were assumed to be alive. This allowed any bias resulting from their indeterminate status to be a problem of understatement rather than overstatement. This study recognized the unavailability of any organized scheme to minimize the number lost to follow-up or assumption to be made concerning those lost [135].

Statistical analyses were performed on a Wang[1] Series 700 Advanced Programmable Calculator.

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[1]Wang Laboratories, Inc., Tewksbury, Massachusetts 01876.

CHAPTER V

DATA INTERPRETATION AND DISCUSSION

The mortality experience of former Oklahoma City firefighters, observed from 1930 to 1973 and statistically analyzed for four separate and equal time periods, presents some distinctive inter-period trends. The 43-year period of analysis included a total of 259 observed deaths representing 5,389 person-years (1974 years) of exposure for active and pensioned personnel.

Inspection of the vital experience for all occupational categories and all causes of death for the entire study period is indicative of certain influences affecting this group's mortality. Table 2 in APPENDIX B displays mortality, longevity and working life characteristics of all decedents in summary form. Interpretation of these data have certain qualifications since the observed means were derived from a population demographically dissimilar from the standard population. Additionally, the absolute size, age distribution, work schedules and mortality experience of the study group varied over time as Table 3 in APPENDIX B illustrates. It should be noted from Table 3 that most figures were weighted by the higher and more reliable values of the two later study periods, i.e., the larger populations and numbers of deaths for 1952-1962 and 1963-1973.

The mean age of death for all firefighters was 58.94 years.

This is approximately 10 years beneath the current U.S. mean life expectancy for white males. The mean death age of 65.93 for service-retired personnel suggests respectable longevity due principally to the influence of self-selection and secondarily to pre-employment screening [22-24, 54, 98]. Other factors effecting this improved status may relate to an adaptation by the firefighter to his occupational milieu. The firefighters alarm reaction, or initial physiochemical response to stress, may undergo some psychosomatic accomodation over time. It is also possible that changes in duty assignments through vertical promotions which lessen his physical burden may also have some salutary effects on his longevity. The growth of the department under study expanded the membership in the older age categories in the later years, therefore these figures were regarded as having strong reliability.

With reference to the disability-retired personnel and service retirees, the contrasting in Table 2 of the mean ages of accession, separation and death and the mean person-years of exposure, length of service and post-separation survival years, underscores some markedly different characteristics between these occupational categories. The groups could not be differentiated on the basis of firefighter rank, educational attainment, entering physical condition, socio-economic, racial, ethnic or marital status; however, the age of accession characteristic between these two groups has explanatory value.

A mean difference of 4 years in entrance ages was likely to be partially responsible for decreased longevity, shorter working lives and decreased post-separation survival time among the disability-retired group. Entrance into the fire service at an older age may be incompatible

with a low-risk, disability-free occupational history and long tenure - the notion being the older, lower ranking worker, would have a higher risk of incurring a disability or illness than a younger, lower ranking firefighter. With fire department membership having undergone a mean growth of 2.3 per cent per year since 1930, the average age of accession has also increased from 29.05 years (1930 - 1951) to 30.50 years (1952 - 1973). The inference that newer members to the fire service in the later years are proportionately less healthier than firefighters who entered in an earlier period - may be supported by increasing numbers of individuals experiencing disability-retirement at younger ages. The lower mean age of death for those dying on active duty as displayed in Tables 2 and 8 also furthers this hypothesis. Data not presented tabularly but disclosed by this inquiry indicated that of the individuals having entered the fire service between the ages of 30 and 34, their mean service contribution in person-year units was proportionately shorter (27.15 person-years) than all other age categories. The age group having entered the fire service between the ages of 25 to 29 had the longest mean experience of 30.26 person-years. Additionally, 8.9 per cent of all deaths occurred between the ages of 30 and 39 contrasted with 2.3 per cent between the ages of 20 and 29. Post-separation survival time was also more favorable for those entering between the ages of 25 and 29 (13.00 years) as compared to the 30-34 year age group (12.52 years).

Recognition of the disability-retired group accounting for 30 per cent of all retirements is indicative of some negative selection factor(s) being associated with this sub-group of the retired population.

Mortality for All Causes of Death

It is well known that a disproportionate share of the general mortality decline from the turn of the century to around 1950 has been due to the preventive and curative medical efficacy associated with infectious, parasitic and respiratory diseases [147]. Since 1960 there has been little progress in lowering death rates which may be a result of medical technology having reached an irreducible biological minimum [148]. Notwithstanding this general reduction in mortality, an analysis of U.S. age-color-sex specific death rates for 1948-1968 indicates that the white male death rate has indeed trended upward [149].

Findings of this study appeared to correlate positively with these national trends for the 1930 - 1963 period. The overall mortality experience for the study population also corresponded with extra mortality decreases recently witnessed in many occupations. These decreases, attributed to improved working conditions and a higher living standard were likely to have had a similar effect on the study population's mortality experience. Study findings were also consistent with Guralnick's [24] earlier observations concerning service workers. The age-specific death rates during the four time periods, which display noticeable and often significant variations, appear to present sufficient statistical strength to challenge the primary hypothesis that firefighters, through pre-employment examinations and self-selection, enjoy a health status superior to that of the general population.

Examination of Table 4 in APPENDIX B substantiates that significantly different patterns of mortality between the Oklahoma City firefighting group and the white male population of the State of Oklahoma

have occurred during the 1930-1940 period.

The S.M.R., used as the age-independent summary measure of comparative mortality was calculated for two age spans, namely the 20-69 year age group and the 20-70- population - the former being the more reliable figure [24]. As a summary figure, it may obscure some differences in the age-specific rates. For this reason, individual S.M.R.'s were derived for each age group in all four time periods. The reliability of the S.M.R. is also affected by defective rates due to limited number bases; interpretations of these rates should therefore take into account the proportion of deaths occurring in each age group. These proportions for all time periods are: 2.3 per cent for ages 20-29, 8.9 per cent for 30-39, 15.8 per cent for 40-49, 22.8 per cent for 50-59, 20.1 per cent for 60-69, and 30.1 per cent for 70-. A more discrete breakdown by cause may be reviewed in Table 8.

There does not appear to be any intra-period trend between the age groups studied in Table 4. Three age groups, 20-29, 30-39 and 50-59 displayed elevated levels of mortality with significance at the .01 level being demonstrated for the latter group. The favorable mortality experience of the 40-49 year age group in the face of adjacent higher values can not be readily explained; however, some understanding might be gained with better policy information concerning promotion practices or more discriminate (multivariate) analyses of this group's demographic character, ages of accession and entrance criteria at the time of their admission to the fire department. It is likely that entrance standards were initially promulgated when the fire department was chartered as a full-time municipal service at the turn of the century which may have

affected this group. Entrance standards and revisions thereof were not available for the earlier periods of this inquiry.

A pattern of relatively lower rates was observed for the 60-69 year age category in all time periods (Tables 4 through 7). It is likely that this is a real decrease due to self-selection although some artifact bias due to recording errors is also highly probable in this age group.

The 70 and over age category had few deaths recorded between the years of 1930 and 1940. This was due to limited membership in the older age groups and extreme difficulties of tracing separated members.

It will be noted that significance at the .1 and .01 levels was recorded for ages 20-69 and 20-70- respectively although in opposite directions. The most reliable figure, the higher S.M.R. of the 20-69 group is similarly reflected in the next time period.

Table 5 displays the age-specific mortality for the 1941-1951 period. An elevated S.M.R. is again demonstrated in the 30-39 year group with considerable significance at the .001 level. This peak, the highest S.M.R. recorded for any age group between the years of 1930 and 1973 is likely to be the result of occupational performance factors associated with the higher ages of accession described in the first section of this chapter.

The S.M.R. value for the 20-29 year age group would initially indicate that the firefighting population enjoyed a mortality experience almost one-half that of the general population. This value is somewhat illusory however, for the impact of the war years on this generally healthy population mitigates the reliability of this figure.

Inordinate numbers of personnel, who would normally be expected to experience long tenure [142], voluntarily separated during this period and because of irregular recording practices were lost to observation.

It is probable that additional responsibilities befell the older, lower ranking and less tenured age groups which explains the elevated S.M.R.'s for personnel in the 30-49 year age bracket.

A decrement in the mortality of 50-59 year old firefighters was recorded although its significance at the .3 level weakens its interpretation. It was understood that workers in this earlier period tended to have longer occupational histories and later retirements. The force of self-selection typically exerted its most powerful influence at the younger ages probably as a result of early identification of physical inabilities or job dissatisfaction. It is therefore reasonable to expect the older populations to represent a healthier cohort. Additionally, no personnel who died in this age span after having separated in an earlier time period were included in this cell.

Significance was demonstrated for the differences in the age-specific rates of the 20-69 (.02) and 20-70- (.01) age groups. Separated personnel lost to observation and those terminated from earlier time periods affect the reliability of both statistics; the S.M.R. for the 20-69 year population, however, should be accepted as the more reliable approximation indicating higher overall mortality.

Table 6 in APPENDIX B illustrates the mortality history for the 1952-1962 period. As the fire department increased its membership by over 50 per cent during this period, the concern for qualified personnel and the force of self-selection account for the favorably lower, but not

significant, S.M.R. in the younger age groups of 20-39.

Firefighters between the ages of 40-59 displayed a somewhat unfavorable mortality experience. Because no outstanding administrative changes occurred which would pose additional risks to this group, the expression of a higher S.M.R. was regarded as the product of increasing occupational burdens (described later) being assumed by this group, earlier errors in pre-employment screening and the successful identification and tracing of terminated personnel from earlier periods. This latter fact also accounted for the significantly higher mortality in the 70 and over group.

Higher S.M.R.'s for both the 20-69 and 20-70- groups were noted with the latter being significant at the .001 level. The finding of higher mortality for the 20-69 year old population is consistent with trends noted for the 1930-1951 period and falls within 2 percentage points of that noted by Guralnick [24] for service workers in the same period, ages 20-64.

Age-specific mortality figures recorded in Table 7 continued to show a declining overall trend with decreasing significance as measured by the S.M.R.

The influence of pre-employment screening and self-selection appeared to demonstrate a significant (.3) impact on the individuals in the 20-39 year age categories. These S.M.R.'s represent the lowest recorded among all time periods and are consistent with this inquiry's hypothesis.

Adverse longevity factors (related to their age of accession as earlier described) encountered by individuals in the 40-49 year group

and related to their age of accession as earlier described, appeared to exert an unfavorable impact on their mortality. The difference in age-specific rates between the standard and study populations in the 49-49 year category was significant at the .1 level. Factors contributing to this group's occupational loading or burden may also have contributed to this increase.

Although the S.M.R. calculated for the 50-59 year group is approaching unity (.97), it is reasonable to expect a wider variation from the general population if the firefighters' health was indeed superior. Sharing a health status with a similar cohort in the general population does not support the primary hypothesis.

The difference in age-specific rates for the 70 and older population, although not significant, was largely due to successful tracing of personnel separated in the earlier periods.

The S.M.R.'s of 91 and 98 for the 20-69 and 20-70- age group respectively were significant at the .2 level for the former category and at the .3 level for all ages past 20. These figures continue to reflect and coincide with general mortality trends. While they do approximate parity with the general population, these differences in mortality do not demonstrate a highly significant increment in longevity which might be expected based on the stringent selection supposedly exercised for entrance into the occupation.

The 1930-1973 S.M.R. for ages 20-69 was 1.01 and 1.05 for those 20-70-. A definite trend was shown in that the S.M.R. declined as the follow-up period decreased, however, these figures, for the entire study

period, were induced to understate the actual prevalence and magnitude of mortality. Some factors which had an additive understating effect were the use of a non-demographically comparable standard population, the inclusion of individuals in non-exposure categories in the denominator who could not be identified and therefore excluded, the exclusion of non-white and support personnel from the numerators and the successful tracing of only 10 per cent of the separated, mobile non-pensioned personnel. Although these biases could not be corrected for, they should be acknowledged in interpreting the previously described ratios and age-specific rate differences.

In assessing the influences of firefighting experienced by the decedents during the period of analysis and before, description of several occupational variables is also indicated.

Firefighters have undergone eight changes in their work schedule since 1900, the formal organization of a full-time paid department. These changes are outlined in Table 3. Recognizing that personnel in the earlier years were exposed for much longer periods, it is difficult to independently assess the impact of this factor without accounting for the gradual improvements in training, protective and safety devices, extinguishing agents, construction practices and firefighting equipment. Additionally, the number of fire calls (still alarms, fire alarms, and special calls) should be correlated with each period to determine actual occupational loading. As these records for Oklahoma City were destroyed, a similar Standard Metropolitan Statistical Area (SMSA) with comparable demographic statistics, climatological characteristics and insurance ratings was selected for the identical period of study. The experience

of the Norfolk, Virginia Fire Department was examined for comparative purposes and yields a reliable estimate of total experience. Accepting their alarm history to be representative, the Oklahoma City Fire Department underwent a 3 per cent decrease in personnel and a 2 per cent increase in total alarms from 1930 to 1940. For 1941 to 1951 the department was expanded by 34 per cent with only a 4 per cent increase in alarms. The 1952 to 1962 period witnessed a 12 per cent increase in personnel but a 19 per cent increase in alarms. The last period of study, 1963 to 1973, recorded a departmental expansion of 45 per cent with a considerably smaller increase in alarms of 28 per cent. These approximations indicate that the overall burden assumed by the study population was reduced by larger increases in the addition of personnel than the increase of fire alarms. This interpretation is contingent upon the correct ratio of firefighters to fire incidents existing initially at the base period of 1930.

Policy decisions affecting the distribution of firefighters have also had an undoubtable effect. Since 1930, the ratio of firefighters per 10,000 population has increased from 13 per 10,000 to 17 per 10,000 in 1973 while the distribution of firefighters per square mile has decreased from 10 per square mile to one per square mile. Accompanying this decreased property protection has interestingly been a concomitant increase in the cost of fire protection per unit of land area. Because of the enormous responsibility for the protection of property over such a large land area, the distribution of firefighters per square mile is a more credible measurement of occupational loading.

The rendering of actual fire services also indicated an increase

for the period of available figures, the years 1960 through 1970. Fire calls have increased from 21 to 30 per 10,000 in this limited time frame. Accepting the premise that fire prevention activities have a definite relationship to the occurrence of fire incidents, this growth in service demand may have a logical basis since fire prevention personnel have undergone a reduction in fire department representation. With a decrease from 3.1 per cent in 1939 to 1.5 per cent in 1973, the increase in fire calls may be more easily understood.

The collective impact of the above described occupational conditions, operating during the study period, are not to be discounted in identifying risks endured by this population. Some counterbalancing effects should result from the introduction of improved and more efficient equipment, more extensive training and more elaborate safety equipment and practices. The increase of fire calls and decreased distribution of firefighters per square mile were regarded as the most significant areas of health and safety concern, particularly as they relate to mortality.

Proportionate Mortality

Each decedent's cause of death was recorded through death certificate retrieval and is displayed in Table 8. With most improvements in death registration and cause of death classification taking place in the later years and the fact that deaths were distributed throughout the entire study period, as may be seen in Table 3, the cause of death statements have varying degre of reliability [133]. Rubrics under which the firefighters causes of death were tabulated in Table 8

were selected from the Eighth Revision of the International Classification of Diseases. With multiple causation statements, the selection of the actual cause of death, one biometric problem in this study, was determined to be that disease process, condition or circumstance ultimately responsible for the individual's death. Factors such as location of the individual at death, specialty of the certifying physician and state-of-the-art questions are all acknowledged to have affected the accuracy of the cause of death statement [141].

It is accepted that mortality does not always reflect disease incidence [136] and the use of death certificates to identify increased occupational risk(s) has been described as a somewhat insensitive method. However, when these risks are found they have been likely to understate the true risk [150]. Additionally, the understating influence of the over 10 per cent ill-described and unknown causes of death in Table 8 was of relative importance when compared to the 1 to 2 per cent that was expected [151].

While the number of deaths by cause was too dispersed for comparative mortality risks to be determined, analysis was worthwhile. The method of choice for presentation and analysis was the Proportionate Mortality Ratio (P.M.R.) [144] - the disadvantages and advantages of which have been discussed by Doll [109]. Specific disorders statistically associated with firefighting were sought with the recognition that causality in an ultimate sense could not be determined without demonstrating a causative mechanism [51].

Table 8 in APPENDIX B categorizes firefighter deaths by cause and distributes them by age, period and occupational status at death.

As the table makes clear, the limited frequency in most cells and considerable dispersion for all causes except cardiovascular-renal disease, cancer and accidents proscribes more extensive statistical analysis.

Accidental deaths, one of the chief hazards of firefighting [10], were more frequent on the job as the active cell displays but not solely concentrated in this category. Consistent with an earlier observation concerning higher risks among older workers, the absolute number of accidents appeared to be more frequent in the 30 and over age groups and appeared to show a noticeable increase in the last decade.

Although respiratory disease continues to be dominant as the leading cause of disability absenteeism in industrial worker populations and the major cause of permanent disability payments [152], unusual mortality trends due to respiratory disorders were not manifested. The P.M.R. for respiratory cancer was slightly elevated in some cells but was recorded mostly in the older age groups. This pathological condition along with other respiratory diseases was anticipated to be much higher in all cells [31-37, 125, 153, 154]. Pneumonia and tuberculosis did not demonstrate unusual prevalence. One case of pulmonary emphysema was also observed.

The P.M.R.'s for all cancers were distributed with increasing frequency within the older age cells. The P.M.R. of 18 per cent for 1952-1962 was somewhat higher than the total national P.M.R. of 15.7 per cent for 1963 [148] while the most recent 1963-1973 firefighter P.M.R. of 14.0 was somewhat below the 1972 U.S. figure of 17.7 per cent. The other two values for the periods covering 1930-1951 were also below the United States figures for comparable time periods. Since the crude

P.M.R.'s were not within exceptional ranges by age or period, further analysis was not performed.

Inspection of the P.M.R. for the cardiovascular-renal (CVR) classification indicated additional review. Because diseases within this classification have been of a typically chronic and degenerative nature and usually concentrated at the older ages, their appearance in the study population's younger age groups was a source of concern. Since only marginal progress in the reduction of these pathologies has been made, national white male and firefighter death rates have varied from the declining trend of the mortality curve. For the above age 45 population, the rates for U.S. have been level or slightly decreasing while the P.M.R. has remained about the same [158]. Bogue [148] has speculated that "this may reflect a condition of stagnation in medical and health technology or a substantial progress that is being offset by a rising incidence of this class of disorder". Part of the leveling off might also have been due to certain artifacts - i.e., improved vital registration.

Repeated citations of the incidence of these disorders in firefighting populations [12, 16, 26, 53, 128], the unavailability of satisfactory statistics to establish relative risk [15, 110, 155] and the impact of certain variables on other metropolitan and working populations [86, 156, 157] supported the selection of this classification for assessment similar to the analysis for mortality from all causes [95]. A somewhat different and more sensitive statistical test was selected utilizing the Poisson distribution as described in the "Methods" section of this work [146]. As will be noted in Table 9, such a technique has

allowed the direct comparative analysis of the S.M.R.

As Table 8 displays, mortality experience from the CVR category was observed in all cells except the 20-29 year age group. It is well represented in every time period with the highest value being recorded in the 1941-1951 era.

Mortality experience from CVR diseases for the 1930-1940 period is illustrated in Table 9. There was some noticeable fluctuation in these observed rates and no definitive trends were observed for the period. It should be parenthetically added that expected rates for this period were computed by applying the United States white male death rates for 1935, the mid-point of the study period (Oklahoma rates were not available). Because these rates are categorically higher and less representative than Oklahoma statistics, appreciable bias existed to understate the force of mortality on firefighters during this era. Of the four cells displaying rate differences (ages 30-39, 40-49, 50-59, 70-) the three lesser age groups demonstrated markedly higher S.M.R.'s, notwithstanding understatement. The differences in the 30-39 and 50-59 year categories were found to be significant at the .05 level. Tracing difficulties for the older age group (70-) similar to those described in the "Mortality from All Causes" section of this chapter, also operated in this portion of the analysis; it is suggested that the one lower rate and S.M.R. are due purely to this artifact. Further discussion of the influences explaining the CVR mortality experience for all periods and their significance will be undertaken at the end of this section.

The rate differences and respective S.M.R.'s for the 1941-1951 era did not present a uni-directional trend. Of the five age groups

with recorded differences, three displayed higher values (30-39, 40-49, 60-69) one of which was significant at the .05 level (30-39), two age groups (50-59, 70-) showed lower values and almost identical S.M.R.'s. The rate difference for the 70- group is not considered highly reliable [24] while the lower S.M.R. for those aged 50-59 is regarded as genuinely representative and somewhat unexpected. This expression of superior health status was probably a cyclic result of effective pre-employment screening and self-selection [106] from earlier periods although successful tracing of personnel terminated in earlier periods would undoubtedly inflate the subject S.M.R. [92]. As rate differences are inspected in the 60-69 year age group for all time periods, it should be noted that the 1941-1951 period was the only era with an irregular S.M.R. variation in this age category - a result indicative of the maturing of a significantly unhealthier 50-59 year old cohort in the previous, 1930-1940, era.

Death rates, observed for the 11 year period ending in 1962, all showed variation for those above age 40 as may be seen in Table 9. The S.M.R. for firefighters aged 30-39 achieved unity with the general population and has enjoyed a declining S.M.R. for CVR deaths since that time. This inter-period rate decline was the most dramatic for any age group and could likely be a combined result of a significantly healthier post-war population, improved diagnostic and treatment techniques, self-selection and the overall higher standard of living long known to be associated with improved longevity [6]. For those above age 40, similar and higher S.M.R.'s were detected for the 40-59 year age group and a significantly higher value (.05) for the 70- population. The lower

S.M.R. for 60-69 year olds has been previously discussed. Decedents aged 70 or over demonstrated the highest S.M.R. of any age group and the only one with a highly significant (.05) difference. This S.M.R. accurately reflects the unfavorable mortality experience for all classes of retired and separated personnel - many of whom were successfully traced and known to have died in this period.

Elevated CVR S.M.R.'s for the above 40 population covering the years of 1963-1973 were observed. This finer and more discriminate analysis was obscured in Table 7 by the earlier calculation of the S.M.R. for all causes. With the exception of the 60-69 year old category treated earlier, all other ages (40-59, 70-) displayed higher mortality. The 40-49 year age group presented the highest S.M.R. for all periods. The summary S.M.R. for all ages further demonstrated that these observed rate differences were significant at the .05 level. The values illustrated are interpreted with high reliability and should be a source of concern to the community as well as the affected population.

Higher S.M.R. summary values recorded in Table 9 were observed for all periods reflecting rate differences for the age 30 and above population (age 40 and above for 1963-1973). The S.M.R.'s had a range from 1.2 to 2.4. They evidenced only marginal differences and close concordance excluding the extreme 2.4 value. Inspection of Table 9 illustrates the detection of significant differences at the .05 and .01 levels in all periods save 1941-1951.

There are a number of factors which have been associated singly and/or in combination with CVR deaths. It is probable that many of these have influenced the significantly higher observed values in the Oklahoma

firefighting population. The apparent risks of CVR mortality in this population were consistent with that observed in other departments [16, 53, 128, 155] and some working populations [157]. Since no substantive diagnostic, preventive or promotional measures have been instituted, rate reversal or relative declines should not logically be expected.

Recognizing that occupational factors in firefighting have either caused or aggravated CVR disease [15, 21], it is appropriate that they be given recognition in any health assessment or correction efforts. Some of the occupational characteristics which have predisposed individuals to CVR disease include smoke asphyxiation, stresses and strains, shocks superimposed on predisposing conditions such as diseased heart valves and blood vessels [15, 26-30) and the factors identified by Reich [12] in CHAPTER II of this work. A review of Table 1 in APPENDIX A displays studies with not completely consistent results in the area of CVR mortality although some absolute risks have been confirmed in many investigations.

Analyses of studies on other fire departments have further illustrated the importance of nutrition, mental tension [16], and preemployment examinations [53] in the identification and management of CVR conditions.

Certain CVR conditions have been associated with elevated consumption of sodium (typically as NaCl). Although there were no satisfactory statistics indicating level or frequency of ingestion, this relationship could not be discounted as a contributing factor in a population which has frequent occasion for its use in all seasons [159].

Other factors within and without the working environment which have demonstrated associations with CVR disease include the relationship between years of exposure to high environmental temperatures and levels of high blood pressure [59], smoking [5, 160-164], exposure to CO [13, 80, 165, 166] and metropolitan living [86]. All of these agents undoubtedly have the capacity to detrimentally influence firefighter longevity although no quantitation of their magnitude, since 1930, was available.

Smoking, as a habit, was known to be practiced by at least 80 per cent of the current living population [5]. Proper retrospective measurement of smoking's prevalence or significance among the deceased population however, must be determined to assess its true impact.

The effects of CO have been well established and were discussed in CHAPTER II of this work. That it played a significant and additive role in precipitating or aggravating CVR disease is unquestioned. The determination of CO's cumulative effects on the study population would necessarily have to consider the changes of properties in construction material, pyrolysis characteristics in new industrial and household agents and the improvements in personal protective equipment. A review of Oklahoma City's purchasing practices regarding personal protective devices and an examination of the changing nature of pyrolysis products [68] would indicate that a greater impact was incurred by firefighters in the earlier periods.

Tenure of Employment and Mortality

Efforts were undertaken to disclose whether firefighter longevity was influenced by duration of employment. In this connection,

it was assumed that relative environmental exposures and actual degrees of risk could be inferred from a retrospective epidemiological evaluation of the death experience after adjusting for duration of employment and length and continuity of exposure associated with rank and assignment.

The reconstruction of personnel records in this portion of the study yielded fragmented work histories and incomplete accountings of firefighter promotions and job descriptions. Adjustments for these deficiencies could not logically be accomplished. Table 10 in APPENDIX B represents an analysis of active and pensioned firefighter working lives by duration of employment. As these figures illustrate, individuals experiencing longer durations of employment had higher ages of accession and more favorable longevity. The former finding reinforces an earlier observation in the first section of this chapter concerning productivity, tenure and performance as it relates to the age of accession.

The observations in Table 10 represent, to a great extent, experience of the less mobile population in the earlier years. The figures are based on each decedent's number of person-years exposure (1974 years) and include all causes of death, all occupational categories (ranks) and excepting terminated personnel, all categories of separation. Incomplete follow-up of terminated personnel, who primarily represent the force of self-selection, significantly bias these computations. When terminated personnel could not be traced, the extra mortality from those with pathological or other non-specific life-shortening conditions with long latent periods between onset and death, could not be observed. Excluding the 25-person-year exposure category, it should also be noted

that conclusions in Table 10 are based on small sample sizes in the three other classifications.

The lower ages of death associated with shorter working lives mainly reflect individuals who died early in their careers from accidents or pre-existing conditions. The tautological nature of the data rendered these findings non-definitive since this correlative situation is not applicable to understanding whether longevity is, in fact, affected by duration of employment and can only be fairly determined by cohort analysis.

Mortality Determinants

Mortality has been variously associated with other than occupational influences. Although it has been revealed that occupation may affect the disease pattern in different ways, "...by exposure of the worker to a specific hazard inherent in the type of work performed, by the adverse conditions in which the work may be carried out, and thirdly by the operation of the social class influence appropriate to the occupation" [167], several other plausible influences were assumed to contribute to or affect the course of firefighter mortality and should also be considered in any assessment effort.

A number of factors associated with extra mortality from CVR disease were discussed in the "Proportionate Mortality" section of this chapter. Other considerations entering the mortality equation include,

(1) marital status differences [148, 168]

(2) ethnic extraction particularly where church sanctioned behavior enters

(3) geographic influences of urbanization [86, 169, 170]

(4) climate [62, 63, 87]

(5) pollution [80, 171]

(6) revision in entrance standards and the selection of different somatotypes over time

(7) personal values related to physical conditioning

(8) hobbies

(9) chance variation

(10) artifacts related to the reporting of age

(11) dissimilar occupational experiences of those separated from the fire service

(12) part-time employment [111].

All of these factors with special reference to part-time employment are known to variously affect firefighter mortality trends although their respective impacts have not been appropriately cross-tabulated; this has prevented objective and integrated assessments of their multiple effects [96].

Because occupational mortality differentials are so intimately associated with socio-economic status and because occupational groups have been used as indicators of socio-economic level [24, 172], some elaboration of this variable is indicated.

Other epidemiological investigations of occupational mortality have correlated socio-economic class rather than occupation with excess mortality statistics [102] but it is "occupation which indicates adequately both economic status and the social frame of reference" [98]. Although the trend of age-specific death rates has been to rise as one proceeds down the socio-economic scale [148, 168], the rising standard

of living which includes improved medical care, has tended to reduce the significance of social class gradients and their association with mortality in many sub-groups of the population.

In determining mortality, this inquiry applied the age-specific white male mortality experience for the State of Oklahoma to ascertain whether self-selection and pre-employment screening of firefighters exerted enough influence to effect a significant decrement in the study population's differential mortality. Since both the test and standard populations benefited from the above mentioned medical-social improvements associated with lowered mortality (i.e., improved diets, hygiene, housing, home heating, water supplies, waste disposal, education, scientific advances in medical theory and treatment, health legislation, rehabilitation and retirement schemes [148]) and similarly suffered from the forces of chronic degenerative disease, pollution, population density and the civilized excesses of smoking, drinking and obesity, the net determinations of mortality described in this chapter accurately reflect the extra mortality and longevity experienced by this population.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The absence of any unequivocal data on the long term health effects of firefighting stimulated an inquiry into the mortality experience of a metropolitan fire department. The study retrospectively examined the variation in total and cause-specific mortality among an urban firefighting force as contrasted with a comparable standard population. Deaths of 259 active, pensioned and separated firefighters were observed and analyzed from a variety of record sources for the period 1930-1973.

By investigating the mortality experience of a sub-group of the population which routinely faced unpredictable and unregulated occupational exposures, assessment of the working environment's impact on mortality were made. Contributing factors influencing the response variable were also identified.

Data were analyzed in order to provide descriptions of disease prevalence to indicate specific health problems of the study population. CVR disease was specifically examined to detect life shortening effects as evidenced through excess mortality.

Based upon the findings of this inquiry, the following conclusions were made.

1) The long-term mortality experience of a select occupational

group generally corresponds with that observed in a standard population. Non-specific life-shortening effects are observable over time through excess mortality measurements notwithstanding the social and demographic changes associated with improved longevity. S.M.R.'s ranged from 0.12 to 4.00 and were slightly elevated for the entire study period. Understating influences distorted the magnitude of this excess mortality but were still insufficient to firmly support the study hypothesis. The expectation that the firefighting populations, through pre-employment screening and self-selection, would be healthier than the general population had greater merit in the later years (1963-1973 period) [22-24, 54, 98, 106, 168]. Excess mortality as measured by the S.M.R. averaged over 104 per cent in approximately 46 per cent of all age groups while decreased mortality demonstrated a mean difference from unity of 33 per cent in 54 per cent of all age groups.

2) The lack of routine medical evaluations to assess non-service related chronic or acute disabilities in terms of early identification of high-risk personnel, exerted a countervailing force on the beneficial effects of pre-employment screening.

Significantly increased mortality from CVR disease was observed in the study population for all periods. Failure to identify a declining trend through significant changes in the S.M.R. was sufficient to reject any suggestion that improved mortality experiences necessarily followed improved services [93]. The course of mortality due to CVR disease indicated a

significant decrement in the life span for this group; the control of occupational factors such as smoke asphyxiation [21, 48], nutrition and mental tension [16], sodium consumption [159], extreme environmental temperatures [12, 59], CO exposure [13, 80, 165, 166] and physical stresses [26-30] known to either cause or adversely influence CVR disease, did not appear sufficient to express a significantly lower cause-specific mortality among this group. Changing national patterns of CVR disease were not similarly reflected in mortality ratios of the firefighter.

Although necropsy data from other causes of death were not available, inspection of such records would undoubtedly further increase the prevalence of CVR disease.

3) Individuals who have entered a stressful occupation such as firefighting at an older age have been occupationally associated with a disability experience. The inference that higher ages of accession somehow predisposed individual firefighters to premature and chronic disability was warranted since the population of disability-retired personnel demonstrated a markedly higher mean entry age. Through either errors in pre-screening or "negative" self-selection (i.e., a firefighter, with a pre-existing condition known to himself, voluntarily elects to expose himself to hazards of the fire service) 30 per cent of all retired personnel were disabled.

4) Due to self-selection and pre-employment screening, firefighters with longer service histories experience improved longevity.

Definitive findings could not be made in reference to the

question of whether longer duration of employments demonstrate a significant relationship to longevity since firefighters who died early in life naturally had shorter careers.

Based upon the results of this study, the following recommendations can be made.

a) The prevalence of CVR disease, which has been primarily responsible for excess mortality among active duty firefighters, should be recognized by the Oklahoma City firefighting population and its administration as an absolute risk which can be caused or aggravated by agents in their working environment.

With many CVR related deaths having occurred in both the apparently healthy and unhealthy firefighters from the population [157], procedures should be instituted to clinically identify predisposing conditions or metabolic abnormalities among the currently employed and incoming firefighter populations. Individuals should be carefully screened and those with CVR disease who are currently employed either reassigned to less hazardous duties or transferred to other departments.

b) Occupational factors earlier identified which may affect the physical well-being of the firefighter should be controlled by corrective, protective or preventive measures; non-occupational factors such as non-smoking should be included as a criterion for entrance to the fire service. Firefighters who do sustain injury through smoke inhalation should have the benefit of clinical examination, arterial blood gas and carboxyhemoglobin analysis regardless of the apparent severity of exposure [13,20].

c) Consideration should be given to lowering the current entrance age limit of 35 based on the disability experience of the decedent population. The 30 per cent disability experience of this population and higher mean ages of accession for the disabled, have predictive value as a firefighter selection criterion. Findings are suggestive that a lower age limit coupled with more discriminate physical requirements should result in fewer disability retirements, longer service histories and extended post-separation survival time.

d) The findings of this study reinforce the need for voluntary compliance with the Occupational Safety and Health Administration's recordkeeping requirements. A safekeeping policy including requirements for the maintenance of active, pensioned and terminated personnel records should be instituted. Vital information on all current and incoming firefighters should be collected to facilitate future and more discrete epidemiological analyses. For follow-up purposes, this information should at least include full legal names, social security numbers of the firefighter and his wife if applicable, selective service and Veterans Administration numbers, former addresses, former and current employments (part-time, etc.), name of personal physician and location, place of birth, full date of birth, and if married, number of children sired by the firefighter. Improved medical histories should additionally include any family history of diseases.

e) To determine the correlation, if any, between longevity and

duration of employment, cohort analysis employing a generation life-table should be considered. Data from this effort should be evaluated more on the basis of competing risks if sufficient records and personal histories are available [134].

This study has disclosed sufficient evidence to warrant further investigation into the area of firefighter morbidity with special reference to cardiovascular disease [51]. This might embrace such areas as susceptibility research, somatotype and behavioral analysis or the association of cause-specific disease recidivism with the advent of various types of personal protective equipment.

f) The traditional labor/management emphasis of establishing special benefits for disabled workers should shift to effecting more substantive improvements in the work environment [52]. The development or improvement of any comprehensive safety and health program should not be solely oriented to mechanical compliance with standards and should be extended to include active participation by the entire fire department membership in safety and health analysis.

Feasible improvements in the work environment should yield benefits for employees such as a decrease in lost wages [52], lower insurance premiums [155], reduced medical expenses and a stronger retirement fund. The community and management should gain with higher productivity by a reduction in absenteeism and a generally healthier working class, decreased compensation benefits and lower administrative costs particularly in the areas of claims litigation and replacement personnel retraining.

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APPENDICES

APPENDIX A

TABLE 1

FIREFIGHTER MORTALITY DATA REVIEW

Study Title	Author/Source (F = Foreign)	Personnel Studied	Area of Study	Study Issued	Findings	References
Mortality Among Insured Lives Engaged in Certain Occupations Involving Additional Hazards	Hunter, A./ Tr. Am. Soc. Actuarians	Insured Firemen, Drivers, Hosemen Only	U.S.	1907	Observed mortality of study group consistent with expected figures	15
Medico-Actuarial Mortality Investigation: Effect of Occupation on Mortality	Actuarial Society of America and The Assoc. of Life Ins. Dir.	Insured Classes	U.S.	1913	Higher mortality observed for all categories studied	15
Report on the Pension Fund of the City of New York	New York City Commission on Pensions	All Personnel Entered in Pension Rewards	New York, New York	1916	High death rate from actual performance of duty. General mortality experience ranked 7th out of 11 similar rates for city. High disability-associated death rate. Mortality of regular service pensioners not above average.	15
Influence of Occupation Upon Mortality	Hunter, A. and Rogers, O./Tr. Actuarial Soc. America	Insured Classes	U.S.	1920	Higher ratings indicated for life insurance purposes	15
Occupational Mortality	Hunter, A./ Tr. Actuarial Soc. America	Insured Classes	U.S.	1927	Investigator cited significant disparities between life insurance companies in their experience with firefighters.	15
Joint Occupation Study of 1928	Actuarial Soc. of America and The Assoc. of Life Ins. Dir.	Insured Classes	U.S.	1929	Significant excess of deaths from all causes. Death rate influenced largely by accidental deaths. High death rate from cirrhosis of the liver	15, 92
A Mortality Experience of City Firemen	Jenkins, W.B./ Rec. Am. Inst. Actuaries	Primarily (90%) Chicago Firemen	Chicago, Illinois	1930	General mortality and accidental deaths well above average in city firemen. Mortality from tuberculosis exceptionally low.	15
Causes of Death by Occupation	Dublin, L. and Vane, R./Bureau of Labor Statistics	Insured Classes	U.S.	1930	Insureds showed lower standard relative mortality index for respiratory tuberculosis, pneumonia, and cardiovascular disease. A high index was recorded for accidental and violent deaths.	15, 91

TABLE 1--Continued

Study Title	Author/Source (F = Foreign)	Personnel Studied	Area of Study	Study Issued	Findings	References
Firemen, Occupational and Health Brochure	Chajes, B./ International Labor Office	All Classes	International	1930	Higher pension rates noted. Increased incidence of accidents, poisoning, and several diseases without statistical support. Indicated prevalence of some digestive diseases.	15
Death Rates by Occupation	Whitney, J./ National Tuberculosis Association	All Classes	U.S. (10 states)	1934	Lower death rate among firefighters. Findings not standardized for age.	91, 92, 99
Occupational Mortality	Registrar-General, England and Wales/ Decennial Supplement	All Classes	England and Wales	1938	Standardized mortality ratio consistent with other occupied classes. Some elevated cause-specific mortality likely from peptic ulcer, buccal and pharyngeal cancers. Reduction in tuberculosis deaths statistically significant	15, 91
Occupational Mortality Experience of Insured Wage Earners	Dublin, L. and Vane, R./Monthly Labor Review	Insured Classes	U.S.	1947	Age-specific mortality rates indicated slight elevations for certain organic diseases but no unusual mortality patterns generally. Sharp drop in standardized relative mortality index. Cardiovascular disease index higher for any occupation. Low incidence of pneumonia and no unusual cancer trends.	119
Report of Mortality and Morbidity Experience	Society of Actuaries	Insured Classes	U.S.	1951	Higher mortality experience. Risk of accidental death high.	15
Annual Report on the Vital Statistics of Massachusetts	Commonwealth of Massachusetts	All Classes	Commonwealth of Massachusetts	1951	Higher proportion of cardiovascular-renal deaths. Lower proportion of deaths from respiratory diseases, tuberculosis, digestive diseases. Cause-specific death rates not standardized for age.	15
Registrar-General's Decennial Supplement: Occupational Mortality	Registrar-General, England and Wales	All Classes	England and Wales	1958	Favorable mortality experience is clear among firefighters. Standardized mortality ratio is lower or equivalent to all occupied men. Mortality from respiratory disease is significantly lower.	15, 120
Mortality in City Firemen	E. Mastromatteo	All Classes	Toronto, Canada	1959	Highly significant excess of cardiovascular-renal deaths among city firemen. Reduction in respiratory and tuberculosis deaths. No significant difference in mortality from all causes, from cancer, from violence and accidents, from digestive diseases, or genitourinary diseases.	121

TABLE 1--Continued

Study Title	Author/Source (F = Foreign)	Personnel Studied	Area of Study	Study Issued	Findings	References
Mortality by Occupation and Industry	Guralnick, L./ Public Health Service, Vital Statistics Division	All Classes	U.S.	1962	Standard mortality ratio among service workers (included firemen), out of 9 categories was 8th highest. Of the 9 service worker divisions, firemen had the 3rd highest standard mortality ratio.	24
Mortality by Occupation and Cause of Death	Guralnick, L./ Public Health Service, Vital Statistics Division	All Classes	U.S.	1963	Proportionate mortality ratio is significantly higher for cancer of the intestine and rectum and diseases of the cardiovascular system. Firemen show high standard mortality ratio in the 20-64 year age group for all causes (132).	122
Mortality by Industry and Cause of Death	Guralnick, L./ Public Health Service, Vital Statistics Division	All Classes in Intermediate Industry Classifications	U.S.	1963	Firefighters included in general category of Intermediate Industrial Classification System. Findings are obscured by broad groupings.	54
Mortality by Occupation Level and Cause of Death	Guralnick, L./ Public Health Service, Vital Statistics Division	All Classes in Intermediate Occupational Classification	U.S.	1963	Data collected on firefighters mortality by grouping under Intermediate Occupational Classification System. Data shows high standard mortality ratio for cardiovascular diseases and duodenal ulcers.	123
1967 Occupation Study	Society of Actuaries	Insured Classes	U.S.	1967	Relative mortality ratio of firemen has fallen from 134 to 120 per cent of that among standard risks in the last 4 decades. Extra deaths are quite high at ages 50-59 mostly due to natural causes.	6, 7 124
A Prospective Mortality Study of Several Occupational Groups.	Dunn, J.E. and Weir, J.M./ Archives of Environmental Health	All Classes	Regional U.S.	1968	Demonstrated higher incidence of oral cancer but were not determined to suffer excess mortality as a result of occupation.	125
U.S. Estimated Occupational Death Rates	Home Office Life Underwriters Association	Insured Classes	U.S.	1970	Disabling injuries resulting in death showed a decrease over a 5 year period. Firefighters were ranked 12th of the 49 major categories in their death rate per 1000.	126

TABLE 1--Continued

Study Title	Author/Source (F = Foreign)	Personnel Studied	Area of Study	Study Issued	Findings	References
A Close Look at Fire Fighters' Deaths and Injuries	Ralph, R./ Redmond Symposium	All Classes	Toronto, Canada	1971	Cardiovascular related deaths have decreased significantly among active firefighters and longevity increased among pensioners.	127
Firefighter Special Survey	Atwood, R./ Redmond Symposium	All Classes	Approximately 21 Municipalities	1971	High cardiovascular disease and death rate. Data not calculated on age-specific basis.	25
Detroit Special Study	Krohn, L.H./ Redmond Symposium	All Classes	25 U.S. Cities	1971	Demonstrated a significant distribution of heart-deaths and factors which reduced the incidence of cardiovascular related mortality.	128
Congressional Subcommittee Hearings	U.S. House of Representatives	All Classes	U.S.	1972	Firefighters were reported to have an inordinately high accidental death rate for the period 1960-1970 where almost 800 firefighters died in the line of duty - almost 1% of their work force.	14
Injury Rates in Industry	Department of Labor, Bureau of Labor Statistics	All Classes	U.S.	1972	Firefighters demonstrate the third highest per cent of disabling injuries resulting in death among government workers. The Injury Severity Rate is the highest of all workers.	7, 129
Firefighter Injury Classification System	National Bureau of Standards	All Classes	U.S.	1972	Death and injury data currently being collected on a pilot basis. System was developed as a result of the Redmond Symposium.	130
Annual Death and Injury Survey	International Association of Firefighters	All Classes	U.S.	1972	Accidental deaths shown to be inordinately high but trending downward since 1970. Occupational disease rate has undergone a significant increase.	10

APPENDIX B

TABLE 2

MORTALITY, LONGEVITY AND WORKING LIFE CHARACTERISTICS BY CENTRAL TENDENCY OF THE OKLAHOMA CITY FIRE DEPARTMENT 1930-1973 BY OCCUPATIONAL STATUS AT DEATH

Occupational Status at Death (By Separation) Category	Total Number by Category	Per Cent By Category	Mean Accession Age (Years)	Mean Separation Age	Mean Age At Death	Mean Person-Year Exposure (1974 Years)	Mean Length of Service (Years)	Mean Number of Years Survived Between Separation and Death (Excludes Active Deaths)
All	256	100	27.44[a]	46.63[a]	58.94	28.40[a]	18.57	13.68[a]
Service Retired	105	41	26.2	47.88	65.93	34.82	22.60	15.60
Disability Retired	44[b]	17[b]	30.05	48.43	57.51	26.16	17.45	9.97
Active Duty Deaths	40	16	27.05	39.23	39.23	17.27	12.19	-
Terminations (Resigned, Dismissed, Transferred, Leave of Absence)	67	26	-	-	61.24	8[a]	6[a]	-

[a]Includes 24% of terminations.

[b]30% of all retirees.

TABLE 3

ACCUMULATED PERSON-YEARS EXPERIENCE AND DEATHS WITH CORRESPONDING WORK SCHEDULES BY EMPLOYMENT AND OBSERVATION PERIODS

Employment Period	Work Schedules in Hours Per Year by Employment Period	Accumulated Person-Years Experience by Observation Period		DEATHS All Causes, All Separation Categories, All Ranks by Observation Period	
		Number	Per Cent	Number	Per Cent
1900					
.	7384				
.					
1919					
1920					
.	6552				
.					
1929					
1930					
1931					
1932					
1933					
1934					
1935					
1936	4200	2659	13.1	26	10.8
1937					
1938					
1939					
1940					
1941					
1942					
1943					
1944					
1945					
1946		3300	16.2	28	11.6
1947					
1948					
1949					
1950					
1951	3912				
1952					
1953					
1954					
1955					
1956					
1957		5349	26.3	75	31.1
1958					
1959					
1960					
1961	3624				
1962					
1963					
1964					
1965					
1966	3600	9046	44.4	112	46.5
1967					
1968					
1969	3228				
1970					
1971					
1972					
1973	3072				
Total	-	20,354	100.0	241	100.0

TABLE 4

AGE-SPECIFIC MORTALITY FOR FIREFIGHTERS
1930 - 1940

Age	Expected Rate/1000	Observed Rate/1000	Chi Square	Degrees of Freedom	SMR	p < (.30-.001)
20 - 29	3.50	6.45	0.77	1	1.85	NS
30 - 39	4.60	5.00	0.03	1	1.08	NS
40 - 49	7.40	5.97	0.23	1	0.81	NS
50 - 59	13.70	35.16	8.72	1	2.57	.01
60 - 69	31.30	25.32	0.19	1	0.81	NS
70-	87.40	10.31	7.23	1	0.12	NS
20-69 =	7.80	9.80	9.95	5	1.23	.10
20-70-=	10.80	9.80	17.18	6	.90	.01

NS Figures Not Significant p < .3

TABLE 5

AGE-SPECIFIC MORTALITY FOR FIREFIGHTERS
1941 - 1951

Age	Expected Rate/1000	Observed Rate/1000	Chi Square	Degrees of Freedom	SMR	p < (.30-.001)
20 - 29	2.40	1.25	0.44	1	0.52	NS
30 - 39	2.80	10.83	12.79	1	4.00	.001
40 - 49	5.60	7.43	0.49	1	1.33	NS
50 - 59	12.70	8.46	1.18	1	0.66	.30
60 - 69	26.90	22.73	0.15	1	0.84	NS
70-	79.50	31.91	2.91	1	0.40	.10
20-69 =	7.60	7.8	15.05	5	1.03	.02
20-70-=	9.40	8.5	17.96	6	0.88	.01

NS Figures Not Significant p < .3

TABLE 6

AGE-SPECIFIC MORTALITY FOR FIREFIGHTERS
1952 - 1962

Age	Expected Rate/1000	Observed Rate/1000	Chi Square	Degrees of Freedom	SMR	p < (.30-.001)
20 - 29	1.60	.99	0.23	1	0.62	NS
30 - 39	2.50	2.39	0.01	1	0.97	NS
40 - 49	5.60	7.91	0.97	1	1.42	NS
50 - 59	12.70	17.51	1.79	1	1.38	.20
60 - 69	30.50	26.52	0.28	1	0.86	NS
70-	86.40	200.00	25.34	1	2.33	.001
20-69 =	7.70	8.50	1.29	5	1.11	NS
20-70-=	9.90	14.00	28.63	6	1.42	.001

NS Figures Not Significant p < .3

TABLE 7

AGE-SPECIFIC MORTALITY FOR FIREFIGHTERS
1963 - 1973

Age	Expected Rate/1000	Observed Rate/1000	Chi Square	Degrees of Freedom	SMR	p < (.30-.001)
20 - 29	1.80	.65	1.14	1	0.37	.30
30 - 39	2.40	2.16	0.06	1	0.90	NS
40 - 49	5.80	8.88	3.33	1	1.54	.10
50 - 59	14.10	13.61	0.03	1	0.97	NS
60 - 69	31.50	22.65	2.95	1	0.72	.10
70-	92.90	102.83	0.45	1	1.11	NS
20-69 =	9.10	8.30	7.52	5	0.91	.20
20-70-=	12.70	12.40	7.97	6	0.98	.30

NS Figures Not Significant p < .3

TABLE 8

PROPORTIONATE MORTALITY[a] BY OCCUPATIONAL STATUS,
AGE AND PERIOD OF DEATH

Code Number and Diagnosis International Classification of Diseases 1968 (8th Revision)	Service Retired	Disability Retired	Active	Termin-ations	20-29	30-39	40-49	50-59	60-69	70-	1930-40	1941-51	1952-62	1963-73	Total P.M.R.	Average Age
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Years
404 Cardiovascular-Renal	18.90	7.6	5.7	11.7	-	1.93	6.17	11.20	10.03	14.67	47	52	44	45	44.0	61.83
199 All Cancer	5.30	2.3	.4	4.9	-	.77	1.93	2.32	3.09	5.41	3	3	18	14	13.5	65.29
162 Respiratory Cancer	1.50	.4	-	1.9	-	.39	-	.39	2.32	1.16	-	-	5	5	4.30	63.70
436 Cerebrovascular Accidents	2.30	1.5	.8	1.5	.39	.39	.77	.39	1.54	2.70	6	-	4	8	6.20	60.94
486 Pneumonia	1.14	.4	.8	-	-	.77	-	.39	.39	.39	3	-	-	2	1.90	53.40
E929 All Accidents	1.14	.8	4.9	2.7	1.93	2.32	2.7	2.32	-	-	9	21	5	9	9.30	39.91
E958 Suicides	.80	-	1.14	.4	-	.77	.39	1.16	-	.39	3	-	2	3	2.70	48.67
571 Liver	1.14	.8	-	.4	-	-	.39	1.16	-	.39	3	7	4	1	1.90	55.30
569 Gastro-Intestinal	.40	.4	.4	.4	-	-	1.16	.39	-	-	-	2	1	1	1.50	46.75
011 Tuberculosis	.40	-	-	-	-	-	-	-	.39	-	-	1	-	-	.40	60.00
796 Other and Ill-described Cases	1.9	1.14	.4	1.14	-	-	.77	1.5	.77	1.5	13	-	4	2	4.60	62.08
796 Unknown	6.1	2.7	1.14	1.5	2.32	1.54	1.54	1.54	1.54	3.47	13	14	13	10	9.70	58.80
Total	40.5	17.5	15.5	26.5	-	-	-	-	-	-	100	100	100	100	100.0	58.94

[a]Based on 259 deaths.

TABLE 9

COMPARATIVE CARDIOVASCULAR-RENAL MORTALITY AMONG FIREFIGHTERS
1930 - 1973

	Study Periods															
	1930 - 1940				1941 - 1951				1952 - 1962				1963 - 1973			
Age	Expected Rate/ 1000	Observed Rate/ 1000	SMR	P Value	Expected Rate/ 1000	Observed Rate/ 1000	SMR	P Value	Expected Rate/ 1000	Observed Rate/ 1000	SMR	P Value	Expected Rate/ 1000	Observed Rate/ 1000	SMR	P Value
20-29	.2	-	-	-	.08	-	-	-	.1	-	-	-	.07	-	-	-
30-39	.5	3.0	5.9	.05	.3	3.6	12.0	.05	.6	.6	1.0	NS	.51	-	-	-
40-49	1.8	2.4	1.3	NS[a]	1.5	2.5	1.7	NS	2.3	4.0	1.7	NS	2.1	3.9	1.9	NS
50-59	5.1	23.4	4.6	.05	4.7	3.6	.77	NS	6.5	10.3	1.6	NS	6.1	8.0	1.3	NS
60-69	12.7	12.7	.99	NS	11.1	18.2	1.6	NS	17.1	15.2	.89	NS	14.5	14.0	.96	NS
70-	39.3	10.3	.26	NS	28.3	21.3	.75	NS	56.8	110.0	1.9	.05	41.5	64.3	1.5	NS
30-69	2.3	5.5	2.4	.01	3.2	4.6	1.4	NS	4.5	5.3	1.2	NS	6.4[b]	7.7	1.2	NS
30-70-	3.9	6.0	1.5	NS	4.1	5.2	1.3	NS	6.3	9.0	1.4	.05	9.1[c]	12.0	1.3	.05

[a]Not significant at the .05 level.

[b]40-69

[c]40-70-

TABLE 10

WORKING LIFE OF ACTIVE AND PENSIONED FIREFIGHTERS BY DURATION OF EMPLOYMENT IN 1974 PERSON-YEARS

Person-Years Exposure	Mean Age of Accession by Exposure Category	Number	Per Cent	Mean Death Age by Exposure Category	Number	Per Cent
< 5	25.7	10	5	30.6	10	5
5-14	25.7	20	11	37.85	20	11
15-24	27.4	36	19	49.92	36	19
25-	28.12	121	65	65.00	120	60