Economic Evaluation Of Injury And Injury Prevention Interventions In The U.S. Fire Service

ECONOMIC EVALUATION OF INJURY AND INJURY PREVENTION INTERVENTIONS IN THE U.S. FIRE SERVICE

by

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As members of the Dissertation Committee, we certify that we have read the dissertation prepared by Stephanie C. Griffin, titled Economic Evaluation of Injury and Injury Prevention Interventions in the U.S. Fire Service and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

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DEDICATION

To my loving family, Winward, Benjamin, Mom, Joe, DeAnna and Mary Lee, who saw me through this process. And, to my grandparents, Ted and Dot Philippi, who instilled in me in the importance of education from a very early age.

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ABSTRACT

Previous research has shown that firefighters and emergency services personnel are at increased risk of fatal and non-fatal occupational injury compared to other U.S. workers. Analyses of injury and workers' compensation claims data in this population has demonstrated that injuries are both common and an economic burden on the fire service, especially those caused by overexertion and that lead to sprains/strains. The increased risk of injury is associated with specific job tasks, including physical exercise, patient transport and fireground work, and with personal characteristics such as physical fitness. The economic evaluation of injury and injury prevention can help inform decision making on the part of leadership, including the identification and evaluation of potential targets for injury prevention programs.

The aims of the current study were to: 1) evaluate a fitness intervention for new firefighters in terms of health, fitness, injury outcomes as well as workers' compensation claims costs; 2) to analyze workers' compensation claims data for trends in cause and injury type, as well as the effect of worker age; and 3) to model the expected change in back injury frequency and costs among emergency medical services personnel following the implementation of electrically powered stretchers. Primary data for the current study, including injury surveillance and workers' compensation claims data, were provided by the Tucson Fire Department (TFD), Tucson, Arizona.

The Probationary Firefighter Fitness Program (PFF-Fit) was designed by University of Arizona researchers in partnership with TFD. The program was implemented in the 2012 recruit academy. Outcomes, including measures of health and fitness, injury, workers' compensation claim frequency and claims costs, were measured

over 17 consecutive months for the intervention class, and compared to outcomes from controls comprised of the three most recent TFD recruit classes for the same time period. Comparing the intervention class to controls, health and fitness outcomes were statistically equivalent. The intervention group experienced statistically significantly fewer injuries, filed significantly fewer claims, and accrued aggregated claims costs approximately $33,000 less than the controls with an estimated equivalent reduction in indirect costs for a total of $66,000. The program implementation costs were nearly $69,000, leading to a one-year return on investment of -0.52 if based only on direct costs (workers' compensation claims) or -0.048 if an estimate of indirect costs is included.

Injury in the U.S. fire service has been the subject of many previous studies but the pattern of workers' compensation claims has been studied much less frequently. Specifically, the effect of increasing worker age on the frequency and cost of claims has not been studied in this population. Routine injury surveillance and workers' compensation data from TFD were merged and costs were described by mechanism of injury, injury type, body region and by age of the worker. The analysis of claims data shows that acute overexertion injuries are significantly more costly than injuries caused by other mechanisms, and that sprain/strain injuries are significantly costlier than other injury types. Results also show that age is an important predictor of claims cost in this population, with claims costs for firefighters over age 50, 120 to 144% greater than claims for workers under age 30.

Back injury is common and costly among emergency services employees, including firefighters and emergency medical services providers, who transport patients. Previous research has demonstrated that electrically powered stretchers (EPS), which lift and lower the patient and stretcher between the loading and transport positions, are an effective means of reducing back injury among emergency medical services (EMS) providers, but to date no economic evaluation of this device has been conducted. A Markov decision analysis model simulation of a cohort of emergency services employees for incident back injury, disability and associated costs was used to compare outcomes with and without the use of the EPS. Implementation of the EPS resulted in an average cost savings of $4,617-$5,422 per emergency services employee over the service life of the equipment.

Results of the current study show the PFF-Fit program may be a worthwhile program to reduce injury and claims costs but further research is needed to better understand the program's potential effectiveness. We observed reductions in injury frequency and compensation costs among PFF-Fit program participants compared to controls; however, the mechanisms by which the PFF-Fit program were believed to be effective did not appear to be responsible for this difference. Workers' compensation claims data analysis results continue to highlight the importance of targeting injuries caused by acute overexertion and injuries that result in sprain/strain. The results also indicate that targeting injury prevention efforts toward the specific needs of older workers may lead to important cost savings for the fire service. The EPS is likely an effective intervention to reduce back injuries and claims costs among fire and emergency services personnel, but further research is needed to evaluate injury and claims costs following implementation at several departments.

1. INTRODUCTION

1.1 Explanation of the problem

Firefighters and EMS employees have been shown to suffer injury at higher rates than other U.S. workers (Maguire et al., 2005; Reichard et al., 2012;U.S. Department of Labor, 2013; Poplin et al., 2014). Injury in the U.S. fire service has been the subject of previous research, but the economic consequences of injury and injury prevention efforts have been studied less frequently in this population. Walton et al. (2003) studied the cause, nature and cost of workers' compensation claims for injury in the fire service and found that overexertion injuries and injuries that resulted in sprains/strains are the most common and are costlier than others. Average injury claims costs have been estimated to be between $5,168 to $13,420 in the fire service (Walton et al., 2003; Leffer and Grizzell, 2010). Fire and EMS departments typically have limited resources to dedicate to implementing and evaluating injury prevention efforts due to financial/budgeting considerations, highlighting the need for research in this area to improve the understanding of the costs of injury and of the economic benefits of injury prevention programs.

Injury prevention interventions and programs have the goal of reducing the frequency and severity of injuries among the target population. The **S**trategies to **P**revent **I**njuries among **Fi**refighters (SPIFi) project is a partnership between the University of Arizona, Johns Hopkins University and the Tucson Fire Department (TFD), funded by the National Institute for Occupational Safety and Health (NIOSH), which has introduced a risk management process to improve worker health and safety. The current study focuses on the economic consequences of injury at the TFD from 2004-2012 and evaluates the injury and economic consequences of implementing injury prevention interventions.

1.2 Goal and specific aims of dissertation

The goal of the current study is to improve the understanding of the economic consequences of injury and injury prevention in the U.S. fire service. The specific aims of this study represent three separate manuscripts appended to this dissertation: 1) to evaluate a fitness intervention for new firefighters in terms of health, fitness, and injury outcomes and workers' compensation claims frequency and costs; 2) to analyze workers' compensation claims data for trends in cause and injury type, as well as the effect of age; and 3) to model the expected change in back injury frequency and costs among emergency medical services personnel following the implementation of an injury prevention intervention, the EPS.

1.3 Significance of dissertation

The current study contributes to the field's body of knowledge in the following ways: First, we evaluate the consequences of a fitness intervention in new firefighters, for outcomes including health, fitness, injury and claims costs. Economic evaluation of health and injury interventions is uncommon in the fire service (Leffer and Grizzell, 2010; Kuehl et al., 2013), especially for new firefighters. Second, we explore the workers' compensation claims experience of TFD commissioned personnel, confirming the findings of previous research in another population of firefighters regarding the cost of overexertion and sprain/strain injuries. We also begin to explore the effect of increasing age on the cost of injury claims among firefighters, an issue which has not been previously explored in this population.

Finally, we use modeling methods not commonly found in health and safety evaluations to estimate the change in back injury incidence and associated costs for emergency services employees following implementation of the EPS, a device which reduces back strain associated with patient transport. The potential impact of this research includes the improved understanding of the cost of injury in the U.S. fire service, as well as expanding the methods and techniques used to evaluate the economic consequences of injury prevention interventions.

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APPENDIX A - EVALUATION OF A FITNESS INTERVENTION FOR NEW FIREFIGHTERS

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Key Words: Risk management, Fire service, Fitness, Return on Investment

ABSTRACT

Background Firefighting is a dangerous profession and firefighters suffer workplace injury at a higher rate than most U.S. workers. The most common cause of firefighter line-of-duty death is sudden cardiac death. Decreased physical fitness is associated with cardiovascular heart disease, sudden cardiac death, and injury in firefighters. A physical fitness intervention was implemented among Tucson Fire Department recruit firefighters in 2012 with the goals of increasing fitness and decreasing cardiovascular heart disease risk, injury and compensation claims frequency during the recruit academy and over the probationary year.

Methods The current study evaluates the health, fitness, injury and workers' compensation claims outcomes of the 2012 recruit class compared to controls from three historical classes, from the recruit academy through the 12-month probationary period.

Results Health and fitness outcomes were statistically equivalent, comparing the intervention class to controls. The intervention class experienced significantly fewer injuries overall and during the probationary year, filed statistically significantly fewer claims, and experienced claims cost savings of approximately $33,000 (2012 U.S. dollars) from avoided injury and reduced claims costs, with an estimated equivalent reduction in indirect costs for a total of $66,000. The estimated costs for program implementation were over $69,000 leading to a one-year return on investment of -0.52 if based only on direct costs (workers' compensation claims) or -0.048 if an estimate of indirect costs is included.

Conclusions We observed reductions in injury frequency and compensation costs among PFF-Fit program participants compared to controls; however, the mechanisms by which

the PFF-Fit program were believed to be effective did not appear to be responsible for this difference. The PFF-Fit program may be a worthwhile program to reduce injury and claims costs but further research is needed to better understand the program's potential effectiveness. Future research on this and other health and fitness interventions should also evaluate outcomes over a longer time period.

BACKGROUND AND INTRODUCTION

Firefighting is a dangerous profession that often requires strenuous work in dynamic and unpredictable environments. Firefighters and emergency medical services (EMS) employees have been shown to be at higher risk of non-fatal injury than most other U.S. workers (Maguire et al., 2005; Reichard et al., 2011; Poplin et al., 2012; U.S. Department of Labor, 2012). In 2012, the 1.1 million career and volunteer firefighters in the U.S. suffered an estimated 69,400 injuries, a rate of 6.1 injuries per 100 firefighters (Karter and Stein, 2013; Karter and Molis, 2013). Firefighting has also been shown to be one of the highest risk occupations for fatal injuries (Fosbroke et al., 1997). There were 64 firefighter fatalities in 2012, including three (5%) strokes and 27 (42%) sudden cardiac deaths (SCD) (Fahy et al., 2013). According to the National Fire Protection Association, stress, exertion and related medical conditions typically cause the largest number of firefighter fatalities, accounting for nearly half of line-of-duty deaths (Fahy et al., 2013).

Previous research has established the relationship between risk factors for cardiovascular heart disease (CHD), SCD and physical fitness in firefighters. Modifiable risk factors including hypertension, dyslipidemia, diabetes mellitus, smoking and obesity have been associated with an increased risk for CHD fatalities and premature retirements (Soteraides et al., 2011). Obesity, which is associated with the clustering of CHD risk factors including hypertension, dyslipidemia, and elevated blood glucose (Soteriades et al., 2005) has also been associated with an increased risk of job disability, injury and absenteeism in firefighters. Soteriades et al. (2008) reported that each one-point increase in body mass index (BMI) led to a 5% increased risk of job disability and Jahnke et al. (2013a) found obese firefighters ($BMI \geq 30$ kg/m^2) were over five times as likely to suffer incident musculoskeletal injury as normal weight firefighters (18 kg/m$^2 \geq BMI \leq 24.9$ kg/m^2). Poston et al. (2011a) reported that absenteeism due to occupational injury was strongly associated with BMI, with each one-unit increase in BMI leading to a 9% increase in lost work days from injury. This absenteeism added significantly to the financial cost to departments, an estimated $74.41-$1,682.90 per firefighter per year in costs from lost work days and backfill (Poston et al., 2011a). Obese firefighters have also been found to have three times the odds of filing a workers' compensation claim for injury, compared to those with normal BMI (Kuehl et al., 2012). Researchers have advocated for the use of physical exercise training and nutrition counseling to help firefighters achieve a more desirable body weight and improve cardiorespiratory health to reduce risk factors for CHD and SCD (Moe et al., 2002; Soteriades et al., 2005; Smith, 2011; Durand et al., 2011).

On-duty exercise has been promoted as one way to improve measures of health and fitness in this population (Hilyer et al., 1999; IAFF, 2008; Poston et al., 2013) and research has demonstrated the potential positive impact of improved fitness on injury. Poplin et al. (2014) found that firefighters with lower levels of fitness ($VO_{2max} < 43$

mL/kg/minute), were 2.2 times as likely to suffer injury as those with VO_{2max}>48 mL/kg/minute. Similarly, firefighters who exercise regularly on-duty were found to have nearly half the odds of suffering a non-exercise related injury compared to those who do not regularly exercise on duty (Jahnke et al., 2013b). Paradoxically, research has shown that nearly one-third of injuries reported among firefighters were the result of physical training or exercise (Poplin et al., 2012; Jahnke et al., 2013b) and that those who report exercising regularly on duty are over four times as likely to suffer exercise-related injury compared to firefighters who do not regularly exercise on duty (Jahnke et al., 2013b). So, while there is evidence that improving measures of health and fitness among firefighters has a positive effect on non-exercise related injury and cardiac outcomes, improved structure and management of on-duty physical exercise programs for firefighters may be needed to mitigate the risk of exercise-related injury.

There are a limited number of studies examining the economic costs and benefits of fitness interventions for firefighters. Leffer and Grizzell (2010) calculated a return on investment (ROI) for the Physician-Organized Wellness Regime (POWR) using the cost savings of avoided injury and associated lost time and found that after two years the program saved $4.60 for every dollar invested. A recent economic evaluation of the Promoting Healthy Living: Assessing More Effects (PHLAME) intervention revealed that workers' compensation claims and medical costs were significantly lower among two participating departments compared to two control departments, and that the team-based intervention had a beneficial ROI of $4.61 dollars saved for every dollar invested in the program (Kuehl et al., 2013). The third edition of the Wellness-Fitness Initiative (WFI), a comprehensive department-level health promotion program developed by the

International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (IAFC), included an evaluation of workers' compensation claims, days lost from work, costs per claim and total incurred costs in four WFI-participating departments and four non-participating departments, comparing the seven year pre-implementation period to the seven year post period (IAFF, 2008). The participating departments experienced a 5% increase in average claims costs and a 3% increase in total incurred costs compared to a 22% increase in average claims and a 58% increase in total incurred costs experienced by non-participating departments. Participating departments also experienced a 28% decrease in days lost from work while non-participating departments saw a 55% increase over the study period.

To help prepare the firefighter for the physiological demands of fireground activities, including cardiovascular strain, heat stress, dehydration and fatigue, researchers have advocated for physical exercise programming to improve aerobic and anaerobic capacity, muscular strength and endurance (Barklage, 2000; Smith, 2011; Poplin et al., 2012; Poplin et al., 2014). The PFF-Fit program was designed by researchers at the University of Arizona in partnership with the Tucson Fire Department (TFD), Tucson, Arizona, as part of a NIOSH-funded risk management intervention study, Strategies to Prevent Injuries among Firefighters (SPIFi). The PFF-Fit program aimed to establish a foundation of fitness behaviors among probationary firefighters to improve measures of health and fitness while reducing both exercise-related and non-exercise related injury (Figure 1).

Details of the design and implementation of the program have been described elsewhere (Nash et al., manuscript in draft). Briefly, the PFF-Fit program was implemented over an approximately 17 month period. TFD Peer Fitness Trainers (PFT) designed and conducted functional fitness training three days per week at the 2012 recruit academy (RA). These functional workouts consisted of strength, cardiovascular and flexibility training that integrated movement found in emergency response (e.g., abdominal training including hose pulling or upper body and core training integrating axe swings). PFTs were then assigned as peer mentors to fire recruits during the 12-month probationary year, where they were available for in-station and/or electronic (e.g., phone, email and text) exercise and nutrition consultation. The PFTs also conducted periodic in-station fitness assessments with their Probationary Firefighters (PFFs), with the intent of motivating the PFFs to maintain the same level of fitness they reached over the course of the RA. The PFF-Fit program expanded the role of the department's PFTs, who are typically responsible for providing TFD commissioned personnel assistance with personalized exercise programs or advice about fitness and nutrition on an as-needed basis, following the recommendations outlined in the WFI (IAFF, 2008). TFD PFTs also conduct the annual fitness assessments for those under age 40 (approximately 50% of commissioned personnel), prior to their annual physical examination. These assessments include the Gerkin VO_{2max} treadmill test, push-ups, sit-ups (replaced with plank test in 2013), and flexibility (sit and reach). TFD PFTs are certified through the IAFF/IAFC or the American Council of Exercise (ACE) at the Department's expense. The PFF-Fit program also included a nutrition intervention; a registered dietician (RD) provided the 2012 recruit class with information and guidance during the RA.

The hypotheses are that, because of the improved physical training and maintenance of peak fitness levels through the probationary year, the 2012 recruit class will experience improved measures of fitness and health and decreased injury (both exercise-related and non-exercise related) compared to the historical controls, and that the PFF-Fit program will have a positive ROI from the cost savings of avoided injuries. The current study aims to evaluate the injury, health and fitness outcomes as well as the ROI of the PFF-Fit program, comparing the cohort in the pilot intervention to historical controls from previous TFD firefighter recruit classes.

MATERIALS AND METHODS

The current study uses data for recruit and probationary commissioned personnel of TFD. It is a medium-sized metropolitan department that operates 21 fire stations and employs nearly 600 career fire fighters; the overall department population has been described previously (Poplin et al., 2012; Poplin et al., 2014). Fire recruits participate in an eight hour per day, five day per week training for a period of 21 to 22 weeks at the City of Tucson's Public Safety Academy. Successful graduates of the RA are then assigned to a station and shift where they work 24-hour shifts on a rotating three-shift schedule and complete their training as PFFs for a period of 12-14 months, at which time they are considered firefighters. Reasons for not completing the RA include failure to meet minimum performance standards on written tests and evaluations of practical skills, as well as injury that requires the recruit to miss more than 24 hours of physical training and/or drilling time. Data for the four most recent classes of the TFD RA were used: the 2007, 2008 and 2009 classes served as historical controls and the 2012 class received the PFF-Fit intervention. The University of Arizona's Institutional Review Board provided approval for and oversight of the use of voluntary human subjects' data for this project.

TFD requires each commissioned employee to complete a pre-employment and annual physical examination for medical clearance; these data were provided by TFD's servicing occupational health clinic for all employees who completed the probationary year. Employees complete a Health Risk Assessment during the clinic visit where they self-report smoking status and other health behaviors. Physiological and fitness measures include anthropometric measures (height, weight, body composition, waist circumference and BMI, systolic and diastolic blood pressure, and fasting blood lipids (triglycerides (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL), low-density lipoprotein cholesterol (LDL), and TC/HDL ratio). Annual medical surveillance also includes tests of cardiorespiratory fitness (maximal oxygen consumption by volume, VO_{2max}), muscular strength and endurance (push-ups, sit-ups/plank) and flexibility (sit and reach), which are collected concurrently for the pre-employment physical. For the first annual physical, fitness measures are collected for members under age 40 by a TFD PFT prior to scheduling the clinic visit; fitness data for members over age 40 are collected during the clinic visit. Data from the pre-employment and first annual physical were used to calculate the Framingham/ATP III risk score for 10-year cardiovascular disease risk (NCEP, 2002). Physical fitness assessments are also conducted periodically during the RA, with each class completing four or five timed 1.5 mile runs, site and reach and counts of pull-ups, push-ups, sit-ups in one minute (replaced by a timed plank test in 2013). Data for the subjects' first and final fitness assessments were used to calculate the change in fitness over the RA.

The participants' height was measured to the nearest 0.5 inch using a stadiometer and weight was measured to the nearest 0.5 pound on a beam balance platform scale.

BMI is calculated as weight in kilograms divided by height in meters squared. A standard tape measure was used to measure waist circumference at the widest point of the midsection. Body composition (percent body fat) was measured using bioelectrical impedance (ELG-III Metabolic Analyzer). Blood pressure was measured before the physical examination with the subject sitting with his/her feet off the floor, using an appropriately sized calibrated blood pressure cuff. Blood samples were drawn following a 12-hour fast and analyzed using standardized methods. Maximal aerobic capacity (VO_{2max}) was estimated using a motor driven treadmill (Quinton Medtrack T55) and maximal treadmill machine controller (Quinton Q4500) using the Gerkin protocol (Gerkin et al., 1997), following guidelines found in the WFI (IAFF, 2008). The participant's index finger is placed in a pulse/oxygen uptake monitor (BCI model 33001) and the patient is made to walk and then run on the treadmill. The treadmill's speed and incline are increased at pre-specified time points until the subject's target heart rate is reached allowing estimation of VO_{2max}. Strength, endurance and flexibility measures (push-ups/one minute, sit-ups/one minute, 90-second plank, sit and reach) are collected following the WFI guidelines (IAFF, 2008) for annual medical surveillance and the RA assessments.

TFD injury surveillance reports and workers' compensation claims data were used to measure injury frequency and claims costs. TFD records on-the-job injuries if the incident meets the Occupational Safety and Health Administration's injury reporting requirements, or if the injury has the potential to progress and require a workers' compensation claim. Medical events such as heat exhaustion, stress, and cardiac events (e.g., stroke, heart attack) were excluded from the injury analysis (although none of the subjects suffered a cardiac event). Injury and claims rates were estimated for the RA using the total number of recruits, and for the probationary year using the number recruits who successfully completed the probationary year.

The costs of the PFF-Fit intervention, primarily personnel time, were estimated based on time spent by TFD and other personnel implementing the intervention. Costs incurred by University of Arizona researchers for program development and research-specific tasks (e.g., consenting study subjects) are excluded. TFD participates in the WFI, and the department maintains a cadre of trained and certified PFTs who provide a variety of services to TFD personnel (IAFF, 2008). Costs of beginning and maintaining a PFT program are not estimated here.

Data analysis was completed using Stata version 11 (College Station, TX, 2012). Frequency data, including recruit drop-out status, gender and injury count, were analyzed using Fisher's exact test. An ordinary least squares (OLS) regression[1] was used to analyze age, annual medical surveillance, and RA physical fitness data. Classification by Framingham Risk Score was analyzed using a logistic regression[2]. Workers' compensation claims data were adjusted to constant 2013 dollars using the Consumer Price Index (U.S. Department of Labor, 2014). For all statistical tests including regression models, workers' compensation claims costs were transformed using the natural log after adding $1 to zero cost claims. Descriptive statistics (e.g., mean, median,

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[1] $E(y_{it}) = x_{it}\,\beta$, y~N( ) (Statacorp, 2009)
y = subject age, annual medical surveillance data (weight, BMI, etc.) and RA physical fitness data (1.5 mile runs, sit-ups, etc.)
x = intervention status (controls compared to PFF-Fit participants)
xtset = RA class (2007, 2008, 2009, 2012)
[2] $\text{logit}\{E(y_{it})\} = x_{it}\,\beta$, y~Bernoulli (Statacorp, 2009)
y = Odds of Framingham risk score greater than 1%
x = intervention status (controls compared to PFF-Fit participants)
xtset = RA class (2007, 2008, 2009, 2012)

maximum) were calculated on the non-log transformed claims data. Injury and workers' compensation claims frequency were analyzed using Poisson regression[3] and claims costs were analyzed using OLS[4]. All regression models were adjusted for intra-class correlation (i.e., models were clustered on recruit class) using generalized estimated equations (GEE). All tests compared differences between the controls (2007, 2008 and 2009 classes) and the intervention class (2012). Statistical significance was defined as a *p-value* less than 0.05.

RESULTS

The study population is described in Table 1. A total of 109 recruits participated in the four recruit classes and 77.1% of all recruits successfully completed the RA and the probationary year. Drop-out status and gender differed significantly by recruit class. Notably, less than half of the 2007 recruit class completed the probationary year, compared to 74-85% of other classes.

Health and fitness outcomes

Annual medical surveillance data for measures of fitness and health are summarized in Table 2. An average of 387 (s.d.= 87.6) days passed between the pre-employment and first annual physicals (range, 223-715). The TFD threshold for "Tier-1 fitness" is 30 push-ups completed in 1 minute and 30 sit-ups completed in 1 minute or

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[3] Poisson regression used for count data (injury and compensation claims frequency)
$\ln\{E(y_{it})\} = x_{it}\,\beta$, y~Poisson (Statacorp, 2009)
y = Claims and injury count (frequency)
x = intervention status (controls compared to PFF-Fit participants)
xtset = RA class (2007, 2008, 2009, 2012)
[4] $E(y_{it}) = x_{it}\,\beta$, y~N( ) (Statacorp, 2009)
y = Compensation claims costs (log transformed)
x = intervention status (controls compared to PFF-Fit participants)
xtset = RA class (2007, 2008, 2009, 2012)

90-second plank test, and 90-97% of participants stopped these tests upon reaching these thresholds rather than continuing to their personal maximum; data for these tests are not presented. Health measures did not differ for the controls and intervention classes, except for weight, HDL, VO_{2max} and sit and reach. None of the intervention group and one of the controls self-reported smoking at the time of the pre-employment physical, and no one reported smoking at the time of the first annual physical. The odds of having a Framingham risk score of 1% or greater (Table 3) did not differ between recruit classes or between annual and pre-employment physicals. Recruit academy fitness assessments were used to compare fitness levels before and after completing the RA and are presented in Table 4; these data were only available for those who successfully completed the RA and probationary year. While there were several measures of fitness with statistically significant differences between the control and intervention classes, there was no discernable pattern of improved fitness for the 2012 intervention class relative to the controls (Table 4).

Injury and workers compensation claims

Injury frequency and workers' compensation claims data are presented in Table 5. A total of 55 claims were filed by members of the control classes, for a total incurred cost of $95,582, and 13 claims were filed by the 2012 class for a total incurred cost of $6,679. One workers' compensation claims case in 2009 remained open at the time of analysis. TFD's third-party payer reported that $3,782 had been paid to date and an additional $1,218 was held in reserve to cover any future costs. For the purposes of this analysis, the paid and reserved amounts were used to estimate the total cost of $5,000 for the open claim. All other claims, including those for the 2012 recruit class, were closed at the time of analysis. Results of the Poisson regression models (Table 6) show that claims and injury frequency differed significantly for the probationary year and for overall injuries, but not for injuries occurring during the RA or for exercise-related injuries. Compared to controls, the difference in the log count of overall injuries, injuries during the probationary year, and claims frequency were significantly lower among the intervention group. The linear regression model showed that workers' compensation claims costs were 13% lower than controls (Table 6). The 2012 recruits experienced a 30% reduction in claims frequency compared to the control classes and a reduction of $1,224 in average cost per claim, which results in an estimated savings of $32,786. Similarly, claims cost per recruit decreased by $1,033 in the intervention year, resulting in an estimated savings of $33,056. The estimated savings in claims costs is therefore approximately $33,000.

Costs of the intervention

The costs of the PFF-Fit program included personnel costs and materials costs and are detailed in Table 7. The TFD Safety and Health Captain invested approximately 15% of his time for a period of 18 months, which cost TFD approximately $27,602.64 in wages and benefits for his time. Four PFTs were assigned to the RA, one on a full-time basis and up to three PFTs visiting the RA to help conduct workouts with the recruits. Two visiting PFTs conducted functional fitness workouts three days per week (Monday, Wednesday and Friday) and one visiting PFT participated once a month for long-distance runs (>1.5 miles) on Thursdays. Wages and benefits costs for the full-time PFT are estimated to be $20,888. These costs were paid out of the department's training budget and represent costs for this PFT's time, as this PFT was taken out of his/her normal duty rotation for 20 weeks of the RA. The overtime wages and benefits costs for visiting PFTs are estimated to total $9,792.50. These PFTs completed their regular department duties during the RA and were paid overtime for their participation in the PFF-Fit program. During the probationary year, PFT mentors completed up to four in-station visits with their assigned PFFs. An estimated $10,063.44 in overtime costs was incurred, above the PFTs' usual wages, for these in-station visits. A nutritionist (Registered Dietician, RD) spent 11 hours in meetings and preparing materials and presentations, then provided a one-hour presentation and spent another hour reviewing health records for the 2012 recruit class. The total costs for these services were $661.90. Other personnel costs for program implementation (e.g., time spent by Station Captains, PFFs) were minimal, as their involvement rarely exceeded what was expected in their normal job tasks; these costs are excluded. Materials costs, beyond those that are normally incurred for the RA, were minimal. TFD produced fitness logs for each of the 32 members of the 2012 recruit class at an estimated cost of $150. An estimated total of $69,158.48 was invested in the PFF-Fit program implementation.

Return on investment of the intervention

The costs of the program totaled $69,158.48, while the benefits totaled approximately $33,000 saved in workers' compensation claims costs, yielding a one-year ROI, defined as (cost reduction – program costs)/program costs, of -0.52 (Table 8). Previous research has demonstrated that the indirect cost of injury, including backfill, administrative and investigative costs, incurred by a suburban fire department in southern Arizona was approximately equivalent to the claims costs paid by the insurance company (Pena et al., manuscript in draft). Applying the indirect cost multiplier in this study would yield an approximate cost savings of $33,000 in indirect cost savings in addition to the $33,000 in claims costs savings, and would yield a one-year ROI of -0.048.

DISCUSSION

The current study evaluated the injury, health and fitness outcomes as well as the costs and financial benefits of the PFF-Fit program, comparing the intervention class to historical controls from three previous TFD firefighter recruit classes. The results show that health and fitness outcomes were similar among controls and intervention classes, and that there was no discernable pattern of improved health and fitness measures among those who participated in the intervention. We observed significantly lower injury and workers' compensation claim frequency, comparing the intervention group and control group, and a statistically significant difference in claims cost was detected in the regression analysis. The ROI for the PFF-Fit program is -0.52 if based only on direct costs (workers' compensation claims) or -0.048 if an estimate of indirect costs is included. While this ROI is lower than what has been reported in other health intervention studies in the fire service (Leffer and Grizzell, 2010; Kuehl et al., 2013), we observed important decreases in probationary year and overall injury and claim frequency and overall workers' compensation costs.

Different approaches could be used to estimate the program costs which would affect the ROI estimate. For example, one could choose to exclude personnel costs (wages and benefits of the program supervisor and PFT assigned to the RA academy) since these costs are paid by the department regardless of how the personnel time is used. This would have significantly reduced the estimate of program costs and would have improved the ROI. If the PFF-Fit program is repeated in future RA classes, the ROI may improve if costs decrease as personnel resources are used more efficiently. For example, oversight time may decrease for the Safety and Health Captain, since PFTs are now experienced at implementing the program at the RA and during the probationary year, and the nutritionist will need less preparation time to conduct the training. A program evaluation is currently underway allowing participants to provide feedback on the design and implementation of the PFF-Fit program. The lessons learned from this program evaluation could help to further refine the program, and may lead to greater efficiency and/or improvements in the program that will help reduce the frequency of injury in future recruit classes. For example, PFTs may use the program evaluation to refine training type and frequency if the PFFs indicate certain exercises were problematic or associated with injury. We also did not attempt to quantify or monetize the “intangible” benefits, such as the benefits of PFT interaction with other commissioned personnel during the PFF-Fit in station visits, which may have positively influenced the ROI.

Previous evaluations of fitness interventions in the fire service have demonstrated limited success in increasing physical activity and reducing injury and risk factors for CHD. Participants in the 5-ALARM fitness program reported significant increases in minutes spent participating in moderate and vigorous exercise in the weeks following the intervention (Rengert, 2011). Similarly, fitness scores improved among firefighters participating in an exercise and nutrition intervention; however, no statistically significant differences were found in body composition over the nine month study period (McNear, 2011). In their evaluation of a physician-organized wellness regime (POWR) in a population of career firefighters, Leffer and Grizzell (2010) reported a 60% reduction in injuries post-implementation of the intervention as well as a significant decrease in the number of obese firefighters. The PHLAME Study, a randomized trial focusing on nutrition, physical activity and maintenance of healthy body weight, compared medical monitoring to two treatment modalities, an individual and a team-based intervention. While the intervention groups gained less weight and experienced improved measures of overall well-being (compared to controls) over the one-year study period, intervention participants did not experience significant improvements in fitness levels, measured using peak oxygen uptake. A recent evaluation of the WFI showed that firefighters employed by WFI participating departments were significantly less likely to be obese and were significantly more likely to regularly exercise, meet the NFPA 12.0 METS fitness standard and exercise at the station (Poston et al., 2013). However, this study also found that firefighters at WFI-participating departments experienced significantly more injuries resulting in a workers' compensation claims than firefighters at non-WFI departments (ibid.).

One limitation of the current study is the short follow-up time. In their five-year study of a mandatory exercise program for 24 male firefighters, Green and Crouse (1991) found improvements in mean triglycerides, percent body fat, blood pressure and total cholesterol values in the first year but those improvements did not continue over the study period. The authors state, "these data bring into question the longitudinal effectiveness of the programs that demonstrated significant results in short-term analysis" (Green and Crouse, 1991). They also caution that the observed changes, while statistically significant, may be of little clinical or practical value, which "brings into question the practical significance of the improvements and the cost-effectiveness of the associated exercise program" (ibid.). Future research on this and other health and fitness interventions in the fire service should aim to measure intervention outcomes over a longer time period to ensure that measured improvements do not diminish rapidly once the intervention is complete. The potential long-term benefits of a successful program like PFF-Fit could be reduced risk of CHD and injury over years, perhaps over the length of a career, and such long-term benefits should be the subject of future research.

The hypothesis for the study was that participants in the PFF-Fit program would experience improved measures of fitness and health and decreased injury (both exercise-related and non-exercise related) compared to the historical control classes, and that cost savings of avoided injuries would lead to a positive ROI for the PFF-Fit program. Improved health and fitness was, therefore, one of the primary mechanisms through which the program was thought to be potentially effective. Previous research has demonstrated that firefighters with VO_{2max}>48mL/kg/minute were less likely to suffer injury than those with VO_{2max}<43mL/kg/minute (Poplin et al., 2014). We did not detect any evidence that the 2012 recruit class improved their fitness more than the control classes. The 2012 class did, however, have significantly higher mean VO_{2max} than the controls, but that appears to be because they started the RA with higher VO_{2max} than the controls. This may indicate a higher level of fitness overall in the intervention class, compared to the historical controls, which may have limited our ability to detect improvements in fitness from the intervention. We did not design the study to specifically measure the differences in training and the impact this may have had on injury, especially exercise-related injury. The apparent success of the PFF-Fit program may have been due, at least in part, to safer fitness training routines that put the 2012 class at lower risk for injury, regardless of their overall fitness levels. The *a priori* mechanisms by which the PFF-Fit program was believed to be effective did not appear to be responsible for the observed differences in injury and claims outcomes. The PFF-Fit program may be a worthwhile program to reduce injury and claims costs but further research is needed to better understand the program's potential effectiveness.

Another important consideration is that the PFF-Fit program was not the only intervention taking place at TFD. The University of Arizona has been working with the department for four years, implementing a broad risk management intervention with a focus on injuries occurring on the fireground, during patient transport and during physical fitness training. This department-wide intervention could have reduced injuries at the RA even in the absence of the PFF-Fit program. The current study is unable to parse out any potential effect that the risk management intervention may have had on the training environment at the 2012 RA or during the probationary year. Another important limitation is that other analyses of workers' compensation claims data at TFD indicates that the overall department experienced a high number of injuries and claims in 2007, 2008 and 2009, and a marked decline in injury and claims frequency and costs in 2012, which may explain some of the reductions in injury and claims we observed. Data on 2013 injury and claims have not been analyzed yet but it may not be possible to separate the effects of the PFF-Fit program from overall downward temporal trend in injury and claims during the study period. The current study relied on historical controls, which is rarely a definitive approach, and there was a multiyear gap during which TFD did not conduct RA classes in the years 2009-2011. Future research using different study designs is needed to overcome the challenges of using and interpreting historical data.

The current study also failed to account for injury that may have occurred off-duty but that was reported as a workers' compensation claim. While there is no reason to believe this is a systematic problem at TFD, there is the possibility that excluding such injuries would have changed the findings. We also did not examine injury severity specifically. Instead, the presumption is that increased claims cost is a proxy for increased severity. There is also the possibility that the 2012 recruit class, who knew they were being studied for health, fitness and injury outcomes, could have behaved differently than the historical controls, not because of the intervention but because of the Hawthorne effect or a perceived need to not report injury to help improve the study results. Given the fact that the 2012 recruit class reported injuries and claims in both the RA and the probationary year, we have no reason to suspect these biases affected the study results; however, the potential influence of these biases were not specifically tested in this study.

CONCLUSION

We observed reductions in injury frequency and compensation costs among PFF-Fit program participants compared to controls; however, the mechanisms by which the PFF-Fit program were believed to be effective did not appear to be responsible for this difference. The PFF-Fit program may be a worthwhile program to reduce injury and claims costs but further research is needed to better understand the program's potential effectiveness. Future research on this and other health and fitness interventions should also evaluate outcomes over a longer time period as the potential benefits of reduced CHD and injury risk could potentially accrue for years.

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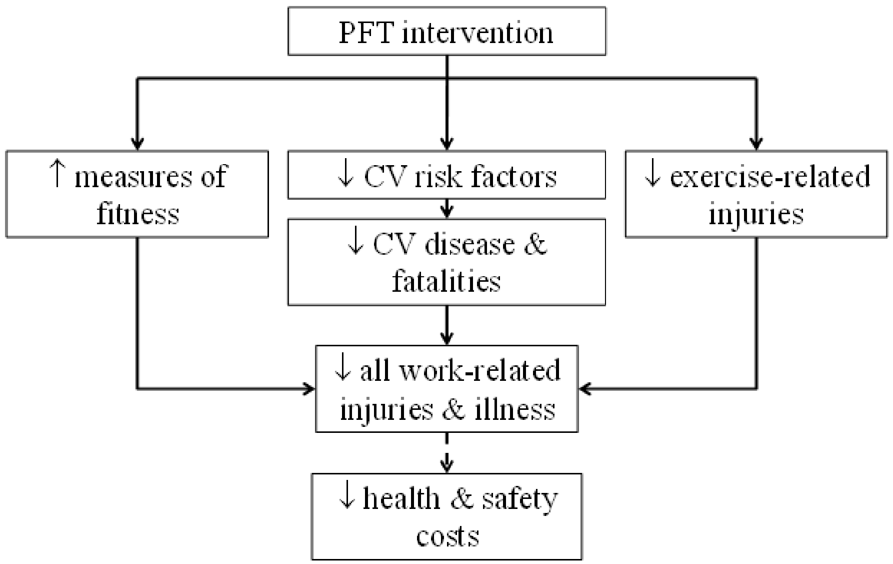

Figure 1. Anticipated benefits of a peer fitness trainer based exercise intervention.

Table 1. Study population

	Control classes				Intervention	Total
	2007	2008	2009	Total controls	2012	
Starting class size, n	19	40	18	77	32	109
RA Drop-outs Injury, n (%)	1 (5.3)	0	1 (5.6)	2 (2.6)	1 (3.1)	3 (2.8)
Other, n (%)	8 (42.1)	5 (12.5)	1 (5.6)	14 (18.2)	4 (12.5)	18 (16.5)
Prob. year drop-out, n (%)	1 (5.3)	1 (2.5)	2 (11.1)	4 (5.2)	0	4 (3.7)
Successful completion, n %	9 (47.4)	34 (85.0)	14 (77.8)	57 (74.0)	27 (84.4)	84 (77.1)*
Age, mean (sd)**	25.3 (3.4)	28.2 (5.8)	29.3 (6.1)	28.0 (5.7)	28.4 (5.1)	27.5 (5.3)
Female, n (%)	3 (15.8)	0	2 (11.1)	5 (6.5)	1 (3.1)	4 (3.7)***

*Drop-out status differed significantly by year, p=0.013.

**Age at time of pre-employment physical. These data are missing for many recruits who failed to complete the recruit academy. 2007: n=10; 2008: n=36; 2009: n=16; 2012, n=28 (p=0.41).

***Total does not equal column totals: One female participated in the 2007 and 2009 RAs; another female participated in the 2009 and 2012 RAs. These are treated as independent observations for the statistical tests (p=0.025).

Table 2. Annual medical surveillance data for pre-employment and 1st annual physicals, presented as mean (s.d.)

	Weight*	BMI	%BF	SBP	DBP	TC	LDL	HDL*	TG	VO_{2max}*	Sit & reach*
2007 (n=9)											
Pre-employment	188.2 (35.7)	25.8 (2.4)	17.8 (4.3)	122.9 (14.9)	71.3 (8.8)	147.1 (23.3)	87.0 (20.8)	52.7 (13.3)	70.0 (51.1)	45.0 (3.3)	6.2 (2.2)
1st annual physical	188.0 (31.0)	25.9 (2.1)	15.3 (5.7)	117.7 (8.7)	72.2 (6.3)	151.8 (28.9)	89.4 (22.9)	49.7 (15.2)	64.2 (20.1)	57.8 (7.5)	6.1 (2.0)
Change	-0.2 (11.1)	0.14 (1.5)	-2.6 (3.4)	-5.2 (14.1)	0.9 (8.9)	4.7 (27.4)	2.4 (29.5)	-3.0 (10.2)	-5.8 (44.9)	12.8 (6.0)	-0.1 (2.1)
2008 (n=34)											
Pre-employment	186.7 (21.5)	26.7 (3.1)	18.0 (4.5)	115.2 (7.9)	75.9 (5.5)	171,7 (35.3)	105.5 (31.0)	50.0 (10.0)	92.3 (56.9)	44.5 (2.2)	5.9 (2.5)
1st annual physical	189.6 (23.5)	27.1 (3.5)	17.4 (5.6)	116.4 (9.0)	73.7 (7.6)	172.7 (37.8)	105.9 (30.9)	51.6 (12.1)	87.0 (49.2)	61.0 (7.7)	6.2 (2.7)
Change	3.0 (10.8)	0.44 (1.6)	-1.0 (4.0)	1.1 (10.4)	-2.2 (7.9)	0.9 (27.6)	0.4 (18.9)	1.7 (10.0)	-5.3 (54.5)	16.8 (7.5)	0.3 (2.2)

Table 2, Continued

	Weight*	**BMI**	**%BF**	**SBP**	**DBP**	**TC**	**LDL**	**HDL***	**TG**	**VO_{2max}***	**Sit & reach***
2009 (n=14)											
Pre-employment	188.3 (27.5)	26.7 (2.7)	16.6 (2.9)	118.6 (6.1)	77.3 (6.9)	160.2 (39.5)	97.0 (31.1)	51.9 (10.9)	78.5 (53.7)	63.1 (6.4)	6.8 (1.8)
1st annual physical	193.6 (31.0)	27.5 (3.7)	16.6 (3.9)	110.3 (7.3)	73.4 (5.7)	172.8 (35.6)	101.1 (25.2)	57.0 (14.7)	97.4 (88.5)	66.5 (7.9)	6.2 (2.6)
Change	5.3 (7.1)	0.75 (1.0)	-0.1 (3.1)	-8.3 (8.7)	-3.6 (7.2)	12.6 (28.4)	4.1 (35.6)	5.1 (5.3)	18.9 (42.7)	3.4 (8.6)	-0.6 (2.2)
Total controls (n=57)											
Pre-employment	187.3 (25.0)	26.6 (2.9)	17.6 (4.1)	117.3 (9.2)	75.5 (6.6)	165.0 (35.5)	100.5 (30.0)	50.9 (10.6)	85.4 (55.0)	49.2 (8.9)	6.2 (2.3)
1st annual physical	190.4 (26.3)	27.0 (3.3)	16.8 (5.2)	115.1 (8.8)	73.5 (6.9)	169.4 (36.3)	102.1 (28.6)	52.6 (13.3)	85.9 (58.4)	61.9 (8.1)	6.2 (2.5)
Change	3.1 (10.1)	0.47 (1.4)	-1.0 (3.7)	-2.2 (11.3)	-2.1 (7.9)	4.4 (27.7)	1.6 (25.1)	1.8 (9.3)	0.6 (50.7)	12.8 (9.4)	0.0 (2.2)
2012 (n=27)											
Pre-employment	189.0 (26.0)	26.4 (3.2)	18.9 (4.3)	114.1 (6.4)	73.4 (6.1)	169.7 (29.1)	101.0 (31.9)	57.1 (11.2)	80.7 (40.7)	62.7 (7.1)	7.9 (2.6)
1st annual physical	193.7 (24.3)	27.1 (3.0)	18.4 (5.8)	116.3 (7.2)	72.5 (6.6)	172.6 (30.8)	101.4 (29.7)	61.9 (12.6)	83.1 (44.0)	66.6 (7.7)	5.1 (1.8)
Change	4.7 (10.1)	0.66 (1.4)	-0.4 (4.0)	2.2 (8.1)	-0.9 (7.2)	2.9 (22.2)	0.4 (19.8)	4.8 (16.0)	2.4 (49.1)	3.9 (9.6)	-2.8 (2.5)
Total											
Pre-employment	187.9 (25.3)	26.5 (3.0)	18.0 (4.2)	116.2 (8.5)	74.9 (6.5)	166.5 (33.4)	100.7 (30.4)	52.9 (11.2)	83.9 (50.7)	53.6 (10.5)	6.7 (2.5)
1st annual physical	191.4 (25.5)	27.1 (3.2)	17.4 (5.4)	115.5 (8.3)	73.2 (6.8)	170.4 (34.5)	102.0 (28.8)	55.6 (13.7)	85.0 (54.0)	63.4 (8.2)	5.8 (2.4)
Change	3.6 (10.0)	0.5 (1.4)	-0.8 (3.7)	-0.8 (10.5)	-1.7 (7.7)	3.9 (25.9)	1.25 (23.4)	2.8 (11.9)	1.2 (49.9)	9.9 (10.3)	-0.9 (2.7)

*$p<0.05$

Table 3. Distribution of Framingham Risk Score categories

		Control classes				Intervention	
	Framingham Risk Score	**2007**	**2008**	**2009**	**Total controls**	**2012**	**Total**
Pre-employment physical	<1%	9 (100)	29 (85.3)	12 (85.7)	50 (87.7)	26 (96.3)	76 (90.5)
	1%	0	5 (14.7)	2 (14.3)	7 (12.3)	1 (3.7)	8 (9.5)
1st Annual physical	<1%	9 (100)	30 (88.2)	13 (92.9)	52 (91.2)	25 (92.6)	77 (91.7)
	1%	0	3 (8.8)	1 (7.1)	4 (7.0)	2 (7.4)	6 (7.1)
	3%*	0	1 (2.9)	0	1 (1.8)	0	1 (1.2)

* This observation was collapsed into the 1% category for the logistic regression model.

Table 4. RA physical fitness assessments, presented as mean (s.d.)

	2007 (n=9)	Control classes 2008 (n=34)	2009 (n=14)	Total controls (n=57)	Intervention 2012 (n=27)	Total (n=84)
1.5 mile run (mm:ss)						
First	9:55 (0:48)	10:39 (1:08)	10:03 (0:59)	10:24 (1:05)	10:27 (0:58)	10:27 (1:03)
Final	9:06 (0:45)	9:13 (0:48)	9:13 (0:41)	9:13 (0:46)	9:28 (0:47)	9:18 (0:46)
Change	-0:49 (0:33)	-1:85 (0:40)	-0:49 (0:30)	-1:11 (0:40)	-1:06 (0:37)	-1:19 (0:39)
Push-ups*						
First	29.4 (8.0)	32.2 (6.7)	32.3 (6.1)	31.8 (6.7)	33.6 (9.6)	32.3 (7.7)
Final	37.3 (7.1)	38.1 (9.5)	42.8 (8.6)	39.1 (9.0)	35.1 (6.3)	37.8 (8.4)
Change	7.9 (7.8)	5.9 (5.9)	10.5 (8.6)	7.3 (7.0)	1.5 (7.7)	5.8 (7.8)
Sit-ups**						
First	37.1 (13.5)	38.3 (9.4)	64.1(37.2)	44.5 (23.0)	1:14 (0:11)	n/a
Final	80.0 (52.3)	65.3 (22.3)	72.6 (45.6)	69.4 (34.6)	2:04 (0:40)	n/a
Change	42.9 (41.4)	26.9 (16.5)	8.4 (38.4)	24.9 (29.5)	0:41 (0:40)	n/a
Pull-ups*						
First	5.8 (5.0)	7.3 (4.2)	11.4 (4.6)	8.1 (4.8)	11.3 (6.5)	9.1 (5.6)
Final	14.6 (7.0)	13.6 (5.0)	17.0 (5.8)	14.6 (5.6)	16.8 (6.8)	15.3 (6.0)
Change	8.8 (3.7)	6.3 (3.4)	5.6 (2.8)	6.5 (3.4)	5.4 (2.7)	6.2 (3.2)
Weight*						
First	183.0 (29.3)	186.5 (20.5)	183.6 (27.7)	185.2 (23.5)	186.6 (24.4)	185.7 (23.7)
Final	179.3 (25.5)	182.6 (20.6)	188.3 (29.1)	183.5 (23.4)	191.1 (21.9)	185.9 (23.1)
Change	-3.7 (6.2)	-3.9 (7.8)	4.7 (4.3)	-1.7 (7.7)	4.5 (6.8)	0.3 (8.0)

*p<0.05

**Sit-ups/one minute replaced with 90-second plank test for all TFD personnel in 2013 and for the entire 2012 RA training

Table 5. Injury and workers' compensation claim frequency, costs and estimated rate in the recruit academy, probationary year, and over the total study period.

	Control classes 2007	2008	2009	Total controls	Intervention 2012	Total
RA (n)	13	17	6	36	11	47
- Exercise related	5	6	3	14	8	22
- WC claim	13	17	6	36	10	46
($) Mean (s.d.)	1255 (1946)	1194 (1053)	6806 (10492)	2152 (4689)	453 (412)	1783 (4199)
Median	783	1073	3313	867	363	782
Range	64-7637	87-3825	376-27769	64-27769	78-1546	64-27769
Prob. Year (n)	2	24	5	31	3	34
- Exercise related	0	6	0	6	1	7
- WC claim	0	15	4	19	3	22
($) Mean (s.d.)	-	736 (835)	1761 (2774)	952 (1418)	710 (298)	919 (1318)
Median	-	451	508	451	683	555
Range	-	0-2899	136-5896	0-5896	427-1022	0-5896
Total (n)	15	41	11	67	14	81
- Exercise related	5	12	3	20	9	29
- WC claim (n)	13	32	10	55	13	68
($) Mean (s.d.)	1255 (1946)	979 (970)	4788 (8396)	1737 (3905)	513 (393)	1503 (3543)
Median	783	801	1258	815	427	729
Range	64-7637	0-3826	136-27769	0-27769	78-1546	0-27,769
Total*	16,331	31,360	47,890	95,582	6,679	102,262
$/recruit	859	784	2,660	1,241	208	938
Injury and claims rate, n (%)						
- RA	13/19 (0.68)	17/40 (0.43)	6/18 (0.33)	36/77 (0.47)	11/32 (0.34)	47/109 (0.43)
- RA Exercise related	5/19 (0.26)	6/40 (0.15)	3/18 (0.17)	14/77 (0.18)	8/32 (0.25)	22/109 (0.20)
- Prob. Year	2/10 (0.20)	24/34 (0.71)	5/14 (0.36)	31/57 (0.54)	3/27 (0.11)	34/84 (0.41)
- Prob. Year Exercise related	0	6/34 (0.18)	0	6/57 (0.11)	1/27 (0.037)	7/84 (0.083)
- Total	15/19 (0.79)	41/40 (1.03)	11/18 (0.61)	67/77 (0.87)	14/32 (0.44)	81/109 (0.74)
- Total Exercise related	5/19 (0.26)	12/40 (0.30)	3/18 (0.17)	20/77 (0.26)	9/32 (0.28)	29/109 (0.27)
- WC claim	13/19 (0.68)	32/40 (0.80)	10/18 (0.56)	55/77 (0.71)	13/32 (0.41)	68/109 (0.62)

* Totals may not agree due to rounding

Table 6. Results of regression models, comparing the frequency and cost of claims in the intervention class to historical controls

	Coef.	s.e. β	95% CI	p-value
Injury freq. – during RA	-0.52	0.42	-1.34, 0.30	0.212
Injury freq. – probationary year	-1.43	0.60	-2.61, -0.25	0.018
Injury – overall	-0.89	0.34	-1.55, -0.22	0.009
Exercise-related injury (overall)	-0.23	0.51	-1.22, 0.77	0.658
Claims frequency	-0.79	0.36	-1.50, -0.088	0.028
Claims cost*	-0.14	0.058	-0.26, -0.026	0.016

*Costs compared using linear GEE model with gamma distribution and log link, clustered on recruit class;
All other outcomes (injury and claims frequency) compared using Poisson GEE model, clustered on recruit class.
$(e^{\beta 1} - 1)*100$ = 13% reduction in claims costs, comparing intervention group to controls.

Table 7. Summary of costs of the PFF-Fit program, presented in 2013 U.S. dollars.

Program supervision	No. of personnel	Hours/ week	No. of weeks	Total hours	Hourly wages	Benefits*	Overhead costs**	Total costs***	Cost type
Safety and Health Captain	1	6	78	468	37.57	12.02	9.39	27,602.64	Personnel
Recruit Academy	No. of personnel	Hours/ week	No. of weeks	Total hours	Hourly wages †	Benefits	Overhead costs	Total costs	Cost type
RA PFT**	1	40	20	800	16.63	5.32	4.16	20,888.00	Personnel
Visiting PFT –M/W/F workouts	2	6	20	240	24.95	7.98	6.24	9,400.80	Overtime
Visiting PFT – once monthly run day	1	2	5	10	24.95	7.98	6.24	391.70	Overtime
Probationary Year	No. of personnel	Hours/ visit	No. of visits	Total hours	Hourly wages †	Benefits	Overhead costs	Total costs	Cost category
PFT – station visits with PFFs	27	2	4	8	29.67	9.50	7.42	10.063.44	Overtime
Personnel - Other	No. of personnel	Prep. hours	Interv. hours	Total hours	Hourly rate	Mileage	Benefits & Overhead	Total costs ††	Cost category
Nutritionist	1	11	2	13	50.00	11.90	n/a	661.90	Contractor
Program materials								Binders	
								$150.00	Materials
Total program costs									
								48,490.64	**Personnel**
								19,855.94	**Overtime**
								661.90	**Contractor**
								150.00	**Materials**
								$69,158.48	**Total**

*TFD calculates benefits as 32% of the hourly wage rate.

**Overhead costs were estimated at an additional 25% of hourly wages.

***Total costs = number of personnel x total hours x (hourly wages + benefits + overhead).

† TFD estimates the base hourly rate for the rank of firefighter to be $16.63; Engineers/paramedics, $19.78; Captains, $22.93. Overtime wage rates are 1.5 times base hourly. PFTs with the rank of firefighter were selected for assignment to the RA. The median overtime wage rate (Engineers/paramedics) was used to estimate costs of the in-station visits during the probationary year.

†† Nutritionist total cost = (Total hours x hourly rate) + mileage.

Table 8. Summary of estimated costs and benefits of the PFF-Fit program (in dollars)

Program costs		Program benefits	
Personnel costs	48,490.64	WC claims*	
Overtime costs	19,855.94	- mean cost per claim	-1,224
Nutritionist (RD) contractor	661.90	- mean cost per recruit	-1,033
Program materials	150.00		
Total	$69.158.48	Approx. Total	$33,000
		Estimated indirect costs	$33,000
		Total, claims and indirect costs	$66,000
Return on Investment		(Claims cost reduction – Program cost) / Program cost	
Workers' compensation costs only:		(33,000 –69,158)/69,158	- 0.52
Workers' compensation and indirect costs:		(66,000 – 69,158)/69,158	- 0.048

*If the intervention class experienced the same claims rate as controls (0.71), they would have filed 22.72 claims over the study period, at a mean cost per claim of $1,737 for a total cost of $39,465. The actual costs accrued by the 2012 class were $6,679, a difference of $32,786. The mean claims costs per recruit were $208 for the intervention group, compared to $1,241 for the controls, a difference of $1,033. For 32 total recruits, this yields a decrease of $33,056 in claims costs, comparing interventions to controls.

APPENDIX B –INJURY AND WORKERS' COMPENSATION CLAIMS IN THE TUCSON FIRE DEPARTMENT

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Key Words: Occupational injury, Workers' compensation, Aging, Fire service

ABSTRACT

Background Firefighters are at higher risk of non-fatal injury than most U.S. workers. While the injury experience of firefighters has been well characterized, the pattern of workers' compensation claims costs has been studied much less frequently in this population. The effect of increasing age on claims frequency and cost has not been previously studied in the U.S. fire service.

Methods Routine injury surveillance and workers' compensation claims data from a medium-sized metropolitan fire department during 2004-2012 were merged and costs were described for mechanism of injury, injury type, body region and worker age.

Results 85% of claims were successfully merged with injury surveillance data. The mean costs of merged claims was $4,189 (s.d.=13,311) with a median cost of $677. Acute overexertion was the mechanism of injury for 59.5% of injuries and 71.8% of injuries were sprains and strains. Claims costs are 92.3% higher for injuries with a mechanism of injury of acute overexertion compared to other mechanisms of injury, and 99.2% higher for injuries that result in sprains/strains compared to all other injury types. Claims costs also increase with age, with claims costs for firefighters over age 50 120 to 144% greater than workers age 20-29.

Conclusions The results of this study confirm findings from previous research in the fire service regarding the cause and type of injury and are similar to studies in other worker populations regarding aging and the costs of injury. Future research on the effect of aging on injury and claims in the fire service should examine the influence of physical demands on the relationship between aging and injury costs.

BACKGROUND AND INTRODUCTION

Firefighters and emergency services employees have been shown to be at a higher risk of non-fatal injury than most other U.S. workers (Maguire et al., 2005; Reichard et al., 2011; Poplin et al., 2012; U.S. Department of Labor, 2013). In 2012, firefighters experienced an estimated annual rate of 6.1 injuries per 100 firefighters (Karter and Stein, 2013; Karter and Molis, 2013). While the injury experience of U.S. firefighters has been well characterized, the pattern of workers' compensation claims has been studied much less frequently in this population. Previous research has demonstrated that most injuries in firefighters are caused by overexertion (Poplin et al., 2012; Walton et al., 2003) and that overexertion injuries are costlier than other types of injuries (Walton et al., 2003).

The effect of increasing age on claims frequency and cost has been explored in other populations but, to our knowledge, not in the U.S. fire service. In a study of injury and compensation claims frequency in heavy industry in Australia, Guest et al. (2014) found that workers under age 30 had the highest injury rate. Breslin and Smith (2006) found that age and job tenure have a strong inverse association with claims rate in workers covered by the Ontario Workplace Safety and Insurance Board in Ontario, CA. While the claims rate may be lower for older workers, the cost of claims may be higher among older workers. Schwatka et al. (2013) found that the mean cost of claims filed by construction workers over age 65 was nearly three times higher than those filed by workers age 18-24, but those over age 65 filed less than 1% of claims in the 10-year study period. The purpose of this study is to describe the workers' compensation claims in the U.S. fire service and begin to explore the impact of aging on claims frequency and costs in this population.

MATERIALS AND METHODS

The current study uses routine injury surveillance and workers' compensation claims data for all commissioned personnel of Tucson Fire Department (TFD) who suffered at least one injury and filed a workers' compensation claim from January 1, 2004 – December 31, 2012. TFD, located in Tucson, Arizona, is a medium-sized metropolitan department that operates 21 fire stations and employs nearly 600 career fire fighters. The overall department population has been described previously (Poplin et al., 2012; Poplin et al., 2014). TFD records on-the-job injuries in their injury surveillance database if the incident meets the Occupational Safety and Health Administration (OSHA) injury reporting requirements, or if the injury has the potential to progress and require a workers' compensation claim. Medical events such as blood borne pathogens exposure, heat exhaustion and cardiac events were excluded from this analysis. Injury surveillance (n=1,284) and workers' compensation claims data (n=1,204) were matched based on the common elements between the two databases (employee identification number (EID), date and body region) and verified using the comments field in the injury surveillance database. In addition to EID, date of claim, and body region, the workers' compensation database included information about the claim type (i.e., indemnity or medical-only), claim status (open or closed), and the costs paid to date, reserve costs and total costs. Indemnity claims are those that include payment for lost time; medical only claims have only incurred costs for medical treatment. Open claims typically have a reserve cost associated with them to cover any future incurred costs. Total costs are the sum of paid and reserve costs.

Workers' compensation claims costs were transformed to constant 2013 U.S. dollars using the Consumer Price Index (U.S. Department of Labor, 2013). For regression models, workers' compensation claims costs were transformed using the natural log after adding $1 to zero cost claims. Descriptive statistics (e.g., mean, median, maximum) were calculated on the non-log transformed claims data. Claim type (e.g. medical only or indemnity) data were imputed for three observations using the comment and lost time variables in the injury surveillance data. Claim status (e.g., open or closed claim) frequency was analyzed by year and by claim type (e.g., medical only costs versus indemnity) using a chi-square test and mean costs by claim status and claim type were analyzed using paired t-tests. The reserve costs of open claims were used to estimate the total claims costs. An unpaired t-test was used to compare the mean claims costs of matched and unmatched claims. Ordinary Least Squares (OLS) regression[5] was used to analyze claims cost by mechanism of injury (MOI), nature of injury, body region, year of claim and age. All regression models were adjusted for within-subject correlation (i.e. clustered on subject id) using generalized estimated equations (GEE). Data analysis was completed using Stata version 11 (College Station, TX, 2012). The University of Arizona's Institutional Review Board provided approval for and oversight of the use of human subjects' data for this project.

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[5] $E(y_{it}) = x_{it}\beta$, y~N( ) (Statacorp, 2009)
y = mechanism of injury, nature of injury, body region
x = age category
xtset = employee identification number

RESULTS

Table 1 provides a comparison of the number of injuries and number of claims in the study period. Overall, 85.4% of claims were successfully matched with an injury surveillance report. Generally, there were more injury reports (column A) than claims (column B), which is to be expected in an organization with a strong injury reporting culture. In some years, however, this was not the case (column D) and there is no explanation available at this time, beyond possible problems with record keeping. The mean cost of matched claims (n=1,028) was $4,189 (s.d.=13,311) with a range of $0-236,159 and a median of $677. The mean cost for all unmatched claims over the time period (n=176) was $3,392 (s.d.=10,710) with a range of $0-77,873 and median of $287. Twenty-two (2.2%) of matched claims and 29 (16.5%) of unmatched claims had zero cost. The distribution of unmatched claims costs differed significantly from the matched claims; the matched claims have a higher mean cost than the unmatched claims ($p<0.001$).

A total of 87.9% of matched claims had a status of closed at the time of analysis (Table 2). The portion of open claims by year ranged from 7.3% to 19.2%; however, the chi-square test show that claims status did not differ significantly by year ($p=0.214$). Of the 388 indemnity claims in the study period, 117 (30.2%) were open, compared to only 7 (1.1%) of the 640 medical only claims, a statistically significant difference in frequency (chi square test, $p<0.001$). Indemnity claims had a mean cost of $9,851 (s.d.=20,425) and a median of $2,485. Medical-only claims averaged $757 (s.d.=920) with a median of $411. Results of the t-test show that open claims are significantly costlier than closed claims, and that the costs of medical-only claims are significantly lower than indemnity claims (Table 3).

Acute overexertion was the MOI for 59.5% of injuries and 71.8% of injuries were sprains and strains (Table 4). On average the costliest injuries were transportation-related, acute overexertion, and falls. Fractures and dislocations, sprains and strains, and burns were the costliest injuries when categorized by nature of injury. Of the 612 injuries with a MOI of acute overexertion, 588 (96.1%) resulted in sprain/strain; other injury types associated with acute overexertion were fractures (n=14) and medical (n=4). By body region, the costliest injuries on average affected multiple body regions, lower extremity, upper extremity and the spine. Results of the linear regression models on MOI and nature of injury, adjusted for year of claim and employee age, are presented in Table 5. The exponent of the coefficient for acute overexertion (0.654) is 1.923 and the exponent for the coefficient for sprain/strain (0.689) is 1.992. Acute overexertion injuries are 92.3% costlier than injuries caused by other mechanisms, and sprain/strain injuries are 99.2% costlier than other injury types, when worker age and year of claim are fixed.

Demographic data for age were only available from TFD for 2013 and are presented in Table 6. In 2013, TFD commissioned personnel ranged in age from 22 to 61 years. If the proportions of TFD commissioned personnel in each age category are assumed to remain relatively constant over the study period, then younger workers, especially those under age 30, have contributed 21% of injury claims but only account for less than 10% of the population. Conversely, workers over age 50 account for 21% of the population but contributed only 12.6% of claims. Average cost per claim is $9,000 among workers over age 50, compared to just $2,052 among those age 20-29. There appears to be a linear trend, with mean cost per claim increasing in each age category. Examining injury costs by age and MOI, this pattern of increasing costs by age category is evident in electrical/radiation, acute overexertion, transportation and “other and unspecified” injuries. Similarly, when examined by nature of injury, fracture/dislocation and sprain/strain injuries show a pattern of increasing cost by age category. Neck, spine and lower extremity injuries are least costly for workers under age 30 and most costly for workers over age 50. Regression analysis of costs by body region show that injuries affecting multiple body regions are the only injuries significantly different from head injuries, which served as the reference category (Table 7). Spearman’s rank correlation test showed the variable “rank” is highly correlated with age ($p<0.001$); however, a pattern of increasing costs with increasing rank is not as obvious as with age category (Table 8). Injuries suffered by those with the rank of Chief were costliest at $5,616, and recruits had the lowest average cost per claim at $2,109.

DISCUSSION

The current study described the distribution of claims costs at TFD by the MOI, nature of injury, body region, and employee age at the time of injury for all claims filed between 2004 and 2012, matched to injury surveillance data. Similar to previous research in the fire service (Walton et al., 2003; Karter and Molis, 2013) acute overexertion was the most common MOI and sprains/strains were the most common injury type. Age was significantly associated with increasing costs in all the regression models. Total claims costs for workers over age 50 were 120 to 144% greater than claims for workers age 20-29, and cost increases were observed in each category over age 30, in models controlling for year of claim, acute overexertion, sprain/strain injury type, and body region. This is comparable to findings in the construction industry (Schwatka et al., 2013). Workers over age 50 filed 12.6% of claims overall compared to the 21.1% of claims filed by workers age 20-29, but the mean claims costs for the older workers was over four times higher than younger workers. A similar pattern of increasing mean cost of injuries caused by acute overexertion and sprain/strain injuries for older workers was observed.

This study provides, to our knowledge, the first examination of the influence of age on compensation claims cost and highlights the economic significance of injury among older firefighters. Explicit examination of the physical work demands of all firefighters may be valuable. Research of workers in Canada found that health care costs, lost work days and long-term disability claims were higher for older workers and for workers with greater physical demands (e.g., lifting) (Smith et al., 2014). Smith et al. (2014) also noted the importance of improving our understanding of the healthy worker effect when studying age and physical demands as they relate to injury and compensation claims, because older workers in poor health may leave the work force or attempt to promote out of physically demanding work while those in good health remain at risk but are inherently less likely to suffer injury. Future research on injury and injury prevention in the fire service should focus on older workers to better understand how health status influences injury risk and outcomes, and to help reduce injury frequency and severity in this population.

The current study relied on two administrative databases, TFD's injury surveillance database and the third party payer workers' compensation claims database, neither of which was designed and maintained for research purposes. This leads to several important limitations of the current study. First, we have limited information about the claim status and are unable to distinguish between injuries that require long-term care but that are managed as one claim, versus injuries to the same person and body region that are managed as multiple claims. We, therefore, do not know how decisions are made regarding defining episodes of care from an administrative perspective, and how changes or inconsistency about the definition of episode of care could have affected the study results. Another limitation of the current study is that we were not able to separate costs into the medical and indemnity components; data were only available on the total cost of claim, comprised of paid and reserve components. In their study of construction workers, Schwatka et al. (2013) found that each one year of aging was associated with a 3.5% increase in indemnity costs but only a 1.1% increase in medical costs. Future research on this subject should examine indemnity and medical cost components, as well as total claims costs.

The injury surveillance and claims databases are not integrated with the department's medical or personnel data management systems. Therefore, other data not available for this study included gender, body mass index, race/ethnicity, marital status or other personal or workplace characteristics. This limited our ability to control for potential confounders and may have introduced omitted variable biases into the statistical tests. Finally, age data on the incumbent workforce were not available for the time period of the study data, only for 2013. In order to compare injury frequency and costs by age group, we assumed that the age distribution in 2013 is comparable to the previous nine years. We did not have data on job tenure, and the available information on rank is incomplete, which limits are ability to compare our results about rank and job tenure to studies in other populations (Breslin and Smith, 2006). We do not have information on the number of hours worked by each claimant or their wages and benefits, a problem noted in other research relying on claims data (Schwatka et al., 2013). Finally, while the current study utilized GEE models to adjust for within-subject correlation, advanced statistical methods may be needed to account for autocorrelation of the year of claim variable; these methods will be explored in future analyses of these data. Despite these limitations, these data are novel for the fire service and we hope our analysis of injury and compensation claims in this population is useful to firefighters and department leadership in the future.

CONCLUSIONS

The current study found that claims costs are significantly higher for injuries with a MOI of acute overexertion, and for injuries that result in sprains/strains. Claims costs also increase with age, with claims costs for workers over age 50 120 to 144% higher than claims costs for workers under age 30. Future research on the effect of aging on injury and claims in the fire service should distinguish between indemnity and medical costs, and should examine the influence of physical demands on the relationship between aging and injury costs.

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Table 1. Summary of claims and injury surveillance data, matched by EID, date of injury and body region

A	B	C	D	E	F	G
Year	Injury frequency	Claims frequency	Difference (B– C)	Total claims matched with injuries n (%)	Unmatched injuries frequency	Unmatched claims frequency
2004	129	118	11	104 (88.1)	22	14
2005	128	117	11	110 (94.0)	16	7
2006	148	158	-10	138 (97.3)	10	20
2007	174	200	-26	157 (78.5)	17	43
2008	199	148	51	135 (91.2)	64	13
2009	124	137	-13	113 (82.5)	11	24
2010	143	118	25	92 (78.0)	51	26
2011	140	117	23	104 (88.9)	36	13
2012	110	91	19	75 (82.4)	35	16
Total	1295	1204	91	1028 (85.4)	262	176

Table 2. Claim status (open/closed) by claim type (medical-only/indemnity) and year of claim

	Medical only (MO) n (% of MO claims)		Indemnity n (% of Ind. claims)		Total MO n (% of year total)	Total Indemnity n (% of year total)	Total open n (% of year total)	Total closed n (% of year total)	Total matched claims n (% of total claims)
	Open	Closed	Open	Closed					
2004	0	65 (100)	16 (41.0)	23 (59.0)	65 (62.5)	39 (37.5)	16 (15.4)	88 (84.6)	104 (10.1)
2005	0	69 (100)	8 (19.5)	33 (80.5)	69 (62.7)	41 (37.3)	8 (7.3)	102 (92.7)	110 (10.7)
2006	1 (1.3)	74 (98.7)	15 (23.8)	48 (76.2)	75 (54.3)	63 (45.7)	16 (11.6)	122 (88.4)	138 (13.4)
2007	0	89 (100)	18 (26.5)	50 (73.5)	89 (56.7)	68 (43.3)	18 (11.5)	139 (88.5)	157 (15.3)
2008	3 (3.3)	89 (96.7)	12 (27.9)	31 (72.1)	92 (68.1)	43 (31.9)	15 (11.1)	120 (88.9)	135 (13.1)
2009	0	74 (100)	16 (41.0)	23 (59.0)	74 (65.5)	39 (34.5)	16 (14.2)	97 (85.8)	113 (11.0)
2010	1 (1.7)	59 (98.3)	8 (25.0)	24 (75.0)	60 (65.2)	32 (34.8)	9 (9.8)	83 (90.2)	92 (9.0)
2011	2 (2.9)	68 (97.1)	18 (52.9)	16 (47.1)	70 (67.3)	34 (32.7)	20 (19.2)	84 (80.8)	104 (10.1)
2012	0	46 (100)	6 (20.7)	23 (79.3)	46 (61.3)	29 (38.7)	6 (8.0)	69 (92.0)	75 (7.3)
Total	7 (1.1)	633 (98.9)	117 (30.2)	271 (69.8)	640 (62.3)	388 (37.7)	124 (12.1)	904 (87.9)	1028

Table 3. Results of t-tests on ln(total claims cost) by claim status (n=1,028) and claim type (n=1,028)

	Difference	s.e. β	95% CI	p-value
Model with indicator variable for Claim Status = Open claims	3.21	0.15	2.92, 3.50	<0.001
Model with indicator variable for Claim Type = Medical only	-1.70	0.11	-1.49, -1.91	<0.001

Note: Difference = difference in mean costs, comparing open claims to closed claims and medical only claims to indemnity claims.

Table 4. Summary of total workers' compensation frequency and cost of injury by mechanism of injury, nature of injury and body region

	n	%	Mean (sd) ($)	Median ($)	Max ($)
All	1,028		4,189 (13310)	677	236,159
Mechanism of Injury					
Fall	55	5.4	4,558 (12434)	1,014	79,989
Struck by/caught between	76	7.4	2,076 (4981)	479	38,856
Cutting/piercing	71	6.9	903 (2325)	197	16,053
Foreign body in natural orifice	25	2.4	735 (799)	429	3,479
Chemical Effect	7	0.7	855 (1129)	274	3,026
Thermal Effect	21	2.0	4,447 (18048)	347	83,184
Electrical/radiation or other wave energy	11	1.1	3,786 (6416)	205	18,394
Acute overexertion	612	59.5	5,017 (15368)	837	236,159
Transportation-related	17	1.7	7,478 (17378)	895	69,955
Other, and unspecified	133	12.9	3,585 (9972)	520	69,323
Nature of Injury					
Burn	24	2.3	3,943 (16885)	351	83,184
Contusion/laceration	150	14.6	1,993 (7355)	377	79,989
Electrical injury	1	0.1	667	667	667
Eye	20	2.0	435 (520)	281	2099
Fracture/dislocation	41	4.0	9,657 (20115)	1,135	83,702
Inhalation	5	0.5	1,125 (1261)	486	3,026
Medical	27	2.6	2,945 (5512)	314	12,594
Puncture	22	2.1	360 (449)	180	1,832
Sprain/strain	738	71.8	4,627 (14149)	825	236,159
Body region					
Head	21	2.0	1,375 (3407)	311	16,053
Face	68	6.6	1,264 (3057)	295	18,394
Neck	15	1.5	2,462 (4856)	191	17,794
Thorax	27	2.6	1,415 (2284)	337	9,820
Abdomen	13	1.3	1,695 (3023)	503	9,874
Spine	281	27.3	3,876 (17,066)	740	236,159

Table 4, continued

	n	**%**	**Mean (sd) ($)**	**Median ($)**	**Max ($)**
Upper Extremity	206	20.0	4,389 (11748)	549	83,702
Lower Extremity	365	35.5	5,245 (13,206)	839	86,709
External and other	3	0.3	1,537 (772)	1,801	2,142
Multiple	29	2.8	6,282 (14,042)	1,234	73,670

Table 5. Results of OLS regression on ln(total claims costs) on indicator variables for acute overexertion (n=1,028) and sprain/strain (n=1,028), adjusted for year of claim and employee age

Independent variables	Model with indicator for MOI=acute overexertion Coef. (s.e.)	Model with indicator for nature of injury=sprain/strain Coef. (s.e.)
Intercept	6.121 (0.22)	6.047 (0.23)
MOI = acute overexertion	0.643 (0.12)*	
Nature = sprain/strain		0.688 (0.13)*
Year = 2004 (REF)		
Year = 2005	-0.601 (0.25)*	-0.629 (0.25)*
Year = 2006	-0.178 (0.23)	-0.216 (0.23)
Year = 2007	-0.062 (0.23)	-0.130 (0.23)
Year = 2008	-0.263 (0.23)	-0.325 (0.23)
Year = 2009	-0.437 (0.24)	-0.456 (0.24)*
Year = 2010	-0.391 (0.26)	-0.353 (0.26)
Year = 2011	0.003 (0.25)	0.0285 (0.25)
Year = 2012	-0.578 (0.28)*	-0.534 (0.27)
Age = 20-29 (REF)		
Age = 30-39	0.325 (0.15)*	0.325 (0.15) *
Age = 40-49	0.520 (0.15)*	0.505 (0.15)*
Age = 50+	0.875 (0.20)*	0.788 (0.20)*

* $p < 0.05$. Note: The exponent of the coefficient for acute overexertion = 1.923 and the exponent for the coefficient for sprain/strain = 1.992. Acute overexertion injuries are 92.3% costlier than injuries caused by other mechanisms, and sprain/strain injuries are 99.2% costlier than other injury types.

Table 6. Frequency and total workers' compensation claims costs by age group, 2004-2012.

		20-29	**30-39**	**40-49**	**50+**	**Total**
2013 TFD, n (%)		58 (9.6)	220 (36.5)	198 (32.8)	127 (21.1)	603
Claims, n (%)		217 (21.1)	377 (36.7)	305 (29.7)	129 (12.6)	1028
Claim cost	**mean (sd)**	2,052 (6,131)	3,428 (10,364)	4,617 (11,794)	9,000 (26,058)	4,189 (13,310)
	median	643	610	768	945	678
	maximum	65,544	83,702	86,709	236,159	236,159
Mechanism of Injury	Fall	7 (12.7)	16 (29.1)	26 (47.3)	6 (10.9)	55
presented as		985 (1256)	8556 (19795)	1734 (2500)	10299 (17630)	4557 (12433)
n (%)		156	1062	916	1945	1014
Mean (s.d.)	Struck by/caught between	13 (17.1)	29 (38.2)	25 (32.9)	9 (11.8)	76
Median		1376 (1663)	1116 (1604)	3876 (8195)	1185 (1664)	2076 (4918)
		900	419	734	665	479
	Cutting/piercing	17 (23.9)	25 (35.2)	20 (28.2)	9 (12.7)	71
		499 (1064)	1668 (3700)	497 (625)	440 (430)	903 (2324)
		145	250	203	355	197
	Foreign body in natural orifice	4 (16.0)	11 (44.0)	8 (32.0)	2 (8.0)	25
		848 (399)	602 (573)	893 (1245)	607 (477)	735 (798)
		807	414	296	607	428
	Chemical Effect	0	4 (57.1)	2 (28.6)	1 (14.3)	7
			222 (186)	1038 (1080)	3026	855 (1128)
			162	1038	3026	274
	Thermal Effect	8 (38.1)	9 (42.9)	3 (14.3)	1 (4.8)	21
		453 (461)	9557 (27611)	542 (296)	2143	4447 (18047)
		254	343	709	2143	347
	Electrical/radiation or other wave energy	0	3 (27.3)	6 (54.6)	2 (18.2)	11
			348 (277)	3996 (7318)	8318 (8182)	3787 (6416)
			204	154	8318	205
	Acute overexertion	135 (22.1)	228 (37.3)	177 (28.9)	72 (11.8)	612
		2523 (7481)	3655 (10054)	6025 (13869)	11530 (32612)	5017 (15368)
		683	777	1041	1225	838

Table 6, continued

		20-29	30-39	40-49	50+	Total
	Transportation-related	2 (11.8) 502 (555) 503	6 (35.3) 1240 (1487) 486	4 (23.5) 2013 (2393) 1162	5 (29.4) 22127 (28637) 8886	17 7478 (17378) 895
	Other, and unspecified	31 (23.3) 2046 (3830) 780	46 (34.6) 3168 (9256) 530	34 (25.6) 4319 (12571) 545	22 (16.5) 5490 (12793) 335	133 3584 (9972) 520
Nature of Injury ***presented as*** ***n (%)***	Burn	10 (41.7) 450 (408) 358	10 (41.7) 8823 (26135) 349	4 (16.7) 475 (276) 492	0	24 3944 (16885) 351
Mean (s.d.) ***Median***	Contusion/laceration	33 (22.0) 870 (1915) 197	58 (38.7) 3020 (10764) 398	47 (31.3) 1733 (5105) 407	12 (8.0) 1135 (1425) 751	150 1993 (7354) 377
	Electrical injury	0	1 (100.0) 667 667	0	0	1 667 667
	Eye	4 (20.0) 713 (551) 695	8 (40.0) 288 (182) 293	6 (30.0) 531 (814) 184	2 (10.0) 185 (117) 185	20 435 (519) 281
	Fracture/dislocation	8 (19.5) 1845 (1907) 1498	21 (51.2) 8219 (21764) 677	8 (19.5) 11465 (12502) 5139	4 (9.8) 29208 (34181) 23252	41 9657 (20225) 1335
	Inhalation	0	3 (60.0) 265 (200) 220	1 (20.0) 1801 1801	1 (20.0) 3016 3026	5 1125 (1261) 485
	Medical	4 (14.8) 147 (240) 44	6 (22.2) 147 (240) 44	13 (48.2) 3651 (6761) 314	4 (14.8) 7040 (5764) 5957	27 2946 (5511) 314
	Puncture	0	5 (22.7) 312 (211) 204	11 (50.0) 499 (587) 171	6 (27.3) 147 (147) 96	22 360 (448) 179
	Sprain/strain	158 (21.4) 2492 (7070) 781	265 (35.9) 3198 (8058) 764	215 (29.1) 5466 (13349) 1036	100 (13.6) 9980 (28450) 1074	738 4626 (14149) 825

Table 6, continued

		20-29	30-39	40-49	50+	Total
Body region	Head	8 (38.1) 368 (381) 158	6 (28.6) 3423 (6220) 1373	5 (23.8) 553 (487) 310	2 (9.5) 1313 (299) 1312	21 1375 (3407) 311
	Face	11 (16.2) 692 (702) 428	30 (44.1) 499 (516) 309	21 (30.9) 1903 (4458) 156	6 (8.8) 3901 (5380) 1738	68 1264 (3057) 294
	Neck	1 (6.7) 170 170	4 (29.7) 171 (88) 153	7 (46.7) 3342 (6500) 142	3 (20.0) 4229 (4217) 3138	15 2463 (4856) 192
	Thorax	9 (33.3) 2029 (3228) 658	9 (33.3) 1339 (2208) 261	7 (25.9) 637 (570) 338	2 (7.4) 1711 (1860) 1711	27 1415 (2284) 338
	Abdomen	1 (7.7) 503 503	7 (53.9) 404 (217) 404	2 (15.4) 5056 (6813) 5056	3 (23.1) 2866 (3402) 1652	13 1695 (3022) 503
	Spine	47 (16.7) 1534 (2762) 680	117 (41.6) 2703 (6340) 799	86 (30.6) 2989 (8764) 750	31 (11.0) 14313 (46953) 636	281 3876 (17066) 740
	Upper extremity	36 (17.5) 3693 (12405) 428	67 (32.5) 2797 (10455) 399	75 (36.4) 5003 (11508) 936	28 (13.6) 7517 (14141) 1032	206 4389 (11748) 549
	Lower extremity	99 (27.1) 1945 (4424) 783	120 (32.9) 4989 (13614) 763	97 (26.6) 7126 (15801) 1044	49 (13.4) 8816 (16760) 792	365 5245 (13205) 839
	External and other	0	1 (33.3) 667 667	1 (33.3) 1801 1801	1 (33.3) 2142 2142	3 1537 (772) 1801
	Multiple	5 (17.2) 4023 (7080) 1230	16 (55.2) 8626 (18231) 2445	4 (13.8) 529 (331) 562	4 (13.8) 5481 (5371) 4416	29 6282 (14042) 1234

Table 7. Results of OLS models on ln(total claims cost) by body region, adjusted for year of claim and age (n=1,028).

	Coef (β)	s.e. β	95% CI	p-value
Head (REF)				
Face	-0.625	0.45	-1.46, 0.32	0.212
Neck	-0.439	0.61	-1.56, 0.84	0.558
Thorax	-0.0225	0.53	-1.05, 1.01	0.968
Abdomen	0.0414	0.65	-1.17, 1.40	0.860
Spine	0.334	0.41	-0.43, 1.18	0.366
Upper Extremity	0.356	0.42	-0.44, 1.20	0.365
Lower Extremity	0.607	0.41	-0.17, 1.42	0.126
External and other	0.753	1.12	-1.30, 3.09	0.423
Multiple	1.104	0.52	0.16, 2.19	0.024
Year = 2004 (REF)				
Year = 2005	-0.635	0.25	-1.12, -0.15	0.010
Year = 2006	-0.236	0.23	-0.70, 0.22	0.315
Year = 2007	-0.197	0.23	-0.65, 0.25	0.391
Year = 2008	-0.388	0.24	-0.85, 0.073	0.099
Year = 2009	-0.505	0.25	-0.99, -0.023	0.040
Year = 2010	-0.398	0.26	-0.90, 0.11	0.122
Year = 2011	0.0829	0.25	-0.41, 0.57	0.740
Year = 2012	-0.576	0.28	-1.12, -0.034	0.037
Age = 20-29 (REF)				
Age = 30-39	0.340	0.15	0.041, 0.64	0.026
Age = 40-49	0.535	0.16	0.23, 0.84	0.001
Age = 50+	0.890	0.20	0.42, 1.20	0.000
Intercept	6.190	0.44	5.34, 7.04	

Table 8. Frequency and total workers' compensation claims costs by rank, 2004-2012.

		Chief	Captain	Engineer	Firefighter	Recruit	Total
Claims, n (%)		197 (19.2)	128 (12.5)	265 (25.8)	302 (29.4)	136 (13.2)	1208
Claim cost	**mean (sd)**	5,616 (13,477)	3,606 (8,985)	4,925 (18,337)	3,798 (11,376)	2,109 (7274)	4,189 (13,310)
	median	793	488	839	577	776	678
	maximum	86,709	54,889	236,159	83,702	79,989	236,159

APPENDIX C – MODELING OCCUPATIONAL BACK INJURY AND COMPENSATION COSTS IN EMERGENCY MEDICAL SERVICES PERSONNEL FOLLOWING IMPLEMENTATION OF ELECTRICALLY POWERED STRETCHERS

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Key Words: Markov model, Emergency medical services, Fire service, Occupational health, Back injury

ABSTRACT

Background Back injury is common and costly among emergency services employees (ESE) who transport patients. Recent research has found electrically powered stretchers (EPS) are an effective means of reducing back injury among EMS providers, but no peer-reviewed economic evaluation has been conducted to date.

Methods A Markov decision analysis model, based on primary and secondary data, simulated a cohort of ESEs for incident back injury, disability and associated costs, with and without the use of the EPS.

Results Implementation of the EPS resulted in a 50% reduction in the average number of injuries and disabilities per ESE, and an average cost savings of over $4,600 per EMS ESE and $5,422 per fire department ESE, over the service life of the equipment. These results were sensitive to the probability of injury.

Conclusions The EPS is likely a cost-effective intervention for the reduction of back injury, disability and associated costs among ESE. The results of the current study need to be validated with a long-term evaluation of back injury following implementation of the EPS, preferably at several departments.

BACKGROUND AND INTRODUCTION

Back injury is common and costly in industries where workers transport patients, including healthcare, emergency medical services (EMS) and the fire service (Gershon et al., 1995; U.S. Bureau of Labor Statistics, 2002; Walton et al., 2003). Injuries reduce the quality of life of emergency services employees (ESE) and diminish their ability to function at work. Back injury also poses a financial burden to the fire service and EMS.

Injury claims in the fire service have been estimated to cost, on average, $5,168 to $13,420 (Walton et al., 2003; Leffer and Grizzell, 2010). Fire and EMS departments typically have limited resources to dedicate to their injury-prevention efforts and generally have no easy way of forecasting the cost-effectiveness of interventions.

One frequently performed hazardous job task completed by ESEs involves the lifting of patients and stretchers. ESEs move the patient on to the stretcher and then lift the patient and the stretcher off the ground into the ambulance (Workers' Compensation Board of British Columbia, 2001). Recent research has found that electrically powered stretchers (EPS), which lift and lower the patient between the low position near the ground and the elevated position required to move the stretcher, are an effective means of reducing injuries among EMS professionals (Studnek et al., 2012; Workers' Compensation Board of British Columbia, 2001), though they are more costly and heavier than their manual lift counterparts (Wang et al., 2009). Fewer injuries leads to lower medical and workers' compensation claims costs; however, these devices represent a substantial financial investment for departments. Several studies of patient lifting devices in health care have demonstrated their cost-effectiveness (Spiegel et al., 2002; Chhokar et al., 2004; Collins et al., 2004; Alamgir et al., 2007; Garg and Kapellusch, 2012). To date, there has not been any peer-reviewed economic evaluation of EPS in the fire service or EMS.

The current study uses a Markov model simulation to estimate the expected back injury incidence and associated costs for an emergency services department, with and without EPS, from the department's perspective. Markov models are often used to evaluate health technologies, and are increasingly common in the evaluation of public health interventions, including injury prevention (Graham et al., 1997; Frick et al, 2004; Burdorf et al., 2006; Dong and Buxton, 2006; Gerald et al., 2010; Burdorf et al., 2013). Modeling is one way to overcome the short post-intervention follow-up period often found in patient transport intervention evaluation studies (Yassi et al., 2001; Evanoff et al., 2003; Collins et al., 2004; Wardell, 2007; Studnek et al., 2012; Burdorf et al., 2013). The objective of the current study is to model the change in injury and associated costs in a theoretical cohort of emergency services personnel tasked with patient transport, including emergency medical technicians, paramedics, and firefighters.

MATERIALS AND METHODS

The Markov decision analysis model simulates a cohort of ESEs for incident back injury with or without the use of EPS for patient transport over the service life of the equipment. For the purposes of this study, a back injury is defined as nonspecific "musculoskeletal soft tissue problem/pain/injury of the spine (thoracic or lumbar)…with or without radiation, without specific underlying pathologies such as tumors, fractures, infection, and inflammatory disorders" (Crook et al., 2002) that results in the filing of a workers' compensation claim (Walton et al., 2003; Park et al., 2009). This model requires estimation of parameters including the costs of injury claims and patient transport equipment, and the probability of back injury with and without the EPS. Primary data on device costs, including purchase and maintenance, were provided by the equipment manufacturer and a mid-sized urban all-hazards fire department in southern Arizona. Injury costs were derived from previous studies and from analysis of claims data provided by two fire departments in southern Arizona. Back injury incidence and transition probabilities were based on reviews of published studies on occupational back injury among those who transport patients, including EMS, fire service and healthcare, from *PubMed* and *Web of Science*. An estimate of disability frequency was also provided by an occupational health provider serving southern Arizona ESEs. All costs, including those derived from previous studies, were transformed to constant June 2013 U.S. dollars using the Bureau of Labor Statistics standard Consumer Price Index (U.S. Department of Labor, 2013). This study takes the departmental perspective and therefore does not include the expenses borne by injured workers or society. The outcome of the model will be the difference in back injury incidence, injury-related costs, and intervention costs, comparing the EPS to the manual lift stretcher.

Equipment and Injury costs

Stretcher cost. Stryker EMS and the Tucson Fire Department (TFD) provided cost data for the stretchers. The 2013 list prices for two popular models of manual lift stretchers, the Stryker MX Pro (model 6082) and the Performance Pro (model 6086) are $5,474 and $6,997, respectively; while the EPS, Stryker Power Pro XT (model 6506), has a list price of $15,059 (Espinoza, 2013). The stretchers have an expected service life of five years for the MX Pro and seven years for both the Performance Pro and the Power Pro XT (Stryker EMS, 2011). In the model, the equipment and maintenance costs for the MX Pro were multiplied by 7/5 to estimate the equipment costs over a seven year service life. The maintenance costs for the manual lift stretcher are estimated by TFD to be $75 per year in parts and 2 hours/month at $60/hour for labor ($120 labor/stretcher/month) for a total of $1,515 per year per stretcher. For the EPS, Stryker offers a maintenance contract which costs approximately $3,500 per stretcher and covers all parts, labor and travel, as well as two preventive maintenance checks per year for the entire seven year service life (Espinoza, 2013). The Tucson Fire Department (TFD) employs approximately 650 ESE and maintains 22 stretchers, a ratio of nearly 30 ESE per stretcher. The EMS departments profiled in the case studies provided by Stryker EMS (Stryker EMS, 2013) maintained one stretcher for 5-21 ESEs. For the model, a ratio of 10 ESEs per stretcher was used to present the equipment costs per employee of an EMS department, and a ratio of 30 ESE per stretcher was used to present results per fire department ESE. These ratios were tested in a sensitivity analysis using values ranging from 5 to 15 ESE per stretcher for EMS and 20 to 40 ESE per stretcher for fire departments (Table 1).

Injury claims costs. The direct costs of injury to a fire department typically include workers' compensation insurance premiums, wage replacement and uninsured medical expenses. The indirect costs of injuries include backfill costs, administrative and investigations costs, and the training of injured and/or replacement workers. Previous research has found that the department direct and indirect costs are approximately equal to the total workers' compensation claims paid (Pena et al., manuscript in draft). In other industries, indirect costs have been estimated to be 0.75 to 4 times the firm's direct cost of injury (Oxenburgh, 1997; Huang et al., 2009; Sun et al., 2006) and 2 to four times the workers' compensation costs (Snook and Webster, 1987; Snook, 1988). For the model, the point estimate of department costs is equal to the claims cost; this value was be tested over a range of 0.5 to 3 in the sensitivity analysis. The model therefore estimates both the insured losses using workers'compensation claims and the direct and indirect costs borne by the department.

For the period 2004-2012, the mean workers' compensation claim paid by the TFD insurance provider was $4,063 (s.d.=$12,931) with an inter-quartile range (IQR, 25-75th percentile) of $217-$1,878 in total (medical and indemnity) costs. Back injury claims had a mean cost of $3,403 (s.d.=$16,042) with an IQR of $246-$1,869. Of the nearly 1,200 claims paid at TFD over this time period, the most costly was a back injury with a total medical and indemnity cost of $235,595 (unpublished data). Evaluation of workers' compensation claims at Northwest Fire Department (NWFD, Tucson, AZ) revealed the average claims costs to be $4,776 for all injuries, $277 for back injuries with only medical costs and $4,948 for back injuries with indemnity (Pena et al., manuscript in draft). The most costly claim paid at NWFD during the six year study period was for a back injury, with a total cost of $349,243. In a study of compensable injury in the fire service, Walton et al. (2003) found the mean workers' compensation claims cost for injury was $7,531; over-exertion injuries had a mean claims cost of $14,156. In a study evaluating the effects of a wellness intervention in a cohort of firefighters, Leffer and Grizzel (2010) estimated the mean cost of workers' compensation claims in one department to be $14,394. In an analysis of data from a national insurance provider, Webster and Snook (1990) estimated the mean workers' compensation claims cost for low back pain at $14,542. Patient-handling claims in Washington State rural hospitals averaged $5,723 to $9,545 over a six year study period (Charney et al., 2006). In an analysis of workers' compensation costs for musculoskeletal injuries related to patient lifting by health care workers, Lipscomb et al. (2012) determined the mean claims cost to be $5,366. The model point estimate for the cost of injury claims was $4,000 with a range of $250-$250,000, based primarily on claims data from TFD and NW Fire (Table 1).

Injury Transition Probabilities. The model includes two health states, "working" and "not working." Injury is treated as an event, rather than a health state, due to the challenge of modeling the highly skewed length of impairment from back injury (Pengel et al., 2003). The theoretical cohort began the simulation injury free, in the working health state. The transition probability to injury was derived primarily from the study by Studnek et al. (2012), which compared injury rates pre- and post-implementation of EPS in one urban EMS department. Using the manual lift stretcher, the department had an overall injury rate per 100 full-time employees (FTE) of 61.1; rates of neck and back injury between 12.7 and 18.2; and a sprain/strain injury rate of 22.6 (Table 2). Following the implementation of the EPS, the overall injury rate fell to 28.8 per 100 FTE, and the rates of neck/shoulder/back/knee, neck/back, sprains/strains fell to 8.9, 5.1 and 9.6, respectively. The greatest change in injury rate occurred in the category of injuries caused by stretcher lifting or lowering, which had a pre-intervention rate of 6.6 and a post-intervention rate of 2.0 (Studnek et al., 2012). Rates were transformed to annual probabilities using the formula, $p=1-e^{-rt}$ (Fleurence and Hollenbeak, 2007) and ranged from 0.06 to 0.46 for the manual lift stretcher and 0.02-0.25 for the EPS. The pre-intervention overall injury rate of 61.09 per 100 FTE found by Studnek et al. (2012) is high compared to other studies of injury among ESE. In a descriptive study of firefighter injury at TFD from 2004-2009, Poplin et al. (2012) found an overall annual injury rate of 17.7 per 100 FTE and a back sprain/strain rate of 3.9 per 100 FTE. Schwartz et al. (1993)

reported a back injury prevalence rate of 24.8 per 100 FTE among EMTs in New England. Maguire et al. (2005) reported annual rates of 34.6 and 9.5 per 100 full time workers for overall injury and back injury among EMS personnel. For the model, the transition probability to injury was estimated to be 0.2 (0.1-0.5) for the manual lift stretcher and 0.1 (0.05-0.25) for the EPS. These rates, and the resulting transition probabilities, conform well to studies of patient lift interventions in healthcare (Evanoff et al., 2003; Collins, et al., 2004; Li et al, 2004; Charney et al., 2006; Burdorf et al., 2006; Burdorf et al., 2013).

Disability transition probability and costs. The “not working” health state (“disabled” or “disability”) is meant to capture transition out of the working health state related to injury, either as one severe and permanently disabling injury or the cumulative effect of several injuries. Soteriades et al. (2008), defined job disability as any change in employment status, whether caused by injury, employment termination or removal from active duty, premature retirement, illness or line-of-duty death. Of the 358 subjects enrolled in their 6-year study of obesity and job disability in male firefighters, “76 firefighters (23%) experienced a job disability event resulting in lost time” (Soteriades et al., 2008). Permanent disability retirement was awarded in 16 (5%) of the cases, though the authors are not explicit about what types of disability events resulted in permanent disability. A Tucson-based occupational health provider serving southern Arizona ESEs estimates that about one in 1,000 ESE in his patient population leave the service due to a disabling back injury each year (Peate, 2013). In the model, the point estimate for the probability of disabling back injury is 0.001 tested over the range, 0.0005-0.005, in the sensitivity analysis. For members of the cohort who experience greater than one back injury, the transition probability increases to 0.01, a figure based on a study of workers in nursing homes and elderly care facilities that used a Markov model to predict the course of low back pain, sickness absence and disability over a 40-year working life (Burdorf and Jansen, 2006). The transition from sickness absence to permanent disability, defined as sickness absence greater than 365 days due to low back pain, was based on the level of physical load encountered by the worker, and ranged between 0.014 and 0.007, with a point estimate of 0.01 (Burdorf and Jansen, 2006). Not working is the absorbing health state of the model, meaning once a member of the cohort enters this health state they remain there and cannot accrue further injury. The model does not attempt to explicitly estimate the cost of disability; rather, the point estimate and range of the claims cost for transition to the "not working" health state is equivalent to the cost of injury claims ($4,000 with a range of $250-250,000).

Simulations, sensitivity analysis, discounting and adjustment. The model was developed using TreeAge Pro 2013 (Treeage Software, Inc,. Williamstown, MA). The model was analyzed as a microsimulation using tracker variables to count back injury and disability (transitions to the not working health state) over a seven year period, which represents the expected service life of the equipment. The simulation was repeated 5,000 times; each simulation resulted in a mean and distribution of cost and number of injuries and disabilities, comparing the manual lift stretcher to the EPS. One-way sensitivity analysis was conducted on the model's parameters including transition probabilities, costs associated with injury and disability, the department cost multiplier, and the ratio of personnel to stretcher (Table 1). Beginning in year two of the simulation, costs and injury/disability counts were discounted at a rate of 3% per year (Gold et al., 1996). The discount rate was also tested over a range, from 1-10%, to test the model's sensitivity to this variable. Discounting is a means of reducing the value of costs, savings and consequences (in this case, injury) that occur over time, as the perceived value of money and other benefits is diminished by waiting (Frick et al., 2004). All costs are presented in June 2013, U.S. dollars.

RESULTS

The results of the simulations are summarized in Table 3. The two models of manual lift stretcher were comparable in cost and therefore had similar results; only results for the Performance Pro are provided. The hypothesis was that the cohort using the EPS would experience fewer injuries and incur lower costs compared to those using the manual lift stretcher. These results show an average savings of $4,617 per EMS employee and $5,422 per fire department ESE over a 7 year period, comparing the EPS group to the manual lift stretcher group. The number of injuries averaged 1.4 per ESE for the manual lift stretcher and 0.67 for the EPS. These values translate to an approximate annual injury rate of 19.7 and 9.6 per 100 FTE, which is similar to the rates reported in previous studies (Schwartz et al., 1993; Maguire et al., 2005; Poplin et al., 2012; Studnek et al., 2012). In 54% of simulations the EPS is the optimal strategy. The distribution of simulation results is plotted in Figures 2 and 3.

Results of the one-way sensitivity analyses are shown in Figure 4 and Table 4. Using the point estimates described in Table 1, the model estimates an expected cost savings of $4,617-$5,422 ESE over the 7-year period, comparing those using the EPS to those with manual lift stretchers. The tornado diagram shows graphically how the range of values for the selected variables would affect that expected cost savings in one-way sensitivity analyses. Wide bars, such as those found for the cost of injury claims, indicate that variable has a large effect on the expected cost savings. The estimates of cost savings using the low and high values are presented in Table 4. The EPS is the dominant strategy in all scenarios except when the EPS transition probability for injury exceeds 0.198 or the manual lift stretchers transition probability is less than 0.102 (Figure 5).

DISCUSSION

A Markov model was used to estimate the effect of a patient lifting device on back injury incidence and associated costs among ESEs. The results of this analysis indicate the EPS reduces the number of injuries and the associated workers' compensation and departmental costs, compared to manual lift stretchers. An EMS department with 500 employees and 50 EPS (10 ESE per stretcher) could expect a savings of $2,308,500 in workers' compensation claims and department costs over the service life of the equipment, nearly 2.5 times the capital investment of $927,950 required to purchase the equipment. Similarly, a fire department with 500 employees and 17 EPS (30 ESE per stretcher) could expect savings of $2,711,000, 8.6 times the equipment cost of $315,503. The results of these simulations conform to previous studies. Burdorff et al. (2013) used a Markov decision model to estimate the effect of patient lifting devices in healthcare settings and found that the complete restriction of patient lifting led to a predicted reduction in low back pain incidence from 41.9% to 31.4% and claims for musculoskeletal disorder from 5.8 to 4.3 per 100 work-years. A cost/benefit analysis of the Antboxx lift assist device was conducted as part of a larger evaluation of musculoskeletal injury prevention interventions for paramedics by the Workers' Compensation Board (WCB) of British Columbia (2001). The device was an after-market lift assist that was compatible with the Ferno stretchers and is no longer available. However, at the time, the WCB estimated that a 17% reduction in back injuries the first year would be required to break even on the $400,000 needed to retrofit 200 stretchers. With an average cost per back injury of $6,000 (Canadian) and over 400 back injuries per year, the province estimated that a reduction of 68 back injuries in the first year would be needed to recover the equipment investment costs.

The model does not account for the cumulative effect of repeated back injury, and the possible influence this has on a worker's ability or desire to remain in emergency services employment. Soteriades et al. (2008) defined job disability as any change in employment status, including employment termination or removal from active duty and premature retirement. The literature on the frequency of back injury disability among ESEs, or career changes to reduce injury risk in this population, is sparse; however, research in healthcare has revealed that chronic back pain causes an estimated 12 to 18% of nurses to leave the profession annually, while another 12% will consider a job transfer to reduce their injury risk (Owen, 1989; Moses, 1992). To mitigate their injury risk, an ESE who has suffered repeated back injury may attempt to promote out of field jobs, seek employment out of emergency services, or retire earlier than expected. A survey by the International Association of Fire Fighters (IAFF) found that approximately 8% of retirements are due to back injury (IAFF, 2000); however, the report does not describe the demographics of the survey population and may not be generalizable to all working ESEs. In addition, the current study does not attempt to monetize permanent back injury disability, the extremely high cost of a severe and disabling injury would have likely driven the model results toward the EPS even if the probability of such an injury is very low. The EPS is cost-effective compared to the manual lift stretcher even when the point estimate ($4,000) and range ($250-250,000) of the claims cost for transition to the "not working" health state is the same as the cost of injury claims. There is evidence in the literature that recurrent back injury claims are costlier than claims for incident injury with an average cost of $7,838-$11,540 per claim (Wasiak et al., 2006) and workers' compensation claims costs are typically skewed, with means above the median and typically "a few claims account for most of the costs" (Webster and Snook, 1990). Prevention of only one disabling, and extremely costly, back injury claim at a department would only strengthen the case for the EPS. Department costs were estimated using a multiplier of claims costs. A potential limitation of this approach is that higher cost claims may actually have lower associated indirect costs, as a percentage of total costs, than lower cost claims (Manuele, 2011). More research is needed to better estimate indirect costs of injury in the fire and emergency medical services.

One of the challenges presented by this study is that it is difficult, if not impossible, to estimate what portion of injuries the EPS would potentially prevent. It is difficult to separate the injury and back injury risks presented by patient transport job tasks, especially when refined to just the risk associated with the stretcher. Gershon et al. (1995) retrospectively reviewed medical records data for injuries and exposures to EMS workers in Baltimore, MD over a one year period and found that 42% of injuries were sprains/strains and that 20% were back injuries: "most incidents were caused by stretchers mishaps, especially during transport of heavy patients." Sixty percent of injuries "were related to handling of stretchers, with specific causes identified that included: patient moved suddenly (24%), partner shifted suddenly (9%), awkward positioning of stretcher (12%) and obese patient (14%)." In their evaluation of EPS in an urban EMS department, Studnek et al. (2012) analyzed injury surveillance and claims data and found 151 out of a total of 1,478 injuries (10.2%) could be categorized as a "stretcher injury," using the reported cause of stretcher lifting or lowering. Jahnke et al. (2012) found that dislocation, strains and sprains represented 76% of injuries, as self-reported by a random sample of 462 firefighters. There were 111 injuries reported by this study population, of which 12.6% occurred while "lifting people" on scene of a non-fire emergency and an additional 1.8% resulted from lifting people during training, though it was not specified if the lifts involved the use of a stretcher or other device. Poplin et al. (2012) analyzed injury at TFD and found 195 sprain/strain injuries occurred over the six year study period. Of the 152 injuries that occurred during patient transport, 116 (76.3%) were sprain/strain and for 103 (37.8%) the MOI was acute overexertion.

One limitation of the current study is exclusion of potential confounders from the model, including professional classification, age, gender, fitness level, obesity and previous injury, for which there was a lack of suitable epidemiological evidence necessary to refine transition probabilities beyond those identified for injury and disability. Differences between EMTs, paramedics and firefighters were not explicitly explored in the current study. Previous studies have shown differences in back injury frequency comparing EMTs to paramedics (Hogya and Ellis, 1990; Brown et al., 2002); comparing paid providers to volunteers (Heick et al., 2009); and comparing different ranks of firefighters (Poplin et al., 2012). Age has been identified as a possible confounder in the causal pathway between workplace risk factors and back injury. There is evidence that younger ESEs are at higher risk for injury (Hogya and Ellis, 1990;

Nuwayhid, 1993; Maguire et al., 2005; Poplin et al., 2012). The age distributions for ESEs in previous studies reveals that nearly 60% are under age 40 (Maguire et al., 2005; Heick et al., 2009; Reichard and Jackson, 2010; Kuehl et al., 2012). Older and more experienced firefighters and paramedics have been found to experience more pain that affected their ability to work (Beaton et al., 1996). It has been acknowledged that the aging of the nursing workforce adds to the injury risk presented by patient transport, due in part to a decline in strength that occurs by age 40 and worsens as the person approaches age 50 (Fragala and Bailey, 2003). In addition to being a possible confounder between risk factors and back injury, age may also affect the cost of injury: Lipscomb et al. (2012) found that mean claims costs were 5 times higher for workers over age 45 years compared to those of less than 25 years of age. Another possible confounder is gender, with some evidence of female ESEs at higher risk for back injury (Hogya and Ellis, 1990; Studnek et al., 2007; Studnek et al., 2010). The percent female in ESE study populations varies widely from 3% (Beaton et al., 1996) to over 41% (Maguire et al., 2005). Generally, studies of ESEs in the fire service have found a smaller percentage of female employees, from 3-9% (Beaton et al., 1996; Reichard and Jackson, 2010; Leffer and Grizzell, 2010; Poplin et al., 2012), compared to EMS departments, which typically have 30% or more female ESEs (Schwartz et al., 1993; Gershon et al., 1995; Brown et al., 2002; Maguire et al., 2005; Heick et al., 2009; Reichard and Jackson, 2010).

Lower levels of fitness and higher BMI have been associated with increased risk of injury (Poplin et al., 2014) and job disability (Soteriades et al., 2008) among firefighters. While there is evidence in the literature that previous back pain and injury is associated with recurrent back injury and disability (Hogya and Ellis, 1990; Schwartz et al., 1993; Crook et al., 2002; Studnek et al., 2007; Heick et al., 2009), we took a conservative approach with this model and assumed the cohort started the simulation having never suffered a back injury. Back pain and injury among healthcare workers and ESEs who transport patients has been the subject of many previous studies. In a cross-sectional survey of EMTs in New England, Schwartz et al. (1993) found that 10% of study participants reported suffering a back injury during the six-month study period. Brown et al. (2002) found that 16.1% of EMT basics and 27.4% of EMT paramedics reported having back problems within the year prior to completing the study survey. Using a cross-sectional survey of EMS providers, Heick et al. (2009) found that 13.9% of paid EMS providers reported acute back injury during the 12-month reporting period. Maguire et al. (2005) examined back injury in two urban EMS departments and found the back injury rate to be 9.5 per 100 FTE. However, not all injuries rise to the level of a claim, the case definition for the current study. Jahnke et al. (2012) asked firefighters to self-report injuries in the previous 12 months: 66% reported their injuries via departmental report of injury, while only 37% reported to workers' compensation. The benefit of incorporating claims costs into a study is that injury claims provide an insight into both frequency and severity (Lipscomb et al., 2012), but minor injuries that are only internally reported will not appear. These injuries have indirect costs to the department and may be an important predictor of future, and more severe, injuries.

Measures of exposure and risk, 'call volume' and 'patient transport frequency,' were not included in the model. Previous research has shown that 75% of dispatches in a Washington state fire department (Beaton et al., 1996) and 85% of dispatches in an Arizona all-hazards fire department were medical emergencies (Poplin et al., 2012);

however, patient transport job task frequency and type varies markedly among fire departments. Some fire department ESEs never or rarely transport patients, others do some of the tasks, such as preparing the patient for movement and assisting the ambulance companies in loading the patient on the ambulance, and others do all patient transport tasks. It is reasonable to expect that many dispatches in an EMS department would involve patient transport, but it is not possible at this time to characterize the frequency and type of patient transport activities across all emergency services departments. Call volume is frequently used as a covariate in models of injury among ESEs (Studnek et al., 2007; Heick et al., 2009), though call volume is not a perfect proxy for strenuous work activity (Studnek et al., 2010). The transition probabilities for the current model were derived from a study of an urban EMS department with a reported call volume of over 2,100 calls per week (Studnek et al., 2012).

Training costs for the manual lift stretchers are not included in the model. It is assumed that for most departments, training on the manual lift stretcher occurs as part of the routine training process for new hires, and little or no additional training would be required for an ESE once they are working in the field. There are several training options offered by Stryker EMS with the purchase of the EPS: in-person training with all ambulance crews; a train-the-trainer approach utilizing department personnel; and a free training DVD. The in-person training is the more costly from the department's perspective because crews need to come out of service and may need to travel to the training location; however, it was not possible to reliably estimate these costs for inclusion in this model. In addition, the results of the current study may not be generalizable to departments currently using stretchers from a different manufacturer.

The two leading manufacturers of stretchers in the United States are Ferno-Washington (Wilmington, Ohio) and Stryker EMS (Kalamazoo, Michigan) but other equipment is available (Wang et al., 2009). In addition, there may be an economy of scale issue that is not dealt with in this paper, where larger departments can afford an intervention like the EPS that is simply not within reach for a smaller department.

While the results of the current study suggest that the EPS is an effective and cost-effective means of reducing the burden of back injury among emergency services personnel, this device is certainly not a panacea for all patient-transport injuries in this population. There are many other hazards faced by ESEs related to patient transport, including lateral transfer and the movement of patients on stairs (Conrad et al., 2000; Lavender et al., 2000). Heick et al. (2009) described three components of effective back injury prevention programs in healthcare, including mechanical lifts, lift teams and zero-lift policies. The authors note, however, “because of cumbersome equipment, personnel limitations and the diverse nature of the EMS work environment, these interventions are not feasible for prevention of back injury in EMS” (Heick et al., 2009). There is recognition in the back injury prevention literature as it pertains to healthcare workers that simply introducing a device into the workplace is inadequate. It has been noted in studies of nurses that injury associated with patient transport activities not addressed by a particular intervention (such as ceiling lifts) do not change or change less than the injuries targeted by a given intervention (Chhokar et al., 2005; Collins et al., 2004). In addition, improvements in training might improve injury outcomes for ESEs. As noted by Wang et al. (2009), possible training improvements to the Emergency Medical Technician Basic National Training curriculum (U.S. Department of Transportation, 1995) might include the movement of morbidly obese patients and the ergonomics of lifting patients. Further, beyond the introduction of patient transport interventions and training improvements, a shift in individual beliefs and organizational culture, especially the expectation and acceptance of the inevitability of injury, has to be part of the overall strategy to reduce and eliminate injury among ESE. The importance of addressing individual beliefs about injury and shifting workplace culture has been noted in healthcare (Koppelaar et al., 2009; Lipscomb et al., 2012), where nurses were historically socialized to expect and accept back injuries resulting from the care of patients (Kneafsey, 2000). Risk assessment and simultaneous top-down and bottom-up approaches were used to successfully embed an ergonomics intervention into a hospital's culture and structure (Hignett, 2001; Hignett, 2003), approaches that may also prove useful in emergency services.

CONCLUSION

The EPS is likely a cost-effective intervention for the reduction of patient transport back injuries among emergency services employees and the associated workers' compensation and department costs. The results of this study need to be validated with a long-term evaluation of back injury following implementation of the EPS, preferably at several departments.

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Table 1. Model parameters.

	Point estimate (low, high)	Data source
Costs		
Manual – purchase ($)		
MX Pro	5,474	Stryker EMS
Performance Pro	6,997	
Manual – maintenance ($)	1,515/year	TFD
EPS – purchase ($)	15,059	Stryker EMS
EPS – maintenance contract	3,500	Stryker EMS
Injury and Disability – Claims	4,000 (250, 250000)	TFD claims data; Pena et al., manuscript in draft; Leffer and Grizzell., 2010, Walton et al., 2003, Lipscomb et al., 2012
Department costs	1*claims costs (0.5, 3)	Pena et al., manuscript in draft; Huang et al., 2009; Oxenburgh, 1997; Sun et al., 2006
Ratio of ESE:stretcher		TFD, Stryker EMS
EMS department	10:1 (5:1, 15:1)	
Fire Department	30:1 (20:1, 40:1)	
Injury & Disability Probabilities		
In "Working" health state		
Manual Lift – Injury	0.2 (0.1, 0.5)	Studnek et al., 2012
EPS – Injury	0.1 (0.05, 0.25)	
To "not working" health state	0.001 (0.0005, 0.005) with no prior injury; 0.01 for >1 injuries;	Burdorf and Jansen, 2006; IAFF, 2000; Peate, 2013

Table 2. Derivation of transition probabilities for injury (Studnek et al., 2012)

	Annual rate, per 100 FTE		**Annual rate, per FTE**		**Transition probability**	
	pre-EPS	post-EPS	pre/100	post/100	Manual lift	EPS
All injuries	61.1	28.8	0.61	0.29	0.46	0.25
Sprains/strains	22.6	9.6	0.23	0.10	0.20	0.09
Neck/shoulder/back/knees	18.2	8.9	0.18	0.09	0.17	0.09
Neck/back	12.7	5.1	0.13	0.05	0.12	0.05
Stretcher lifting/lowering reported as cause	6.6	2.0	0.07	0.02	0.06	0.02

Table 3. Simulation results. Mean and standard deviation, number of injuries, disabilities and total costs over 7 years, per ESE.

	Manual Lift Stretcher			*EPS*		
	Injuries n (sd)	**Disability n (sd)**	**Cost $ (sd)**	**Injuries n (sd)**	**Disability n (sd)**	**Cost $ (sd)**
EMS Department (10 ESE/stretcher)						
Mean	**1.40 (1.1)**	**0.014 (0.12)**	**12009 (8945)**	**0.68 (0.78)**	**0.007 (0.08)**	**7392 (6258)**
Minimum	0	0	782	0	0	1856
2.5 percentile	0	0	782	0	0	1856
Median	0.98	0	8806	0.82	0	8521
97.5 percentile	3.73	0	30601	2.70	0	23470
Maximum	7.24	1	58734	4.43	1	52738
Fire Department (30 ESE/stretcher)						
Mean	**1.39 (1.1)**	**0.014 (0.12)**	**11400 (8956)**	**0.67 (0.78)**	**0.007 (0.08)**	**5978 (6217)**
Minimum	0	0	261	0	0	619
2.5 percentile	0	0	261	0	0	619
Median	0.97	0	8046	0.83	0	7235
97.5 percentile	3.77	0	30402	2.68	0	22098
Maximum	8.15	1	65462	5.54	1	44906

Note: n = mean number of injuries/disabilities per ESE; $ = mean cost per ESE

Table 4. Results of sensitivity analysis/tornado diagram, in order of uncertainty.

Variable	**Range**	**Low**	**High**	**Spread**	**Risk %**	**Cum. Risk %**
Cost of injury claims	$250 – 250,000	-333,876.9	-1,519.1	332,357.8	0.9989	0.9989
Department cost multiplier	0.5-3.0	-12,515.5	-5,853.2	6,662.2	0.0004	0.9993
Manual Lift – Injury transition prob.	0.1-0.5	-7,185.7	-782.0	6,403.7	0.0004	0.9997
EPS – Injury transition prob.	0.05-0.25	-7,185.7	-1,855.9	5,329.8	0.0003	0.9999
Number of personnel/EPS*	5-15	-9,041.6	-6,567.1	2,474.5	0.0001	1.0000
Discount rate	1-10%	-7,551.8	-6,173.3	1,378.5	0.0000	1.0000
Cost of disability claims	$250-250,000	-8,276.5	-7,169.1	1,107.5	0.0000	1.0000
Disability transition prob.	0.0005-0.005	-7,185.7	-7,168.1	17.6	0.0000	1.0000

Note: Risk % - a measure of total uncertainty represented by the variable, sums to 1. Cum. Risk % - a cumulative version of Risk %.
**Results for fire departments (20-40 ESE/stretcher) were similar to those presented here for EMS. Low = 6258; High = 5794; Spread = 464; Risk % = 0*

Figure 1a. The Markov simulation used to evaluate injury incidence and associated costs, comparing the manual lift stretcher to the EPS. The theoretical cohort begins in the 'working' health state and may transition to the 'not working' health state based on the probabilities presented in Table 1.

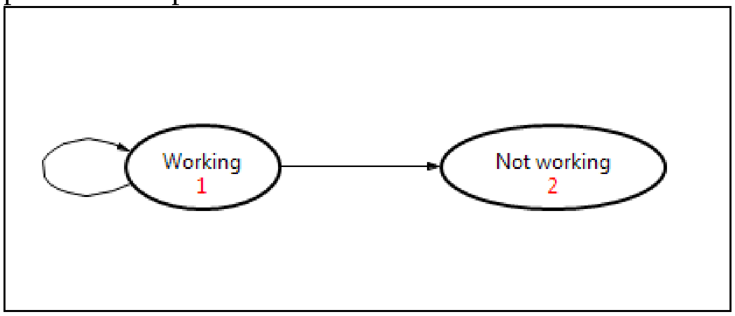
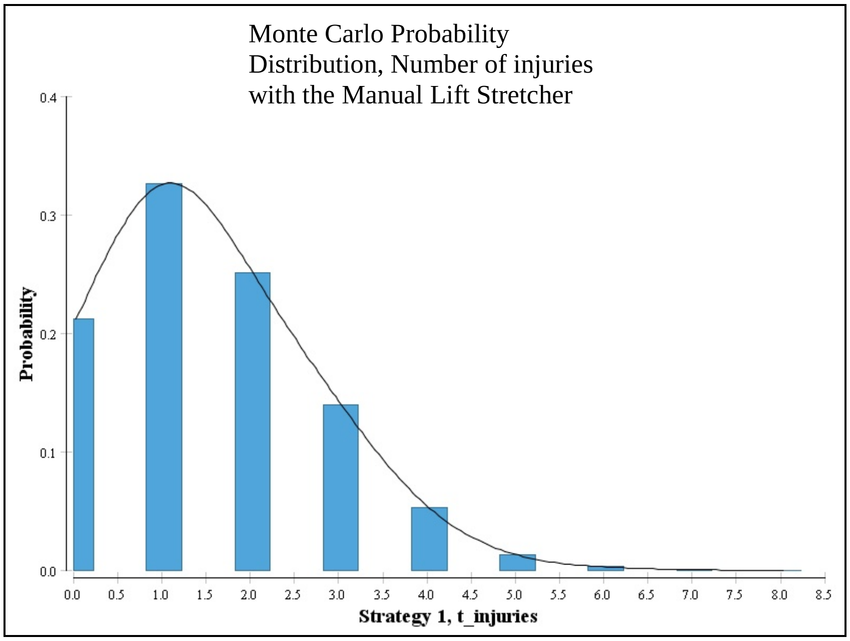


Figure 2. Distribution of number of injuries, manual lift stretcher and EPS. These figures show how the probability of suffering >4 injuries is higher with the manual lift stretcher than with the EPS.



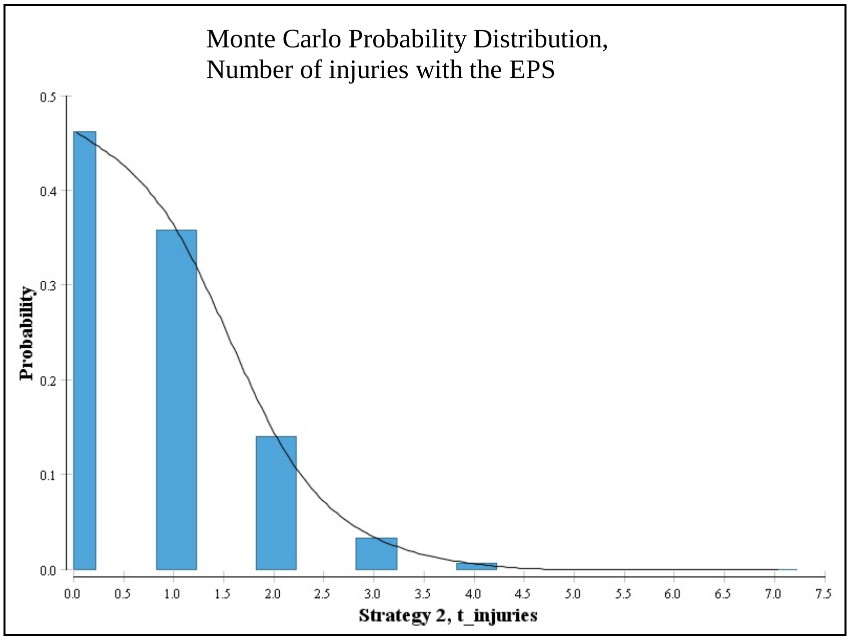
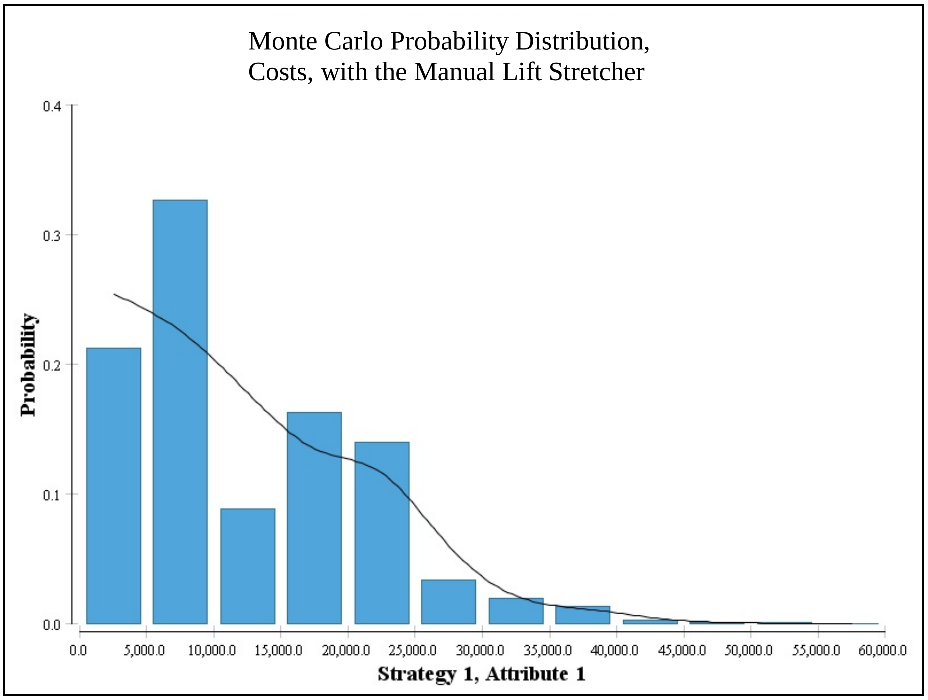


Figure 3. Distribution of costs, manual lift stretcher and EPS. These figures show that the manual lift stretcher leads to a greater probability of higher costs per ESE.



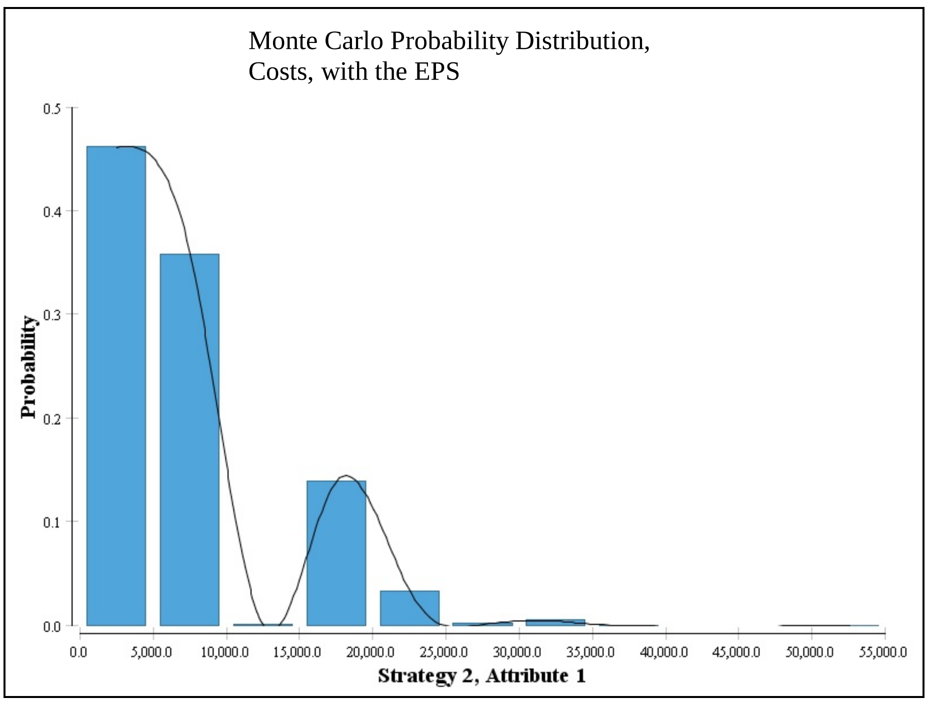


Figure 4. Tornado diagram of the one-way sensitivity analyses on the expected change in costs, comparing the EPS to the ML.

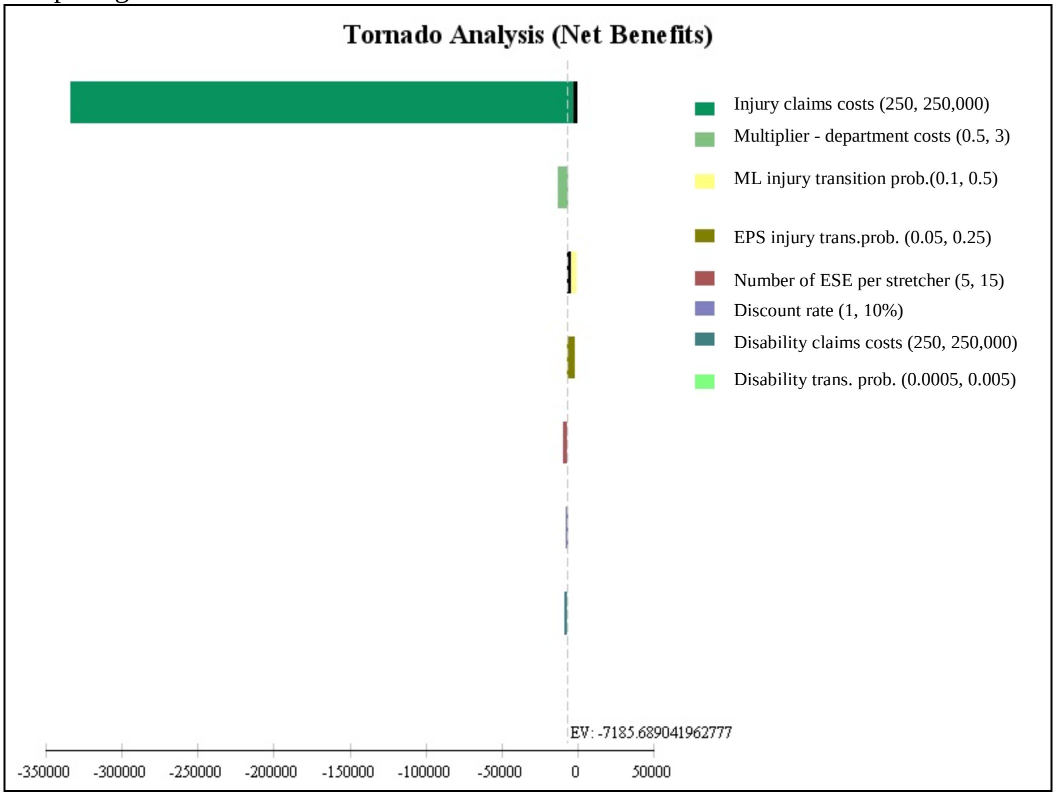


Figure 5. Two-way sensitivity analysis of transition probabilities for injury with manual lift stretcher and EPS. The red area represents the values of the transition probability for injury with the manual lift stretcher that make that device cost-effective compared to the EPS. Likewise, the blue area shows the values for the transition probability for injury using the EPS that make that device cost-effective compared to the manual lift stretcher.