CONTRIBUTING FACTORS TO FIREFIGHTER LINE-OF-DUTY INJURY IN METROPOLITAN FIRE DEPARTMENTS IN THE UNITED STATES

Authored by,

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Abstract

Objective: The objective of this study was to analyze retrospective data from a group of geographically diverse metropolitan fire departments for the years 2005-2006 (two years) to identify and quantify the major factors that contribute to firefighter line-of-duty injury (LOD injury). The identified contributing factors were examined for frequency of occurrence and clustering with other factors. Results should be used to alert participating fire department leaders of the primary factors that contribute to firefighter injuries in their respective departments and to identify clustering patterns of those factors. Results should be used to develop or enhance risk management programs within the participating and similar departments.

***Methods*:** A retrospective study was conducted using data compiled from nine geographically diverse metropolitan fire departments throughout the United States. Source departments include Richmond, Virginia, Worcester, Massachusetts, Charlotte, North Carolina, Miami, Florida, Memphis, Tennessee, Shreveport, Louisiana, Kansas City, Missouri, Phoenix, Arizona, and Contra Costa County, California. For each LOD injury, factors contributing to the injury were recorded from internal departmental reports including official injury reports, victim statements, officer and eyewitness reports. Once compiled, the contributing factors were analyzed for frequency of occurrence and clustering with other factors. No factors were excluded from the cluster analysis. Factors and clusters were stratified according to firefighter age, gender, type of injury, body part injured, location where injury occurred, firefighter years of service, medical treatment required, and post injury status.

***Results*:** There were 3450 injury cases with sufficient information to be included in the study. Frequency analysis revealed that the dominant contributing factors to LOD injury are lack of situational awareness (37.35%), lack of wellness/fitness (28.57%) and human error (10.65%). Cluster analysis was performed revealing

contributing factors frequently occurring together. Four main clusters were identified with these contributing factors. Cluster 1 included equipment failure, lack of training, structural failure, act of violence, civilian error, horseplay, and lack of teamwork. Cluster 2 included crew size, lack of wellness/fitness, firefighter fatigue, and weather/act of nature. Cluster 3 included protective equipment not worn (SCBA or seatbelt) and dangerous substance. Cluster 4 included decision making, lack of communication, standard operating guideline/procedure breech, protocol breech, human error, and lack of situational awareness. Cluster 4 alone, (regardless of other clusters) was shown to be responsible for more than 30.0% of all firefighter on duty injuries during the years studied while cluster 2 was responsible for an additional 26.2%.

***Conclusions*:**

Ninety-four and one half percent of firefighter LOD injuries occurring in 2005-2006 in the departments studied, are attributable to an identifiable cluster of contributing factors. Approximately one third of the firefighter LOD injuries studied are attributable to a cluster of factors that are under the direct control of the individual firefighter and chief officers. The information revealed in this study imposes a considerable burden on fire service leaders as well as firefighters themselves. It offers substantial explanation for the LOD injury occurring within metropolitan departments studied thus providing direction for shaping local fire department policy decisions and operational priorities in those departments.

Keywords:

LOD injury, contributing factor, injury, firefighter

The provision of fire suppression and emergency medical services entails sporadic high levels of physical exertion, uncontrolled environmental exposures, and psychological stress from observing intense human suffering. Firefighters experience inordinate numbers of line-of-duty injuries, injuries due to occupational diseases, and forced retirements. (Moore-Merrell, 2008). NFPA estimates that there were approximately 1,140,900 firefighters in the U.S. in 2006. Of the total number of

firefighters, 316,950 or 28% were career firefighters. Most of the career firefighters (76%) are in communities that protect 25,000 or more people. (Karter, 2007) A large percentage of these firefighters are employed by fire departments in metropolitan areas.

Year after year, there are notable advancements in the fire service industry. These advancements range from building code improvement to sprinkled buildings, from better personal protective gear to technologically advanced apparatus. Many profound advances have also been made in both laws and programs designed to improve worker safety and health for all workers in the United States. In spite of these laws and the improvements mentioned, scores of firefighters are injured in the line-of-duty each year. NFPA estimates that 80,100 firefighter injuries occurred in the line of duty in 2005, an increase of 5.6% from the year before. Almost half of the all firefighter injuries occurred during fire ground operations. An estimated 13,325 occurring during other on duty activities, while 12,250 occurred at non-fire emergency incidents. The leading type of injury received during fire ground operations was strain, sprain or muscular pain. (Karter, 2006) This study specifically examines contributing factors leading to firefighter LOD injury in metropolitan fire departments. Results can be compared with similar studies to hone knowledge and thereby provide opportunities for intervention through departmental training, practices and policy to prevent firefighter injuries.

LITERATURE REVIEW

Currently, there is a dearth of published information on firefighter injuries. Government and industry publications, which rely on voluntary incident reporting and annual survey projections, presently offer the broadest scope of information regarding fireground injuries. (Karter 2007) Academic interest in firefighters' occupational risks and hazards has increased in recent years, but many of these papers analyze contributing factors outside the context of specific fireground incidents and individuals' past firefighting experience and training. The most in depth studies to date identify key areas of risk for firefighter injuries, but many findings suffer from limited predictive value due to small sample sizes. If LOD injuries are to be comprehensively evaluated and risks of firefighter injury minimized to the fullest, future investigation must look both in finer and

greater detail at the particular events unfolding at fire and emergency scenarios as well as overarching trends across geographic regions.

The U.S. Fire Administration's (USFA) voluntary-enrollment National Fire Incident Reporting System (NFIRS) comprises the largest information database used for analysis in most academic and government publications on firefighter injuries and fatalities. Module 5 of the current NFIRS Version 5.0, the Fire Service Casualty Module, includes a firefighter injury reporting form. (NFDC 2008) However, the majority of papers using data from this system examine firefighter fatalities and the risk of death associated with coronary heart disease, structure related trauma, and the risk differences for a variety of factors between career and volunteer firefighters. (CDC 2006, Hodous 2004, Kales 2003) Few studies to date have attempted to quantify incident-level risk factors for firefighter injury using NFIRS data. (Fabio 2002) The National Fire Protection Agency (NFPA) Survey of Fire Departments for U.S. Fire Experience is the industrial counterpart to NFIRS annual data and projects responses from 2,500-3,500 departments into national figures by weighting the results to adjust for the proportion of U.S. population represented by community size. NFPA reports provide annual national estimates of injuries by cause, type of duty, and number of injuries per department by population of community protected. (Karter 2007) Conclusions drawn from either of these datasets are confined by study designs that by necessity exclude certain fire incidents. Thus, NFIRS' voluntary reporting system and NFPA's survey projections give the most extensive accounts of U.S. firefighter injuries, but these estimates are still only partially complete.

Presently, academic literature that attempts to identify and assess factors contributing to firefighter LOD injuries tends to focus on broad risk categories that can be studied using a general knowledge of firefighters' physical duties and potentially hazardous fireground exposures. These papers, which usually address overall firefighter fitness or equipment use, emphasize the fact that public safety depends on the general health of firefighters and medical first responders and that effective equipment use can prevent certain types of injury. (Soteriades 2005) Reduced firefighter fitness and cardiovascular health have so far received the most attention as contributing factors to "adverse employment events" including on-duty injury and disability. (Kales 2002, Soteriades 2002-2008, Sothmann 2004) A few studies of firefighter equipment and ergonomics have

confirmed the use of specific uniforms and vehicle restraints in preventing LOD burn and motor vehicle injuries, as well as identified emergency rescue tasks that cause the most musculoskeletal strain. (Becker 2003, Lavender 2000, Prezant 2000) Likewise, several smaller analyses have affirmed the role that the close-knit structure of a fire company plays in shaping various health promotion attitudes. (Elliot 2004 & 2007, Moe 2002) By addressing issues such as hearing loss, eating habits, and psychological stress in the context of unit-level resources and outcomes, such papers come closer to realizing the occupational experience of many firefighters but are still somewhat removed from line-of-duty incidents (Bacharach 2008, Beaton 1998, Hong 2008, Kales 2001, Tak 2007). Studies of breathing apparatus use during overhaul come nearest to documenting the risks of lung injury during specific incident conditions, but these like the majority of academic papers examine a highly localized sample population. (Austin 2001, Burgess 2001)

If the risks and contributing factors for firefighter LOD injuries are to be fully understood, greater study must be given toward the sequences of events unfolding at and around particular fire incidents and emergency situations. While long-term prevention, health promotion, and technological advancements certainly equip firefighters with individual and sometimes unit-level tools to reduce on-duty risks before an incident occurs, far less research has examined the influence that the interaction of these factors and more dynamic, situation-specific elements have on firefighter LOD injuries during fire operations. A review of the current literature suggests a pressing need for information and analysis that synthesizes diverse populations and incorporates the ways in which individual firefighter fitness, fatigue over time, equipment performance and use, staffing, strategic protocols, incident command, teamwork, and changing environmental factors contribute to situations that protect firefighters or make them more vulnerable to LOD injuries.

METHODS

Study Design

Injury data analyzed in the study were compiled from nine geographically diverse metropolitan departments in the United States. Data were limited to firefighter line-of-duty injuries occurring during the years of 2005-2006 with sufficient information for analysis. Injury data were contributed from metropolitan fire departments in Richmond, Virginia, Worcester, Massachusetts, Charlotte, North Carolina, Miami, Florida, Memphis, Tennessee, Shreveport, Louisiana, Kansas City, Missouri, Phoenix, Arizona, and Contra Costa County, California. Data compiled included case information for each line-of-duty injury as well as known contributing factors to the injury including one or more of the following; officer/incident command, crew size, decision making equipment failure, lack of training, lack of wellness/fitness, firefighter fatigue, lack of communication, standard operating guidelines/procedures breech, protocol breech, structural failure, act of violence, weather/act of nature, human error, civilian error, lack of situational awareness, horseplay, or lack of teamwork. Data for each LOD injury and associated contributing factors were compiled from reports profiling the incident leading to the injury as communicated by the victim, peers, and officers and as recorded by each respective department's injury tracking mechanism. Methods for data collection, recording and reporting varied between departments. Though similar, none of the departments collected or reported firefighter injury in the same way. Therefore, data compilation was conducted on a case-by-case basis to assure proper transfer of information and an accurate transfer of data element definitions to the master database used for analysis. A total of 3450 cases had sufficient information available for inclusion in the study.

Data Synthesis

This study was based on data extracted from nine metropolitan fire department's injury files for the years 2005-2006. These data were cross-referenced with data elements and definitions used in the Near Miss Reporting System to assure industry consistency in use of terms recognized in the fire service industry.

The term 'on-duty' refers to a firefighter being involved in operations at the scene of an emergency, whether it is a fire or non-fire incident, responding to or returning from

an incident, or performing other officially assigned duties such as training, maintenance, public education, inspection, and investigations.

Study Protocol

Descriptive data for each LOD injury and associated contributing factors were compiled from reports profiling the incident leading to the injury as communicated by the victim, peers, and officers and as recorded by each respective department's injury tracking mechanism. Data were submitted using a standard template (Appendix I) and were compiled into a master database for analysis. Data tables were prepared with all study relevant information.

Data were analyzed to assess the frequency of identified contributing factors and the circumstances in which the injury occurred. As injury-relevant circumstances and contributing factors were documented, a variable key was constructed containing each variable name and the definition as referenced in data source reports. Frequency analysis as well as cluster analysis were performed on the overall database. Cluster analysis was used to organize the data into meaningful structures, or develop taxonomies or groups of contributing factors that occur together. The aim of cluster analysis was to sort different factors into groups in a way that the degree of association between two factors is maximal if they belong to the same group and minimal otherwise. Clustering is typically used to discover structures in data without providing an explanation or interpretation as to why they exist. Clusters provide a springboard for future research to better identify why relationships exist between various factors.

Data Analysis

Initial analysis identified the overall dominant contributing factors as well as the dominant factors in each of five strata. Strata included firefighter age, gender, rank, years of service, and scene type. Next, data were analyzed for clustering between contributing factors and the frequency of that cluster. Four oblique clusters of the contributing factors were identified using the VARCLUS Procedure using the SAS software (Version 9.1, SAS Institute). All contributing factors were included in the cluster analysis. A binary score was calculated for each cluster based on

presence/absence of any of its constituent contributing factors. Finally, these contributing factor clusters were evaluated for the significance of their contribution to firefighter LOD injury in the departments studied. The relative contribution of these clusters was also evaluated within each stratum identified previously. All data analyses were conducted using the SAS software.

RESULTS

There were 3450 cases identified with sufficient information for inclusion in the study. Firefighter LOD injury characteristics are shown in Table 1. Age information was not available for fourteen of the cases and gender was not identified in three cases. Additionally, the years of service and rank were not identified in eight and two cases respectfully. Stratified analyses were limited to cases with sufficient strata specific data.

As is expected, based on the make-up of the fire service, the majority of LOD injury cases are male (94.9%). For the years and cases included in the study, more firefighter LOD injury occur in firefighters with less than 6 years of service (30.7%) and in those with between 11-20 years of service (31.9%). The majority of firefighters injured are between the ages of 36-45 (39.4%). According to rank, more firefighter LOD injury occurs in the rank of firefighter (72.1%) than in any other rank.

Table 1

Characteristics of firefighter LOD injury cases included in the study (N=3450)			
Age			
	Less than 26	**185**	**5.4%**
	26-35	**1041**	**30.2%**
	36-45	**1358**	**39.4%**
	46-55	**740**	**21.4%**
	Greater than 55	**112**	**3.2%**
	Unidentified	**14**	**0.4%**
Gender			
	Female	**174**	**5.0%**
	Male	**3273**	**94.9%**
	Unidentified	**3**	**0.1%**
Rank			
	Chief	**77**	**2.2%**
	Civilian	**11**	**0.3%**
	Fire Fighter	**2489**	**72.1%**
	Investigator	**13**	**0.4%**
	Recruit	**84**	**2.4%**
	Captain	**774**	**22.4%**
	Unidentified	**2**	**0.1%**
Years of Service			
	Less than 6	**1058**	**30.7%**
	6-10	**627**	**18.2%**
	11-20	**1100**	**31.9%**
	Greater than 20	**657**	**19.0%**
	Unidentified	**8**	**0.2%**
Scene Type			
	Not Specified	**37**	**1.1%**
	Fireground	**1053**	**30.5%**
	Non-fire Emergency	**862**	**25.0%**
	In-Transit	**200**	**5.8%**
	Training	**344**	**10.0%**
	Other On-Duty	**954**	**27.7%**

Characteristics of the injuries incurred were also assessed. Data were compiled on various aspect of each injury including type of injury, body part injured, medical treatment, and number of days off duty or on light duty. As for circumstances surrounding the injuries, most occur on the fire ground (30.5%) and the most common injury is a fracture or muscle sprain (61.7%). For the cases studied, more than half required medical aid (62.7%) and the most common body part injured was an extremity (42.0%).

Table 2

Characteristics of injuries included in the study (N=3450)			
Number of Days Injured (off normal duty)			
	0 days injured	**2585**	**74.9%**
	1-10 days injured	**546**	**15.8%**
	11-20 days injured	**105**	**3.0%**
	21-30 days injured	**59**	**1.7%**
	30+ days injured	**144**	**4.2%**
	Did not return	**11**	**0.3%**
Number of Days on Light Duty			
	0 LightDuty	**3102**	**89.9%**
	1-10 LightDuty	**176**	**5.1%**
	11-20 LightDuty	**58**	**1.7%**
	21-30 LightDuty	**26**	**0.8%**
	30+ LightDuty	**87**	**2.5%**
	Unidentified	**1**	**0.0%**
Medical Treatment			
	No Aid	**1287**	**37.3%**
	Yes Aid	**2163**	**62.7%**
Type of Injury			
	Not Specified	**46**	**1.3%**
	Fire, Chemical Burn	**189**	**5.5%**
	Inhalation, Respiratory	**188**	**5.4%**
	Wound, Cut, Bleeding	**509**	**14.8%**
	Fracture, Sprain, Muscle	**2128**	**61.7%**
	Heart Attack, Stroke	**150**	**4.3%**
	Skin Exposure	**225**	**6.5%**
	Any Combination	**15**	**0.4%**
Body Part Injured			
	Not Specified	**50**	**1.4%**
	Extremity	**1448**	**42.0%**
	Head/Face/Neck	**367**	**10.6%**
	Trunk/Abdomen/Groin	**490**	**14.2%**
	Back	**741**	**21.5%**
	Heart/Respiratory	**261**	**7.6%**
	Heat Exhaustion	**21**	**0.6%**
	Any Combination	**72**	**2.1%**

Contributing factors were identified for each injury. The factors identified were compiled from reports profiling the incident leading to the injury as communicated by the victim, peers, and officers and as recorded by each respective department's injury tracking mechanism. Each factor identified was defined or described and assigned a

variable name for the study. The contributing factors, definitions and variable names are listed below.

- **Incident Commander (IC)** – Individual responsible for the combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure with responsibility for the management of assigned resources to effectively accomplish stated objectives pertaining to an incident or training exercise (NFPA Standard 1670,424).

- **Crew Size (CREW SIZE)** – (Fire Crew or Company) A group of members: (1) Under the direct supervision of an officer; (2) Trained and equipped to perform assigned tasks; (3) Usually organized and identified as engine companies, ladder companies, rescue companies, squad companies, or multi-functional companies; (4) Operating with one piece of fire apparatus (engine, ladder truck, elevating platform, quint, rescue, squad, ambulance) except where multiple apparatus are assigned that are dispatched and arrive together, continuously operate together, and are managed by a single company officer; (5) Arriving at the incident scene on fire apparatus (NFPA Standard 1710). An organized group of firefighters under the leadership of a crew leader or other designated official (NIFC, 2006).

- **Lack of Training (TRAIN)** – The deficiency of instruction and hands-on practice in the operation of equipment and systems that are expected to be used in the performance of assigned duties (NFPA Standard 600-601).

- **Lack of Communications (COMM)** – A deficiency of radio, telephone and messenger service networks throughout the emergency response system necessary to facilitate direct communication from the incident commander to officers, firefighters and emergency providers in tactical operations (NFPA Standard 130, 502, 1221).

- **Standard Operating Procedures (Guidelines) Breech (SOP)** – A written organizational directive that establishes or prescribes specific operational or

administrative methods to be followed routinely for the performance of designated operations, actions or administrative functions (NFPA Standard 1521).

- **Protocol Breech (PROTOCOL)** – An organizational directive that establishes a common practice or course of action during tactical operations. A protocol aims to streamline particular processes according to a set routine. By definition, protocol is a term for a mandatory procedure. In the EMS arena, a protocol is intended to guide decisions regarding assessment, management, and treatment of patients.

- **Protective Equipment Not Worn/SCBA or Seatbelt (PE)** – The equipment provided to shield or isolate personnel from infectious, chemical, physical, and thermal hazards (NFPA Standard 1670) and physical injury.

- **Lack of Wellness/Fitness (LWF-WELLNESS/FITNESS)** – The state of uniform personnel signifying a deficiency or absence of physical, mental, or emotional capability to withstand the stresses or strains of living and functioning in the workplace. This adverse state results from cumulative factors including job exposures, stress and personal behavior including poor diet and general lack of exercise.

- **Act of Violence (VIOL)** – Exertion of physical force to injure, abuse or cause death.

- **Dangerous Substance (DS)-** This factor includes substances that are explosive and/or flammable, such as petroleum products and gunpowder. It includes radioactive substances, and products such as aerosol cans which can explode when heat or pressure is applied. It also includes *'hazardous substance'* that includes substances used or produced by industries that have the potential to cause mass disaster to people and the environment. Examples of hazardous substances are chlorine, PCB, chlorobenzene, pesticides, etc. Hazardous substances are listed and controlled under the Poisons Act and the Poisons (Hazardous Substances) Rules. The factor also encompasses *toxic industrial*

waste that includes toxic waste from industries, such as spent acids, alkalis, etchants, solvents and waste oils. (NEA, 2008)

- **Weather/Act of Nature (WEA-WEATHER)** – An extraordinary and unexpected natural event, such as a hurricane, tornado, earthquake or even the sudden death of a person.

- **Human Error by Firefighter or Officer (HE)** – A mistake made by a person rather than caused by a poorly designed process or the malfunctioning of equipment.

- **Civilian Error (CE)** – Persons who are members of the general public and who are not fire service or other emergency services personnel (NFPA Standard 180) who in an act or condition of ignorant or imprudent behavior unintentional cause an adverse event.

- **Decision Making (DM-DECISION MAKING)** – can be regarded as an outcome of mental processes (cognitive processes) leading to the selection of a course of action among several alternatives. Every decision-making process produces a final choice. (Carnegie Mellon, 2008)

- **Structural Failure (SF)** – Structural collapse brought on by fire that precludes buildings or structural components from functioning as designed.

- **Emergency Equipment Failure (EF)** – The unacceptable difference between expected and observed performance of emergency equipment.

- **Firefighter Fatigue (FF-FATIGUE)** – a weariness caused by exertion. It can describe a range of afflictions, varying from a general state of lethargy to a specific work-induced burning sensation within one's muscles. It can be both physical and mental. Physical fatigue is the inability to continue functioning at the level of one's normal abilities, (Hawley, 1997)

- **Lack of Situational Awareness (LSA)** – concerns the absence of knowledge and understanding of the environment that is critical to those who need to make decisions in complex areas such as fire ground operations, air traffic control, and military command and control. Situation awareness has been formally defined as "the *perception* of elements in the environment within a volume of time and space, the *comprehension* of their meaning, and the *projection* of their status in the near future" (Endsley, 2000).

- **Horseplay (HP)** – rough or boisterous play.

- **Lack of Teamwork (TMWK)** – refers to an individual rather than group effort. Lack of teamwork is a general lack of the mindset that aligns firefighters in a cooperative and selfless manner, towards a specific purpose. A team player is one who subordinates personal aspirations and works in a coordinated effort with other members of a group, or team, in striving for a common goal.

Following contributing factor identification and definition, raw frequency scores were determined for each factor. Dominant contributing factors were identified by percentage for the overall dataset and in various categories as described in Table 3 below.

Table 3.

Dominant Contributing Factors by Strata (Top 3 Percentages shown)		
Strata		**Contributing Factor (% LOD Injury)**
Overall		**LSA (37.3) LWF (28.5) HE (10.6)**
Age		
	Less than 26	**LSA (39.5) LWF (32.4) PE (13.0)**
	26-35	**LSA (39.2) LWF (25.7) DS (13.3)**
	36-45	**LSA (37.1) LWF (26.8) HE (10.2)**
	46-55	**LSA (35.1) LWF (34.1) HE (10.7)**
	Greater than 55	**FF (36.6) LSA (32.1) COMM (13.4)**
Gender		
	Female	**LSA (48.3) LWF (20.1) HE (12.6)**
	Male	**LSA (36.7) LWF (29.0) HE (10.5)**
Rank		
	Chief	**LWF (36.4) LSA (29.9) FF (9.1)**
	Civilian	**LSA (54.6) DM (27.3) LWF (27.3)**
	Fire Fighter	**LSA (38.4) LWF (27.2) HE (10.8)**
	Investigator	**LSA (53.9) WEA (38.5) LWF (30.8)**
	Recruit	**LWF (51.2) LSA (38.1) FF (17.9)**
	Captain	**LSA (33.9) LWF (29.6) HE (11.0)**
Years of Service		
	Less than 6	**LSA (41.1) LWF (23.5) DS (11.9)**
	6-10	**LSA (37.5) LWF (27.1) DS (10.5)**
	11-20	**LSA (37.3) LWF (29.4) PE (10.0)**
	Greater than 20	**LWF (36.5) LSA (31.2) HE (12.3)**
Scene Type		
	Not Specified	**LSA (29.7) LWF (16.2) HE (5.4)**
	Fire ground	**LSA (38.3) LWF (25.4) FF (13.9)**
	Non-fire Emergency	**LSA (31.0) LWF (24.1) DS (21.4)**
	In-Transit	**LSA (52.0) LWF (16.5) HE (16.0)**
	Training	**LWF (44.2) LSA (37.8) FF (15.1)**
	Other On-Duty	**LSA (38.9) LWF (33.3) HE (12.2)**

According to cluster analysis, four clusters of contributing factors were identified. All contributing factors were included in the cluster analysis. Composite cluster variables are listed in Table 4 below.

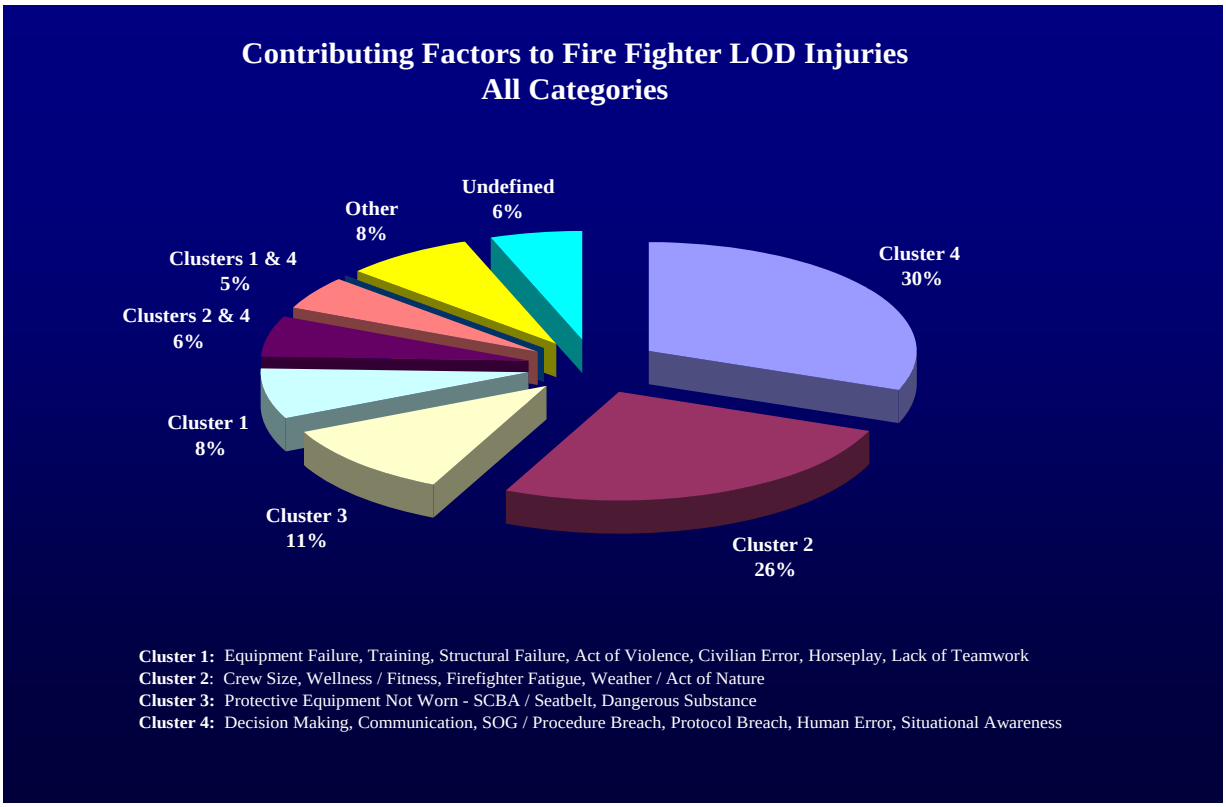
Table 4 Composite Cluster Variables

Cluster 1:	Equipment Failure, Lack of Training, Structural Failure, Act of Violence, Civilian Error, Horseplay, Lack of Teamwork
Cluster 2:	Crew Size, Lack of Wellness / Fitness, Firefighter Fatigue, Weather / Act of Nature
Cluster 3:	Protective Equipment Not Worn - SCBA / Seatbelt, Dangerous Substance
Cluster 4:	Decision Making, Lack of Communication, Standard Operating Guidelines / Procedure Breach, Protocol Breach, Human Error, Lack of Situational Awareness

Though there is no exact pattern to the make-up of the clusters, there seems to be identifiable categorization. For example, Cluster 4 appears to represent the 'human factor' while Cluster 2 represents 'crew size and physical fitness related issues'. Cluster 3 appears to represent 'personal protective equipment' while Cluster 1, with the exception of lack of training/teamwork and horseplay seems to represent 'things that are out of the control of an officer or firefighter'. This categorization is beneficial in honing areas of risk management intervention in the departments studied.

The four clusters identified by the analysis are responsible for 94.49% of all LOD INJURY in the departments studied. The remaining LOD injuries (5.51%) were not explained by any contributing factor cluster. Among the composite clusters, Cluster 4 alone, excluding its interaction with any other contributing factors, is responsible for 30.9% of LOD injury Cluster 2 alone is responsible for another 26.17%, Cluster 3 alone 10.87%, Cluster 1 alone 7.59%, and about 10% were contributed by interactions between clusters as described in Figure 1 below.

Figure 1. Overall Model of Composite Clusters for LOD Injury in Select Metropolitan Departments 2005-2006.



The relative contribution of the clusters was evaluated within various strata in an attempt to hone contributing factor clusters to specific environments making risk management efforts more direct and efficient. Strata evaluated included firefighter age, gender, rank, years of service, and scene type.

Firefighter age strata were defined as 25 and under, 26-35, 36-45, 46-55, and Over 55. Cluster 4 was responsible for more than 29% of LOD injury in firefighters 25 and under while cluster 2 was responsible for an additional 25%. Cluster 4 was also responsible for the majority of injuries in age groups 26-35 and 36-45 (32%). However, cluster 2 was responsible for the majority of injuries in age 46-55 and over 55 with the percentage of attributable injuries increasing with age. Figures 2 – 6 show contributing factor clusters by firefighter age group.

Figure 2. Age Group 25 and Under

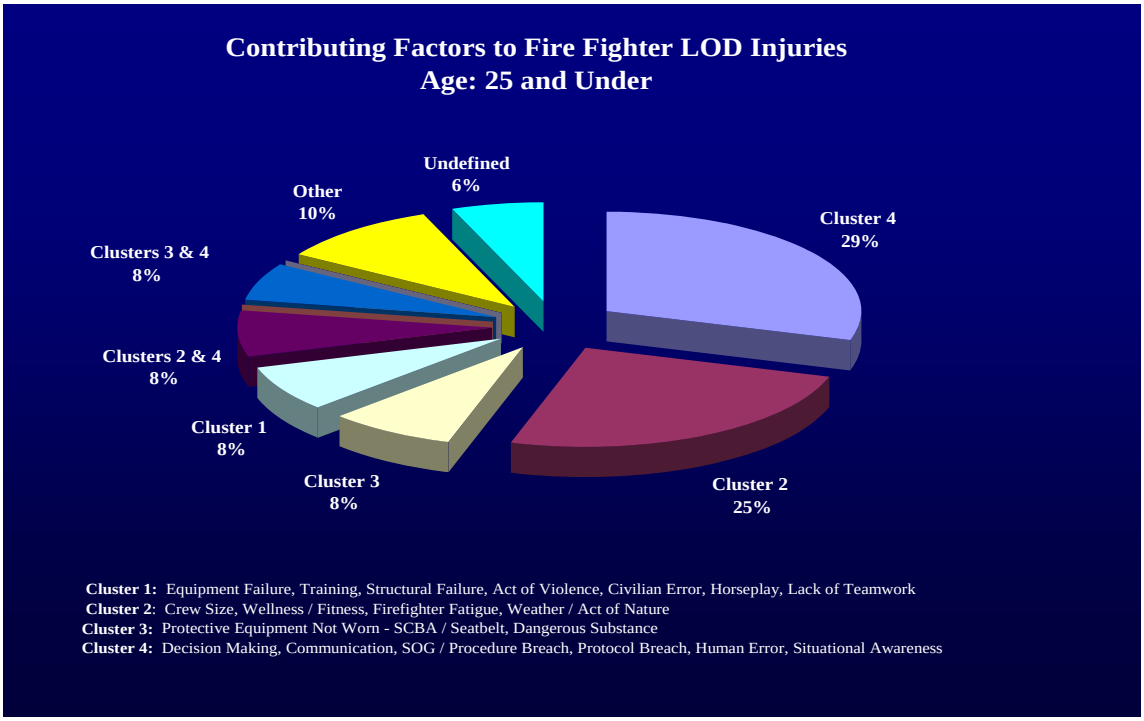


Figure 3. Age Group 26-35

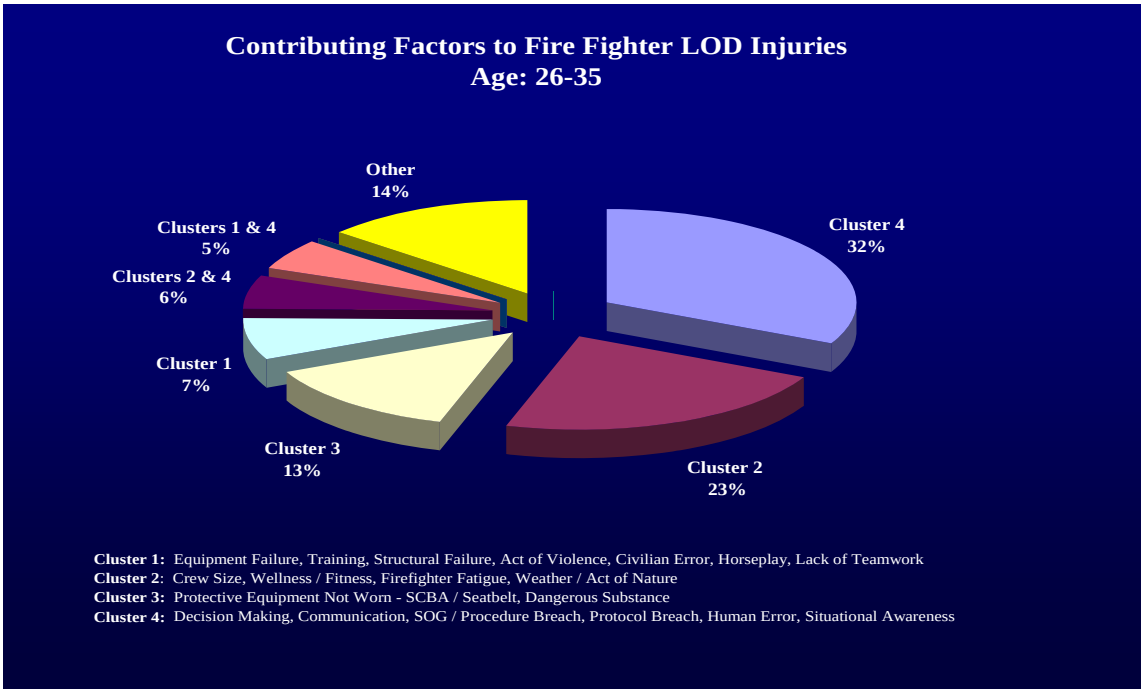


Figure 4. Age Group 36-45

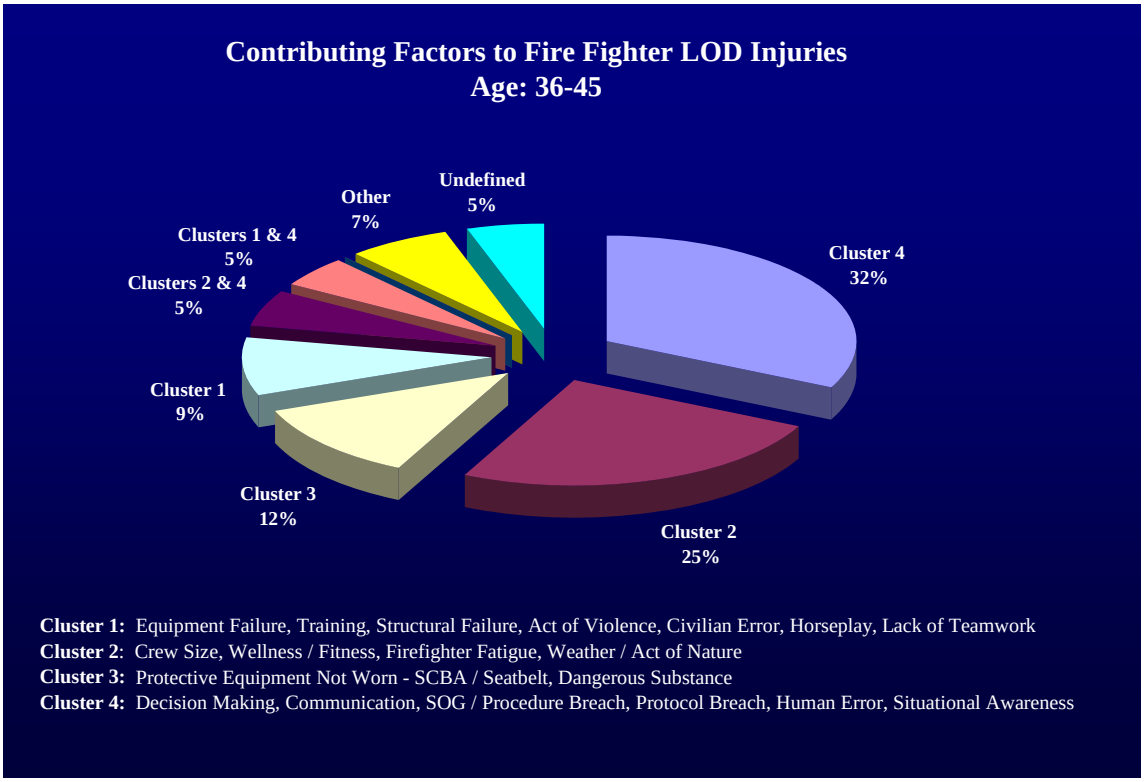


Figure 5. Age Group 46-55

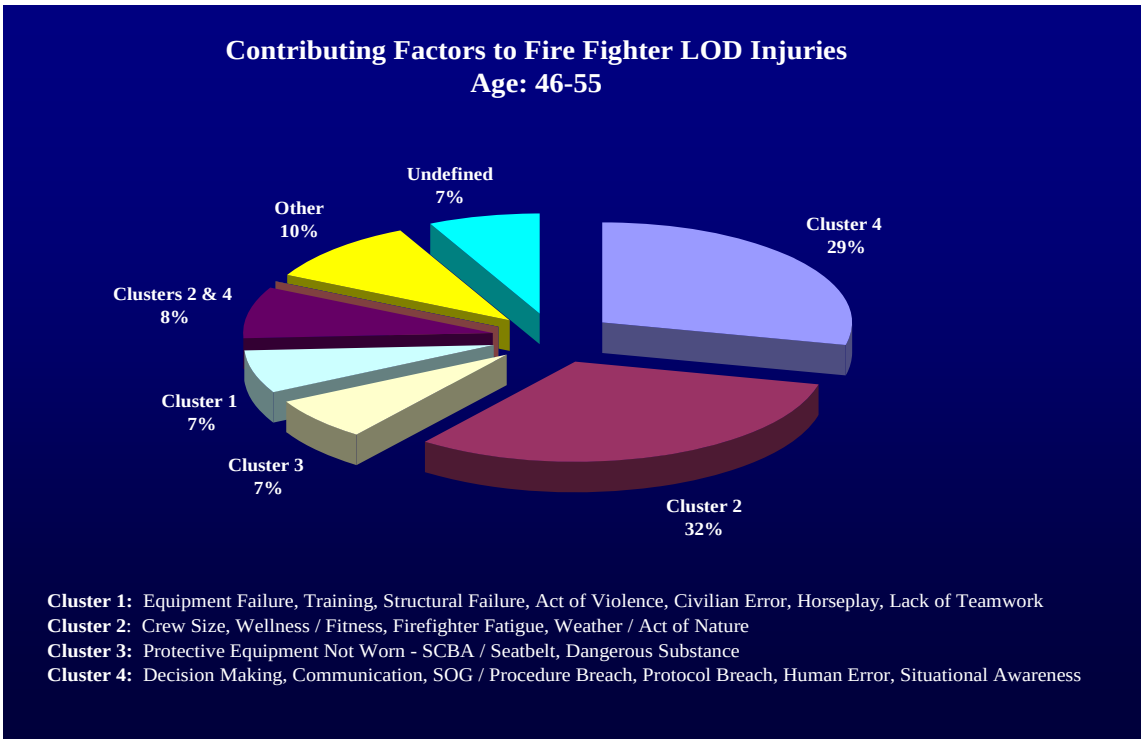
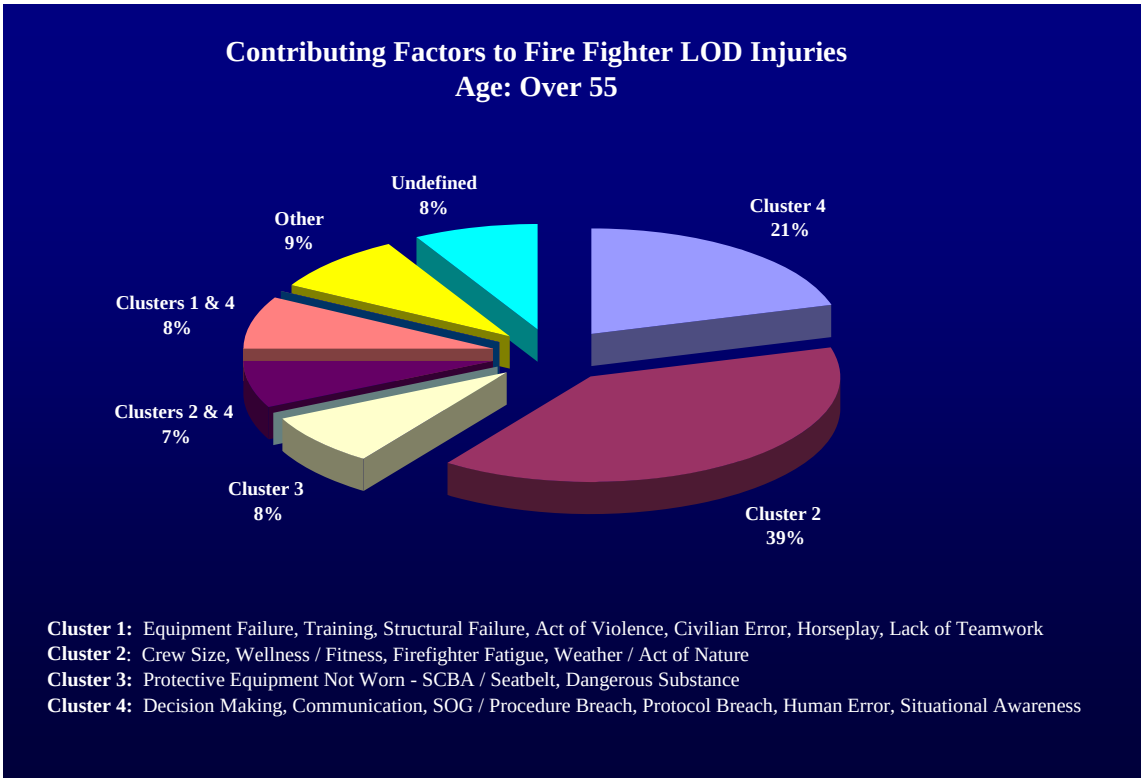


Figure 6. Age Group Over 55



Data were also stratified by years of service to highlight experiential differences in contributing factor clusters. These differences are significant, however reasons for the differences can only be assumed as time on the job and/or experience does not necessarily equal quality performance. Figures 7-10 show the contributing factor clusters most responsible for LOD injury in these strata. Cluster 4 is responsible for the majority of the LOD injuries in firefighters with fewer years on the job particularly in the less than 6 year strata and the 6-10 year strata, while cluster 2 is responsible for the majority in firefighters with greater than 20 years on the job.

Figure 7. Less than 6 Years

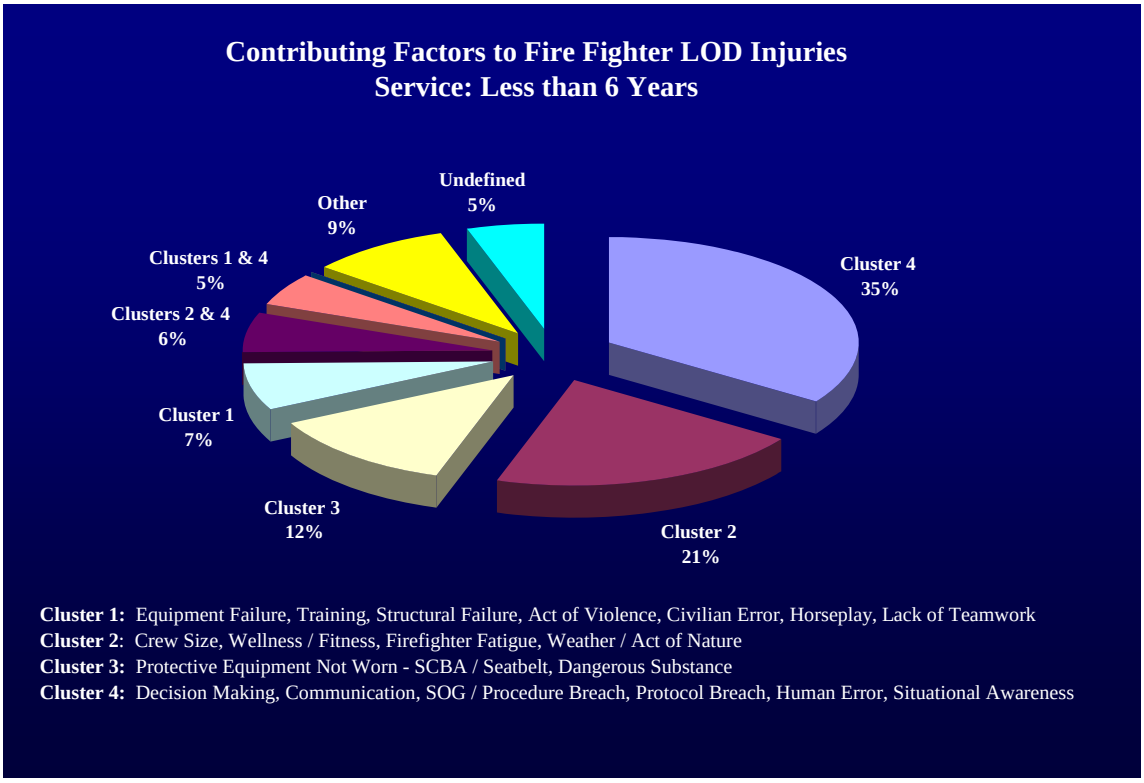


Figure 8. 6-10 Years

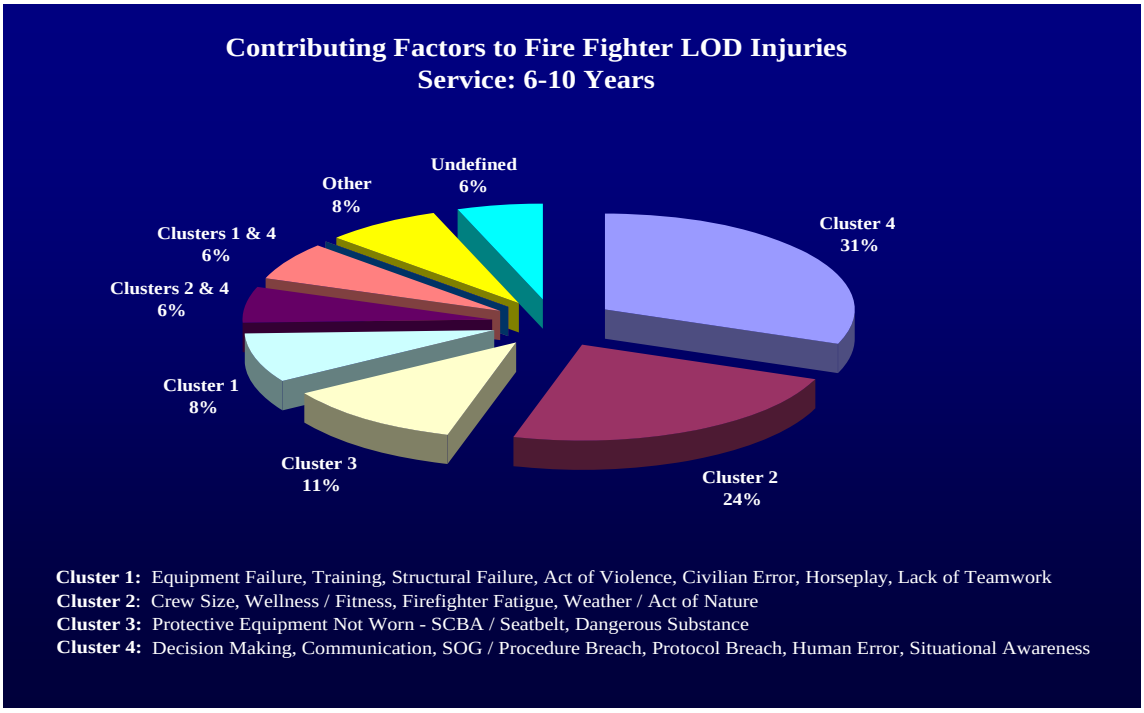


Figure 9. 11-20 Years

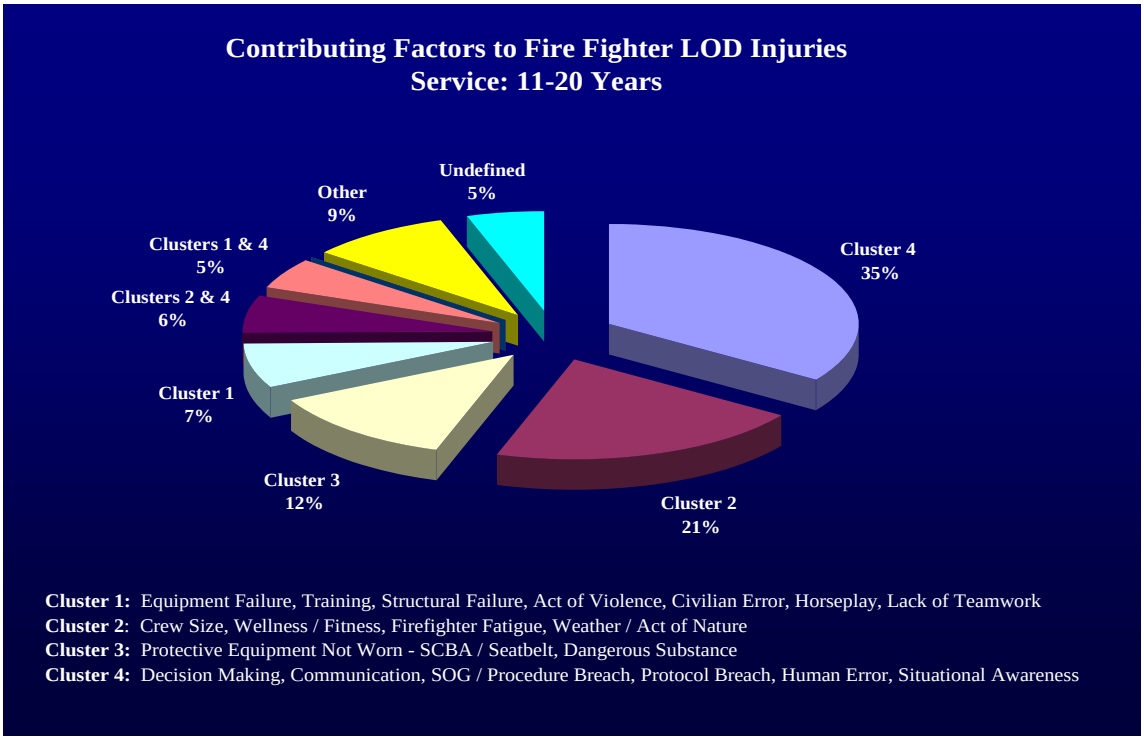
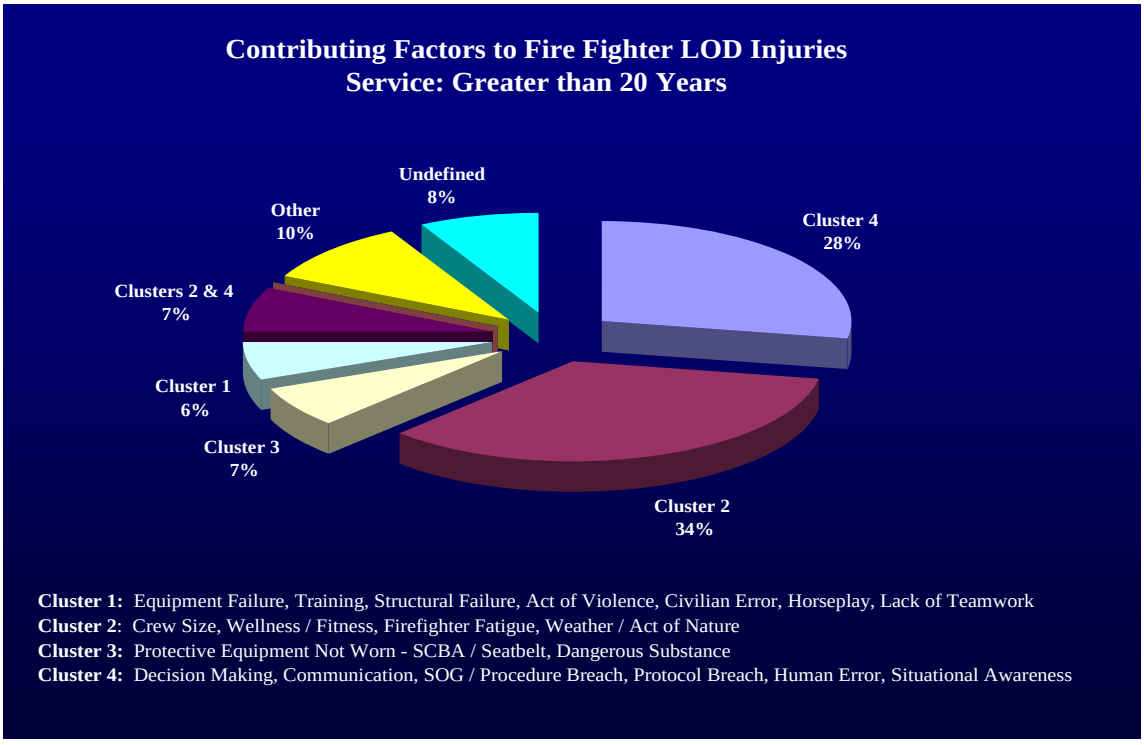


Figure 10. Greater than 20 Years



Data were also stratified by scene type. The various scene types identified include fire ground, non-fire emergency, in-transit, training, and other on-duty activity. As noted in figures 11-15 below, there were differences in the contributing factor clusters responsible for LOD injury between theses strata. Analysis of contributing factor clusters for LOD injury occurring on the fire ground shows that Cluster 4 is responsible for 31% of injuries while Cluster 2 is responsible for another 26%. In the stratum for non-fire emergency, Cluster 4 once again is dominate and responsible for 25% while Cluster 3 is responsible for another 22%. This is not surprising as the non- fire emergency strata contains EMS calls. Cluster 4 is overwhelmingly responsible for LOD injury (50%) in the in-transit stratum. The next scene type evaluated is training. The training stratum shows Cluster 2 as dominant (39%) while Cluster 4, including situational awareness is responsible for an additional 29% of injuries in this arena. The final stratum specifically evaluated was other on-duty activity including apparatus maintenance, station maintenance, meetings, investigation and inspections. In this stratum, Cluster 4 was responsible for the majority of LOD injury (34%).

Figure 11. Fire Ground

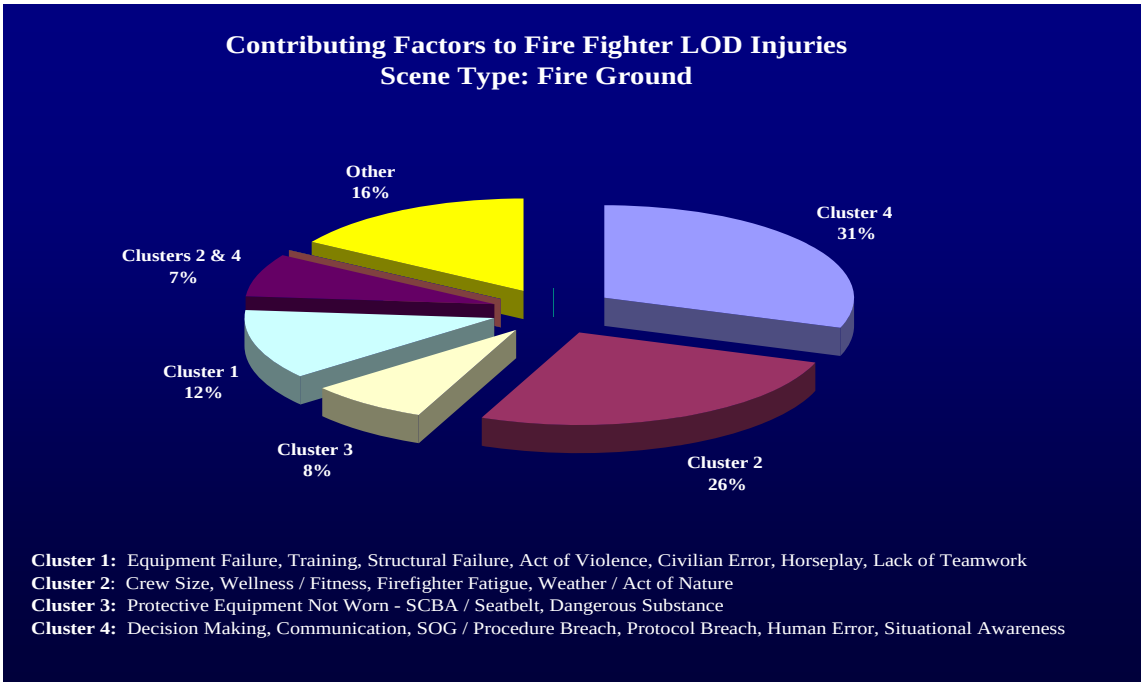


Figure 12. Non-Fire Emergency

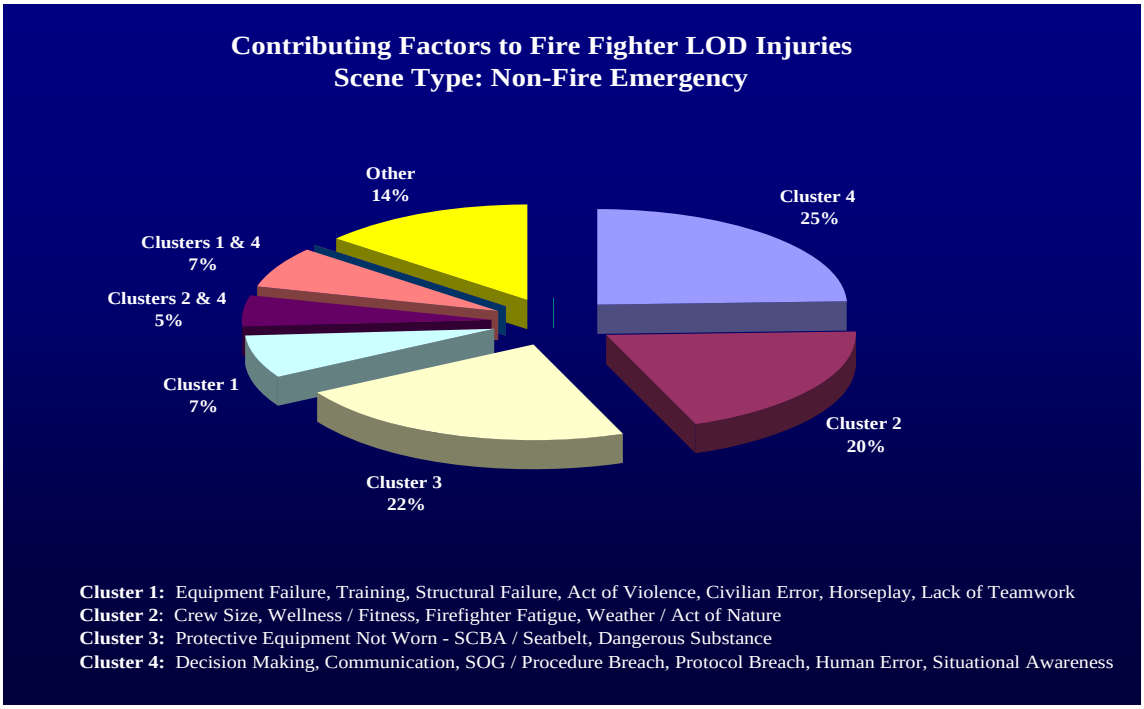


Figure 13. In-Transit

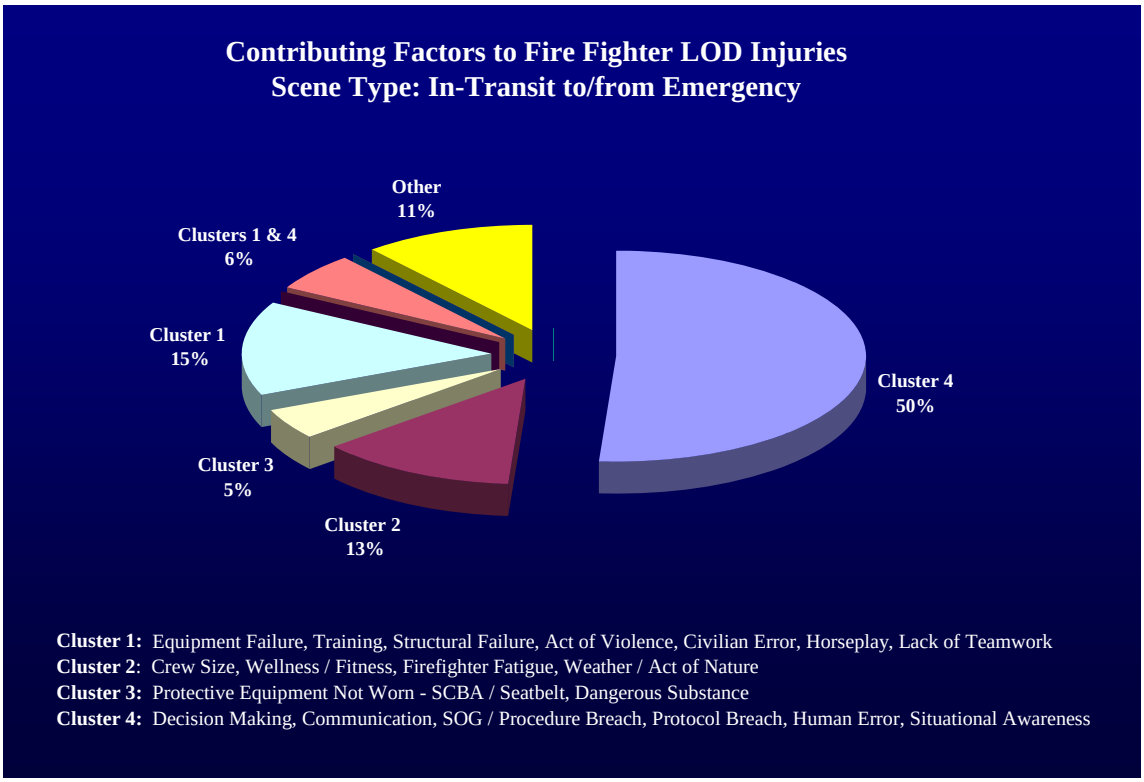


Figure 14. Training

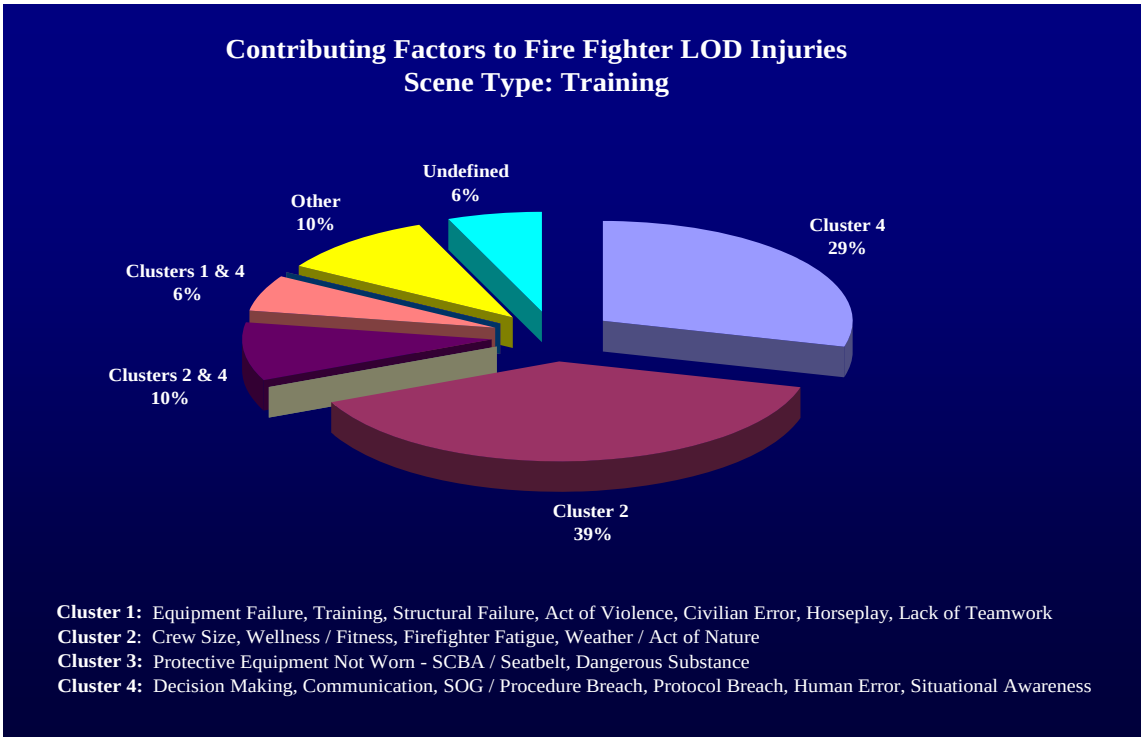
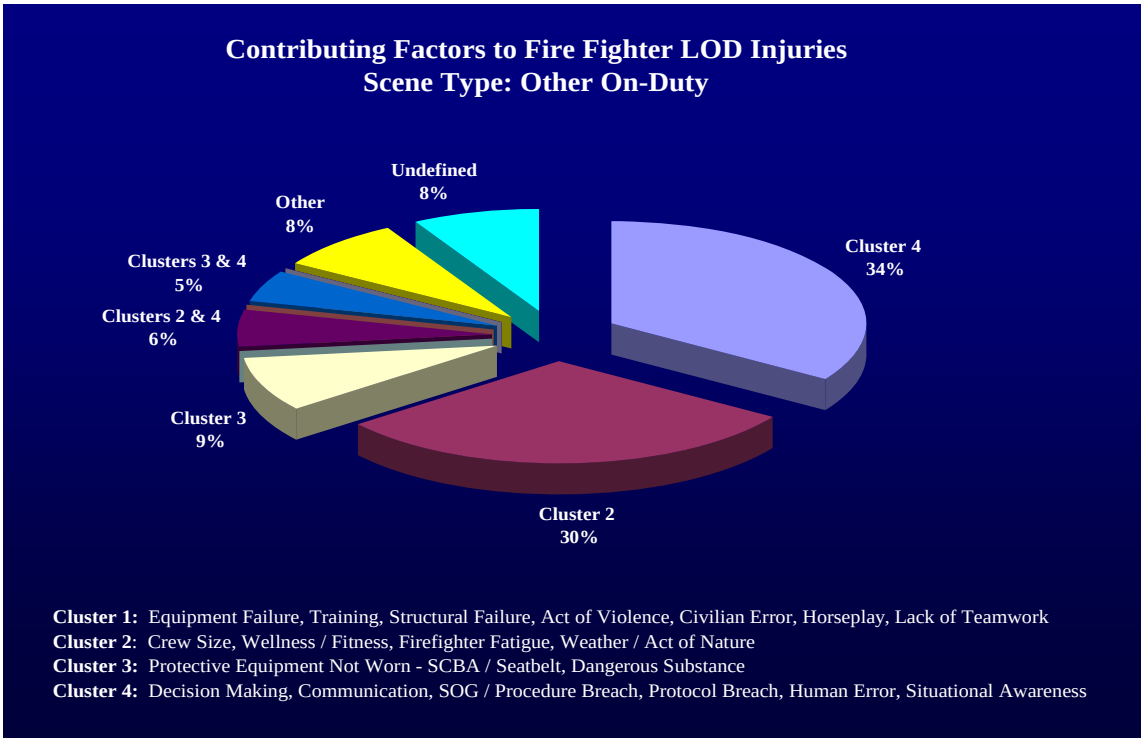


Figure 15. Other On-Duty



Finally, data were stratified by the 'number of days injured' defined as the number of days off normal/regular duty. This stratum was used as a proxy for injury severity assuming that more severe injuries required more days off normal duty. Results show that injuries associated with cluster 4 tended to be more severe requiring longer terms of absence from normal duty though injuries associated with cluster 2 were a close second. For injuries requiring 1-10 days of leave, 41% were associated with cluster 4 while 14% were associated with cluster 2. For those requiring 11-20 days of leave, 35% were associated with cluster 4 while an additional 27% were associated with cluster 2. Finally, the most severe injuries, those requiring leave of 21-10 days or greater than 30 days, 32% were associated with cluster 4 while 25%-28% were associated with cluster 2.

DISCUSSION

During the analysis, it was noted that the actual association between factors within a cluster could not be identified. Factors organized into the same cluster may act independently of each other or they may act synergistically with the interaction of factors presenting a greater total risk than the sum of their individual effects (Moore-Merrell, 2008). Unfortunately, these effects could not be assessed in this study due to the lack of a control group. However, the cluster analysis does provide evidence of the consistency of factors with maximum association as seen in table 4 below.

Table 4. Percent of LOD INJURY contributed by Four Clusters

Cluster	#1	#2	#3	#4
#1	7.59%	1.57%	0.78%	4.87%
#2		26.17%	0.67%	6.26%
#3			10.87%	3.59%
#4				30.9%

* 5.51% LOD INJURY were due to none of these clusters, and additional 1.21% LOD INJURY were due to more than two clusters and are not listed in this table.

LIMITATIONS

There are a number of limitations to the study data, methodology and findings. LOD injury cases were compiled from only nine metropolitan departments and therefore results can only be specifically extrapolated to those departments. However, similar departments should consider benefiting from the results and 'lessons learned' in this group. Additionally, the study only explains the factors contributing to LOD injury that have occurred. Predicting the odds of experiencing a LOD injury in departments where the identified contributing factors/clusters exist could not be completed since data for non-injured firefighters were unavailable. Likewise, trend analysis could not be completed due to the lack of data on firefighters who were not injured on the scenes where a LOD injury was experienced.

This study only examined LOD injury data that were available from nine large fire departments in the U.S. without regard to thousands of firefighter line-of-duty injuries that occur daily in a host of other departments of all sizes. Despite the limitations, the results of this study provide a sense of the relative impact of various factors on firefighter LOD injury in the United States.

CONCLUSIONS

Analysis of the roles of various factors suggests that the most prominent contributing factors to firefighter line-of-duty injury in metropolitan fire departments in the United States are lack of situational awareness (37.3%), lack of wellness/fitness (28.5%), and human error (10.6%). When clustered according to contributing factors most often occurring together, the most prominent cluster is cluster 4 including decision-making, lack of communication, standard operating guidelines/procedure breach, protocol breach, human error, lack of situational awareness. Contributing factor clusters identified explain 94.49% of firefighter LOD injury in the departments studied between the years of 2005-2006. The results presented hold implications for fire department risk management priorities. At the most basic level, they compel examination of the way the

departments track injuries. Most of the contributing factors identified in this study were based on those tracked in each department and those used in the "Firefighter Near Miss Reporting System." Individual departmental tracking of injuries and accumulation of factors and definitions will be essential to quality data collection and analysis in future studies. Based on the results of this study, participating departments can make efforts to interrupt or eliminate factors leading to a firefighter LOD injury.

Policy Development/Alteration Process

It has been noted by fire service leaders that the reasons for firefighter injuries have not changed over time. In spite of the safety programs and practices that are implemented, firefighter's belief, attitude, and behavior regarding safety has not changed. Many firefighters do not follow safety procedures, national standards, or departmental training doctrine. They do not wear assigned safety equipment. Some leaders also suggest that chief officers should be held accountable when it comes to firefighter safety. Leaders must not tolerate or accept safety misconduct, which can result in firefighter injury or death. (Clark, 2008).

Year after year, an estimated 80,100 firefighter injuries occur in the line of duty (Karter, 2006). If heeded, the results of this study can reduce these on-duty firefighter injuries. This study specifically examines contributing factors leading to firefighter LOD injury in metropolitan fire departments. Results can be compared with similar studies to hone knowledge and thereby provide opportunities for intervention through departmental training, practices and policy to prevent firefighter injuries.

Future Policy Analysis Research

If a significant reduction in firefighter injuries is to be realized, fire service leaders must focus directly on the contributing factors as identified. Future research should include individual departments collecting and reporting data using the format created for this study. Establishing a standardized data collection format for firefighter injuries inclusive of specifically defined contributing factors as well as other relevant information surrounding individual injuries will provide invaluable information for individual departments to alter policy based on evidence thereby reducing injuries.

Using a standardize data collection device will allow departments to collect and report incidence and prevalence of firefighter injuries within their department and will also allow comparison to other departments. Through interdepartmental comparison, decision makers can network to share policy and procedures that prove to reduce overall injury rates. Additionally, standardized data collection will provide an opportunity for data compilation nationally to assist in reporting true rates of injury in the fire service.

References

Moore-Merrell L & Zhou, A. et.al, Contributing Factors to Firefighter Line-of-Duty Death, 2008

Karter, M.J. & Molis, J.L., *Firefighter Injuries in the United States*, NFPA, October 2006

Karter, M.J., *U.S. Fire Department Profile*, NFPA, November 2007

Karter, M.J., *U.S. Firefighter Injuries*, NFPA, November 2007

National Fire Data Center (NFDC). *National Fire Incident Reporting System Version 5.0 Design Documentation System*, U.S. Fire Administration (USFA), January 2008

Centers for Disease Control and Prevention (CDC). (2006)."Fatalities among Volunteer and Career Firefighters – United States, 1994-2004". *Morbidity and Mortality Weekly Report (MMWR)* **55** (16):453-55.

Hodous, T.K. & Pizatella, T.J. et al. (2004)."Fire fighter fatalities 1998-2001: overview with an emphasis on structure related traumatic injuries". *Injury Prevention* **10** (4):222-6.

Kales, S.N. & Soteriades, E.S. et al. (2003). "Firefighters and on-duty deaths from coronary heart disease: a case control study". *Environmental Health* **2** (1):14.

Fabio, A. & Ta, M. et al. (2002)."Incident-level risk factors for firefighter injuries at structural fires". *Journal of Occupational and Environmental Medicine* **44** (11):1059-63.

Soteriades, E.S. & Hauser, R. et al. (2005)."Obesity and cardiovascular disease risk factors in firefighters: a prospective cohort study". *Obesity Research* **13** (10):1756-63.

Kales, S.N. & Soteriades, E.S. et al. (2002)."Firefighters' blood pressure and employment status on hazardous materials teams in Massachusetts: a prospective study". *Journal of Occupational and Environmental Medicine* **44** (7):669-76.

Soteriades, E.S. & Kales, S.N. et al. (2002)."Lipid profile of firefighters over time: opportunities for prevention". *Journal of Occupational and Environmental Medicine* **44** (9):840-6.

Soteriades, E.S. & Kales, S.N. et al. (2003)."Prospective surveillance of hypertension in firefighters". *Journal of Clinical Hypertension* **5** (5):315-20.

Soteriades, E.S. & Hauser, R. et al. (2008)."Obesity and risk of job disability in male firefighters". *Occupational Medicine* **58** (4):245-50.

Sothmann, M.S. & Gebhardt, D.L. et al. (2004)."Performance requirements of physically strenuous occupations: validating minimum standards for muscular strength and endurance". *Ergonomics* **47** (8):864-75.

Becker, L.R. & Zaloshnja, E. et al. (2003). "Relative risk of injury and death in ambulances and other emergency vehicles". *Accident Analysis and Prevention* **35** (6):941-8.

Lavender, S.A & Conrad, K.M. et al. (2000). "Biomechanical analyses of paramedics simulating frequently performed strenuous work tasks". *Applied Ergonomics* **31** (2):167-77.

Prezant, D.J. & Freeman, K. et al. (2000). "Impact of a design modification in modern firefighting uniforms on burn prevention outcomes in New York City firefighters". *Journal of Occupational and Environmental Medicine* **42** (8):827-34.

Elliot, D.L. & Goldberg, L. et al. (2004)."The PHLAME firefighters' study: feasibility and findings". *American Journal of Health Behavior* **28** (1):13-23.

Elliot, D.L. & Goldberg, L. et al. (2007)."The PHLAME (Promoting Health Lifestyles: Alternative Models' Effects) firefighter study: outcomes of two models of behavior change". *Journal of Occupational and Environmental Medicine* **49** (2):204-13.

Moe, E.L. & Elliot, D.L. et al. (2002)."Promoting Healthy Lifestyles: Alternative Models' Effects (PHLAME)". *Health Education Research* **17** (5):586-96.

Bacharach, S.B. & Bamberger, P.A. (2008). "Firefighters, critical incidents, and drinking to cope: the adequacy of unit-level performance resources as a source of vulnerability and protection". *Journal of Applied Psychology* **93** (1):155-69.

Beaton, R. & Murphy, S. et al. (1998)."Exposure to duty-related incident stressors in urban firefighters and paramedics". *Journal of Traumatic Stress* **11** (4):821-8.

Hong, O. & Samo, D. et al. (2008). "Perception and attitudes of firefighters on noise exposure and hearing loss". *Journal of Occupational and Environmental Hygiene* **5** (3):210-15.

Kales, S.N. & Freyman, R.L. et al. (2001)."Firefighters' hearing: a comparison with population databases from the International Standards Organization". *Journal of Occupational and Environmental Medicine* **43** (7):650-6.

Tak, S. & Driscoll R. et al. (2007)."Depressive symptoms among firefighters and related factors after the response to Hurricane Katrina". *Journal of Urban Health* **84** (2):153-61.

Austin, C.C., Dussault, G., & Ecobichon, D.J. (2001)."Municipal firefighter exposure groups, time spent at fire and use of self-contained breathing apparatus". *American Journal of Industrial Medicine* **40** (6):683-92.

Burgess, J.L. & Nanson, C.J. et al. (2001)."Adverse respiratory effects following overhaul in firefighters". *Journal of Occupational and Environmental Medicine* **43** (5):467-73.

USFA News Release, February 28, 2008, www.usfa.dhs.gov/media/press/2008releases/022808.shtm

Endsley, M. R. & Garland, D. J. (Eds.) (2000). Situation awareness analysis and measurement. Mahwah, NJ: Lawrence Erlbaum Associates.

Emotional and Decision Making Lab, Carnegie Mellon, 2008 http://content.ksg.harvard.edu/lernerlab/ July, 2008.

National Firefighter Near Miss Reporting System; http://www.firefighternearmiss.com/FAQ.htm (2007)

Hawley JA, Reilly T (1997). "Fatigue revisited". *Journal of sports sciences* **15** (3): 245–6.

Wikipedia.com – Definitions, http://en.wikipedia.org/wiki/Protocol , 2008

NFPA Master Glossary of Terms, as used in Standards 1670

NFPA Master Glossary of Terms, as used in Standards 1521

NFPA Master Glossary of Terms, as used in Standard 1710

National Interagency Fire Center, 2006

NFPA Master Glossary of Terms, as used in Standards 600,601

NFPA Master Glossary of Terms, as used in Standards 130, 502, 1221

NFPA Master Glossary of Terms, as used in Standard 1521

NFPA Master Glossary of Terms, as used in Standard 180

National Environmental Agency (NEA), Code of practice for licensed general wasted collectors: introductions and definitions, http://app.nea.gov.sg/cms/htdocs/article.asp?pid=1246 , 2008

Clark, B. *Firefighters have to get killed, its part of the job,* http://www.everyonegoeshome.com/newsletter/2008/may/partofjob.html , 2008

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