DISSERTATION

PATTERNS OF INJURY AMONG RESIDENTIAL CONSTRUCTION WORKERS BEFORE AND AFTER A SAFETY INTERVENTION PROGRAM, 1994 – 1998

Submitted by

Amy Rowntree Darragh

Department of Environmental Health

In partial fulfillment of the requirements

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Bell & Howell Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY AMY ROWNTREE DARRAGH ENTITLED, PATTERNS OF INJURY AMONG RESIDENTIAL CONSTRUCTION WORKERS BEFORE AND AFTER A SAFETY INTERVENTION PROGRAM, 1994 – 1998, BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

Committee on Graduate Work

Advisor

Co-Advisor

Department Head

ABSTRACT OF DISSERTATION

PATTERNS OF INJURY AMONG RESIDENTIAL CONSTRUCTION WORKERS BEFORE AND AFTER A SAFETY INTERVENTION PROGRAM, 1994 – 1998

This study served two purposes. It evaluated the effectiveness of the HomeSafe Pilot Program, a collaborative safety education and training program designed to reduce injuries among residential construction workers in the Denver-Metropolitan region in Colorado. In addition, the study described the patterns and characteristics of injuries among residential construction workers before and after the intervention program.

Participating companies provided OSHA 200 logs, first reports of injury, workers' compensation loss runs, and total hours worked for each year of the study. Data from these sources were used to evaluate whether overall and lost workday injury incidence rates declined during the intervention period. Data were analyzed using injury incidence rates per 200,000 hours and Poisson regression to control for the effect of antecedent secular trend. Companies representing approximately 11,810 workers reported 1,971 injuries. The rate of injury pre-HomeSafe was 17.4/200,000 hours and the rate post-HomeSafe was 14.4. Lost workday injury rates were 5.8 pre-HomeSafe and 3.4 post-HomeSafe. Injury incidence rates declined significantly following the HomeSafe; however, this effect was not statistically significant once temporal variation was controlled.

The Poisson regression model did, however, indicate positive effects of HomeSafe among specific trade groups, especially among severe injuries.

The leading causes of injuries were cuts, punctures and scrapes, falls, and lifting or other movement injuries. The leading types of injury were strains, lacerations, contusions, punctures, foreign bodies, and sprains, and the body parts most commonly injured were the lower back, hand/wrist, ankle/foot, finger, leg/knee, arm/elbow, and eye. Trade specific analysis revealed distinct differences in the causes and types of injuries experienced by the different trade groups.

The decline in injury rates following HomeSafe cannot be solely attributed to HomeSafe, however, it is likely that the program had an effect on injury rates, especially among specific trade groups. Programmatic and methodologic limitations were potential contributors to the inconclusive results and further research into the hazards, risk perceptions, and behaviors of residential construction workers is needed. Characteristics of injuries experienced by HomeSafe participants are consistent with those identified by prior research, though further investigation of the specific hazards faced by residential construction workers is warranted.

Amy Rowntree Darragh
Department of Environmental Health
Colorado State University
Fort Collins, CO 80523
Spring, 2001

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PREFACE

The following is a series of papers investigating the effectiveness of a construction safety intervention program, the HomeSafe Pilot Program, through the application of epidemiological methods and describing the injury patterns and characteristics among residential construction workers in the Denver Metropolitan Area. The first paper describes the overall patterns of injury among the HomeSafe participants and is the first step in determining the effectiveness of the HomeSafe Program. The paper presents a descriptive analysis of overall and severe injury rates pre- and post-HomeSafe, stratified by mechanism of injury, nature of injury, and body part injured. In addition, median cost of injury is evaluated for overall injuries, and then stratified by mechanism of injury, nature of injury, and body part injured. Injury rates and injury costs, both viewed as measures of severity, are compared for the period pre-HomeSafe, 1994 through the date of company compliance training in 1997, and post-HomeSafe, 1997 (post compliance training) through 1998. Annual time trends for overall and severe injuries are examined graphically to evaluate the effect of time versus HomeSafe on rate reduction. This paper also describes the injuries sustained by program participants in an effort to provide information about residential construction workers, an occupational group that is infrequently studied.

The second paper is a trade-specific analysis of overall and lost workday injury rates. Information about specific trade groups within the residential construction industry is scarce. The research that has been done has shown that the different trades face different hazards and experience injury differently. Overall and lost work day injury rates by trade are compared pre- and post-HomeSafe, and annual time trends among those trades for whom there is a significant decrease in rates following HomeSafe are examined graphically. The specific trades are then compared to each other to determine the causes and types of injuries and body parts injured associated with each trade group.

Finally, the third paper uses a Poisson regression model to evaluate HomeSafe effectiveness by controlling for annual trends. This approach determines whether the rate decreases experienced by the group as a whole and by individual trade groups are greater than would be expected given the effect of time. The focus of this paper is the effectiveness of HomeSafe, including potential explanations for the outcome.

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PATTERNS OF INJURY AMONG RESIDENTIAL CONSTRUCTION WORKERS

BEFORE AND AFTER A SAFETY INTERVENTION PROGRAM

INTRODUCTION

Occupational injury is a major threat to public health. In 1993, work-related injuries incurred an economic cost of $120 - $177 billion per year, with over 6.3 million on the job injuries and over 3 million resulting in lost work time[1]. In 1998, disabling injuries numbered 3.8 million and unintentional work related injuries cost $125 billion[2]. The construction industry typically has one of the highest fatal and non-fatal injury rates compared with other industries, and in 1994 had the third highest fatality rate by major industrial category at 15 per 100,000 full time workers[3]. The nonfatal injury rate for the same year was 11.5 per 100 full time workers, ranging from 9.5 (water well drilling) to 17.2 (roofing, siding and sheet metal work) per 100 full time workers.

These rates include both commercial and residential construction workers involved in all trades. Rates for residential construction workers in particular are more difficult to access. The Bureau of Labor Statistics (BLS) data are the primary sources of data on construction injuries but are reported by Standard Industrial Classification (SIC) code. SIC codes do not differentiate between residential trades and commercial trades, with the exception of residential builders (1521 and 1522). In the United States, the nonfatal injury incidence in 1995 among residential builders was 8.5 and among non-residential builders was 10.9 per 100 full time workers[4]. Construction trades, however, cannot be identified as specifically residential through BLS data, and must be identified through other means, generally by state level rather than national level data.

In a study of residential construction workers in North Carolina, Dement & Lipscomb (1999) examined workers' compensation claims provided by the North Carolina Homebuilders Association[5]. For 1994, they found an overall incidence rate for medical or lost time injuries among all trades of 10.97 per 200,000 person hours worked. The BLS reported a similar rate of 11.8 per 100 full time workers in both residential and commercial construction trades for the same year. According to the BLS, 200,000 hours is the equivalent of 100 full time workers, working 40 hours per week, 50 weeks per year[6]. The Department of Labor reported that, in 1996, 79.0% of employees working for small businesses (the majority of residential construction companies) worked a 40 hour week[7]. Dement & Lipscomb reported that, in 1992, North Carolina construction workers experienced an injury incidence rate of 11.7, residential construction workers experienced a rate of 13.1 and their sample experienced a rate of 14.5 per 200,000 person hours worked[5,8]. Lipscomb et al. (1995) also reported rates based on workers compensation claims among Washington State residential carpenters[9]. For those claims involving eight or more days away from work, the rate was 15.4 per 200,000 hours as opposed to a rate of 5.8 among North Carolina carpenters. Residential drywall workers in Washington State also had higher rates of lost work time injuries than their North Carolina counterparts (11.9 compared to 4.8, respectively).

The construction industry in Colorado has experienced tremendous growth in recent years, employing over 100,000 workers, to match an economy that grew from 1.6 million jobs in 1990 to over 2.1 million in 1996[10]. Unemployment in the State has been 4.2% or lower between 1994 and 1996[10]. The construction industry grew 10% between 1995 and 1996, from 93,000 to 111,000 workers[10]. The economic boom has stimulated the residential construction industry, with new privately owned housing units increasing from 39,700 units started in 1995 to 43,100 in 1997[11]. In addition, earnings in the Colorado construction industry increased from 4,508 million in 1994 to 6,655 million in 1998[12]. Residential construction workers represent a substantial portion of the construction industry labor force, experience unique risks in this industry, and are at similar risk of injury and death as compared to commercial construction workers, based on the limited data available[5,9,13].

Between 1980 and 1989, Colorado had one of the highest average annual construction fatality rates in the country at 28.5 per 100,000 workers[14,15]. In 1991, seven workers died in residential construction. Forty-three construction workers died between 1992 and 1993 and in 1997, Colorado had 25 construction industry fatalities[16, 14]. In a five year period (1994 - 1998), Colorado experienced a higher construction injury fatality rate than the national rate in three of those years (though the rate for 1997 was inflated secondary to a plane crash in which nine people died)[17]. In 1998, among all Colorado occupational fatalities, 26% occurred among construction workers[17]. From 1994 through 1998, 32 construction trade workers were killed and 31 construction laborers were killed.

Following the deaths of the seven workers in 1991, the Home Builder's Association of Metropolitan Denver (HBA) and the Occupational Safety and Health Administration, Region VIII (OSHA) began a collaborative effort to develop an intervention program to address the specific hazards and safety challenges faced by the residential construction industry.

Intervention programs and studies in the residential construction industry are difficult to implement and monitor, primarily because the industry is comprised of many small businesses, multi-employer work sites, temporary work sites, isolated work sites, and transitional or temporary employees[13]. However, because of the need to address the high rates of fatal and non-fatal injury among construction workers, and because the Code of Federal Regulations[18] outlines health and safety standards primarily designed for commercial construction workers, the HomeSafe Pilot Program was conceived, developed and implemented.

The HomeSafe Program

Conceived in 1992, the final product took four years to develop and was completed in 1996. The HBA and OSHA developed the HomeSafe Program based on available injury data in the field of residential construction and packaged it to be easy to understand and practical to use.

The HomeSafe Pilot Program consists of a three-hour safety training and program orientation class, the "Guide to Safe Work Practices for Home Builders: HomeSafe 10 Point List" booklet, and access to optional OSHA Training Institute-approved 10-hour Construction Courses, tailored to the particular needs of residential construction workers. In return for participation in the HomeSafe Program, companies received focused inspections on the contents of the ten points in the HomeSafe booklet from OSHA compliance officers, thus limiting citations for non-serious violations. In addition, if a HomeSafe company was cited, it was eligible to receive the maximum penalty reductions available.

Companies who chose to participate in HomeSafe paid a small membership fee, agreed to provide injury information (OSHA 200 logs, first reports of injury, worker's compensation loss runs, and total person hours worked per year) to the HBA, and agreed to on-site safety audits by the HBA safety and health committee audit team. This information was the basis for program evaluations. The HomeSafe Pilot Program is centered around a 10 Point Program developed to inform residential construction companies about common safety hazards and unsafe practices experienced on the jobsite. The ten topics covered are Company Safety Policy, Personal Protective Equipment (PPE), Scaffolding, Ladders, Construction Electrical Power & Power Cords, Access/Housekeeping, Open Holes and Unprotected Sides and Edges, Fall Protection, Excavations/Trenching, and Power Tools & Motorized Equipment. In addition to the three hour training, HomeSafe also provides written information to participating companies to reinforce the training and to hand out to employees (HomeSafe booklet, "Guide to Safe Work Practices for Home Builders: HomeSafe 10 point list"). The booklet specifically depicts residential construction workers and their everyday hazards in an attempt to increase perceived relevance among workers, and both textually and pictorially summarizes the safety standards and regulations with which they are associated. The HomeSafe booklet provides concise, simple guidelines for the safe use of equipment and correct types and uses of personal protective equipment. To meet the needs of Spanish speaking workers, the booklet is available in Spanish. Additionally, to meet the needs of workers with limited literacy, the booklet provides cartoon depictions of common hazards and solutions to augment the textual information. Finally, the booklet was designed to be small enough for a worker to place in a toolbox or in a pocket for easy reference. Examples of the 10 points include samples of company safety policies, descriptions of PPE, specifications for job-built scaffolding, correct use of ladders, electrical cord repair, guardrail specifications for use around open holes, correct use of slide guards on roofs, and proper use of guards on power tools. The HBA and OSHA expected that companies using this guide to develop safety programs would experience a decrease in workplace injury rates.

The primary purposes of this paper are to evaluate overall pre- and post-HomeSafe injury incidence rates, evaluate lost work day injuries pre- and post-HomeSafe, evaluate injury cost pre- and post-HomeSafe, and evaluate the injuries by mechanism and nature of injury and body part injured.

METHODS

Data Sources

Injury data, gathered from the OSHA 200 logs, the first reports of injury and the worker's compensation loss runs, were used to compare injury incidence rates pre- and post-HomeSafe. OSHA 200 logs provide information on each recordable injury, including date of injury, job title, workplace to which the employee is assigned, description of the injury, days away from work and days of restricted work activity. A recordable injury is one that results in death, loss of consciousness, days away from work, restricted work activity or job transfer, medical treatment beyond first aid, diagnosis by physician, fractured or cracked bone, or punctured eardrum[19]. Each employer is required to keep the annual log for five years. First reports of injury are filled out by the employer or physician to detail the mechanism and nature of the injury and the body part injured, as well as individual data such as age, gender, ethnicity, years of experience, and experience at this particular job. These reports are submitted to the workers' compensation carriers. The first reports of injury submitted by HomeSafe participants varied in origin, from physician forms to forms provided by the workers' compensation carriers. The forms are not standardized and do not all contain the same information. The workers compensation loss runs are annual reports of every injury reported to the compensation carrier, including medical and compensatory costs, mechanism and nature of injury, and body part injured. Some reports differentiate between medical and compensatory costs, others combine the information for total costs per injury. Pre-HomeSafe injuries include all injuries reported during the years 1994-1996. Injuries occurring before a company's HomeSafe compliance training in 1997 also were defined as pre-HomeSafe. Injuries occurring after the company's compliance training and all injuries in 1998 were defined as post-HomeSafe injuries. Compliance trainings occurred each month beginning in January, 1997. Therefore, some participating companies began implementing HomeSafe as early as February, 1997 while some did not begin until December, 1997. Though some companies participated in re-orientations and optional ten-hour courses, no records of the companies that attended the trainings were maintained and this could not be included in the analysis. Companies also submitted total person hours worked for each year of the study for use as denominator data.

Design

A longitudinal intervention study of a quasi-experimental design was implemented to identify and measure the effects of the HomeSafe program. The following outcome variables originally were proposed to measure the effect of HomeSafe: injury occurrence, injury severity, injury deaths, and cost of injury. Characteristics of the outcomes included the nature of injury, the mechanism of injury, and the body part injured. In the final analysis, deaths were not included because in the five years of data collection, only two fatalities were recorded. These fatalities occurred when two men were killed in a single car fire.

Definition of Terms

Injury: any harmful event caused by an interaction between a worker's body and a form of physical energy. Injuries included in this study are any and all injuries reported and documented on one or more of the three injury records we reviewed (200 logs, first reports of injury, workers compensation loss runs). Injuries were coded as: (1) injuries with medical and/or compensation costs, (2) injuries with lost work time, (3) injuries with both medical costs and lost work time, and (4) injuries with no medical costs or lost work time (some injuries are treated on the job site using first aid procedures, for example, bee stings).

Injury incidence rate: Injuries per 200,000 person-hours worked.

Lost work day injury: Measured according to the number of workdays lost. Workdays lost did not include the day of injury, even if the employee left work to seek treatment and did not return. Because investigators did not have access to information on paid versus non-paid lost workdays, all days away from work following the day of injury were included.

Nature of injury: The type of injury the individual received, for example, a contusion, fracture, or laceration.

Mechanism of injury: The cause of the injury, for example, a fall, a powered tool, or being struck by a falling object.

Body part injured: The part of the body sustaining damage.

Cost of injury: Cost of the injury, both medical and compensatory.

Participants

HomeSafe Program participants were construction workers employed in residential construction, primarily single family home building. All HomeSafe participants were members of the Home Builder's Association of Metropolitan Denver (HBA). Of approximately 360 companies enrolled in the HomeSafe program, 97 companies representing approximately 2397 workers and 13 trades submitted information to the HBA, and subsequently to researchers for analysis. Distribution of trades is presented in Table I.

Table I: Distribution of HomeSafe Partners by Trade

SIC	Trade	Distribution of trades among HomeSafe participants
0782	Landscaping	1
1521	Single Family Homebuilders	41
1711	Plumbing, Heating, Air Conditioning	4
1721	Painting and Paper Hanging	3
1731	Electrical Work	6
1741	Masonry and Other Stonework	2
1742	Plastering, Drywall, and Insulation	7
1751	Carpentry	11
1752	Floor laying and Floor Work	2
1761	Roofing, Siding, and Sheetmetal Work	7
1771	Concrete Work	4
1794	Excavation Work	3
1799	Special Trade Contractors	6

Instrument and Intervention

The HomeSafe Program and its "Guide to Safe Work Practices for Home Builders: HomeSafe – 10 Point List" were developed based on risk factors associated with construction safety violations and citations, injury incidence and severity, and construction related deaths. Participating companies received a three-hour orientation and training session on how to integrate the ten points into their current or developing safety programs. For those companies with no safety program in place, the booklet provided sample safety policy statements and resources for establishing a formal program. In addition, all companies received 'HomeSafe 10 Point List' booklets in Spanish and in English, hardhat stickers, and job posters. For all HomeSafe companies, OSHA ten hour courses that emphasized HomeSafe 10 Point core content were available, but not required.

Injury Incidence Rate Calculations

Annual crude incidence rates were calculated by year, 1994-1998, for participating HomeSafe companies. Pre- and post-HomeSafe incidence rates were calculated per 200,000 hours worked for the following types of injuries: 1) all injury cases, 2) cases with lost work time only, 3) cases with medical costs only, 4) cases with both medical costs and lost work time, and 5) cases with neither medical costs nor lost work time. Numerator data included all documented injuries and denominator data included the total hours worked reported by each company annually. The 95% confidence intervals were calculated for each rate with the formula,

$$c \pm 1.96 \times se(c)$$

where

c = incidence rate:

$$c = \frac{d}{N} \times 200{,}000 \textit{ person hours worked}$$

(d = number of injuries and N = total person hours worked) se(c) = standard error of c

$$se(c) = \frac{\sqrt{d}}{N} \times 200{,}000 \text{ person hours worked}$$

Incidence rates also were compared, using the following formula,

$$Z = \frac{c^A - c^B}{\sqrt{[se(c^A)]^2 + [se(c^B)]^2}}$$

where,

c^A = incidence rate for sample pre-HomeSafe

c^B = incidence rate for sample post-HomeSafe

$se(c^A)$ = standard error for sample pre-HomeSafe

$se(c^B)$ = standard error for sample post-HomeSafe

Incidence rates were calculated for mechanism of injury, nature of injury, and body part injured. These categories were defined by a limited version of the American Standard Method of Measuring and Recording Injury Experience of the American National Standards Institute, a system of codes used by two major compensation carriers representing HomeSafe participants[20].

Lost Work Day Injury

For the purposes of this paper, all injuries resulting in one or more days away from work were considered lost work day injuries (LWDI's), whether or not the lost time was paid or not paid. Lost workday injuries served as a surrogate for injury severity, in that an injury resulting in one or more days away from work was considered to be more severe than an injury resulting in no days away from work[5,21]. Lost workday injuries were evaluated categorically and continuously, and were stratified by mechanism, nature and body part injured.

Lost workday injury incidence rates were calculated and compared using the formulae presented above. Lost workday injuries also were categorized by number of days lost. The proportion of injuries in each category pre- and post-HomeSafe were compared using the following formula:

$$Z = \frac{p_1 - p_2}{\sqrt{\bar{p}\,\bar{q}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

where:

p_1 and p_2 = the observed proportion of the pre-HomeSafe and post-HomeSafe samples in a category

n_1 and n_2 = the sample sizes (injuries) pre-HomeSafe and post-HomeSafe

$\bar{p} = \dfrac{n_1 p_1 + n_2 p_2}{n_1 + n_2}$

$\bar{q} = 1 - \bar{p}$

Injury Cost

Injury cost was evaluated dichotomously (cost or no cost) and continuously. Cost of injury also served as a surrogate measure of injury severity, and a higher median cost indicated a more severe injury[5,22]. Any injury incurring a cost, medical and/or compensatory, was included in the cost analysis. Because the sample sizes pre- and post-HomeSafe were not equal and the distributions of the cost of injury were significantly skewed pre- and post-HomeSafe, the Mann Whitney Wilcoxon rank sum test was used to test the equality of the median costs of injury prior to and following HomeSafe.

RESULTS

Overall Injury Incidence Rates

A total of 1,517 injuries were reported during the three pre-HomeSafe years and 493 were reported during the two post-HomeSafe years. Five companies did not report total person hours worked for 1994 – 1996; and, thus, injuries occurring in those companies were not included in the rate calculations. A total of 1,478 injuries pre- and 493 injuries post-HomeSafe therefore were used in the analysis of overall crude rates. Overall rates were evaluated by year, with 1997 reported as 1997 and 1997- post to represent pre- and post-HomeSafe rates (Figure 1). These rates represent all trades, including general contractors and builders. A potential downward trend in injury rates was apparent from 1994 through 1997, with a high of 19.6 injuries per 200,000 in 1994 and a low of 14.3 injuries per 200,000 in 1997. However, post-HomeSafe rates in 1997 increased to 17.4 before dropping again in 1998 to 12.9 per 200,000 person hours worked. In addition to overall incidence rates, rates were calculated for injuries resulting in lost work time and/or medical cost (described above) and are described in Table II. Not all HomeSafe companies provided medical cost or lost work time information, resulting in 1,387 injuries for which lost work time information was available and 1,064 for which medical cost information was available. Of those, information on both lost work time and cost was available for 900 injuries.

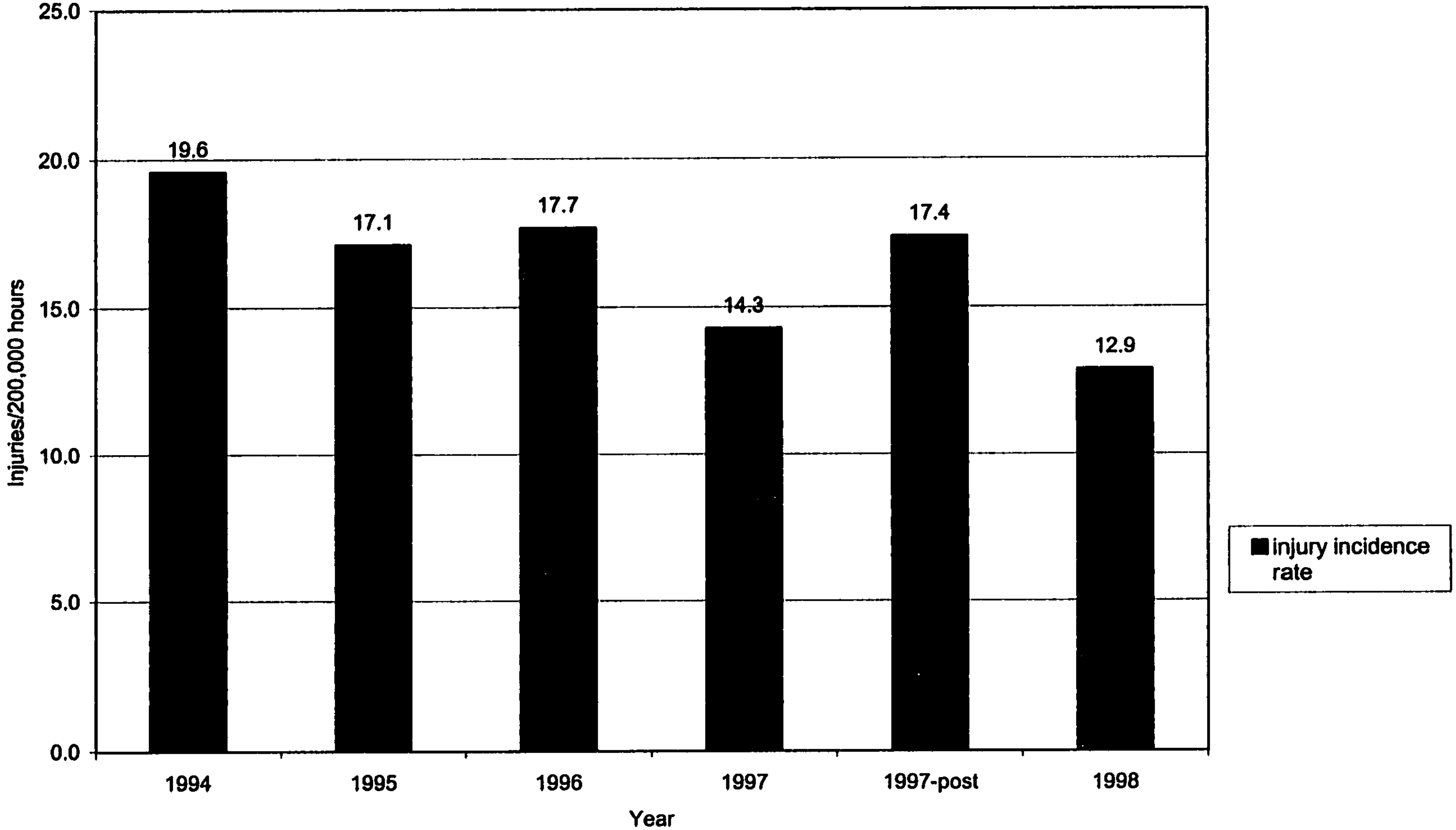

Figure 1
Injury Incidence Rates among HomeSafe Partners, 1994 - 1998

For comparison purposes, only these 900 injuries were used in the rate calculation to maintain consistency in the denominators. Pre- and post-HomeSafe injury incidence rates by type are as follows:

Table II: Injury Rates Among HomeSafe Partners, Pre- and Post-HomeSafe, per 200,000 Hours

	Overall	LWDI (no medical cost)	Medical Cost (no lost work days)	LWDI and Medical Cost	No LWD or Medical Cost
Pre-HomeSafe	17.4 (16.5 , 18.3)*	0.5 (0.3 , 0.7)	6.7 (6.0 , 7.4)	3.8 (3.3 , 4.3)	3.2 (2.7 , 3.7)
Post-HomeSafe	14.7 (13.4 , 15.9)	0.4 (0.1 , 0.7)	5.4 (4.3 , 6.5)	2.2 (1.5, 3.0)	2.2 (1.5 , 3.0)

*95% Confidence Intervals

The overall incidence rate for pre-HomeSafe injuries was 17.4 injuries per 200,000 person hours worked and overall rate for post-HomeSafe injuries was 14.7 per 200,000 person hours worked. Injuries in lost work time and medical cost pre-HomeSafe yielded a rate of 3.8 per 200,000 person hours worked and 2.2 per 200,000 person hours worked post-HomeSafe. The 95% confidence intervals in Table II revealed a significant difference between overall injury rates pre- and post-HomeSafe ($p = 0.0001$) and between injuries resulting in lost work time and medical cost pre- and post-HomeSafe ($p = 0.0004$).

To further describe injuries among HomeSafe participants, injuries were stratified by mechanism of injury, nature of injury, and body part injured, and are detailed in Table III and Figures 2-4. Injuries caused by the following mechanisms had the highest rates per 200,000 hours worked among all trades both pre- and post-HomeSafe: cuts, punctures or scrapes (3.6 and 3.4, respectively), falls (3.2 and 2.9), and strain or injury by lifting or other movement (3.0 and 2.1). There was a significant decrease in incidence rates for injuries caused by lifting or other movements (p=0.004) post-HomeSafe but no significant decrease in the rates of injury among any other causes.

Table III: Number and Percent Distribution of Pre- and Post-HomeSafe Injuries by Mechanism of Injury

Mechanism of Injury	Pre-HomeSafe		Post-HomeSafe	
	#	%	#	%
Cut, Puncture, Scrape By:	307	20.2	113	22.9
Hand Tool	91	29.6	25	22.1
Powered Hand Tool	86	28.0	30	26.6
Miscellaneous	130	42.4	58	51.3
Fall:	272	17.9	96	19.5
From Different Level	98	36.0	30	31.3
From Ladder or Scaffolding	50	18.4	15	15.6
Other Fall	82	30.2	34	35.4
Slipped, Did Not Fall	42	15.4	17	17.7
Strain or Injury By:	256	16.9	70	14.2
Lifting	110	43.0	40	57.1
Carrying, Holding, Pushing, Pulling, Reaching, Other	146	57.0	30	43.9
Miscellaneous:	167	11.0	55	11.2
Foreign Body In Eye	130	77.8	31	56.4
All Other	37	22.2	24	44.6
Striking Against or Stepping On	110	7.3	31	6.3
Strike Against Machinery, Object, Stationary Object, Other	36	32.7	8	25.8
Stepping On Something Sharp	74	67.3	23	74.2

Hand tools and power tools were the major causes of cuts, punctures, and scrapes, accounting for 58% pre- and 49% post-HomeSafe. Other causes included, for example, broken glass, wire/cable, and wood fragments. Falls from different levels and falls from ladders or scaffolding were the major causes of falls, representing 54% and 47% of falls pre- and post-HomeSafe. Falls from different levels include falling into a hole or trench. Other falls included, for example, slipping on liquid, ice, or grease and falling on the same level. Lifting was by far the greatest single mechanism of injury in the strain or injury by movement category, representing 43% pre-HomeSafe and 57% post-HomeSafe.

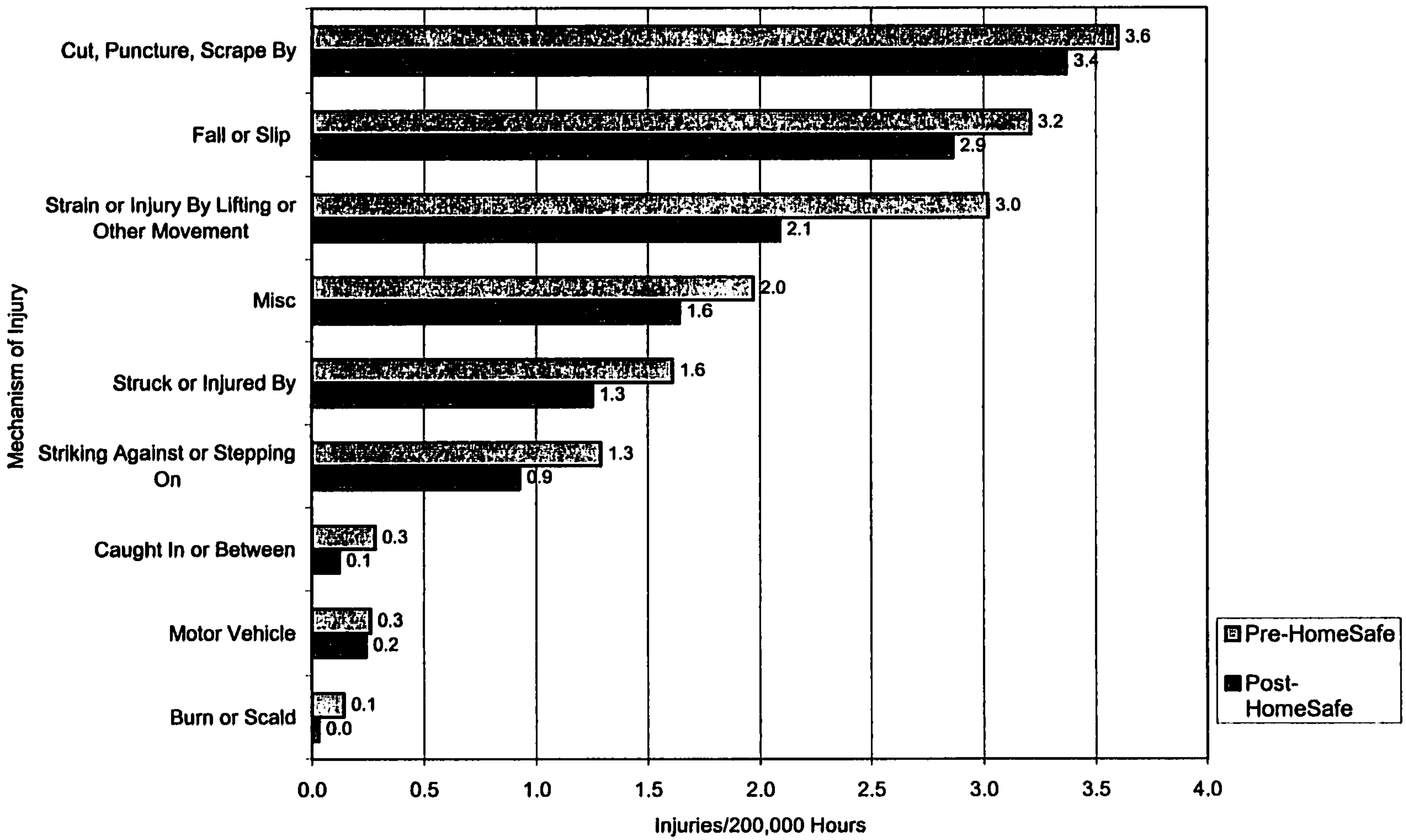

Figure 2
Injury Incidence Rates By Mechanism of Injury, pre- and post-HomeSafe

Though the overall pre- and post-HomeSafe rates were lower than for the above three categories, miscellaneous causes warrants further description secondary to the distribution of injuries in that category. Of nine possible causes, 78% of injuries categorized as miscellaneous causes pre-HomeSafe and 56% post-HomeSafe were "foreign body in eye". For injuries classified as striking against or stepping on, out of six possible causes, 67% and 74% pre and post were "stepping on something sharp".

Detailed analysis of injury rates by nature of injury is presented in Figure 3. Strains (4.4 and 3.6), lacerations (3.6 and 3.5), contusions (2.2 and 1.6), punctures (1.9 and 1.8), foreign bodies (1.8 and 1.1), and sprains (1.4 and 1.0) had the highest pre- and post-HomeSafe injury rates. Injury rates by body part are presented in Figure 4. Lower back (2.4 and 1.8), hand/wrist (2.2 and 2.0), ankle/foot (2.2 and 1.6), finger (2.1 and 1.8), leg/knee (1.8 and 1.6), arm/elbow (1.7 and 1.6), and eye (1.7 and 1.0) injuries had the highest rates of injury.

Lost Work Day Injuries

A total of 63 companies representing 1,387 injuries pre-HomeSafe and 47 companies representing 438 injuries post-HomeSafe were included in the rate calculations. Lost work time injury rates for the years 1994 – 1998 are presented in Figure 5. A downward trend is evident, indicating a decrease in the rate of severe injuries over time.

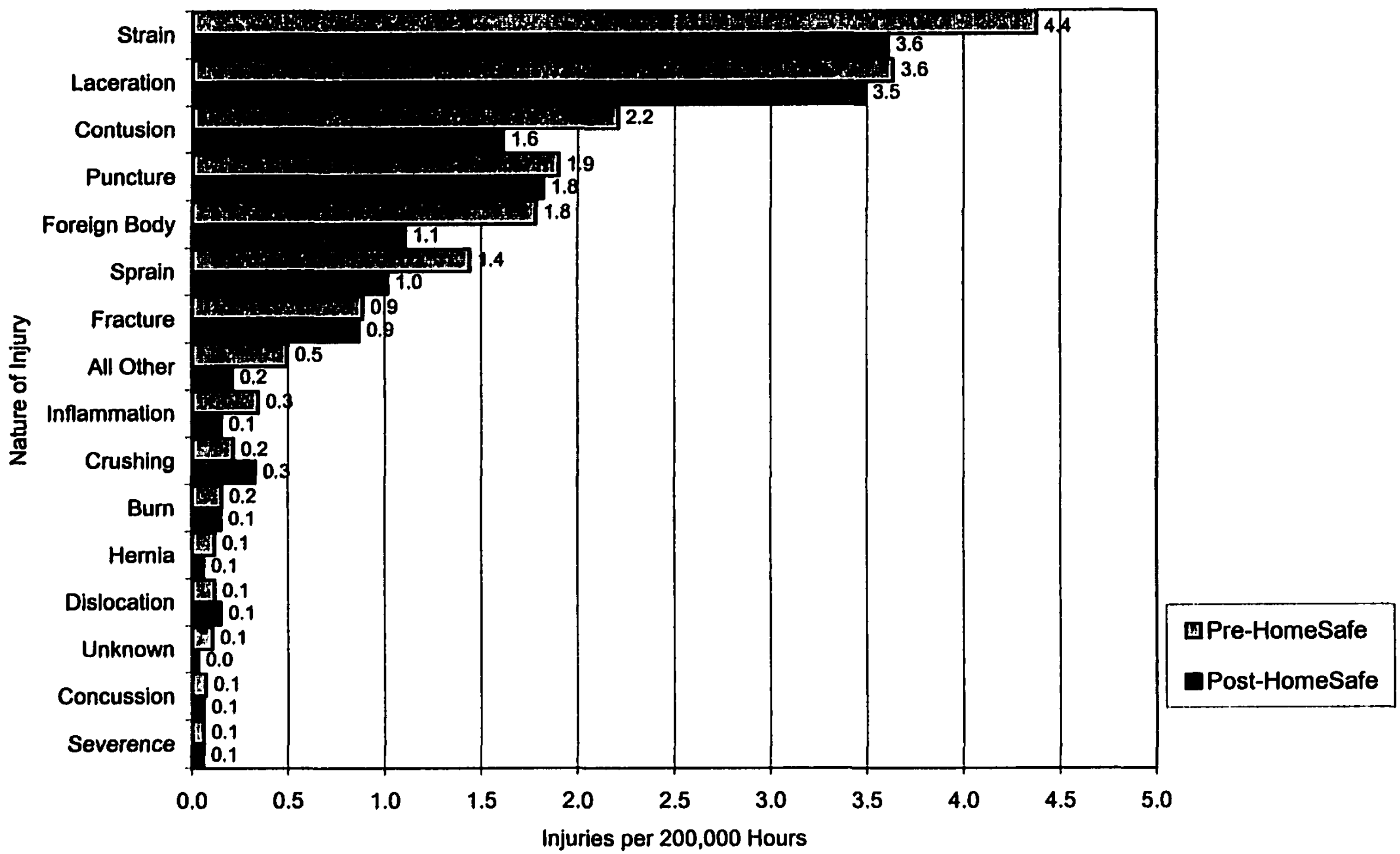

Figure 3
Injury Incidence Rates By Nature of Injury, pre- and post-HomeSafe

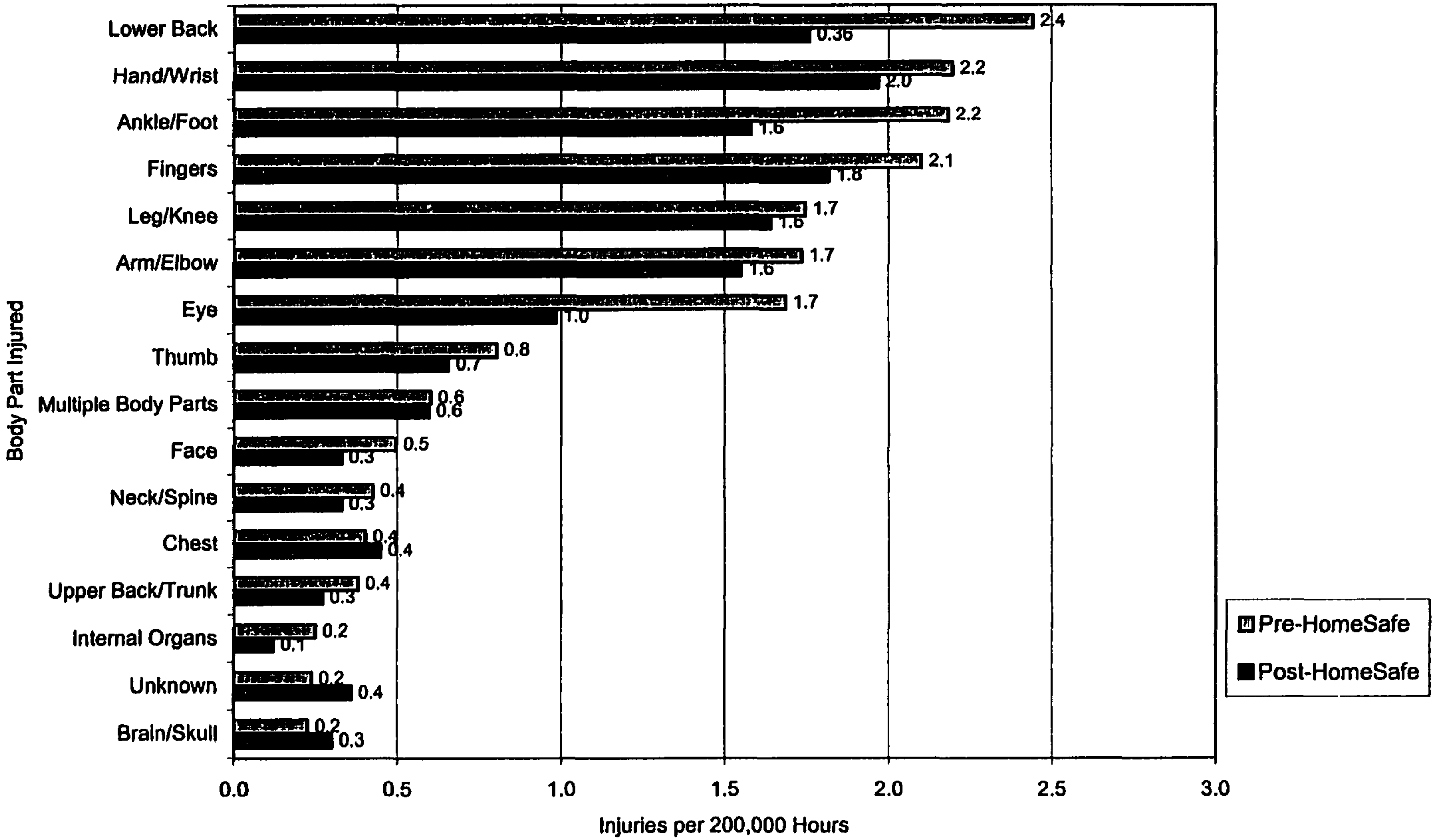

Figure 4
Injury Incidence Rates By Body Part Injured, pre- and post-HomeSafe

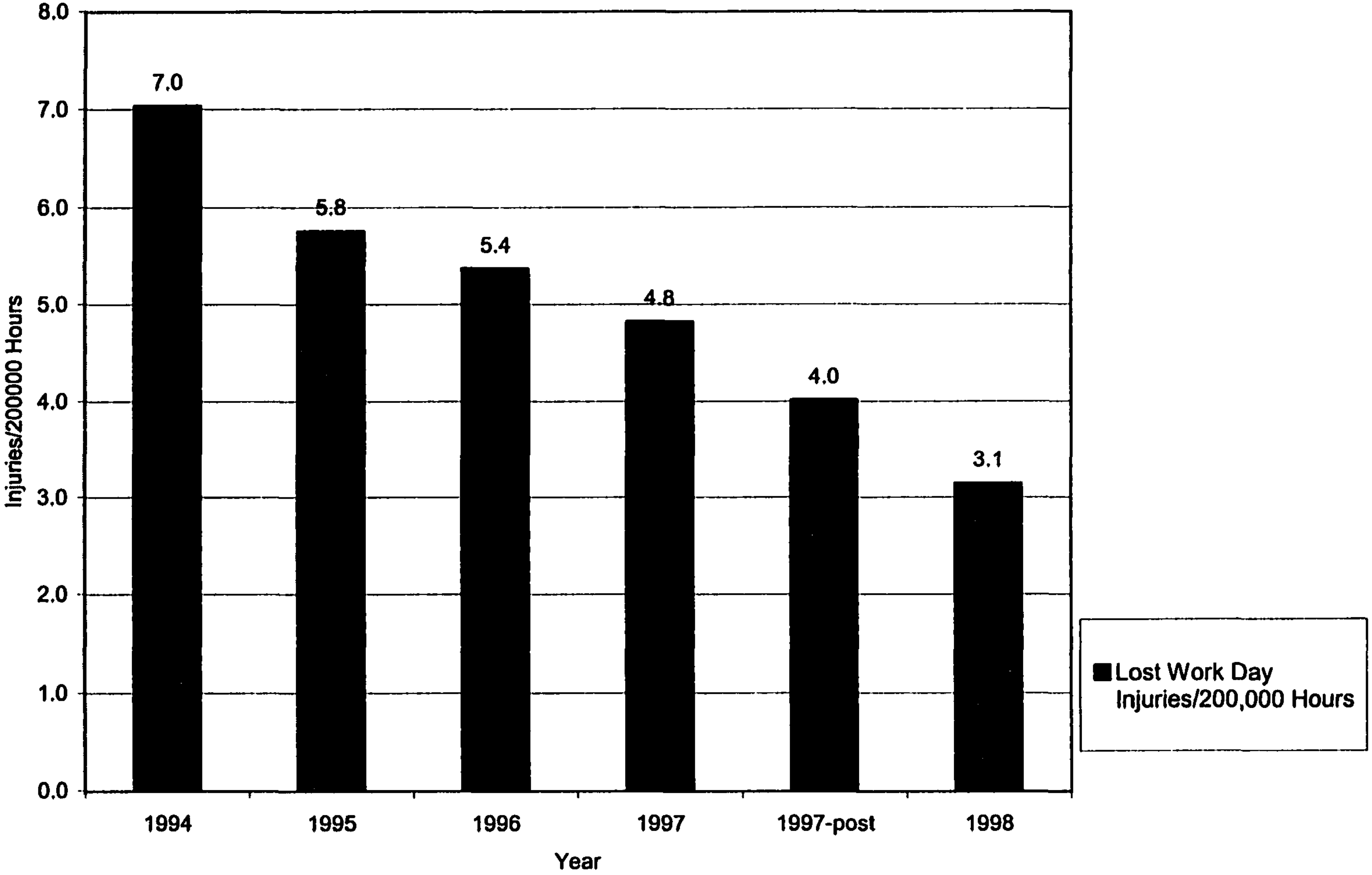

Figure 5
Lost Work Day Injury Incidence Rates among HomeSafe Partners, 1994 - 1998

In an effort to define lost work time more specifically, lost workday injuries (LWDI's) were categorized by number of days lost as outlined in Table IV. Overall, most injuries (66.0% and 73.0%) resulted in no lost work days, with the percent of injuries decreasing as a function of increasing work days lost. A comparison of pre- and post-HomeSafe injuries indicates a significant increase in the proportion of injuries which did not require any lost work time (p=0.004). Additionally, an overall analysis of lost work day versus no lost work day indicates that the proportion of injuries resulting in lost work time decreased significantly following HomeSafe, from 34.0% to 26.7% (p=0.004), demonstrating an overall decrease in lost workday injuries. Injuries resulting in 1 – 3 work days lost accounted for 15.4% of pre-HomeSafe injuries and 11.4% of post-HomeSafe injuries (p=0.038).

Table IV: Comparison of Proportion of Lost Workday Injuries (LWDI's) by Number of Days Lost, pre- and post-HomeSafe

Number of Lost Work Days	Pre-HomeSafe		Post-HomeSafe		Difference in proportions between pre-HomeSafe and post-HomeSafe
	#	%	#	%	
0	915	66.0	321	73.3	p = 0.004
1-3	214	15.4	50	11.4	p = 0.038
4-10	131	9.4	35	8.0	p = 0.358
11-20	36	2.6	10	2.3	p = 0.710
21-50	43	3.1	13	3.0	p = 0.892
51-100	24	1.7	7	1.6	p = 0.855
101-150	13	0.9	1	0.2	p = 0.139
>150	11	0.8	1	0.2	p = 0.203
Total	1387		438		

Note: 185 injuries were not included because of missing data.

Injury incidence rates for lost workday injuries pre- and post-HomeSafe are presented in Table V. A comparison of injury incidence rates for lost workdays also demonstrates a significant difference between rates pre-HomeSafe and rates post-HomeSafe, a decrease from 5.8 LWDI's per 200,000 hours worked to 3.4 LWDI's per 200,000 hours worked. LWDI's include all lost workday injuries, regardless of information about cost; hence, they differ from the rates provided in Table II.

Table V: Rates of LWDI's pre- and post-HomeSafe per 200,000 Hours

	Lost work day injury	95% confidence interval*	No lost workday injury	95% confidence interval
Pre-HomeSafe	5.8	(5.3 , 6.3)	11.3	(10.6 , 12.0)
Post-HomeSafe	3.4	(2.8 , 4.0)	9.6	(8.6 , 10.7)

*comparison of rates yields $p<0.001$

Because lost workday injuries generally represent more severe injuries, investigators examined mechanism and nature of injury and body part injured in relation to lost workday injuries[5]. Lost workday incidence rates for all causes were calculated (Figure 6). The top three causes were the same as for overall injuries. During the pre-HomeSafe period, injuries caused by a fall or slip had the greatest rate of lost work day injuries at 1.6, strain and/or injury by lifting or other movement was next with 1.1, and cut, puncture, and scrape injuries were next with 0.7 per 200,000 hours worked. During the post-HomeSafe period, injuries by fall or slip remained the primary cause of lost workday injury with a rate of 0.9 per 200,000 hours worked, a statistically significant rate decrease ($p=0.001$). Injuries caused by cuts, punctures and scrapes had a rate of 0.4 per 200,000 ($p=0.037$), also a significant decrease. Finally, the incidence rate of injuries caused by lifting or other movements, 0.6 per 200,000, also was significantly less following HomeSafe ($p=0.006$). No other cause of injury experienced a statistically significant decrease in injury incidence rate.

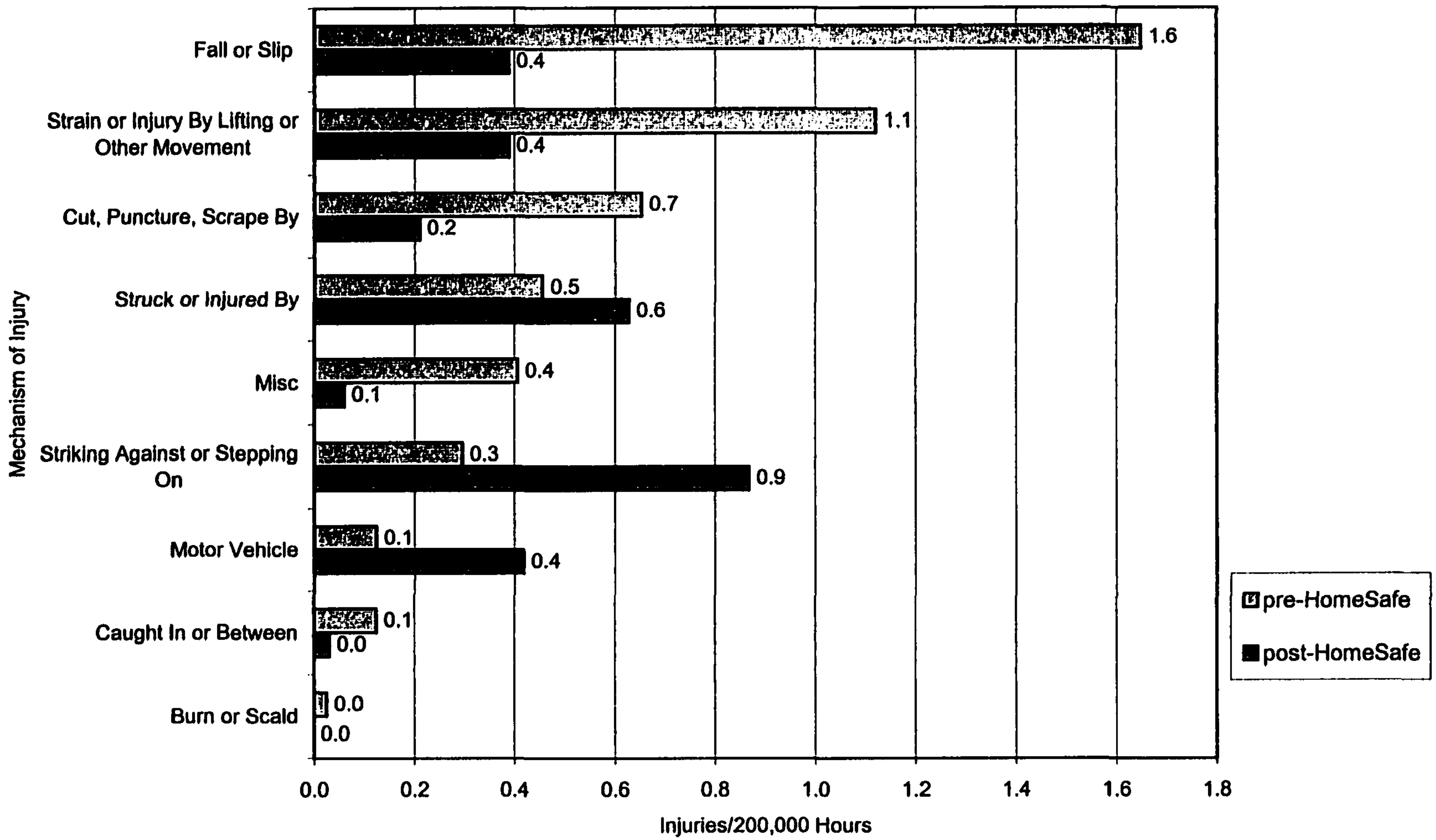

Figure 6
Lost Work Day Injury Incidence Rates by Mechanism of Injury, pre-and post-HomeSafe

Investigators then examined these injuries by nature of injury and body part injured (Figures 7 – 8). Prior to HomeSafe, strain injuries had the greatest incidence rate (1.6 per 200,000 hours worked) and accounted for 28% of the lost workday injuries. Incidence rates for contusions and sprains were next, each with 0.8 lost workday injuries respectively. Lacerations accounted for 12% of the lost workday injuries with an incidence rate of 0.7 per 200,000 hours worked. Fractures accounted for 0.6 lost workday injuries per 200,000 hours worked. Post-HomeSafe, strains remained the primary type of injury with an incidence rate of 0.90 per 200,000 hours worked. The rate of strain injuries was significantly lower following HomeSafe ($p = 0.0012$). Lacerations and fractures were next, with rates of 0.4 and 0.5 per 200,000 hours worked, respectively. The rate of lacerations was significantly lower post-HomeSafe ($p = 0.0427$). The rate of fractures did not change following the intervention. Also significantly less following HomeSafe were incidence rates for contusions ($p = 0.0048$) and sprains ($p = 0.0002$).

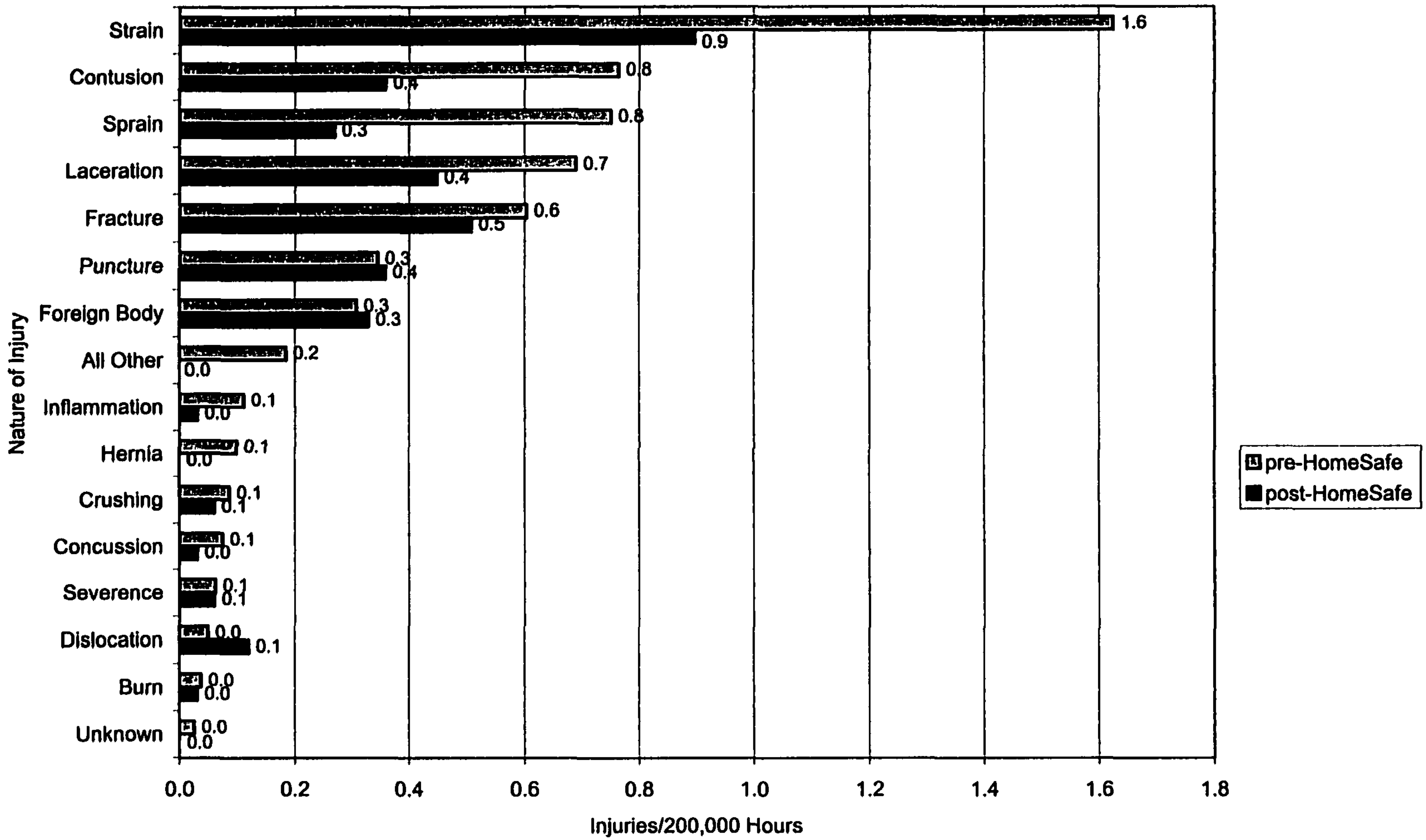

Figure 7
Lost Work Day Injury Incidence Rates by Nature of Injury, pre- and post-HomeSafe

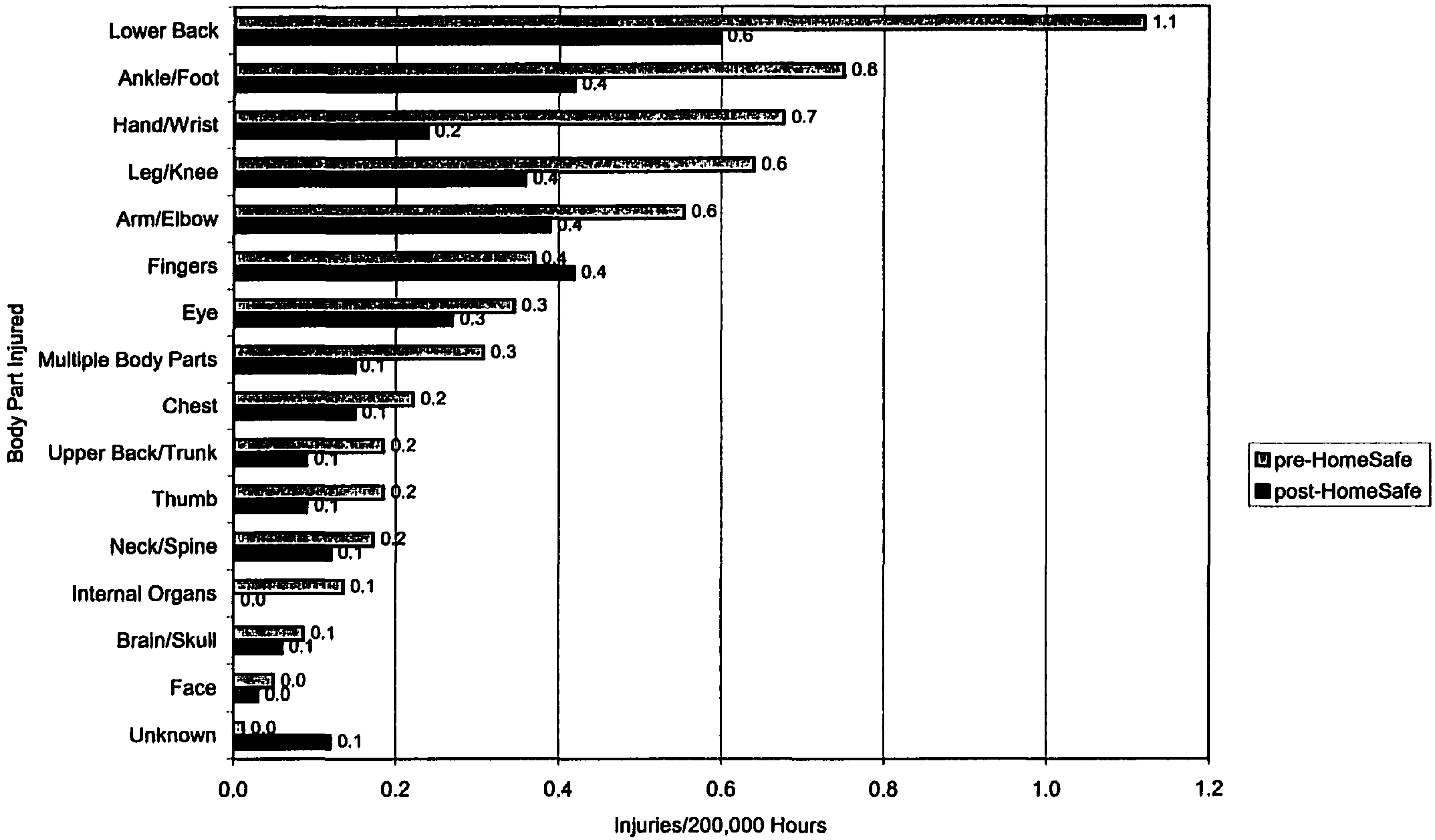

Figure 8
Lost Work Day Injury Incidence Rates by Body Part Injured, pre- and post-HomeSafe

Among lost workday injuries, the body parts most frequently injured prior to HomeSafe included lower back (1.1/200,000), ankle/foot (0.8/200,000), hand/wrist (0.7/200,000), leg/knee (0.6/200,000), and arm/elbow (0.6/200,000). Post-HomeSafe, injuries to the lower back, fingers, and ankle/foot had the highest rates: 0.6, 0.4, 0.4 per 200,000 person hours worked, respectively (Figure 8). None of the rates for body part injured differed significantly between the pre- and post-HomeSafe time periods.

The distributions of the nature of injury and the body part injured are presented in Tables VI-VIII for the three major causes: fall or slip; strain or injury by lifting or other movements; and cuts, punctures, or scrapes. Fall and/or slip injuries most commonly resulted in fractures, contusions, and sprains. Body parts most often injured included leg/knee, ankle/foot, lower back and arm/elbow. Strain or injury by lifting or other movements most commonly resulted in sprains and strains to the lower back. Cut, puncture, or scrape injuries most often resulted in lacerations and punctures to hand/wrist and fingers.

Table VI: Proportion of Fall or Slip Injuries by Nature of Injury and Body Part Injured

	% Pre-HomeSafe	% Post-HomeSafe
Nature of Injury		
Contusion	22.4	27.6
Fracture	22.4	31.0
Laceration	3.0	6.9
Sprain	22.4	17.2
Strain	20.2	6.9
All Other	9.7	10.3
Body Part		
Ankle/Foot	17.9	17.2
Arm/Elbow	10.5	13.8
Hand/Wrist	10.5	6.9
Leg/Knee	18.7	24.1
Lower Back	14.9	0.0
All Other	27.6	37.9

Table VII: Proportion of Strain or Injury by Lifting or Other Movements by Nature of Injury and Body Part Injured

	% Pre-HomeSafe	% Post-HomeSafe
Nature of Injury		
Contusion	0	0
Fracture	2.2	4.8
Laceration	1.1	0
Sprain	13.2	4.8
Strain	72.5	85.7
All Other	11.0	4.8
Body Part		
Ankle/Foot	3.3	0
Arm/Elbow	7.7	14.3
Hand/Wrist	1.1	0
Leg/Knee	8.8	4.8
Lower Back	55.0	66.7
All Other	24.2	14.3

Table VIII: Proportion of Cut, Puncture, or Scrape Injuries by Nature of Injury and Body Part Injured

	% Pre-HomeSafe	% Post-HomeSafe
Nature of Injury		
Contusion	3.8	7.1
Fracture	0.0	0.0
Laceration	60.4	57.1
Puncture	24.5	28.6
All Other	11.3	7.1
Body Part		
Ankle/Foot	11.3	0.0
Arm/Elbow	5.7	0.0
Fingers	15.1	42.9
Hand/Wrist	28.3	14.3
Leg/Knee	13.2	14.3
All Other	26.4	28.6

Injury Cost

Cost of injury also was explored, as displayed in Table IX. Cost information was available for forty companies pre-HomeSafe and twenty-two companies post-HomeSafe.

Table IX: Cost of Injury Pre- and Post-HomeSafe

Pre/Post HomeSafe	Number of injuries with information on cost	Mean cost (dollars)	Median cost (dollars)*	Range of cost (dollars)	% of injuries incurring medical and/or compensation costs
Pre	861	3,065	192	0 – 220,668	71.7
Post	203	1,299	144	0 – 49,674	65.0

*p = 0.0507

The cost of injury pre-HomeSafe was higher than post-HomeSafe and the proportion of injuries incurring medical or compensation costs was higher pre-HomeSafe compared to post-HomeSafe. To evaluate the cost of injury, cost data were analyzed using the Mann-Whitney-Wilcoxon Rank Sum test. Results of this test indicated no significant difference in the median cost of injury (p= 0.0507) pre- and post-HomeSafe.

Injuries with costs associated were stratified by mechanism of injury (Table X). Median cost of injury was compared by each mechanism to median cost of all injuries, pre- and post-HomeSafe.

Table X: Median Cost of Injury by Mechanism of Injury, pre- and post-HomeSafe

Mechanism	n	Median Cost Pre-Home Safe* (dollars)	n	Median Cost Post-HomeSafe& (dollars)	95% Confidence Interval Pre- versus Post-HomeSafe
Burn or Scald	7	735	0	N/A	N/A
Caught In or Between	10	491	2	7869	(-12151.2 , -1285.1)*
Cut, Puncture, or Scrape	139	261	39	263	(-64.1 , 83.9)
Fall or Slip	133	540	27	700	(-287.1 , 458.0)
Miscellaneous	75	225	15	242	(-283.0 , 81.1)
Motor Vehicle	12	861	0	N/A	
Strain or Injury By	122	430	24	292	(-109.4 , 239.1)
Striking Against or Stepping On	39	173	10	94	(-3.8 , 230.1)
Struck By	61	262	13	226	(-41.6 , 246.9)

*significant at p=0.002

Pre-HomeSafe injuries caused by a motor vehicle had the highest median cost ($861), followed by injuries caused by a burn or scald ($735) or a fall or slip ($540). Post-HomeSafe, caught in or between injuries had the highest median cost per injury ($7869.), however, this must be interpreted with caution as there were only two events in this category, one that cost $7869 to treat and one that incurred no costs. Injuries caused by a fall or slip had a median cost of $700 per injury.

Median cost of injury was compared pre- and post-HomeSafe for each mechanism. This analysis revealed only one significant difference: caught in or between injuries had a higher median cost following HomeSafe intervention. Again this must be interpreted with caution as the cost post-HomeSafe represents treatment of one injury.

Pre-HomeSafe, the type of injury with the highest median cost ($6009) was hernia (Table XI). Dislocations ($2540) and fractures ($2108) had the next highest cost when compared with all other types of injuries. Punctures and foreign body injuries had the lowest median cost $211 and $213, respectively). Post-HomeSafe, crushing injuries had the greatest median cost ($7869), though this cost was incurred by one injury. Contusions ($650) and fractures ($1797) also had median costs that were higher than other injury types. Punctures and lacerations were associated with the lowest costs ($203 and $243).

The pre- and post-HomeSafe comparison yielded only one significant difference: the median cost of a contusion injury was significantly higher after participation in the HomeSafe project.

Table XI: Median Cost of Injury by Nature of Injury, pre- and post-HomeSafe

Nature of Injury	n	Median Cost Pre-HomeSafe (dollars)	n	Median Cost Post-HomeSafe (dollars)	95% Confidence Interval Pre- versus Post-HomeSafe
Burn	8	535	0	N/A	
Contusion	75	260	11	650	(1075.3 , 12101.4)*
Crushing	5	571	2	7869	(-12196.3 , -2213.2)
Dislocation	4	2541	0	N/A	
Foreign Body	56	213	6	456	(-762.5 , 59.9)
Fracture	30	2108	7	1797	(-1645.1 , 7888.3)
Hernia	4	6009	0	N/A	
Inflammation	8	235	7	448	(-670.0 , 10153.9)
Laceration	123	249	32	243	(-61.1 , 107.9)
Puncture	61	211	20	203	(-28.9 , 164.3)
Sprain	44	285	10	301	(-182.90 , 238.0)
Strain	169	511	33	292	(-12.3 , 377.1)

*significant at p=0.0479 (cost is more Post-HS)

Costs were evaluated by body part injured (Table XII). Pre-HomeSafe data indicated that internal organ injuries had the greatest median cost ($3140), followed by multiple body part injuries ($1248). Eye injuries were associated with the lowest median cost ($221).

Post-HomeSafe, injuries to multiple body parts had the highest median cost ($1919), followed by upper back/trunk ($440) and eye injuries ($456).

Although eye injuries had a higher median cost port-HomeSafe, the increase was not statistically significant. There were no other significant differences in median cost when pre- and post-HomeSafe data were compared.

Table XII: Median Cost of Injury by Body Part, pre- and post-HomeSafe

Part of Body Injured	n	Median Cost Pre-HomeSafe (dollars)	n	Median Cost Post-HomeSafe (dollars)	95% Confidence Interval Pre- versus Post-HomeSafe
Ankle/Foot	68	264	20	237	(-68.2 , 179.8)
Arm/Elbow	65	324	7	222	(-133.1 , 1439.0)
Eye	57	221	4	456	(-1754.1 , 7.8)
Face	19	202	0	N/A	N/A
Fingers	65	249	18	249	(-205.1 , 86.6)
Hand/Wrist	76	332	18	369	(-242.2 , 117.6)
Internal Organs	11	3140	0	N/A	N/A
Leg/Knee	67	347	18	277	(-91.4 , 395.1)
Low Back	94	456	19	293	(-136.7 , 326.1)
Multiple Body Parts	28	1248	4	1919	(-42839.1 , 5603.7)
Thumb	32	260	6	282	(-192.9 , 198.0)
Upper Back/Trunk	28	420	12	440	(-300.5 , 1079.5)

BLS Comparison

The overall injury rates for the residential construction workers who participated in HomeSafe were higher than the reported statistics for the same trade groups reported to the BLS (1520, 1710, 1720, 1730, 1740, 1750, 1760, 1770, and 1790), before and after HomeSafe intervention. However, the BLS statistics include both commercial and residential construction workers and all trades within a four digit SIC code (e.g. SIC 1740 includes 1741, 1742, etc.). The HomeSafe participants were companies whose primary work was residential. The trades within HomeSafe were identified more specifically by SIC code. Nevertheless, the injury rates among HomeSafe partners were higher (Figure 9) throughout the years of study, though the HomeSafe rates decreased sharply in 1998. The BLS rates suggest a slow decrease throughout the study period, from 11.9/200,000 hours to 8.7/200,000 hours worked.

Pre-HomeSafe lost workday injury rates also were higher than those reported by the BLS for the same trade groups (Figure 10). However, following HomeSafe, lost workday injury rates fell below those reported by the BLS in 1997 and were similar in 1998. BLS rates declined steadily between 1994 and 1998. HomeSafe rates fell steadily over time, with a rate of 3.8/200,000 hours in 1998.

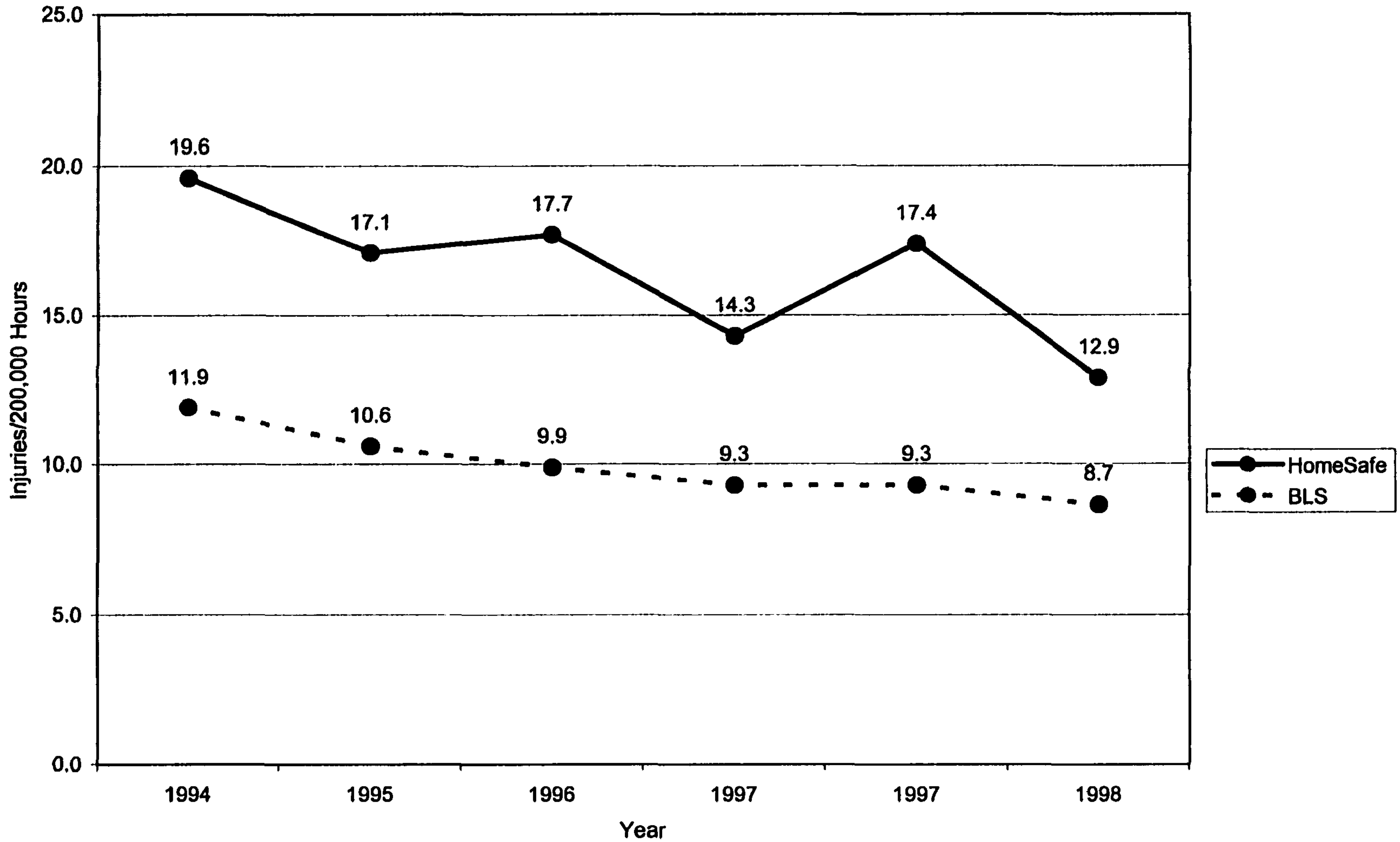

Figure 9:
Injury Incidence Rates among HomeSafe Partners and Construction Workers, 1994 - 1998

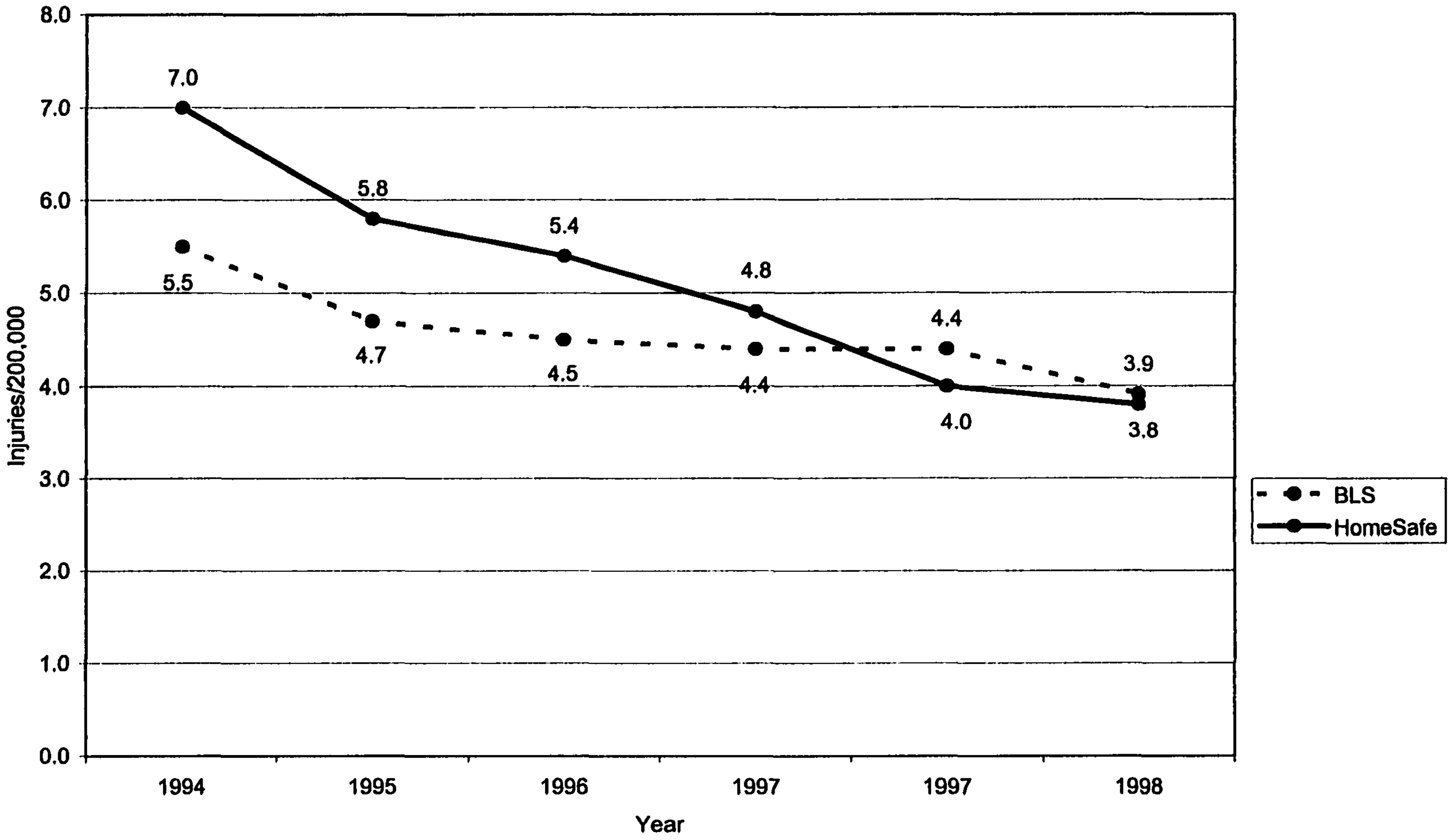

Figure 10:
Lost Work Day Injury Incidence Rates among HomeSafe Partners and Construction Workers, 1994-1998

DISCUSSION

This study afforded researchers the opportunity to examine the effectiveness of the HomeSafe Program and to describe injury patterns and trends among a specific subset of construction workers. Injury information about residential construction workers is extremely limited. The injury rates for construction workers are not reported by four-digit SIC codes, thereby restricting our ability to examine single-family homebuilders (1521) versus other residential builders (1522). In addition, SIC codes for trades do not differentiate between companies involved in, for example, residential plumbing, heating and air conditioning and commercial plumbing, heating and air conditioning, thereby making trade specific analysis among residential construction workers difficult. Among HomeSafe participants, this information was available to investigators and all trade companies reported their primary business was residential construction.

Another challenge in describing injury patterns among residential construction workers is the nature of the industry. In general, workers in the construction industry frequently change employers and work sites, work for more than one employer at a time, and have inconsistent work schedules[13]. It was not uncommon for first reports of injury to read, "employee never returned to work" following a relatively minor injury. The perception that being injured on the job damages an employee's personnel record may contribute to this phenomenon, and the injured worker may simply change employers. Gillen et al. (1997) reported that approximately 6% of their sample participants were fired before they returned or when they returned to work, perhaps providing some support for the validity of this belief[23]. In addition, many residential construction companies are sole proprietorships or employ ten or fewer employees, exempting them from reporting injuries on the OSHA 200 log. In our sample, most employers had fewer than fifty employees (78%), and 40% had ten or fewer employees.

HomeSafe Evaluation

Injury rates among the residential construction workers in this study for the pre-HomeSafe period (17.4 per 200,000) were significantly higher than those rates during the post-HomeSafe years (14.7 per 200,000). Incidence rates for lost work day injuries were also higher pre-HomeSafe (5.8/200,000) than post-HomeSafe (3.4/200,000). Attributing this decline solely to HomeSafe is difficult. There has been a national trend toward decreasing injury incidence rates in private industries, including overall occupational injury rates and injury rates in construction[4,24,25,26]. Injury rates in construction also have decreased in Colorado[15]. With this in mind, it makes intuitive sense that combined rates pre- and post-HomeSafe would be different. In fact, HomeSafe injury rates do decrease annually. When the annual rates are examined more closely (Figures 1 and 5), downward trends over time are apparent, especially for lost work time injuries. However, a side by side comparison of HomeSafe and BLS annual rates for the same trade groups (Figures 9 and 10) indicates a sharper decrease in injury incidence rates among HomeSafe partners as compared to BLS rates. HomeSafe injury rates were higher until the time period post-HomeSafe, when lost workday injury rates fell below BLS rates. It remains plausible, then, that HomeSafe was a contributing factor in the decline of the injury rates among participating companies.

Cost of injury was compared as another measure of program effectiveness. Cost was stratified by cause of injury, type of injury, and body part injured and compared pre-and post-HomeSafe. No significant differences emerged barring an increase in cost associated with caught in or between injuries and an increase in cost associated with contusion injuries. These differences may be attributed to a small number of injuries in those categories. For example, following HomeSafe, only two caught in or between injuries were reported, and one had a cost of $7868, much higher than most injuries attributed to this cause (the employee crushed his thumb and required surgical intervention to repair it).

Cost also may be viewed as a proxy indicator of severity[22]. That there were no differences in the cost of injuries pre- and post-HomeSafe indicates that, among injuries that do occur, HomeSafe may not have reduced the severity of injuries.

Injury Patterns among Residential Construction Workers

When injuries were evaluated by mechanism, nature, and body part, the major causes and types of injuries remained the same pre- and post-HomeSafe. Of the top causes: cuts, punctures, and scrapes; falls or slips; and strain or injury by lifting or other movements, two were identified as hazards and addressed in the HomeSafe program.

Cut, Puncture, and Scrape Injuries

Injuries caused by cuts, punctures, and scrapes had the highest rates of injury and accounted for the greatest proportion of injuries. Overall, injuries caused in this way resulted in an average of one day away from work and a lower median cost than other causes of injuries. The vast majority of these injuries did not result in time away from work. However, this remained a leading cause of lost workday injury. Of those injuries that resulted in at least one lost workday, injured workers lost an average of five days of work. Hand and power tools accounted for the majority of these injuries, though nearly half were attributed to miscellaneous causes.

Other studies also have reported that cuts, punctures and scrape injuries have high rates among construction workers[27,28]. In their study of emergency room visits among construction workers, Hunting et al. (1994) reported that 25.8% were due to cutting or piercing objects[27]. In their 1999 study of the same emergency department, Hunting et al. (1999) reported that cutting or piercing objects caused 26.8% of the emergency room cases among construction workers. Interestingly, injuries caused by sharp objects accounted for 20.4% among construction laborers as compared to almost 30% among construction tradesmen[29]. The HomeSafe participants reported very similar numbers: 20.2% pre- and 22.9% post-HomeSafe.

No significant reduction in overall rates of cutting injuries were apparent among the HomeSafe participants but a significant reduction in the rate of severe injuries caused by cuts, punctures, or scrapes was evident. The HomeSafe project identified power tools as a major cause of injury. HomeSafe addressed safety issues such as positioning, guarding, and eye protection both in training and in the pocket guide. In addition, the HomeSafe program identified personal protective equipment designed to protect workers using power and hand tools from injury, for example, sturdy boots to protect from punctures to the foot.

A possible explanation for the lack of overall effect is that approximately 50% of the injuries caused in this manner were described as "other," indicating, perhaps, unidentified hazards. Another explanation may lie with the perceived severity of these types of injuries by workers. The perceived severity of the injury is impacted not only by the emotional response to the thought of the injury, but the cognate processes around the effect the injury will have on a person's life[30]. In addition, perceived susceptibility to the injury and the control a person has over the prevention of the injury also affects the preventive behaviors[30]. Research in the behavioral sciences has demonstrated that the probability an individual will take precautions against illness or injury is greatly affected by characteristics of the 'threat', for example, familiarity, predictability, visibility, and catastrophic potential[31,32,33]. Injuries that are familiar, common, perceived as under the employees' control, and do not result in lost time or long term disability may not be viewed as serious and worthy of a behavior change. Darragh et al. (1998) reported that among adolescent farm workers, injuries such as whiplash and fractures were not perceived as serious, therefore, the behaviors leading to those injuries need not be altered[34]. Weinstein (2000) reported a case study of twelve individuals who were presented with 201 hazards, their severity and their likelihood[33]. Their motivation to prevent certain events disappeared when the severity and likelihood scores were zero, indicating the power that individual perceptions can have on the interest or motivation to alter a behavior. Slater (1999) reported that a core problem for many media campaigns is that the audience may not be ready for or interested in behavior change[35]. Workers may make choices about safety behaviors based on the severity of the injury they associate with the task addressed by the behavior change. Time may be well spent in analyzing the risk and injury perceptions of residential construction workers to determine their readiness to change risky behavior before implementing costly intervention studies.

Among severe injuries, injuries caused by cuts, punctures, or scrapes usually resulted in, logically, lacerations and punctures to the wrist, fingers and hand. In almost 30% of the cases, the body part injured was not identified or listed as 'other'. Laceration injuries were associated with a lower cost than all other types of injury pre-HomeSafe, and punctures were associated with a lower cost than all other types pre and post-HomeSafe. Injuries were often the result of utility knives, nail guns, and saws. Striking against wood, metal, or other debris on the site also caused these types of injuries.

Fall or Slip Injuries

Injuries from falls were more well-defined and indicated that falls from different levels (36%) and from scaffolding or ladders (18%) were the major causes of fall injuries both pre- and post-HomeSafe, with no significant reduction in overall injury rate following HomeSafe intervention. Again, four of the ten points included in the HomeSafe program addressed the prevention of just these kinds of injuries, with extensive descriptions of scaffolding and guidelines for use and roof work safety procedures. Of note is that 30% of falls pre-HomeSafe and 35% post-HomeSafe were coded as "other fall", increasing the probability that one challenge of prevention among residential construction workers is a lack of an industry specific injury coding language and that perhaps certain fall hazards have not been identified.

Among lost work day injuries, this category had the highest rate of injuries (1.7/200,000) pre-HomeSafe. Injury incidence rates for severe falls were significantly lower following HomeSafe, dropping to 0.9/200,000 ($p<0.0001$). Falls generally result in more severe injuries and it is not unexpected that this category would emerge as a primary cause of lost workday injury. Severe falls (those resulting in one or more lost workdays) resulted in an average of 19 days away from work while, overall, falls resulted in an average of 6 days away from work. Injuries caused by slips or falls also cost more than other injuries, both pre and post-HomeSafe. While HomeSafe may not have reduced the rate of falls overall, the program may have been effective in communicating hazards associated with falls, prompting employees to protect themselves from more severe or life threatening falls. Workers may have recognized the severity and catastrophic potential of these events and taken some precautions to reduce their risk, as is reflected by the decrease in lost workday fall injuries. These injuries are more likely to result in lost work time in an industry where only 33% of small businesses in the western states offer paid sick time and workers' compensation companies vary in their criteria for paid time off following an injury (personal communication, Jim McMillen, Pinnacol Assurance, February, 2001)[7,5]. For example, in Colorado, an injured worker does not begin to receive compensation payments until he has been out of work for more than three days. Even then the compensation is only about two-thirds of his hourly wage.

In addition, falls are the leading cause of death among construction workers, 30% of lost work day injuries are due to falls, and one study reported that 68% of hospitalized injuries among construction workers were due to falls[36,37, 27,23]. Non-fatal falls among construction workers consistently have been identified as a major hazard among construction workers and have been described by a number of researchers, whose results are similar to those reported here. For example, Lipscomb et al. (1995) found that union carpenters experienced falls as the third most common cause of injury, and experienced a rate of 5.5 per 200,000 hours worked[9]. Gillen et al. (1997) reported that, among those construction workers who fell at work, 30.6% fell from a ladder or scaffolding and 37.7% fell from a different level[23]. Among their participant group, the mean number of days lost from work was 44.3. Of the falls, 35.1% resulted in sprains or strains, 25.3% resulted in contusions, and 16.0% resulted in fractures. They also reported a mean of 2.0 injuries per fall event. Finally, a study of Washington construction companies cited for violating the fall protection standard revealed a workers' compensation claim injury rate of 1.8/200,000 hours worked among those companies who were cited versus a rate of 1.0/200,000 hours worked among those companies who were not inspected or cited[38]. They reported that 64.3% were falls from a different level, and 29.6% were falls from a ladder. While falls from ladders, scaffolding, and different levels have been identified repeatedly, and intervention and safety programs continue to address them, they remain a major cause of severe worker injury, lost work time, and high cost.

Injuries caused by falls most often resulted in contusions, fractures, sprains, and strains to the upper and lower extremities, and to the lower back. Injuries resulting in fractures and strains, and injuries to the low back had a higher median cost than all other types of injury. Fall injuries had the highest cost by cause and resulted in the types of injury and body parts injured that are associated with a higher median cost. Fall or slip injuries included workers who fell through holes in the floor, ground, or on the roof, fell off ladders and scaffolding, or fell off roofs. In some cases, the worker was wearing fall protection. Whether the equipment was faulty or whether the worker donned it incorrectly is unknown. In addition, several incidents were reported of a sales person in a new subdivision falling out the front door of a house because there were no steps or ramps in place, or falling into a hole on the grounds that was not marked.

Strain or Injury by Lifting or Other Movements

Strain or injury by lifting, carrying, holding, pushing, pulling, and reaching accounted for 16.9% of all injuries pre- and 14.2% of all injuries post-HomeSafe. Lifting injuries accounted for about 50% of these injuries, though what the worker was lifting was extremely varied. In some cases it was machinery, in others, lifting boxes, drywall, or wood. Strain or injury by lifting or other movements injuries had the second highest rate of lost work day injury pre- and post-HomeSafe (1.1 and 0.6 per 200,000 hours worked). Injuries caused by lifting or other movements most often resulted in strain injuries to the lower back, both of which resulted in a higher median cost than other injuries pre-, but not post-, HomeSafe. Overall, these injuries resulted in approximately two lost workdays per event. However, among lost workday injuries caused by lifting or other movements, workers averaged thirteen days away from work per event, second only to falls. The HomeSafe ten point pocket guide does not specifically address the prevention of strain injuries. There is one reference to carrying a heavy piece of equipment, but no overall discussion of body mechanics and correct procedures for lifting, carrying, holding, or other movements. In addition, during the years of the study, there was no OSHA standard addressing ergonomic issues. Of particular interest is the fact that injury rates due to this cause were significantly lower following HomeSafe, both for overall injuries and lost work day injuries ($p=0.003$ and 0.006, respectively), even though it was not addressed by HomeSafe. This was the only mechanism of injury for which this is true. Even so, these injuries resulted in extensive time away from work and were a leading cause of injury, indicating more safety training around lifting and other movement activities is likely warranted.

Miscellaneous

Eye injuries occurred at a rate of 1.7/200,000 hours worked pre-HomeSafe and 1.0/200,000 post-HomeSafe. Most of these injuries were caused by a foreign body in the eye, which accounted for 78% of miscellaneous causes of injury. This finding is consistent with Islam et al. (2000) who reported that, among construction workers in West Virginia, foreign body in the external eye was the leading cause of eye injury[39]. Construction workers in their study experienced a rate of eye injury of 1.7 per 100 full time workers. Construction workers, along with agriculture and manufacturing, experienced a higher rate of eye injury than all other trades they examined. Though these injuries tended to cost less than all others, and were not a major cause of severe injury, they contribute significantly to overall health care cost by nature of their frequency.

Limitations

Though the injury rates following HomeSafe intervention were reduced significantly, there are some potential confounders that must be addressed. Primarily, as noted above, the combined rates do not reflect an adjustment for time trend. With injury rates declining annually, we cannot attribute the decline to HomeSafe without further analysis adjusting for time. In article three, the Poisson regression model will be used to evaluate the potential confounding effect of an antecedent time trend and perhaps strengthen the effect of HomeSafe on injury rate reduction.

In addition, the reduction in severe injuries caused by falls is potentially confounded by the OSHA directive STD 3.1, in 1995, which made the OSHA fall protection standard more accessible and relevant to residential construction workers. It is on this standard that HomeSafe is based. Whether the reduction was due to HomeSafe, STD 3.1, or a combination of the two is impossible to determine.

A significant limitation of the HomeSafe Program is the obvious lack of information addressing injuries caused by lifting or other movements. While these injuries were significantly lower following HomeSafe, they are a source of considerable injury, disability, and expense among the workers and companies involved in this program. Dement & Lipscomb (1999) also identified this cause of injury as a significant cause of injury with a rate of 1.97 per 200,000 hours worked among medical or lost work time injuries[5]. We concur with their recommendation for training an education around lifting and movement, in addition to research on engineering solutions to the moving and handling of objects and materials on the job site.

The program evaluation also has limitations worthy of discussion. The follow up period also was short, approximately eighteen months, which limited our ability to examine time trends more closely. However, the response rate for 1999 data among the participants dropped to 9.3%, yielding an insufficient amount for analysis. Additional years of follow up are needed to evaluate the program's effectiveness, as is increased compliance with data submission and program follow through.

Another limitation of this analysis is the lack of trade-specific information. These rates include trades, builders, and general contractors, all of whom experience different hazards and are at varying risk of injury. Trade-specific analysis would provide a more useful view of the injury experiences of the trade groups and how better to address injury prevention.

Strengths

The program did, however, have some significant strengths and benefits aside from its role in injury prevention. One obvious strength of the HomeSafe Pilot Program was the resulting information about the residential construction industry. HomeSafe investigators examined multiple data sources to organize and code the data. There were a number of benefits to this approach. The nature of the industry demonstrates the need to use multiple data sources when evaluating this population. As reported above, many participating companies had ten or fewer employees, and did not maintain 200 logs. As smaller businesses, many did not fill out first reports of injury completely, and some never submitted their loss runs, claiming they were too busy and had no one to take care of those details. Much of the information on the OSHA 200 logs, worker's compensation loss runs, and first reports of injury is duplicative, providing the opportunity for investigators to double check records for coding errors, missing data, and incomplete injury descriptions. For example, some first reports of injury were very difficult to read, however, investigators could confirm the cause, type, or body part on the loss run.

In addition, information that is unique to each data source is available and is important for defining the population. For example, the first report of injury records individual information such as age, ethnicity, years of experience, and years with current employer, the loss runs report the cost of the injury, and the OSHA 200 logs report the number of days away from work. Finally, supporting information on one source helped confirm the accuracy of information on another source. For example, the 200 logs were the only records that reported the number of days away from work, but the first report of injury recorded the date of injury and the date the employee returned to work, which confirmed the accuracy of the reports. In fact, very few discrepancies were noted.

Another strength of the HomeSafe Program was the attempt to make safety information specific to residential construction visible and available to most workers. Not only were participating companies provided with pocket-sized booklets for widespread distribution, they were provided with hard hat stickers and posters. In this way, HomeSafe information was provided in a variety of highly accessible, visible and potentially interesting formats, thus increasing the chance of worker exposure to the information. This method of increasing the salience of the information has been researched and reported as useful in both health and advertising campaigns, especially when the recipient of the information may not be actively engaged or interested in the process of behavior change[35].

Finally, the HomeSafe project actively involved the Home Builder's Association in safety promotion, brought together safety personnel from a number of different and competing companies, and provided the means for the HBA and OSHA to work together for a common goal. The HBA safety committee met regularly, discussed current safety issues, and performed regular jobsite safety audits. Representatives from OSHA attended safety meetings and received updates on the status of the program.

In conclusion, these results suggest that the HomeSafe Program may have had an impact on injury incidence rates among residential construction workers, especially injuries defined as severe. Severe injury incidence rates declined sharply following HomeSafe, and fell below BLS reported rates in 1998. Falls were the primary cause of severe injuries, were heavily targeted in the HomeSafe Program, and experienced a significant decline in incidence rate following the intervention. The rate of lost work time injuries caused by cuts, punctures or scrapes also decreased significantly following HomeSafe. The reduction in rates for lifting and movement injuries cannot easily be explained or attributed to HomeSafe because they were not directly addressed in the program. Why these rates declined is unknown.

Recommendations for Further Research

A trade specific analysis of these data would perhaps provide more useful and practical information for injury prevention and intervention programs and will be investigated in article two. In addition, data of this type will be evaluated in article three using time series or Poisson regression modeling to account for trends over time. Future studies among this occupational group should design a more efficient and organized method of obtaining data from participating companies. Many participants found it cumbersome and too time-consuming. Finally, qualitative research into perceptions of risk among residential construction workers would improve understanding of the culture of residential construction, and the behaviors, values, attitudes of the workers.

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PART TWO

TRADE SPECIFIC ANALYSIS OF INJURY PATTERNS AMONG RESIDENTIAL CONSTRUCTION WORKERS, 1994 - 1998

INTRODUCTION

The risk of non-fatal injury in the construction industry is among the highest of all the occupational trades. In recent years, a clearer picture of the overall patterns and circumstances of injury among construction workers has been provided by a number of researchers[1,2,3,4]. However, to further understand the risks and injury experiences among construction workers, information about the specific trade groups within the construction industry is vital. In addition, an understanding of the specific patterns of injury associated with each trade is crucial for the development of targeted safety education and training programs. Though research in this area is limited, several studies have reported trade specific injury patterns in the construction industry.

Injuries among carpenters perhaps have been the most well-described. Lipscomb et al. (1996) studied the workers' compensation claims of 11,232 union carpenters and reported injury rates based on 7135 claims filed by 3754 carpenters[1]. They found that the carpenters experienced an overall injury incidence rate of 34.8 per 200,000 hours worked. Injuries most often were caused by being struck by an object, overexertion, falls, or being abraded by an object, and the body parts most often injured were the back, fingers, eyes, and hand. Musculoskeletal injuries most often were back, neck and knee sprains[3].

Eye injuries among union carpenters accounted for 12% of workers' compensation claims with a rate of 6.1 per 200,000 hours worked[5].

Hunting et al. (1999) examined the emergency room records of 2,791 construction workers seen in an urban emergency room and evaluated injury patterns among carpenters, electricians, plumbers, and ironworkers[4]. These tradesmen were primarily involved in commercial new construction, commercial renovation and maintenance work. They found that carpenters experienced a higher proportion of injuries caused by getting caught in between objects and a lower proportion of injuries caused by falls and foreign objects in the eye.

Among electricians, Hunting et al. (1999) found an excess of cutting and piercing injuries and more eye injuries than among other construction workers[4]. Islam et al. (2000) reported that foreign body in the eye was the most common type of eye injury among electricians[6]. Gillen et al. (1997) also examined non-fatal fall injuries among construction workers, and found that electricians were under-represented[2].

Roofers, however, were over-represented among their sample[2]. They also found a higher percentage of fractures to the extremities and miscellaneous fractures among ironworkers, roofers, and drywallers, lathers, and plasterers. Roofers had a higher percentage of head injuries. In addition, ironworkers and roofers sustained the most severe injuries (measured by the Injury Severity Score) and ironworkers and drywallers, lathers, and plasterers experienced the greatest functional limitation following injuries (as measured by the Health Assessment Questionnaire). Finally, drywallers, lathers, and plasterers had the most lost work time, with a mean of 59 days. They did not find an association between functional limitations and experience, age, or job title.

Hunting et al. (1999) reported injury characteristics among ironworkers and found that ironworkers experienced more injuries resulting from overexertion and fewer injuries caused by cutting or piercing objects[4]. Injuries among drywall installers have been described by Chiou et al. (2000), who investigated the characteristics of injuries and risk factors associated with injuries among 16,023 workers[7]. They found that drywall installers are at a higher risk for overexertion, falls to a lower level, and being struck by objects. They were most at risk for sprains, strains or tears and most often sustained injuries to the trunk. While these characteristics were similar to the construction industry as a whole, the sources of the injuries were different than those reported by other researchers[7,4]. Specifically, injuries among drywall installers were most often associated with floors, wallboard and bodily motion.

Lipscomb et al. (2000) also described injury patterns among drywall installers. They reported similar findings, with struck by, overexertion and falls as the top causes of injury[8]. They reported cuts to the upper extremity and sprains/strains to the back as the most common type of injury. Finally, they too identified wallboard/sheetrock as a major cause of injury.

Kinn et al. (2000) examined the characteristics of injuries associated with plumbers and pipefitters[9]. They found that lacerations, cuts, and abrasions; strains and sprains; and bruises and contusions were the most common types of injury. Eyes, fingers and backs were the most common body parts injured, and most injuries were caused by parts and materials, worker position or motion, and tools, instruments and equipment. Hunting et al. (1999) reported that plumbers experienced proportionately more injuries caused by falling objects and foreign objects in the eye, and fewer were from falls[4]. Gillen et al. (1997) reported an under-representation of plumbers in the above referenced study of non-fatal falls[2].

These studies included both residential and commercial construction workers. The residential construction industry itself has been less well-defined. Dement and Lipscomb (1999) provided a comprehensive picture of the injury rates and hazards experienced by residential construction workers in North Carolina[10]. In addition to overall rates, they examined specific causes of injuries among trade groups, which more clearly describes hazards associated with a particular occupation. They reported that roofers, insulators, carpenters and drywall installers had the highest rate of falls from a different level. Welders and cutters, insulators, and carpenters had the highest rates of injuries due to being struck by an object, and that mechanics, insulators and electricians had the highest rate of injury due to lifting or other movements. Overall, the most common causes of injury were struck by, lifting or movement injuries, and falls. The body parts most often injured were the back (including shoulders), fingers, hand/wrist, and leg/knee. In another study, among union carpenters involved in residential construction, back sprains had the highest rate of injury, followed by hand and knee contusions[3]. Finally, Gillen et al. (1997) reported that 54% of the falls in their study occurred on residential projects, 34% of commercial projects, and 11% were described as "other"[2].

These studies provide an initial examination of trade specific hazards in the construction industry. More specific analysis of injury patterns among trades within residential construction will help in the design and evaluation of prevention campaigns directed at the risks and hazards faced by the residential construction industry.

This paper more closely examines the experiences of specialty trades participating in the HomeSafe Pilot Program in Denver, Colorado. The program, described in detail elsewhere, was a joint venture between OSHA Region VIII and the Home Builders Association of Metropolitan Denver (HBA)[11]. It was designed to reduce injuries among residential construction workers, with safety information and trainings specifically targeted at the residential construction industry. Implemented in 1997, participating companies received booklets, stickers, posters, and a three-hour safety-training workshop. They were also subject to on-site safety audits based on the specific hazards outlined in the safety training and had the opportunity to attend on-going ten-hour safety training courses. In return they provided company injury data in the form of OSHA 200 logs, first reports of injury, and workers compensation loss runs from 1994 through 1998. They also provided total person-hours worked for each year to allow for the calculation of incidence rates. All participating companies reported their primary business was residential construction.

The primary purpose of this paper is to evaluate trade specific pre- and post-HomeSafe injury incidence rates, evaluate trade specific pre- and post-HomeSafe severe injury incidence rates, and evaluate characteristics associated with overall injuries among the trades.

METHODS

Data Sources

Injury information was obtained from the first reports of injury, workers' compensation loss runs, and OSHA 200 logs submitted by participating companies. Information on mechanism, nature, and body part from the first reports of injury and the 200 logs was coded according to a limited version of the ANSI codes and cross checked with the coding reported on the loss runs. Additional information included some individual characteristics, including age, gender, ethnicity and years of experience. Each company was identified by Standard Industrial Classification (SIC) code according to the self-identified primary profession of the business. Our unit of analysis was the company, not the individual. Therefore, all injuries occurring within each company were coded by the SIC associated with the company, not the individual's job title. Though we received OSHA 200 logs from many companies, the job title section often was not filled out. In addition, as so many of the HomeSafe partners had fewer than 11 employees, we did not have 200 logs from all companies. Finally, we had no way to consistently differentiate between laborers and tradesmen within a company, therefore, all data reflects company trade, not individual trade.

Study Participants

A total of ninety-seven companies submitted enough information to be included in the analysis. Thirteen trades, including single family homebuilders, submitted injury information to researchers. Single-family homebuilders were by far the most represented, though they typically represent the smaller companies because they so often use subcontractors to do much of the site work. One trade was not included in the trade-stratified data: only one landscaping company returned enough data to be included in the analysis. This company had only two employees, including the owner, and did not incur any injuries during the study period. Therefore, they were left out of the trade specific data analysis.

Our study is limited to those companies enrolled in HomeSafe. Attempts were made to establish a control group by randomly contacting residential construction companies in the Denver-Metro area that were not associated with HomeSafe. However, because of the sensitive nature of the information we requested, less than one percent agreed to submit their injury data. After contacting approximately 500 companies with only four positive responses, efforts were abandoned. In addition, we had no way to determine if employees of HomeSafe partners also worked for potential control companies.

Statistical Analysis of Injury Incidence Rates

Injury incidence rates for overall and severe injuries were calculated using the total number of injuries as the numerator and the total number of hours worked as the denominator, and are expressed per 200,000 person hours worked. Rates for the time periods pre- and post-HomeSafe were compared, and among those companies who experienced a significant decrease in injury rate post-HomeSafe, injury rates by year were graphically examined for trend. Overall injuries include all injuries, even those requiring no treatment beyond first aid on site, like a bee sting or minor scrape. Severe injuries were defined as those injuries resulting in at least one day away from work. Only denominator data from those companies who submitted information on lost work time injuries was used to analyze severe injuries.

Injury incidence rates for each trade were compared using the following formula:

$$Z = \frac{c^A - c^B}{\sqrt{[se(c^A)]^2 + [se(c)]^2}}$$

where:

c^A and c^B = incidence rates for sample pre- and post-HomeSafe

$se(c^A)$ and $se(c^B)$ = standard errors for sample pre- and post-HomeSafe

In addition, injury rates among HomeSafe trades were compared graphically with Bureau of Labor Statistics (BLS) data for the same time period. The BLS analyzes recordable occupational injury and illness data from a stratified random sample of establishments with eleven or more employees[12]. The sample is stratified by State, Standard Industrial Classification code (SIC) and establishment size. Approximately forty States participate in the BLS occupational illness and injury survey. Information on fatal, nonfatal and lost work time nonfatal injuries is collected to generate annual national and state injury and illness counts and incidence rates. The BLS uses median days lost and percent distribution of lost work time as measures of injury severity.

Statistical Analysis of Injury Characteristics

Trade specific comparisons were performed to examine the differences between the trade groups and identify the leading causes of injury among each trade. Injuries among the trades were described by mechanism of injury, nature of injury, and body part injured. The leading causes of injury among the trades were calculated, and then the proportions of cause and type of injury for each trade was compared to all other trades with the chi-square test of association, using the following formula:

$$\chi^2 = \sum_i \sum_j \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

where:

O_{ij} = observed frequency in cell (i,j)

E_{ij} = expected frequency for cell (i,j)

Yates' continuity correction was used when the expected cell count was less than five,

$$\chi^2 = \sum_i \sum_j \frac{(O_{ij} - E_{ij} - .5)^2}{E_{ij}}$$

Type or nature of injury also was described according to the body part injured. Because the number of severe injuries that occurred among certain trade groups was so small, trade specific characteristics are reported for all injuries.

RESULTS

Residential construction companies in HomeSafe generally were small, with fewer than 50 employees; however, a few had over 100 employees (see Table I). Forty percent had ten or fewer employees. Among those employees injured, age range was similar across the trades. The average age at injury was 30.0 years, with most in their late twenties to late thirties. Years of experience was more varied. Injured employees of electrical companies had the least experience, with an average of only 1.7 years on the job. Among masonry and other stone work companies, most employees had more than six years of experience, as did single family homebuilders and floor laying/floor work companies. Companies in most other trades had an overall employee average of about five years of experience.

Table I: HomeSafe Partner Demographic Information

Trade	Distribution of Trades Among HomeSafe Participants	Company Size (Mean # Employees)	Age of Injured Employees (Mean Years)	Experience of Injured Employees (Mean Years)
Landscaping	1	2	*	*
Single Family Homebuilders	41	5	36.0	7.2
Plumbing, Heating, Air Conditioning	4	20	33.7	4.1
Painting and Paper Hanging	3	24	30.5	5.9
Electrical Work	6	18	29.5	1.7
Masonry and Other Stonework	2	28	30.0	9.0
Plastering, Drywall, and Insulation	7	52	30.3	4.1
Carpentry	11	15	32.9	5.9
Floor laying and Floor Work	2	21	29.5	6.6
Roofing, Siding, and Sheetmetal Work	7	8	30.0	4.4
Concrete Work	4	50	29.6	1.9
Excavation Work	3	10	26.0	4.0
Miscellaneous Special Trade Contractors	6	35	30.6	2.5

*data not provided

Analysis of individual factors such as age, experience and ethnicity was limited because companies reported these data inconsistently. For example, if a company reported 35 injuries and provided ethnicity information for only one injury, we could not determine rates because denominator data were available only by company, our unit of measure. The potential for over or underestimating rates among any one group was too great; therefore, we did not calculate rates based on individual traits.

Descriptive analysis of the data revealed that women represented about 2.0% of the sample. An analysis of ethnicity demonstrated that 55.4% were Caucasian, 34.8% of those injured were Hispanic, 8.8% chose not to answer, 0.8% were African- American and 0.4% were of Asian descent. The numbers of

African Americans and Asians were too small to allow meaningful comparisons of proportions. Though a comparison of rates was not possible, we were able to compare proportions of lost workday injuries between workers of Hispanic and Caucasian descent. Workers of Hispanic descent experienced a higher proportion of lost workday injuries (versus no lost workday injuries) than Caucasian workers ($p=0.034$).

Overall Injury Rates

Injury rates stratified by trade can be seen in Figure 1. Companies specializing in roofing, siding and sheetmetal work (SIC code 1761), carpentry (SIC code 1751) and plumbing, heating and air conditioning (1711) had the highest rates of injury per 200,000 hours worked pre- and post-HomeSafe. Companies specializing in masonry and other stonework (1741) and floor work (1752) had the lowest rates per 200,000 hours worked pre- and post-HomeSafe. Single family homebuilders, masons and other stoneworkers, and special trade contractors were the only three trades with significantly lower rates following HomeSafe (Table II). When these three trades were evaluated by year (Figures 2, 3, and 4), rates for single family homebuilders appeared to demonstrate a sudden decline in injuries following HomeSafe. Rates for special trade contractors, on the other hand, did not demonstrate this pattern and instead declined sharply immediately following HomeSafe intervention and then rose to 19.3 injuries per 200,000 hours worked again one year post-intervention, the highest rate for all study years. Rates for companies specializing in masonry and other stonework dropped to zero following HomeSafe intervention. Of note is that among companies specializing in floor laying and floor work, rates were increasing prior to HomeSafe and began decreasing following HomeSafe, though no significant difference in rates was found (Figure 5). Annual rates for other trade groups can be found in Appendix A.

Table II: Injury Incidence Rates per 200,000 Hours Worked by Trade: Pre-HomeSafe and Post-HomeSafe Comparison

Trade	SIC	Pre-HomeSafe	Post-HomeSafe	p-value*
Single Family Home Builders	1521	10.9	6.1	<0.001
Plumbing, Heating, Air Conditioning	1711	24.5	24.0	0.932
Painting and Paper Hanging	1721	16.4	12.4	0.326
Electrical Work	1731	11.5	16.3	0.397
Masonry and Other Stonework	1741	8.8	0.0	<0.001
Plastering, Drywall, and Insulation	1742	17.1	14.3	0.194
Carpentry	1751	32.8	31.8	0.745
Floor Laying and Floor Work	1752	9.5	6.8	0.625
Roofing, Siding, and Sheetmetal Work	1761	34.4	27.8	0.075
Concrete Work	1771	11.0	8.3	0.125
Excavation Work	1794	10.2	9.7	0.929
Miscellaneous Special Trade Contractors	1799	15.3	8.7	0.043

*probability value of test of difference between rates prior to and following implementation of HomeSafe

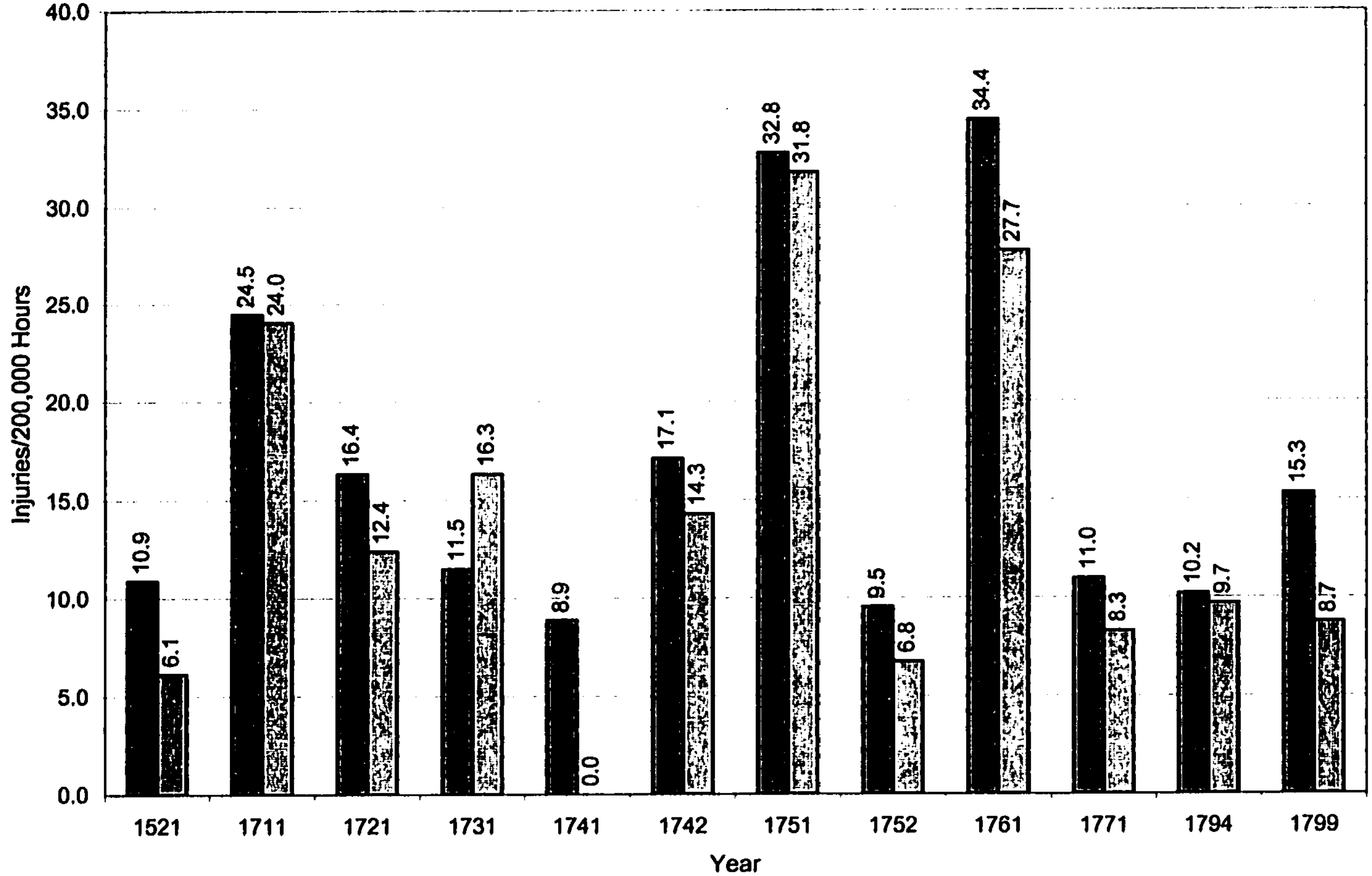

Figure 1:
Injury Incidence Rates By Trade pre- and post-HomeSafe

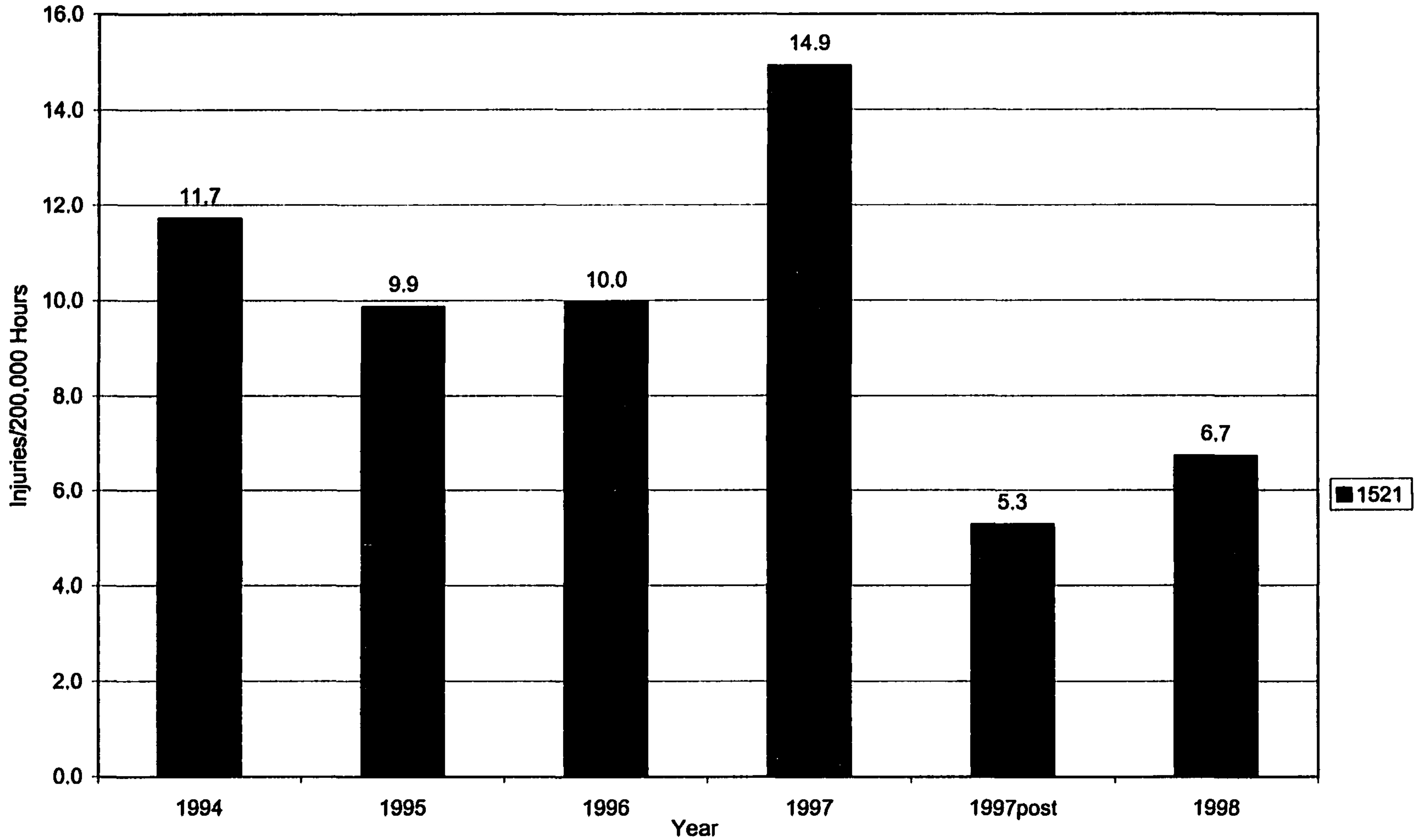

Figure 2:
Injury Incidence Rates among Single Family Home Builders, 1994 -1998

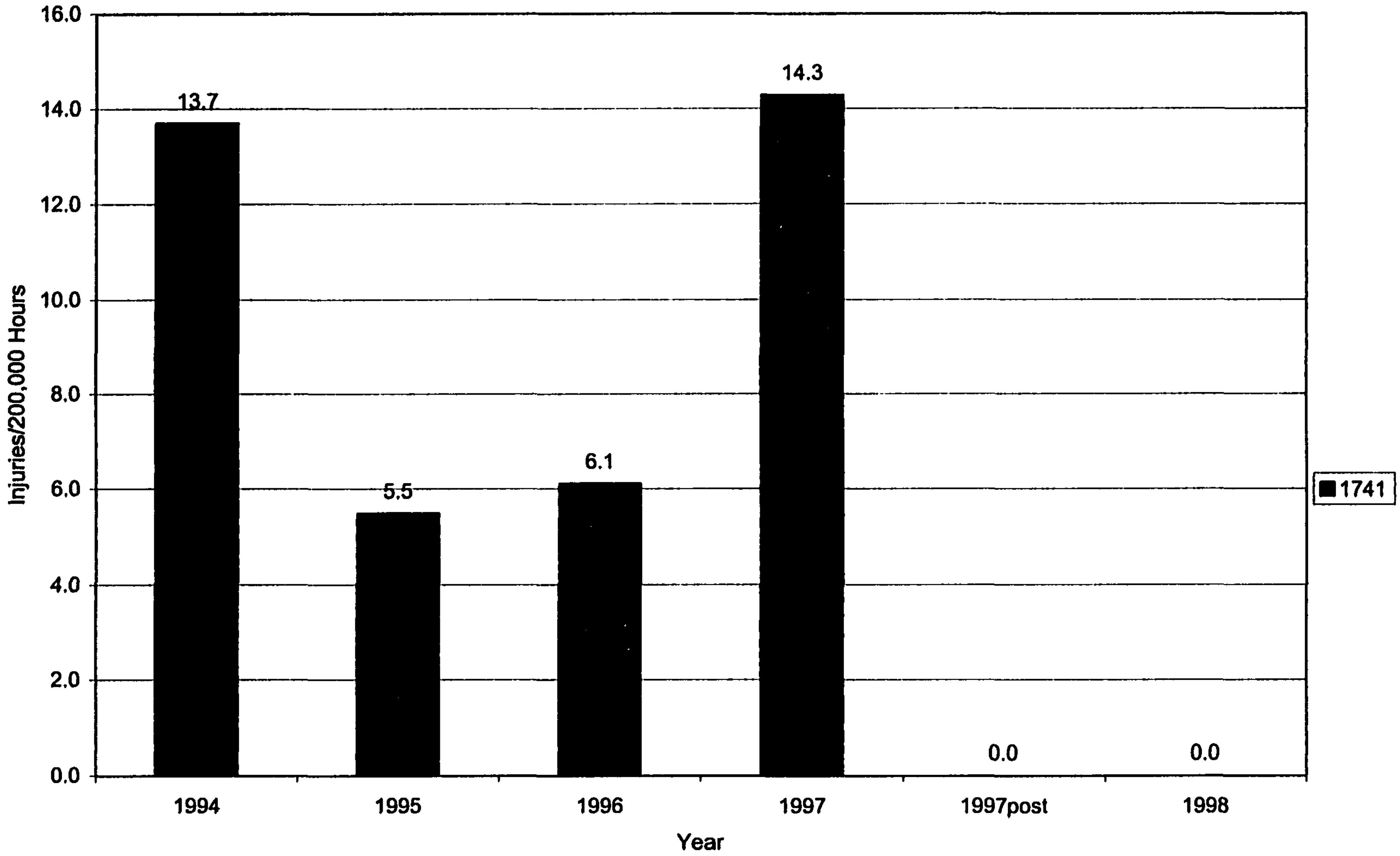

Figure 3:
Injury Incidence Rates among Companies Specializing in Masonry and Other Stonework, 1994 - 1998

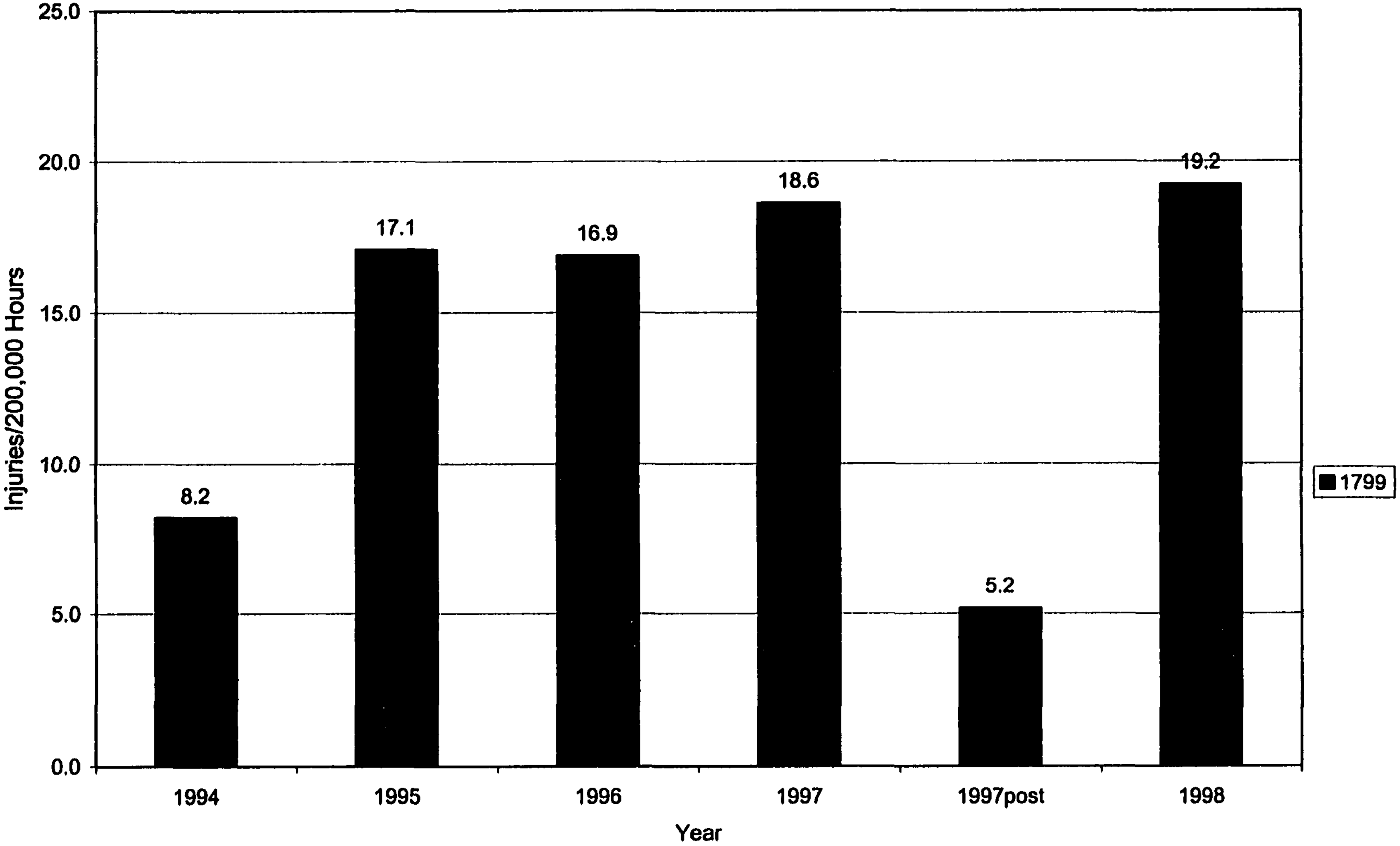

Figure 4:
Injury Incidence Rates among Miscellaneous Special Trade Contractors, 1994-1998

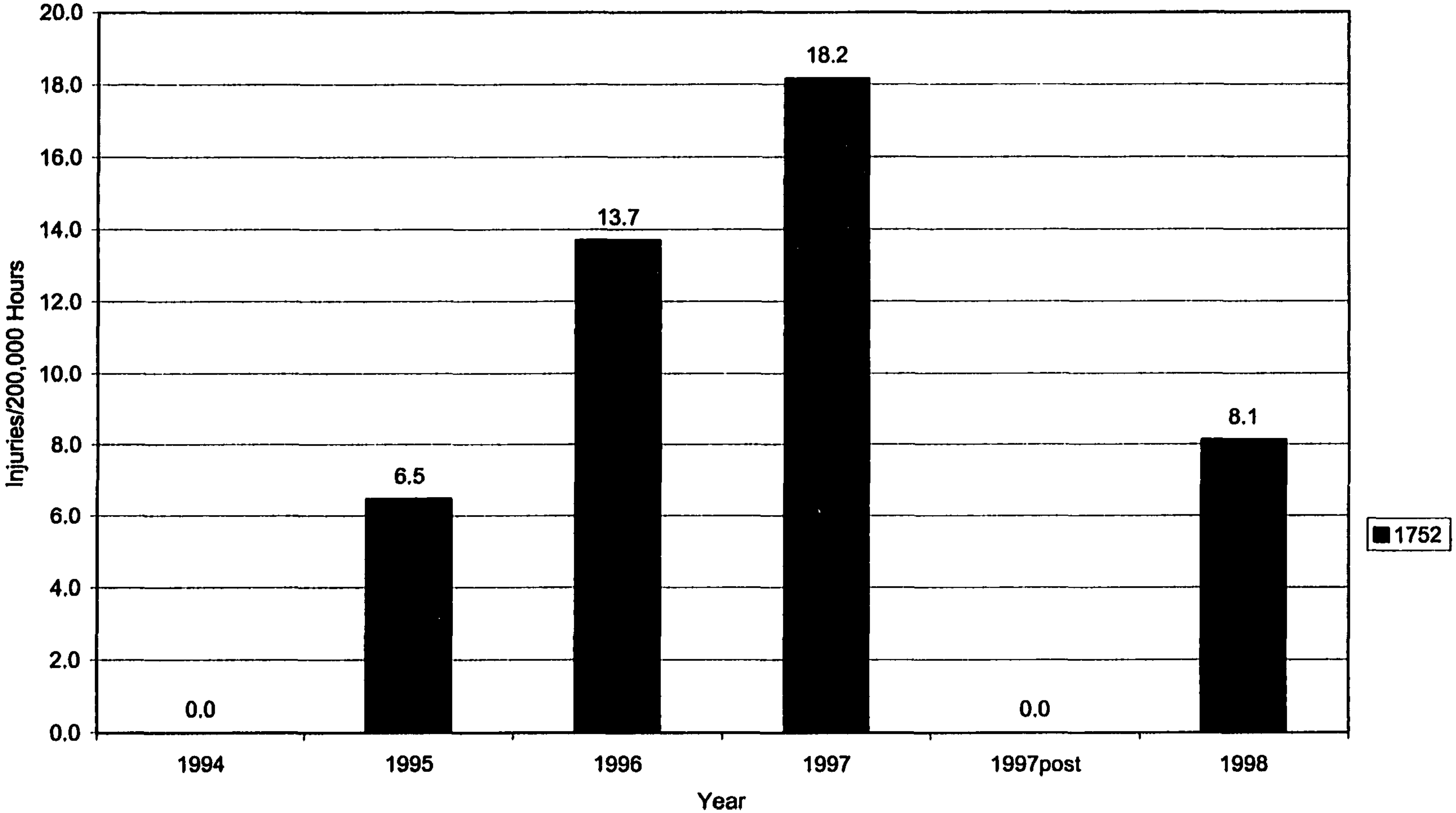

Figure 5:
Injury Incidence Rates among Companies Specializing in Floor Laying and Floor Work, 1994 - 1998

Lost Work Day Injury Rates

Lost work time injuries, a surrogate measure of severity, are those injuries that resulted in one or more lost workdays. The day of the injury event was not included as a lost day, even if the employee left work and did not return that day. Overall lost workday rates by individual trade are shown in Figure 6. As with overall rates, carpentry and roofing, siding, & sheetmetal companies had the highest rates of severe injuries, at 10.2 and 9.6 per 200,000 hours worked respectively. Plastering, drywall and insulation companies also had high rates of severe injuries, with 8.4 lost work time injuries per 200,000 hours worked. Plumbing, heating, and air conditioning companies, while experiencing a high rate of injury overall (24.5 per 200,000), had one of the lowest rates of lost work time injuries (3.3 per 200,000). Single family home builders and floor laying and floor work companies were the only two trades with LWDI rates lower than those for plumbing, heating and air conditioning companies.

Four trades had significantly lower rates following HomeSafe intervention: single family homebuilders, masons and other stoneworkers, plastering, drywall, & insulation workers, and roofing, siding, & sheetmetal workers (Table III).

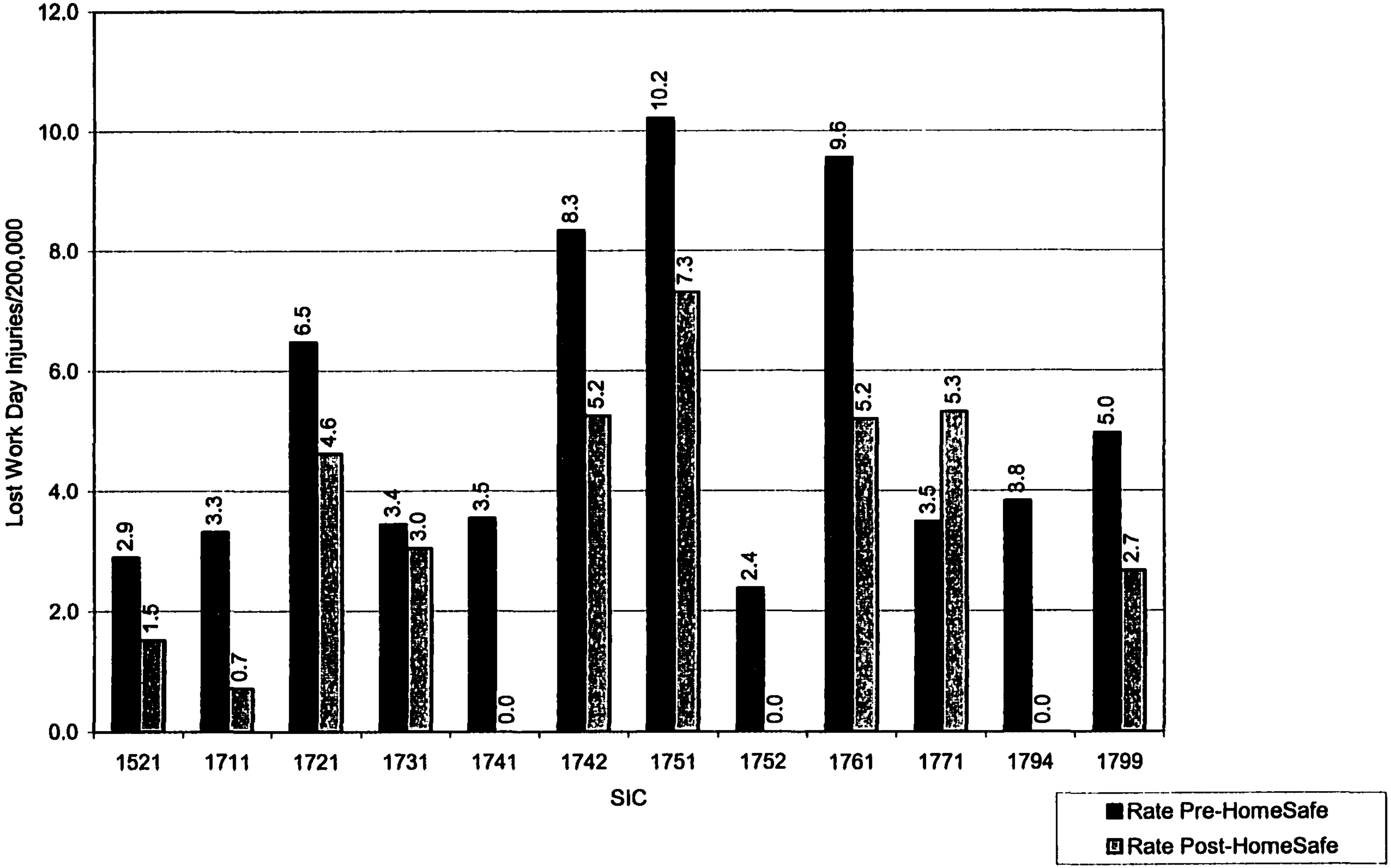

Figure 6:
Lost Work Day Injury Incidence Rates By Trade, pre- and post-HomeSafe

Table III: Lost Workday Injury Incidence Rates per 200,000 Hours Worked by Trade: Pre-HomeSafe and Post-HomeSafe Comparison

Trade	SIC	Pre-HomeSafe	Post-HomeSafe	p-value*
Single Family Home Builders	1521	2.9	1.5	0.007
Plumbing, Heating, Air Conditioning	1711	3.3	0.7	0.072
Painting and Paper Hanging	1721	6.5	4.6	0.455
Electrical Work	1731	3.4	3.0	0.864
Masonry and Other Stonework	1741	3.5	0.0	0.005
Plastering, Drywall, and Insulation	1742	8.3	5.2	0.028
Carpentry	1751	10.2	7.3	0.057
Floor Laying and Floor Work	1752	2.4	0.0	0.081
Roofing, Siding, and Sheetmetal Work	1761	9.6	5.2	0.014
Concrete Work	1771	3.5	5.3	0.245
Excavation Work	1794	3.8	0.0	0.086
Miscellaneous Special Trade Contractors	1799	5.0	2.7	0.191

*probability-value of test of difference between rates prior to and following implementation of the program

To further assess the impact that HomeSafe may have had on these four trade groups, rates were examined by year (Figures 7 - 10). Among single family homebuilders, a sudden decline in lost work time injuries occurred following HomeSafe intervention. Among masons and other stoneworkers, rates appeared stable until 1997, when they jumped from 3.1 per 200,000 hours worked to 14.3 per 200,000 hours worked, then dropped again in 1997 and 1998. However, when the data for 1997 are removed, the difference still exists (p=0.012), indicating a possible positive effect of HomeSafe on injury reduction. No clear trend in LWDI rates is evident among plastering, drywall, & insulation companies prior to or following HomeSafe intervention. In fact, the injury incidence rate rises in 1998, the second year of HomeSafe intervention. Finally, among roofing, siding, and sheetmetal workers, a downward trend prior to HomeSafe intervention is evident. However, injury incidence rates rose during the second year of HomeSafe (1998). This trend does not indicate an effect of HomeSafe on injury rate reduction. Annual rates for other trade groups can be found in Appendix B.

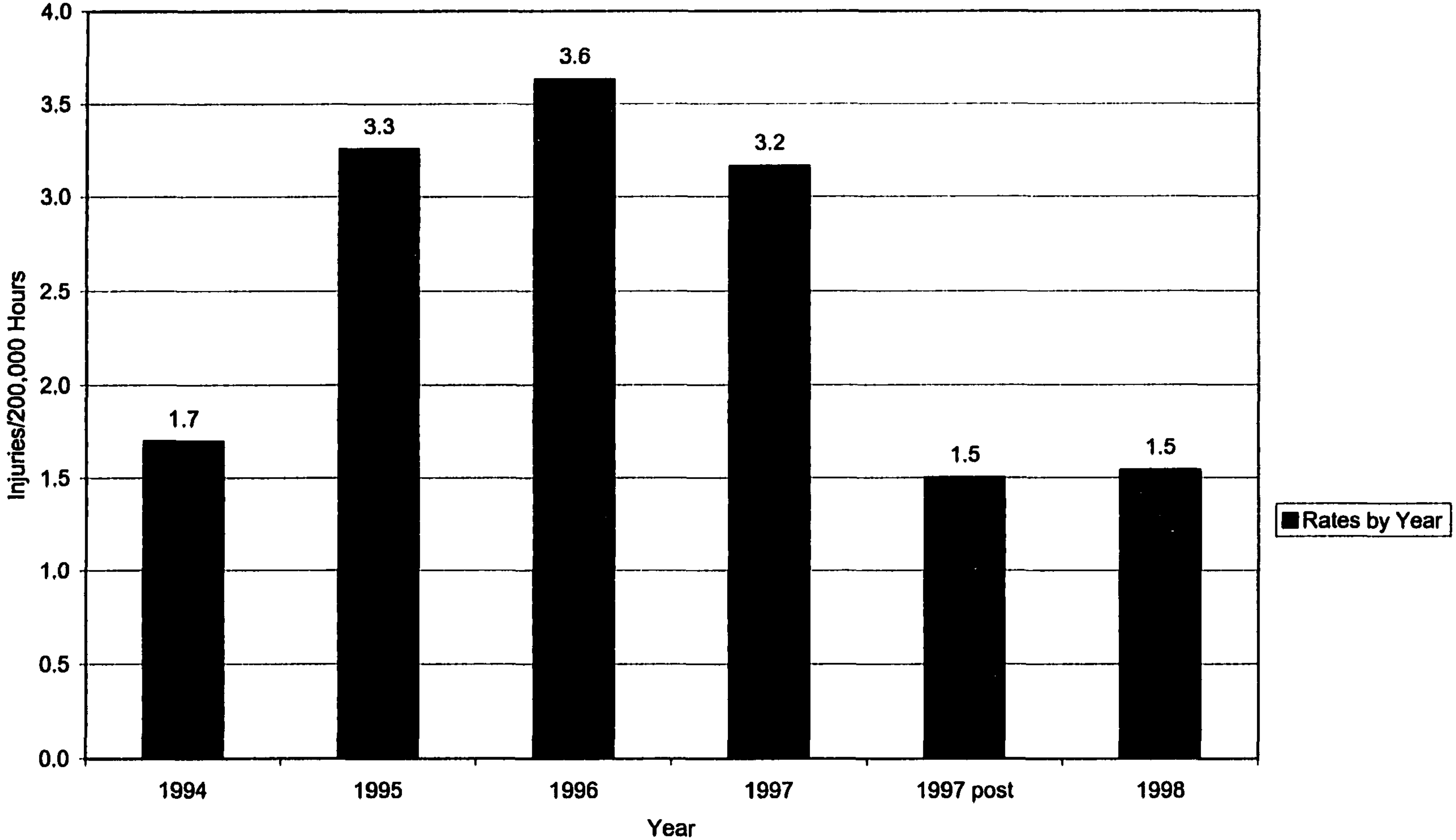

Figure 7:
Lost Work Day Injury Incidence Rates among Single Family Home Builders: 1994-1998

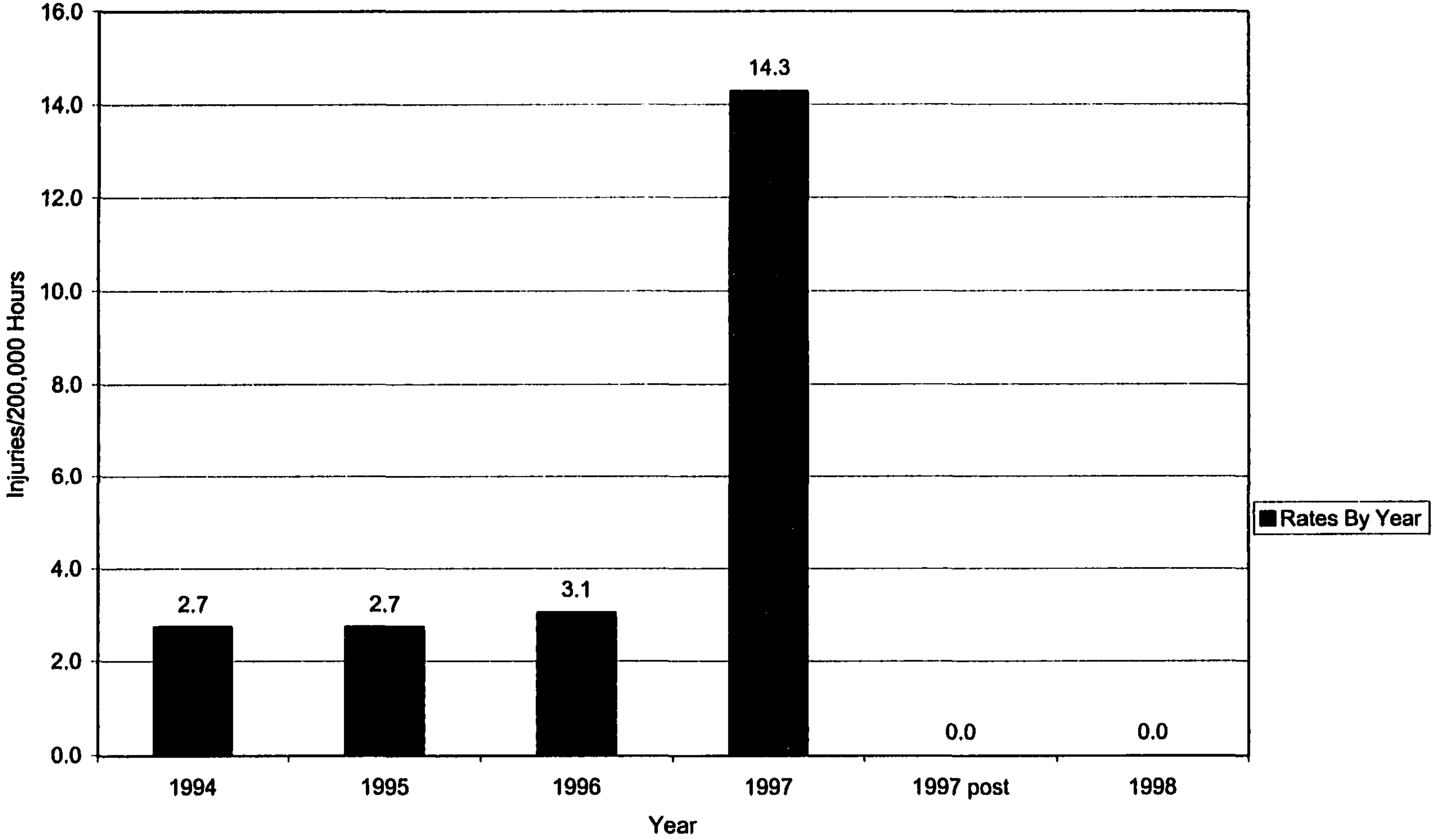

Figure 8:
Lost Work Day Injury Incidence Rates Among Companies Specializing in Masonry and Other Stonework: 1994-1998

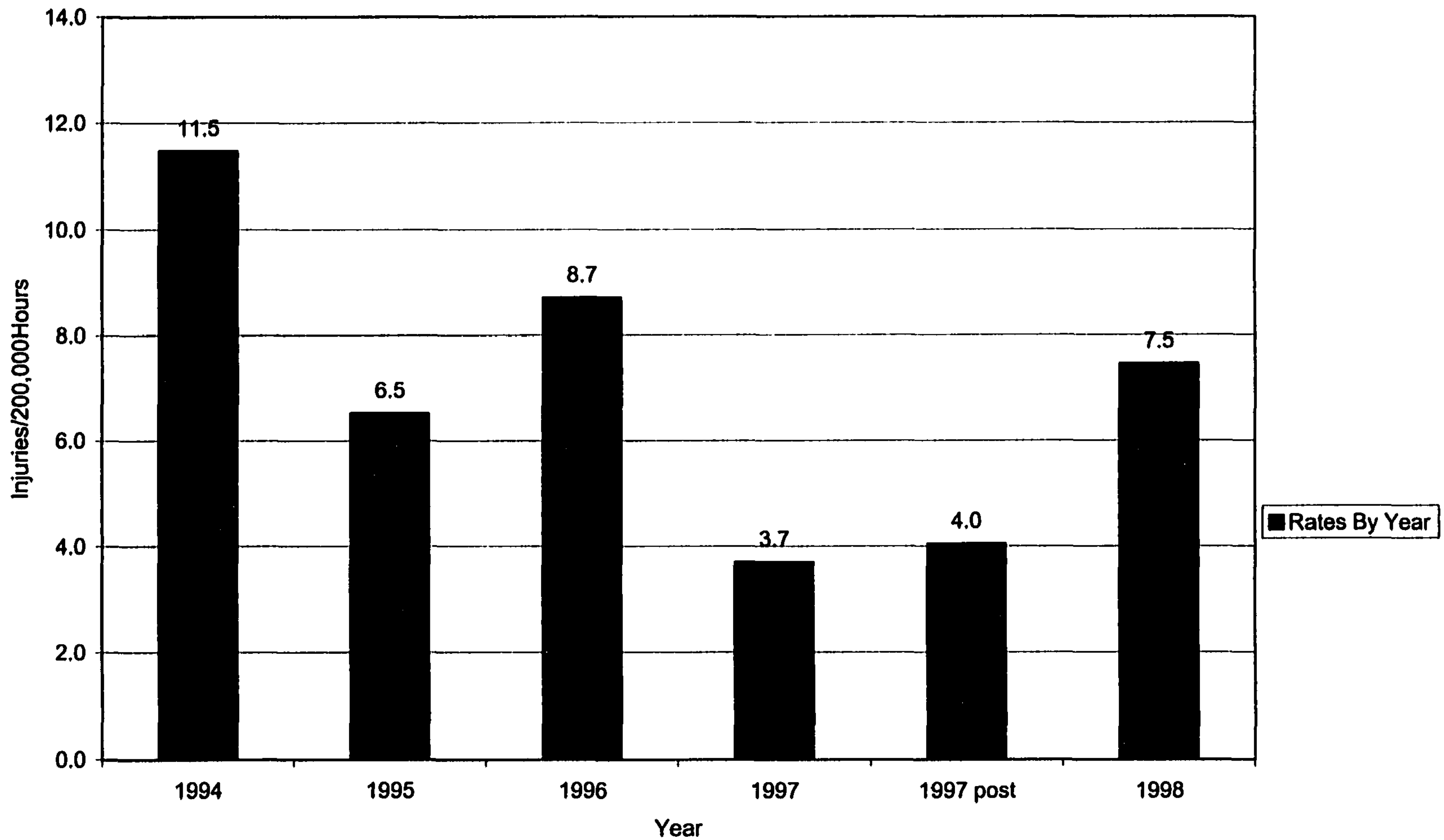

Figure 9:
Lost Work Day Injury Incidence Rates among Companies Specializing in Plastering, Drywall, and Insulation: 1994-1998

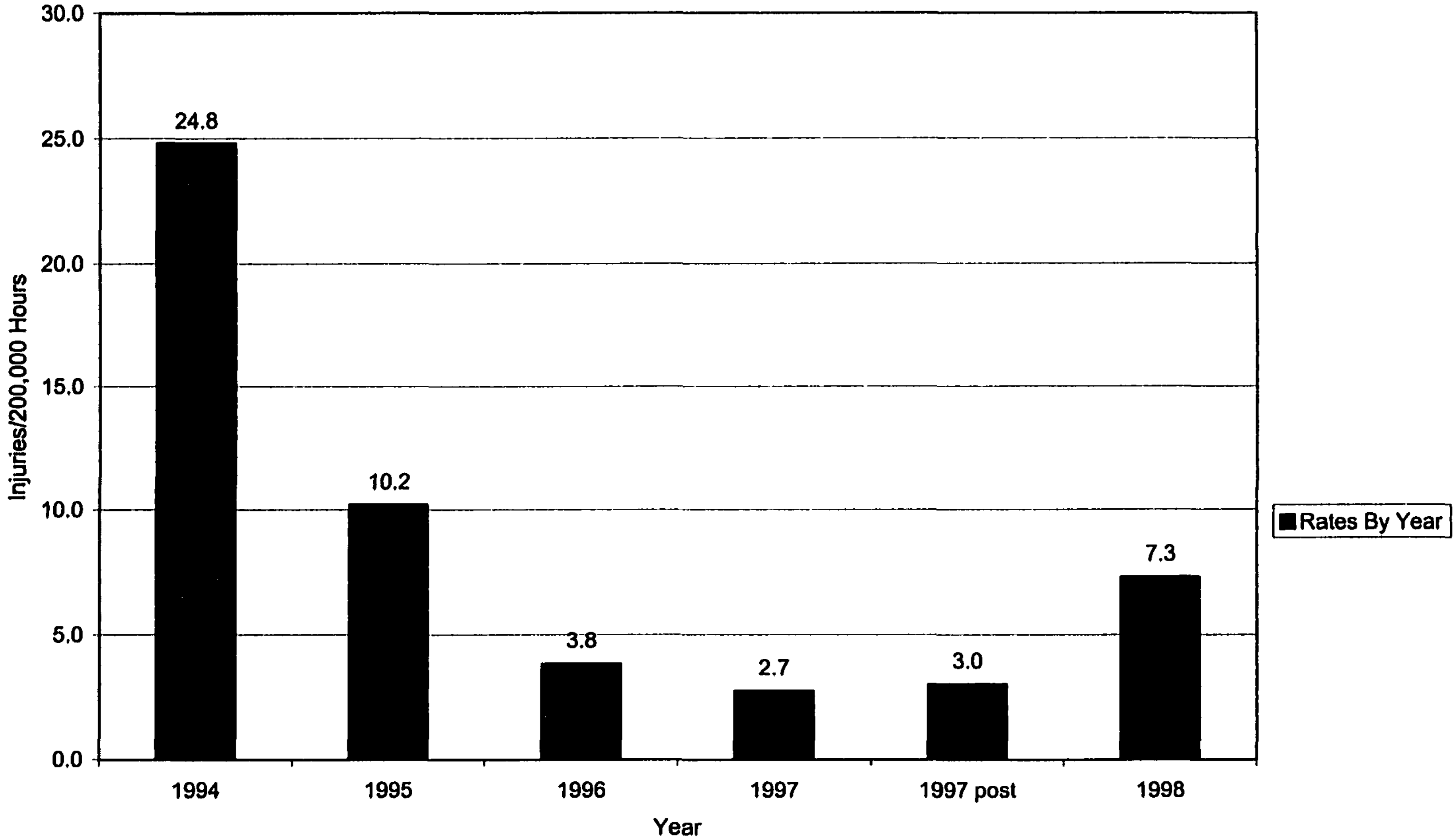

Figure 10:
Lost Work Day Injury Incidence Rates among Companies Specializing in Roofing, Siding, and Sheetmetal: 1994-1998

Characteristics of Injuries among Trades

Because of the small numbers of severe injuries in each trade group, characteristics of each trade included data on all injuries. Characteristics evaluated included the mechanism or cause of injuries, the nature or type of injuries, and the body parts associated with those types of injury.

Causes of injuries among HomeSafe participants

The major causes of injuries in this population have been reported previously[11]. Overall, injuries caused by cuts, punctures, and scrapes accounted for 20.4% of all injuries, falls accounted for 18.0%, and injuries caused by lifting or other movements accounted for 16.9% among all trades pre-HomeSafe. Post-HomeSafe, injuries caused by cuts, punctures and scrapes accounted for 22.9%, by falls for 19.5%, and by lifting or other movements for 14.2%.

Data were evaluated by trade to assess the leading causes of injuries among trade groups and to assess differences in injury proportion by trade group using the chi-square test of association. Yates' continuity correction was used only when the expected cell count was less than five. Comparisons were made by trade versus all other trades and mechanism of injury versus all other causes injuries (Tables IV and V).

Table IV: Percent of Injuries by Mechanism of Injury for Construction Trades, prior to HomeSafe Intervention.

Mechanism	1521	1711	1721	1731	1741	1742	1751	1752	1761	1771	1794	1799
Cut	14.5* p=0.008	19.6	14.6	32.1& p=0.024	28.6	13.7* p=0.006	26.6& p=0.001	8.3	30.0& p<0.001	11.9* p=0.031	0	13.0
Fall	18.8	23.2	39.6& p<0.001	17.9	9.5	26.6& p<0.001	13.2* p=0.011	8.3	16.2	14.9	0	9.3* p=0.015
Strain	24.0& p<0.001	19.6	20.8	10.7	28.6	13.3	15.3	25.0	10.7* p=0.004	14.9	33.3	23.2
Struck	9.4	19.6& p=0.004	6.3	3.6	4.8	4.2* p=0.004	10.1	8.3	5.5* p=0.036	16.8& p=0.004	16.7	14.8& p=0.027
Burn	0.7	1.8#	2.1	N/A	N/A	N/A	0.6	N/A	1.6	2.0	N/A	N/A
Caught	1.0	1.8	N/A	5.4	N/A	1.7#	1.5	N/A	N/A	5.9#& p<0.001	N/A	1.9
Strike	9.7	5.4	4.2	8.9	4.8	7.1	5.2	N/A	9.5	8.9	33.3	1.9* p=0.025
Misc	20.5	7.1* p=0.002	12.5* p=0.043	21.4	14.3	31.5& p=0.010	26.9	50.0	25.0	1.0* p<0.001	16.7	31.5

*The proportion of injuries from selected cause for selected trade versus all other trades is significantly less than that for all other trades
&The proportion of injuries from selected cause for selected trade versus all other trades is significantly greater than that for all other trades
#Yates' continuity correction applied because table contained one or more cells with an expected cell count less than five.
N/A = no injuries were reported in this category

Table V: Percent of Injuries by Mechanism of Injury for Construction Trades, post-HomeSafe Intervention

Mechanism	1521	1711	1721	1731	1741	1742	1751	1752	1761	1771	1794	1799
Cut	22.4	31.3	25.0	44.4	N/A	11.1	28.1	N/A	30.6	2.8* $p=0.003$	N/A	17.7
Fall	27.1	6.3	20.0	N/A	N/A	39.1& $p<0.001$	9.2* $p<0.001$	N/A	24.7	16.7	N/A	11.7
Strain	18.8	18.8	13.3	N/A	N/A	6.3	11.0	50.00	14.1	25.0	N/A	29.4
Struck	5.9	6.3	6.7	22.2	N/A	4.8	6.7	50.00	7.6* $p=0.012$	20.6&# $p=0.002$	N/A	29.4&# $p=0.002$
Burn	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Caught	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Strike	10.6	N/A	6.7	22.2	N/A	10.9	3.1* $p=0.036$	N/A	5.9	2.8	N/A	5.9
Misc/ Unspecified	10.6* $p<0.001$	37.5	33.3	11.1	N/A	29.6	41.5& $p=0.000$	N/A	15.3* $p=0.014$	16.7	N/A	5.9

*The proportion of injuries from selected cause for selected trade versus all other trades is significantly less than that for all other trades

&The proportion of injuries from selected cause for selected trade versus all other trades is significantly greater than that for all other trades

#Yates' continuity correction applied because table contained one or more cells with an expected cell count less than five.

N/A = no injuries were reported in this category

Residential Home Builders (1521)

Pre-HomeSafe, strain and injury by lifting or other movement was the leading cause of injury among residential home building (24.0%). Residential homebuilders also experienced a significantly higher proportion of strain injuries when compared to all other trades ($p < 0.001$). Post-HomeSafe, falls were the leading cause of injury (27.0%). This proportion was not significantly higher than that for other trades.

Plumbing Heating & Air Conditioning (1711)

Pre-HomeSafe, falls were the major cause of injury among plumbing, heating, & air conditioning companies (23.2%). Though they were the major cause of injury, the proportion of falls among plumbing, heating & air conditioning workers was not significantly higher than among the other trades. However, the analysis also revealed a significantly higher proportion of injuries caused by being struck by and object (19.6%) among plumbing, heating, & air conditioning companies as compared to all other trades ($p=0.004$). Post-HomeSafe, falls accounted for only 6.3% of the injuries. Miscellaneous/unspecified (37.5%) and cuts, punctures, or scrapes (31.3%) were the primary causes of injuries. None of these proportions differed when compared to all other trades.

Painting and Paper Hanging (1721)

Pre-HomeSafe, falls were the major cause of injury among painting & paper hanging companies (39.6%). Individuals working for painting and paper hanging companies experienced a significantly higher proportion of fall injuries as compared to all other trades ($p < 0.001$). Post-HomeSafe, falls accounted for

20.0% of the injuries while miscellaneous or unspecified injuries accounted for 33.3% of all injuries.

Electrical Work (1731)

Pre-HomeSafe, cuts, punctures, and scrapes were the major causes of injury among companies involved with electrical work (32.1%). Individuals working for companies involved in electrical work experienced a significantly higher proportion of cuts, punctures and scrapes when compared to all other trades, pre-HomeSafe ($p=0.024$). Cuts, punctures, and scrapes remained the leading cause of injury post-HomeSafe among electrical workers, though the proportion of injuries did not differ significantly from that for all other trades (44.4%).

Masonry and Other Stonework (1741)

Cuts, punctures, and scrapes and strain or injury by lifting or other movement tied for the major causes of injury among companies involved with masonry and other stone work (28.6% each). Masonry and other stonework companies reported no injuries for the years following HomeSafe.

Plastering, Drywall, and Insulation (1742)

Pre-HomeSafe, the leading cause of injury among plastering, drywall, & insulation companies was miscellaneous/unspecified (31.6%). This proportion was significantly higher than that for all other trades ($p=0.010$). Falls were also significantly higher than that for all other trades, accounting for 26.6% of all injuries ($p < 0.001$). Fall injuries were the leading cause of injury post-HomeSafe

(39.1%) followed by miscellaneous/unspecified (29.6%). Neither of these proportions differed significantly from all other trades.

Carpentry (1751)

The leading cause of injury among carpentry companies was cuts, punctures, or scrapes (26.6%). The proportion of injuries due to cuts, punctures, and scrapes also was significantly higher among carpenters than other trades ($p=0.001$). Cuts, punctures, and scrapes (28.1%) was replaced by miscellaneous/unspecified (41.5%) as the leading cause of injury post-HomeSafe. The proportion of cuts, punctures, and scrape injuries did not actually change pre- compared to post-HomeSafe, injuries due to miscellaneous/unspecified causes increased. The proportion of injuries from miscellaneous/unspecified causes was significantly higher from all other trades ($p <0.001$).

Floor Laying and Floor Work (1752)

Pre-HomeSafe, strain or injury by lifting or other movements was the leading cause of injury among floor laying and floor work companies (25.0%). The proportion of injuries resulting from movements was not higher than for other trades. Post-HomeSafe, only two injuries were reported: one strain injury and one struck or injured by injury.

Roofing, Siding, and Sheetmetal Work (1761)

Injury caused by cuts, punctures, or scrapes was the leading cause of injury among roofing, siding, and sheetmetal companies (30.0%). The proportion of injuries caused by cuts, punctures or scrapes also was significantly higher when compared to all other trades (p=0.001). Post-HomeSafe, injury caused by cuts, punctures, or scrapes was again the leading cause of injury in this trade (30.6%). However, the proportion of injuries caused by cuts, punctures, or scrapes was not significantly different from other trades.

Concrete Work (1771)

Pre-HomeSafe, struck or injured by was the predominant cause of injury among concrete workers (16.8%), who experienced a significantly higher proportion of these injuries when compared to all other trades. Strain or injury by lifting or other movements was the leading cause of injury post-HomeSafe (25.0%), however, struck or injured by followed (20.6%) and accounted for a significantly higher proportion of injuries as compared to all trades (p=0.002).

Excavation Work (1794)

Strain or injury by lifting or other movements and striking against were the major causes of injury among excavating companies (33.3% each). Pre-HomeSafe, a total of only six injuries was reported by excavation companies: two strains (one from lifting, one from pushing/pulling), two striking against (one handling an object and one miscellaneous) one struck by and one miscellaneous. Excavation companies reported no injuries during the years following HomeSafe.

Miscellaneous Special Trade Contractors (1799)

Pre-HomeSafe, strain or injury by lifting or other movements was the leading cause of injury among miscellaneous special trade contractors (23.2%). This proportion did not differ significantly when compared to all other trades. However, they did experience a higher proportion of struck by injuries as compared to all other trades (p=0.027). Post-HomeSafe, strain or injury by lifting or other movements again was the primary cause of injury among special trade contractors (29.4%), tied with struck or injured by (29.4%). Struck or injured by again was significantly higher than all other trades (p=0.002).

These mechanisms of injury were then evaluated by circumstance (Tables VI - X). Among electrical, carpentry, masonry & other stonework, roofing, siding, & sheetmetal workers, cut, puncture, or scrape injuries were fairly evenly distributed between hand tools, power tools and miscellaneous causes. Masonry & other stonework companies did have a higher proportion of injuries due to hand tools than power tools or miscellaneous causes. No broken glass injuries were recorded among carpenters, masonry & other stone work, or roofing, siding or sheetmetal workers (Table VI). Of concern is that approximately one-third of all cut, puncture or scrape injuries were due to miscellaneous causes, making targeted intervention difficult.

Table VI: Proportion of Cut, Puncture, or Scrape Injuries to Electrical, Carpentry, Masonry & Other Stonework, and Roofing, Siding, and Sheetmetal Workers, Stratified by Specific Cause

Cut, Puncture, or Scrape	Electrical Work (%)		Carpentry (%)		Masonry & Other Stonework (%)		Roofing, Siding, & Sheetmetal (%)	
	Pre-Home Safe	Post-Home Safe	Pre-Home Safe	Post-Home Safe	Pre-Home Safe	Post-Home Safe	Pre-Home Safe	Post-Home Safe
Broken Glass	11.1	0	0	0	0	0	0	0
HandTool: Not Powered	33.3	25.0	26.4	15.2	50.0	0	30.3	15.4
Powered Hand Tool; Appliance	16.7	0	41.4	41.3	16.7	0	29.0	19.2
Miscellaneous	38.9	75.0	32.2	43.4	33.3	0	31.0	65.4

Among painting and paper hanging companies, falls from scaffolding or ladders were the most common type of fall (Table VII). Among plastering, drywall, and insulation companies, falls from a different level were most common pre and post-HomeSafe, with falls from ladders or scaffolding and slips following closely behind. Pre- and post-HomeSafe, among residential homebuilders, falls on the same level were the most common. Among plumbing, heating and air conditioning companies, falls from a different level and on the same level were the most common types of falls, pre-HomeSafe.

Table VII: Proportion of Fall Injuries among Painting & Paper Hanging and Plastering, Drywall, & Insulation Companies, Stratified by Specific Cause.

Fall or Slip Injury	Residential Home Building (%)		Plumbing, Heating, Air Conditioning (%)		Painting & Paper Hanging (%)		Plastering, Drywall, & Insulation (%)	
	Pre-Home Safe	Post-Home Safe	Pre-Home Safe	Post-Home Safe*	Pre-Home Safe	Post-Home Safe**	Pre-Home Safe	Post-Home Safe
From different level	25.9	26.1	38.5	0	31.6	33.3	39.1	36.0
From ladder or scaffolding	3.7	4.4	7.7	100.0	42.1	0	20.3	24.0
From liquid, ice, grease spill	1.9	0	7.7	0	5.3	0	3.1	4.0
On same level	44.4	56.5	38.5	0	15.8	0	12.5	4.0
Slipped, did not fall	22.2	13.0	0	0	0	0	20.3	32.0
Misc	1.9	0	7.7	0	5.3	66.7	4.7	0

*only one fall injury was reported
**only three fall injuries were reported

Lifting was the most common type of movement injury among builders of single family homes, accounting for almost 50% of all injuries in this category pre-HomeSafe and 43.8% of all injuries in this category post-HomeSafe (Table VIII). Lifting and using a tool or a machine were the most common circumstances of movement injury among masonry and stonework companies (33.3%). Among floor laying and floor work companies, holding/carrying, lifting, and pushing/pulling were evenly distributed, representing 33.3% of all movement injuries each. Finally, miscellaneous special trade contractors were led by holding/carrying injuries (36% pre-HomeSafe and 40% post-HomeSafe), followed by lifting (20% pre-HomeSafe and 40% post-HomeSafe).

Table VIII: Proportion of Strain or Injury by Lifting or Other Movements among Residential Home Builders, Masonry & Other Stonework, Floor Laying and Floor Work, and Miscellaneous Special Trade Contract Companies, Stratified by Specific Cause.

Strain or Injury By	Residential Home Builders (%)		Masonry & Other Stonework (%)		Floor Laying and Floor Work (%)		Miscellaneous Special trade Contractors (%)	
	Pre-Home Safe	Post-Home Safe	Pre-Home Safe	Post-Home Safe*	Pre-Home Safe	Post-Home Safe**	Pre-Home Safe	Post-Home Safe
Holding or carrying	7.3	0	16.7	0	33.3	0	36.0	40.0
Lifting	49.3	43.8	33.3	0	33.3	100.0	20.0	40.0
Pushing or pulling	4.4	18.8	16.7	0	33.3	0	8.0	20.0
Reaching	4.4	6.3	0	0	0	0	20.0	0
Using tool or machine	14.5	0	33.3	0	0	0	4.0	0
Misc	20.3	31.3	0	0	0	0	12.0	0

*no injuries reported
**only one injury reported (lifting)

Pre-HomeSafe, falling or flying objects were the major causes of struck by injuries among plumbing, heating and air conditioning companies, followed by hand tool or machine in use (Table IX). Both pre- and post-HomeSafe, falling or flying objects accounted for most of the struck by injuries among concrete and special trade companies. Of note is the shift in distribution among concrete workers: pre-HomeSafe, hand tool or machine in use accounted for 23.5% and miscellaneous causes accounted for 17.7% of struck by injuries. Post-HomeSafe, 42.9% were classified as miscellaneous with no injuries caused by a being struck by a hand tool or machine in use. Among miscellaneous special trade contractors, lifting or handling objects was another major cause of struck by injuries.

Table IX: Proportion of Struck or Injured by Injuries among Plumbing, Heating & Air conditioning, Concrete, and Miscellaneous Special Trade Companies, Stratified by Specific Cause.

Struck or Injured By	Plumbing, Heating & Air Conditioning (%)		Concrete (%)		Miscellaneous Special Trade (%)	
	Pre-HomeSafe	Post-HomeSafe	Pre-HomeSafe	Post-HomeSafe	Pre-HomeSafe	Post-HomeSafe
Falling or flying object	45.5	100.0	35.3	42.9	43.8	40.0
Hand tool or machine in use	36.4	0	23.5	0	18.8	20.0
Moving parts of a machine	9.1	0	5.9	0	0	0
Object being lifted or handled	9.1	0	17.7	14.3	31.3	40.0
Miscellaneous	0	0	17.7	42.9	6.3	0

Finally, pre-HomeSafe, among plumbing, heating, & air conditioning and painting & paper hanging most of the miscellaneous injuries were due to a foreign body in the eye (75.0% and 66.7%) (Table X). Among plastering, drywall, & insulation, and carpentry companies most of the miscellaneous/unspecified injuries were caused by an unknown or unspecified mechanism (54.0% and 53.4%). Post-HomeSafe, carpenters had a significantly higher proportion of miscellaneous injuries as compared to all trades, with 71.6% classified as unknown and 19.4% classified as foreign body in eye. Among plumbing, heating & air conditioning companies, foreign body in eye was tied with unknown for the most common injury circumstance (50.0%), painting and paper hanging companies experienced equal proportions of unknown and other injuries (40.0%), and plastering, drywall, and insulation companies experienced mainly other miscellaneous injuries (68.4%).

Table X: Proportion of Miscellaneous Injuries to Plastering, Drywall & Insulation and Carpentry Companies, Stratified by Specific Cause

Miscellaneous Causes	Plumbing, Heating & Air Conditioning (%)		Painting & Paper Hanging (%)		Plastering, Drywall & Insulation (%)		Carpentry (%)	
	Pre-Home Safe	Post-Home Safe	Pre-Home Safe	Post-Home Safe	Pre-Home Safe	Post-Home Safe	Pre-Home Safe	Post-Home Safe
Foreign body in eye	75.0	50.0	66.7	0	38.2	31.6	36.6	19.4
Robbery or criminal assault	0	0	0	20.0*	1.3	0	0	0
Unknown	25.0	50.0	0	40.0*	54.0	0	53.4	71.6
Other	0	0	33.3	40.0*	6.6	68.4	10.2	7.5

*Based on only five miscellaneous injuries.

Types of injury and body part injured among HomeSafe participants

The major types of injury and body parts associated with those types of injury are outlined in Table XI. This table includes all trades. The primary types of injury were strains/sprains, lacerations/punctures, contusions, and foreign bodies. This is consistent with previously reported data[11].

Table XI: Distribution of Major Types of Injury by Associated Body Part, All Trades

Type of Injury by Body Part	Pre-HomeSafe Number	Pre-HomeSafe Percent	Post-HomeSafe Number	Post-HomeSafe Percent
Strain/Sprain	493		155	
Low Back	195	39.6	57	36.8
Arm/Elbow	59	12.0	19	12.3
Leg/Knee	62	12.6	16	10.3
Ankle/Foot	52	10.6	19	12.3
Hand/Wrist	25	5.1	6	3.9
Neck/Spine	22	4.5	6	3.9
Multiple Body	7	1.4	7	4.5
All Other	71	14.4	25	16.1
Laceration/Puncture	469		178	
Fingers	115	24.5	41	23.0
Hand/Wrist	85	18.1	37	20.1
Ankle/Foot	85	18.1	24	13.5
Thumb	54	11.5	24	13.5
Leg/Knee	46	9.8	20	11.2
Arm/Elbow	30	6.4	12	7.7
All Other	54	11.5	28	18.1
Contusion	187		54	
Leg/Knee	28	15.0	13	24.1
Multiple Body	33	17.7	6	11.1
Arm/Elbow	22	11.8	9	16.7
Ankle/Foot	22	11.8	4	7.4
Hand/Wrist	19	10.2	3	5.6
All Other	63	33.7	19	35.2
Foreign Body	151		37	
Eye	125	82.8	31	83.8
Fingers	10	6.6	4	10.8
All Other	16	10.6	2	5.4

Type of injury by trade was evaluated to determine leading type of injury and associated body part injured, and to determine if the proportion of any type of injury was significantly higher among one trade versus all trades. Again, the chi-square test of association was used to evaluate differences in injury proportions among type of injury (Tables XII and XIII).

Table XII: Percent of Injuries by Type of Injury for Construction Trades, prior to HomeSafe Intervention

	1521	1711	1721	1731	1741	1742	1751	1752	1761	1771	1794	1799
Strains/ Sprains	36.5	37.5	41.7	21.4	38.1	30.3	35.2	33.3	26.1* (p=0.017)	26.7	33.3	37.0
Laceration/ Puncture	29.5	26.8	14.6* (p=0.013)	41.1	23.8	N/A	37.3& (p=0.005)	16.7	44.3& (p<0.001)	24.8	33.3	26.9
Contusion	12.9	19.6	10.4	16.1	19.1	17.4& (p=0.009)	7.7* (p=0.004)	8.3	9.1	13.9	N/A	13.0
Foreign Body	4.9* (p=0.001)	7.1	8.3	14.3	4.8	15.8& (p=0.001)	11.0	33.3&# (p=0.007)	6.3* (p=0.035)	14.9	N/A	10.2

*The proportion of injuries from selected cause for selected trade versus all other trades is significantly less than that for all other trades

&The proportion of injuries from selected cause for selected trade versus all other trades is significantly greater than that for all other trades

#Yates' continuity correction applied because table contained one or more cells with an expected cell count less than five.

N/A = no injuries were reported in this category

Table XIII: Percent of Injuries by Type of Injury for Construction Trades, following HomeSafe Intervention

	1521	1711	1721	1731	1741	1742	1751	1752	1761	1771	1794	1799
Sprain/ Strain	29.4	18.8	20.0	11.1	N/A	29.7	34.8	100.0	34.1	27.8	N/A	35.9
Laceration/ Puncture	35.3	50.0	26.7	66.7	N/A	28.1	36.6	N/A	44.7	22.2	N/A	35.9
Contusion	12.3	6.3	6.7	11.1	N/A	21.9& (p=0.004)	9.8	N/A	10.6	5.6	N/A	5.9
Foreign Body	4.1	18.8	20.0	N/A	N/A	10.9	9.2	N/A	2.4* (p=0.041)	5.6	N/A	5.9

*The proportion of injuries from selected cause for selected trade versus all other trades is significantly less than that for all other trades
&The proportion of injuries from selected cause for selected trade versus all other trades is significantly greater than that for all other trades
#Yates' continuity correction applied because table contained one or more cells with an expected cell count less than five.
N/A = no injuries were reported in this category

Strains/Sprains

Pre-HomeSafe, strains/sprains was the leading type of injury for residential home builders (36.5%), plumbing, heating & air conditioning (37.5%), painting and paper hanging (41.7%), masonry and other stonework (38.1%), plastering, drywall & insulation (30.3%), concrete (26.7%) and miscellaneous special trade companies (37.0%).

Among residential builders, low back strain/sprain accounted for 55.7% of strain/sprain injuries. Low back strain/sprains accounted for 50% of the strain/sprain injuries among plumbing, heating, and air conditioning companies, 78.6% among painting and paper hanging companies, 66.7% among masonry and other stonework companies, 34.6% among plastering, drywall & insulation companies, 41.2% among concrete companies, and 54.8% among specialty trade companies.

Post-HomeSafe, strains/sprains was the leading type of injury among plastering, drywall & insulation (29.7%), floor laying and floor work (100.0%), and concrete (27.8%) companies. Among plastering, drywall & insulation companies, low back strain/sprain accounted for 46.7% of injuries. Low back strain/sprain accounted for 50.0% of the strain/sprain injuries among floor laying and floor work companies and 55.6% among concrete companies. No one trade experienced a significantly higher proportion of strains/sprains than any other when compared to all trades pre- or post-HomeSafe.

Lacerations

Pre-HomeSafe, lacerations/punctures was the leading type of injury among electrical (41.1%), carpentry (37.3%), and roofing, siding, & sheetmetal (44.3%) companies. Carpentry companies and roofing, siding, & sheetmetal companies experienced a higher proportion of laceration/puncture injuries when compared to all other trades ($p=0.005$ and $p<0.001$, respectively.)

The body part most frequently associated with laceration and puncture injuries among electrical workers was the hand/wrist (40.0%). Among carpenters, 43.2% of lacerations/punctures were to the fingers, 32.4% were to the hand/wrist, and 31.1% were to the foot. 47.1% of lacerations/punctures were to the fingers among roofing, siding, & sheetmetal companies, with 38.2% to the foot.

Post-HomeSafe, lacerations/punctures was the leading type of injury among residential home builders (35.3%), plumbing, heating & air conditioning (50.0%), painting and paper hanging (26.7%), electrical (66.7%), carpentry (36.6%), and roofing, siding, & sheetmetal companies (44.7%). None of these proportions, however, were significantly higher among any one trade when compared to all other trades.

Among residential home builders, 38.3% of lacerations/punctures were to the foot, followed by fingers (19.2%) and the leg/knee (12.8%). Among plumbing, heating & air conditioning companies, 37.5% were to the hand/wrist and 37.5% were to the thumb. 40.0% of laceration/puncture injuries were to the fingers among painting and paper hanging companies, and 30.0% were to the fingers among carpentry companies. Also among carpentry companies, 25.0% of laceration/puncture injuries were to the hand/wrist. Injuries among electrical companies were distributed evenly across thumb, foot, hand, and arm/elbow injuries. Finally, among roofing, siding, and sheetmetal companies, 23.7% of lacerations/punctures were to the fingers, 21.1% were to the hand, and 18.4% were to the foot.

Foreign Body

Pre-HomeSafe, floor laying and floor work companies were led equally by strains and foreign body injuries (33.3%). The proportion of foreign body injuries among floor laying and floor work and plastering, drywall, & insulation companies was significantly higher than all other trades (p=0.007 and p=0.001, respectively). All of the foreign body injuries among floor laying and floor work companies were to the eye. No foreign body injuries were reported by this trade post-HomeSafe. 76.0% of these injuries pre-Homesafe and 85.7% of these injuries post-HomeSafe were to the eye among plastering, drywall, & insulation companies. Foreign body injuries to the finger were reported among the trades less frequently, though carpenters did report splinters in fingers and hands.

Contusions

While not a leading type of injury among these trades, the proportion of contusions pre-HomeSafe among plastering, drywall, and insulation companies was significantly higher than all other trades (p=0.009). Contusions accounted for 17.4% of injuries in this trade group. Contusions were usually associated with arm/elbow (19.1%), multiple body (16.7%), and chest (14.3%) injuries. Post-

HomeSafe, contusions in this trade group were most often associated with arm/elbow injuries (50.0%).

Other

Pre-HomeSafe, injuries among excavation companies were led equally by strains and lacerations (33.3%). Post-HomeSafe, lacerations/punctures and strains/sprains tied for leading type of injury at 35.3% each among special trade contractors.

DISCUSSION

This investigation served two primary purposes: to further evaluate the effectiveness of the HomeSafe project in reducing injuries among specific trade groups and to describe injury patterns and rates among specific trade groups.

HomeSafe Evaluation

Following HomeSafe, single family homebuilders experienced a sharp decline in overall injury rate and in severe injury rate, indicating a potential effect of HomeSafe in reducing injuries among this select group. Single family builders also were the most well represented group, comprising 47% of the HomeSafe partner companies, and most consistently provided investigators with data. Of note is that, following HomeSafe, falls surpassed movement injuries as the leading cause of injury among single family homebuilders, even though fall prevention was heavily emphasized in HomeSafe and lifting or other movement injuries were not.

Companies specializing in masonry and other stone work also experienced a decline in severe injury rates, though the annual pattern is inconsistent enough to bring this finding into question. No other trade, when rates were evaluated by year, demonstrated a clear trend following HomeSafe intervention, bringing into question its effectiveness among all trades. Further evaluation for trend patterns is warranted to confirm all effects.

Injury Patterns and Hazards among Specific Trade Groups: Comparison with BLS Data

The Bureau of Labor Statistics provides rates of overall injury and lost workday injury by trade and by year. In order to compare rates by year and by trade group, we had to combine HomeSafe data for companies with the following SIC codes: 1741 and 1742, 1751 and 1752, and 1794 and 1799, because the BLS reports by three digit SIC code (e.g. 1740, 1750).

In general, HomeSafe participants reported higher rates of overall injuries than the BLS, with the exception of single family home builders and concrete companies (see Table XIV and Appendix C)[13,14,15,16,17]. Builders of single family homes and concrete companies both had lower rates than the BLS data following HomeSafe. There was an especially marked difference between companies specializing in plumbing, heating and air conditioning, painting and paper hanging, carpentry and floor work, and roofing, siding and sheetmetal work, whose rates were consistently higher than the BLS rates. The BLS injury data was fairly consistent over time, with steady declines in injury rates apparent for most trade groups. HomeSafe rates were much more inconsistent, though most do end up lower in 1998 than in 1994.

Table XIV: BLS and HomeSafe Injury Incidence Rates/200,000 Hours by Trade: 1994 -1998

Trade	1994	1995	1996	1997	1997post	1998
Residential Building						
BLS	10.2	8.5	7.9	6.9	6.9	7.5
HomeSafe	11.7	9.9	10.0	14.9	5.3	6.7
Plumbing, Heating and Air Conditioning						
BLS	13.0	12.7	11.2	11.1	11.1	10.0
HomeSafe	29.1	23.6	18.2	26.6	27.4	21.9
Painting and Paper Hanging						
BLS	7.3	7.2	7.0	6.7	6.7	5.9
HomeSafe	17.1	15.5	15.1	19.4	16.9	8.4
Electrical Work						
BLS	10.6	10.7	9.3	9.4	9.4	8.0
HomeSafe	12.7	12.9	5.1	20.0	8.0	34.5
Masonry, Stonework, and Plastering						
BLS	13.8	10.7	11.8	10.3	10.3	9.8
HomeSafe	18.7	12.5	19.4	9.1	15.7	9.0
Carpentry and Floor Work						
BLS	13.4	10.5	10.5	12.1	12.1	10.8
HomeSafe	33.0	28.3	37.1	19.4	46.9	21.6
Roofing, Siding, and Sheetmetal Work						
BLS	17.2	14.6	13.8	10.1	10.1	9.0
HomeSafe	59.2	38.8	29.4	11.6	27.9	27.6
Concrete Work						
BLS	11.0	10.2	8.7	8.6	8.6	9.2
HomeSafe	7.5	15.6	13.4	7.8	8.0	8.3
Miscellaneous Special Trade Contractors						
BLS	11.9	9.4	9.4	8.5	8.5	8.1
HomeSafe	7.9	16.5	17.8	15.1	8.6	9.7

HomeSafe rates of lost workday injury were less consistent (Table XV and Appendix D). Rates of severe injury were lower among HomeSafe participants who specialize in single family home building, plumbing, heating and air conditioning, and concrete workers. Rates of lost workday injuries were higher among painting and paper hanging companies, carpenters and floor work companies, and miscellaneous special trade contractors. Finally, the rates among companies specializing in electrical work, masonry and other stonework, and roofing, siding and sheetmetal were too inconsistent to compare.

Table XV: BLS and HomeSafe Lost Work Day Injury Incidence Rates/200,000 Hours by Trade: 1994 -1998

Residential Building	1994	1995	1996	1997	1997post	1998
BLS	5.0	4.2	3.7	3.2	3.2	3.5
HomeSafe	1.7	3.3	3.6	3.2	1.5	1.5
Plumbing, Heating and Air Conditioning						
BLS	5.2	5.3	4.3	4.7	4.7	3.8
HomeSafe	3.6	1.8	1.8	4.7	2.5	0.0
Painting and Paper Hanging						
BLS	4.1	3.9	3.8	3.7	3.7	3.3
HomeSafe	4.0	7.8	6.1	9.7	5.6	3.4
Electrical Work						
BLS	4.2	4.1	3.9	3.7	3.7	3.3
HomeSafe	3.2	4.0	0.6	6.7	0.0	11.5
Masonry, Stonework, and Plastering						
BLS	7.0	5.4	6.2	5.5	5.5	4.7
HomeSafe	11.7	5.6	7.9	4.6	3.7	6.6
Carpentry and Floor Work						
BLS	5.0	5.3	5.0	5.8	5.8	4.8
HomeSafe	10.0	8.3	10.5	3.5	13.2	4.5
Roofing, Siding, and Sheetmetal Work						
BLS	8.9	7.7	7.0	5.6	5.6	5.1
HomeSafe	24.8	10.2	3.8	2.7	3.0	7.3
Concrete Work						
BLS	5.8	4.9	4.6	5.0	5.0	4.7
HomeSafe	1.7	4.3	4.2	3.4	4.8	3.0
Miscellaneous Special Trade Contractors						
BLS	5.6	4.4	4.3	4.2	4.2	3.7
HomeSafe	3.0	6.9	5.3	3.6	1.1	3.2

There are several explanations for the differences in rates. Overall injury rates among HomeSafe participants included injuries that did not require medical care beyond first aid, such as minor insect stings, cuts and scrapes. The BLS data were based on information provided by the Occupational Safety and Health Administration from the 200 logs. Minor injuries as described above are not reported on the 200 logs and are therefore not reflected in the BLS rates. The rates for injuries caused by cuts, punctures and scrapes included minor injuries, which may account for some of the higher rates. That HomeSafe injury incidence rates were higher is consistent with the findings of Lipscomb et al., who reported a much higher rate of injury among union carpenters in Washington than the BLS data[1].

Differences between HomeSafe and BLS data also may be attributable to the fact that the BLS data were drawn from a probability sample based on logs supplied by OSHA and on employment estimates. The HomeSafe data reflected rates from a defined population using precise denominator data. In addition, OSHA 200 logs (and therefore BLS data) reflected injuries among establishments with eleven or more employees. Forty percent of HomeSafe participants had ten or fewer employees. Finally, the BLS sample was based on information from participating States and Colorado is not a participating State. The HomeSafe data, therefore, represent a specific group of residential construction workers and should not be generalized to construction workers at large.

BLS data on the specialty trades included commercial construction work injuries. The risk of severe injury may be less or more in commercial construction among specific trade groups. For example, concrete workers in residential construction may face fewer serious hazards than commercial concrete workers due to the size or nature of the job, hence the lower rate of severe injury. This is supported by a study of construction workers at the Denver

International Airport[18]. They found a lost work time injury rate in commercial concrete construction of 10.7 per 200,000 hours for the period 1990 – 1994 compared with the HomeSafe rate of 1.7 per 200,000 hours for 1994.

In addition, BLS data were based on three digit SIC codes. The SIC code 1520 includes companies involved in residential building other than single family homes, which may prove more hazardous and result in higher rates. The HomeSafe data were based on single family homebuilders only, who had lower overall and severe injury rates than the BLS data. HomeSafe partners were predominately involved in building residences and many of them contracted the labor out to smaller local trade companies.

Finally, HomeSafe participants were given certain incentives to join the program: focused OSHA inspections, eligibility for the maximum penalty reductions if a company was fined, eligibility for a 5% workers compensation premium discount, and eligibility for Colorado Cost Containment Certification, which leads to an additional 5% workers compensation premium discount. It is possible, then, that the some participating companies had higher injury rates to begin with and the prospect of reduced premiums, penalties, and increased safety training attracted them to HomeSafe.

Injury Patterns and Hazards among Specific Trade Groups: Comparison with Other Research

Overall rates

Information about the hazards faced by the individual trades was consistent with patterns reported by other researchers. Among HomeSafe participants, companies specializing in carpentry, roofing, siding, and sheetmetal work, and plumbing, heating, and air conditioning had the highest overall rates of injury pre- and post-HomeSafe. Dement & Lipscomb (1999) reported overall workers compensation claim rates for residential construction workers in North Carolina[10]. They found that carpenters, plumbers, mechanics, roofers, insulators and welders had the highest rates of injury. HomeSafe partner companies did not include companies specializing solely in welding or companies who identified themselves as mechanics or repairers, and included insulators under the SIC code 1742. For the comparable trades, trades with the highest rates of injury were consistent in both studies (carpenters, roofers, and plumbers). They reported a rate of 22.9 per 200,000 hours worked among carpenters, 21.6 among plumbers, and 29.5 among roofers. HomeSafe rates were higher, however, they include injuries that were not workers' compensation claims and therefore would be higher. Lipscomb et al. (1996) reported overall injury incidence rates among union carpenters in Washington State that are very similar to the HomeSafe rates[1]. They found a rate of 34.8 per 200,000 hours worked, including cases that did not require medical care above first aid. The carpentry companies participating in HomeSafe experienced a rate of 32.8 per 200,000 hours worked, including all injuries.

Mechanisms of injury

Comparisons with other studies of injury causes also showed similar results. Hunting et al. (1999) reported that carpenters and electricians experienced a significantly higher proportion of injuries caused by cutting or piercing objects, with 34.9% and 30.9% of all injuries caused in this manner, respectively[4]. Among HomeSafe carpenters and electricians, injuries caused by cuts, punctures, and scrapes accounted for 26.6% pre- and 28.1% post-HomeSafe (carpenters) and 32.1% pre- and 44.4% post-HomeSafe (electricians). Both trades experienced a higher proportion of these injuries as compared to all other trades pre-HomeSafe but not post-HomeSafe. Finally, among HomeSafe carpenters, 36.4% of injuries caused by miscellaneous mechanisms were attributed to a foreign body in the eye pre-HomeSafe and 19.4% post-HomeSafe. This is much higher than other reported findings. Waller et al. (1989) reported that 15% of the injuries among carpenters were associated with the eye and Lipscomb et al. (1996) reported that 13% involved the eye[1,19]. Islam et al. (2000) reported that, among carpenters, a foreign body in the eye accounted for 39.4% of all eye injuries[6].

Hunting et al. (1999) reported that plumbers experienced a significantly higher proportion of struck by injuries and foreign bodies in the eye than all other trades and a significantly lower proportion of injuries caused by cutting or piercing objects than all other trades (It is important to note that, although the proportion is lower than other trades, cutting or piercing injuries account for the same proportion of injuries as the other two, 15%)[4]. Other research supports this finding[9]. HomeSafe plumbers also experienced a significantly higher proportion of struck by injuries than all other trades (19.64%). Cutting and piercing injuries accounted for 19.6% of the injuries, but this was not significantly lower than other trades. HomeSafe plumbers differ from other studies in that falls accounted for the highest proportion of injuries (23.2%) compared with 11.8% found by Hunting et al. (1999) and less than 10% found by Kinn et al. (2000)[4,9]. HomeSafe plumbers experienced a significantly lower proportion of miscellaneous injuries than all other trades, which includes foreign object in the eye. Kinn et al. (2000) reported that the eye was the body part most frequently injured among plumbers and pipefitters, and Islam reported that foreign body in the eye was the most common form of eye injury among plumbers[9,6]. These differences may be due to the different hazards faced by residential and commercial construction workers as the other studies were not specific to the residential construction industry.

Gillen and colleagues (1997) found that roofers were over-represented among a sample of construction workers who sustained non-fatal construction falls[2]. The trades also included in their sample were carpenters (21%), laborers (16%), painters (9%), drywallers, lathers, & plasterers (8%), plumbers and pipefitters (6%), and ironworkers & welders (6%). Dement et al. (1999) found the highest rates for falls from a different level among roofers (5.54/200,000), insulators (3.53/200,000), carpenters (2.05/200,000), and drywall installers (1.99/200,000)[10]. For falls on the same level, insulators had the highest rate of falls (1.14/200,000). The rate among roofers was 0.74/200,000, followed by drywall installers (0.72/200,000), and welders & cutters (0.72/200,000).

Falls in the HomeSafe sample accounted for 16.2% of all injuries among companies specializing in roofing, siding, and sheetmetal work, with a pre-HomeSafe rate of 5.6/200,000 and post-HomeSafe rate of 6.9/200,000.

Plastering, drywall and insulation companies had a pre-HomeSafe rate of 2.8/200,000 and a post-HomeSafe rate of 3.6/200,000 for falls from a different level, similar to the rates for insulators and drywallers in the Dement et al. (1999) study. For falls on the same level, plastering, drywall and insulation companies had a rate of 0.6/200,000 pre-HomeSafe and 0.2/200,000, lower than the rate reported in the Dement & Lipscomb study. The rate of falls from a different level among carpenters is 2.8/200,000 hours pre and 1.6/200,000 hours post-HomeSafe. Falls from different levels among roofers were 3.3/200,000 hours pre- and 3.3/200,000 post-HomeSafe. Both are similar to the Dement & Lipscomb study, however, HomeSafe rates among roofers are slightly lower. The rate of falls on the same level among carpenters was 0.7/200,000 pre and 0.6/200,000 post-HomeSafe. The rate of falls on the same level among roofers was 1.0/200,000 pre- HomeSafe, very similar to the rate Dement et al. (1999) reported[10].

Nature of injury and body part injured

The types of injury most often seen among HomeSafe partner companies were lacerations and strain/sprain injuries. Lacerations were the most common injuries among electricians, carpenters, and roofers, siders and sheetmetal workers. Strains and sprains were the primary types of injury among residential home builders, plumbing, heating and air conditioning companies, painting and paper hanging companies, masonry and other stonework companies, plastering, drywall, and insulation companies, concrete work companies, and special trade contractors. Foreign body injuries were most common among floor layers and floor workers, and strains/sprains and lacerations/punctures were tied among excavators.

Sprain/strain injuries were the primary type of injury among most HomeSafe trades, resulting primarily from strain or injury by lifting or other movement injuries or from falls. Strain injuries were the leading type of injury in the study of residential construction workers in North Carolina[10]. Lipscomb et al. (1996) reported a rate of 10.54 strain/sprain injuries among carpenters in Washington State and strains/sprains to the back had the highest rate among musculoskeletal injuries sustained by that group[1,3]. Sprain/strain injuries were the second leading type of injury among HomeSafe carpenters, including primarily injuries to the lower back. We re-evaluated our data and found a similar rate of strain injury among HomeSafe partner carpentry companies: 11.5 per 200,000 hours worked pre-HomeSafe and 11.1 post-HomeSafe. The body parts most often injured by strains/sprains were the low back (4.9/200,000 hours), shoulder and upper arm (1.6/200,000), and the hand/wrist (1.1/200,000 hours), again remarkably consistent with the results obtained by Lipscomb (5.7, 0.73, and 0.69/200,000 hours, respectively).

Kisner et al. (1994) reported in their study of injuries among construction workers that sprains/strains accounted for 34.3% of all injuries, with 16.6% of injuries to the back[20]. In the Gillen et al. (1997) study of non-fatal falls, the leading type of injury resulting from a fall was a spinal sprain or strain, accounting for 19% of all types of injury, followed by upper or lower extremity strain or sprain[2]. In their early report of an emergency room surveillance system, Hunting et al. found strains/sprains accounted for 17.9% of injuries, 48% of which were to the back[21]. Among HomeSafe trades, the lower back was the first or second most frequently reported body part injured among 67% of HomeSafe companies pre-HomeSafe and 50% post-HomeSafe.

Lacerations were another leading type of injury among HomeSafe partner companies. In a trade specific study of injuries sustained by construction workers by Hunting et al. (1994), they reported that carpenters and electricians experienced more lacerations to the fingers, thumb, hand and wrist when compared to all other trades[4]. Among HomeSafe carpenters, lacerations to the fingers, hand, wrist and foot were most common. Among electricians, most lacerations were to the hand and wrist. Lipscomb et al. (1996) reported that lacerations (cuts and scratches) accounted for the highest proportion of injury among carpenters, accounting for 32.36% of all injuries, respectively[1]. In their study, the rates of cuts and scratches among union carpenters were 7.38 and 3.88 per 200,000 hours respectively, compared with the rate among HomeSafe partners of 12.2 per 200,000 hours pre-HomeSafe and 11.7 post-HomeSafe[1].

Kisner et al. (1994) found that lacerations were the second most common type of injury, accounting for 16.9% of all injuries and Hunting et al. (1994) found lacerations to be the most common type of injury identified by their emergency room surveillance system among 592 construction workers (38%)[20,21].

Hunting et al. (1994) also found contusions (15.7%) and eye injuries (12.3%) followed lacerations as common types of injury[21]. Among HomeSafe partners, contusions accounted for 12.3% of all types of injuries and foreign body injuries to the eye accounted for 8.2%. Kisner et al. (1994) reported that contusions accounted for 9.0% of all construction injuries, and Dement et al. (1999) reported that contusions had the third highest rate of injury among residential construction workers[20,10]. Among HomeSafe partners, contusions accounted for 17.4% of injuries at companies specializing in plastering, drywall and insulation, a proportion significantly higher when compared to all other trades. Previous research reported that contusions accounted for about 7.3% of all injuries among drywall installers[7]. Finally, foreign body injuries accounted for 10.0% of all injuries, with 82.8% injuries to the eye.

That these findings are so similar to the results found in other studies strengthens the HomeSafe data. This study has the advantage of access to both population information to generate incidence rates (a limitation the authors identified in the Hunting et al. (1999) trade specific analysis) and proportion information. These two measures yielded similar results and served to support the findings.

Limitations

The HomeSafe data were limited by the reduced number of injuries post-HomeSafe. In some cases, there were too few injuries to analyze, in others, there were no injuries reported because only one or two companies provided data. This leaves some uncertainty in the rigor of the results among specific trades. In addition, as stated earlier, HomeSafe participants may not reflect the general population of residential construction workers. HomeSafe participants received incentives for enrolling and were not randomly sampled, and we were not able to compare results to a control group.

A further limitation is the lack of information related to individual character traits, such as age, ethnicity, and experience. Because data were so inconsistently reported, we could not analyze rates. That the proportion of Hispanic workers experiencing severe injuries is higher than Caucasians has been reported elsewhere, and is worthy of follow up.

Finally, we were not able to differentiate between skilled tradesmen and laborers. Research has indicated that laborers are at increased risk of different types of injury than are tradesmen[22]. Increased knowledge about this group of workers would only serve to improve our safety education and training interventions.

Conclusions

The patterns of injury among the trades are similar in many studies of construction workers, whether residential or commercial. That the trades differ in the causes, types, and body parts injured supports the further investigation of injury patterns among specific trades. That many similarities exist leaves us optimistic that general prevention and training programs can be developed for distribution among varying trade groups.

The only trade group with an obvious decline in injury rates following HomeSafe was residential homebuilders. This group represented the greatest proportion of HomeSafe partners, was one of the trades most actively involved in the program, and was the most forthcoming with data. This investment in the

HomeSafe Program may be what differentiates this group from other trades and explains the apparent effect of HomeSafe. This supports current stage theories in behavior change and prevention interventions; that intervention strategies must be designed according to the developmental stage of the group being targeted[23,24,25,26].

Recommendations for further research

HomeSafe injury rates must be analyzed for trend to determine if rate declines following HomeSafe are greater than would have been predicted (see article three). In addition, more trade specific analysis, differentiating laborers, apprentices, and journeymen within trade groups, is recommended to more clearly define the groups at risk.

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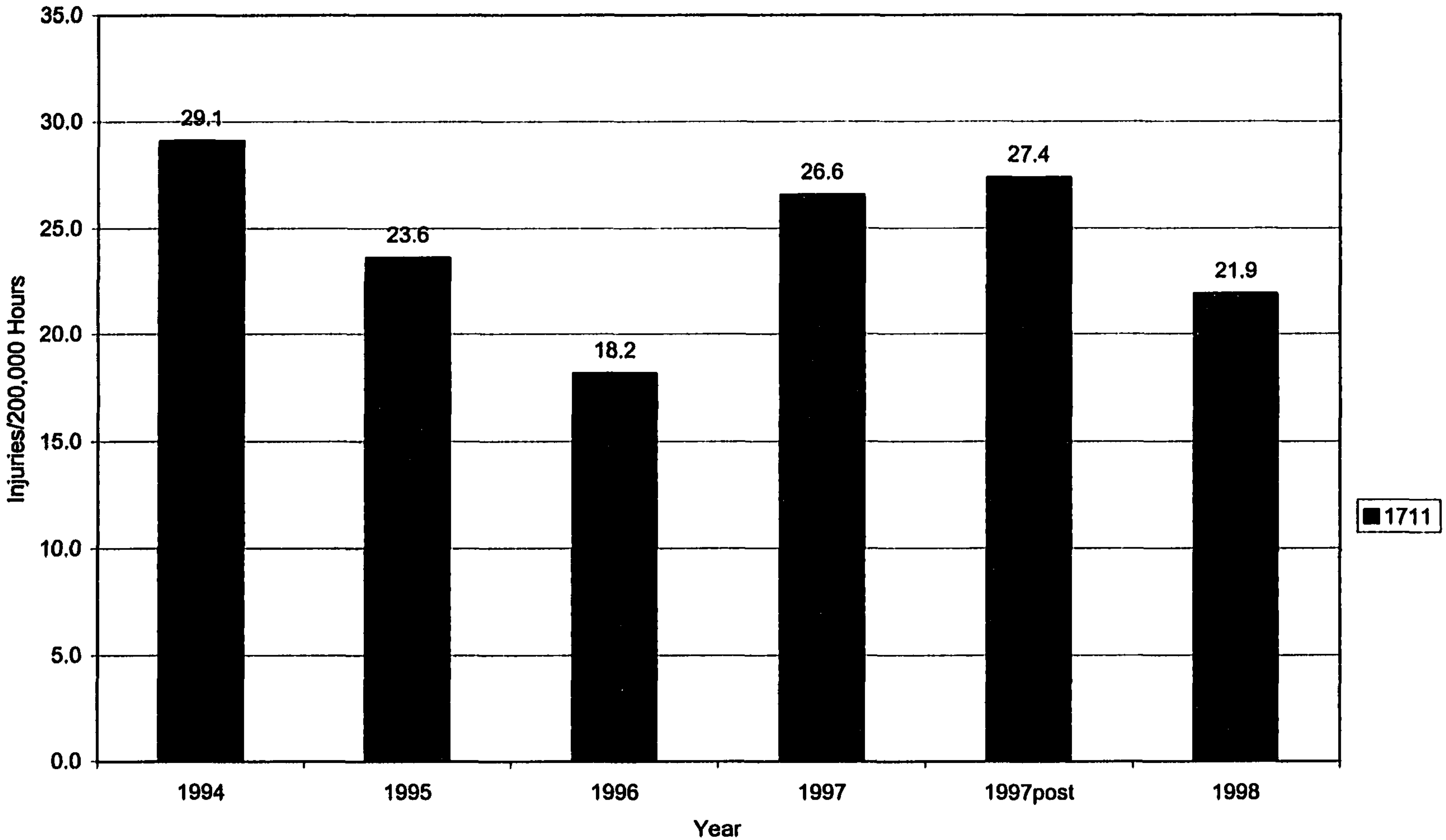
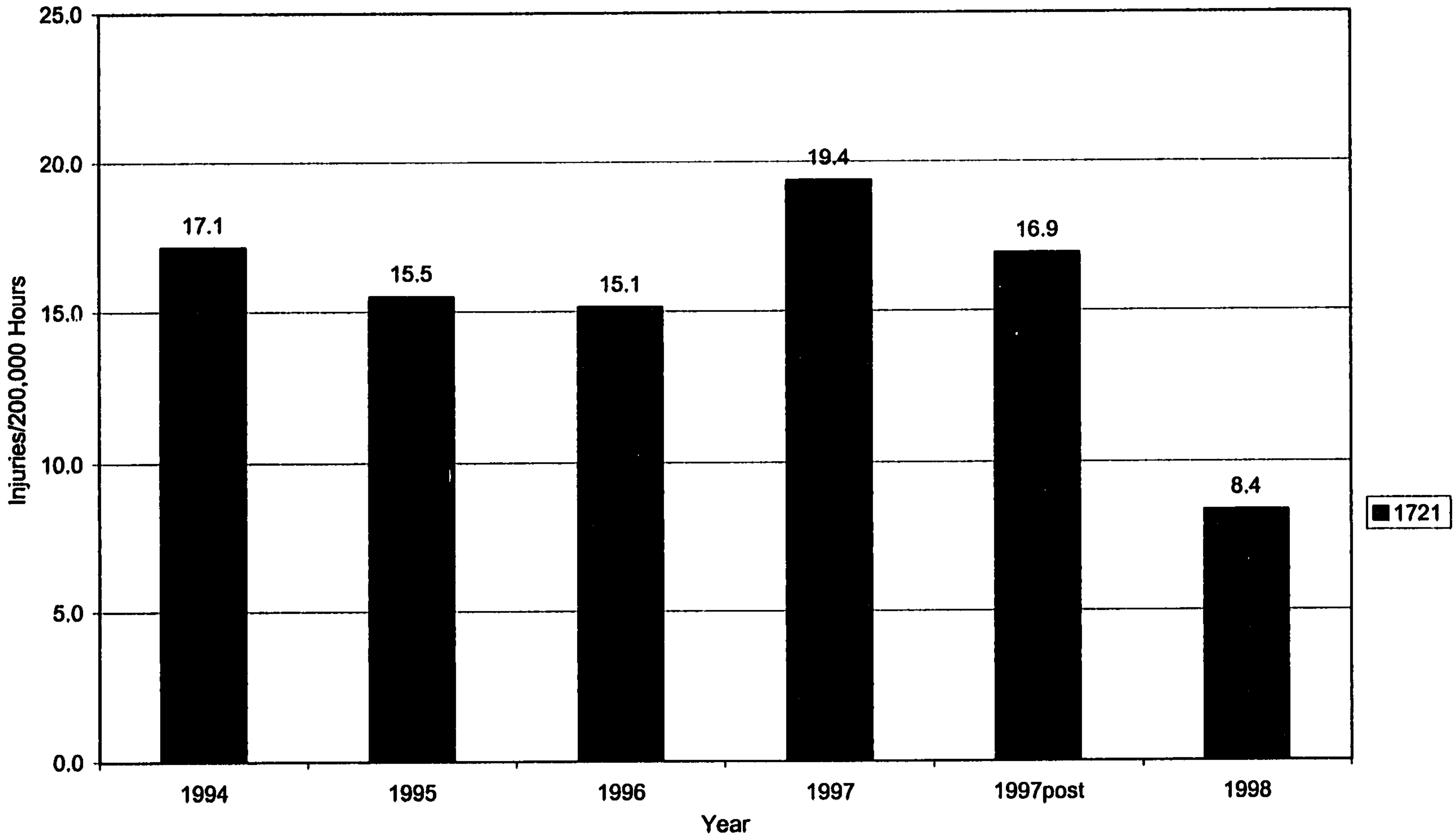
APPENDIX A



Injury Incidence Rates for Companies Specializing in Plumbing, Heating, and Air Conditioning, 1994 - 1998



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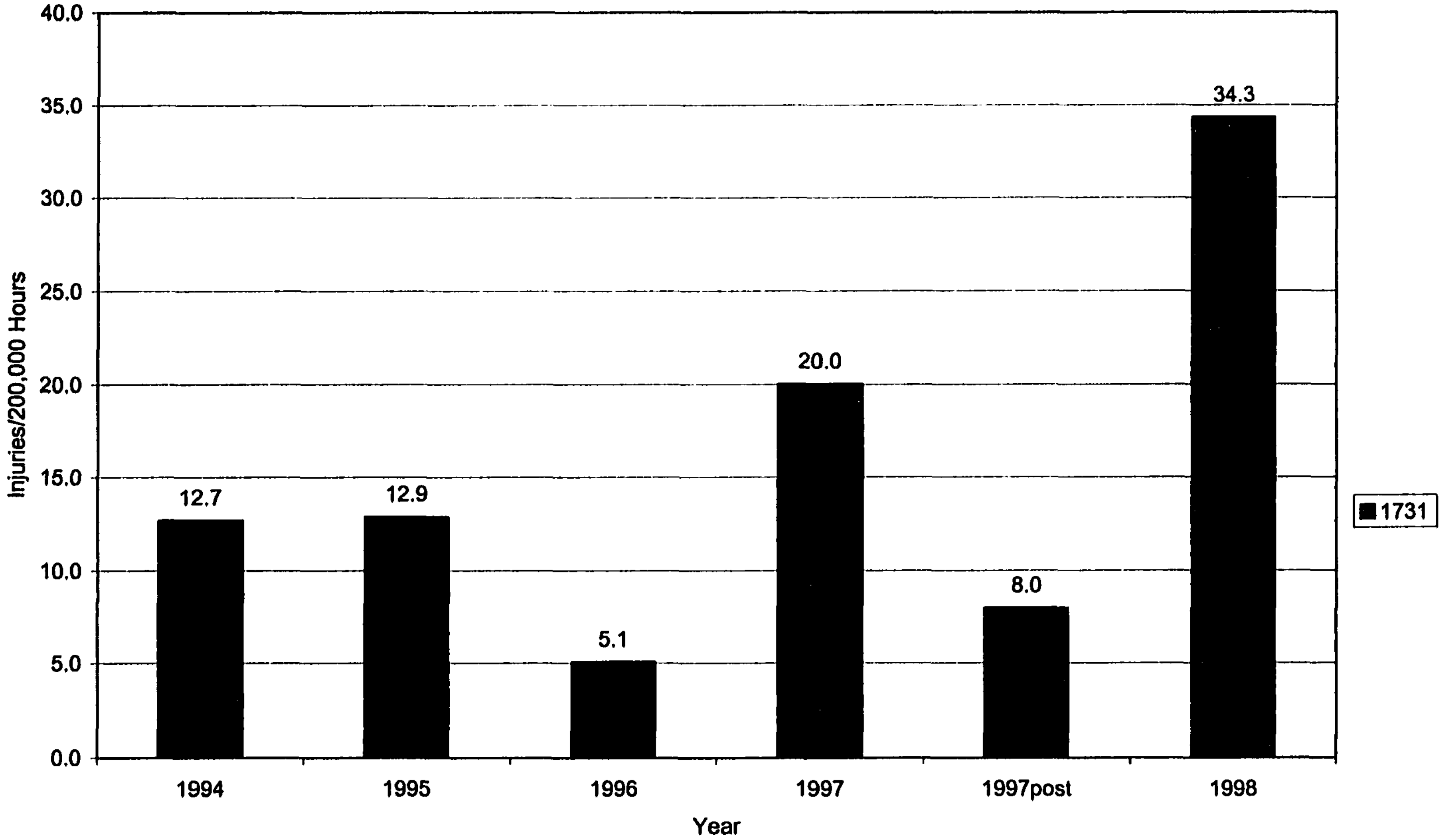

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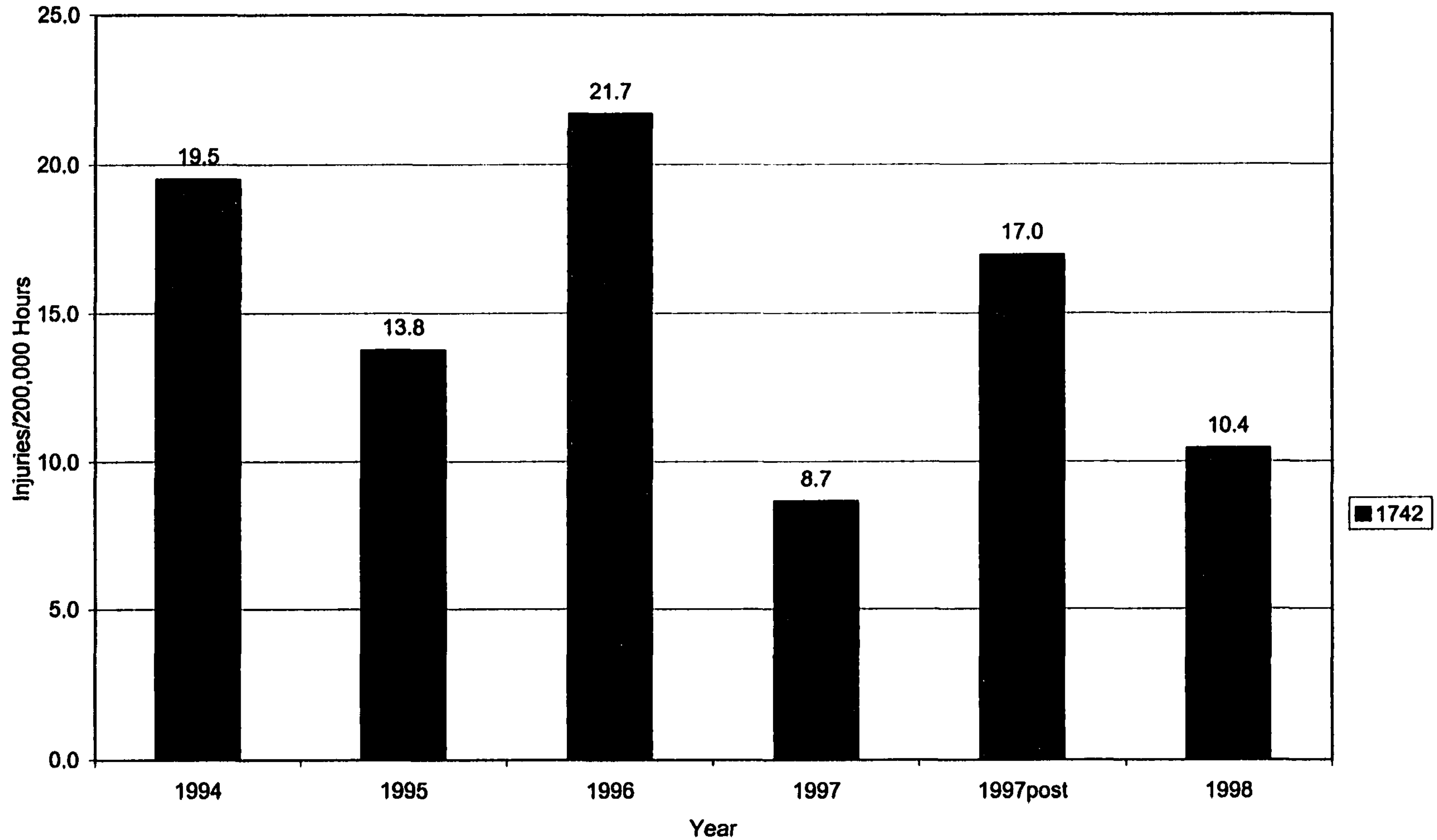

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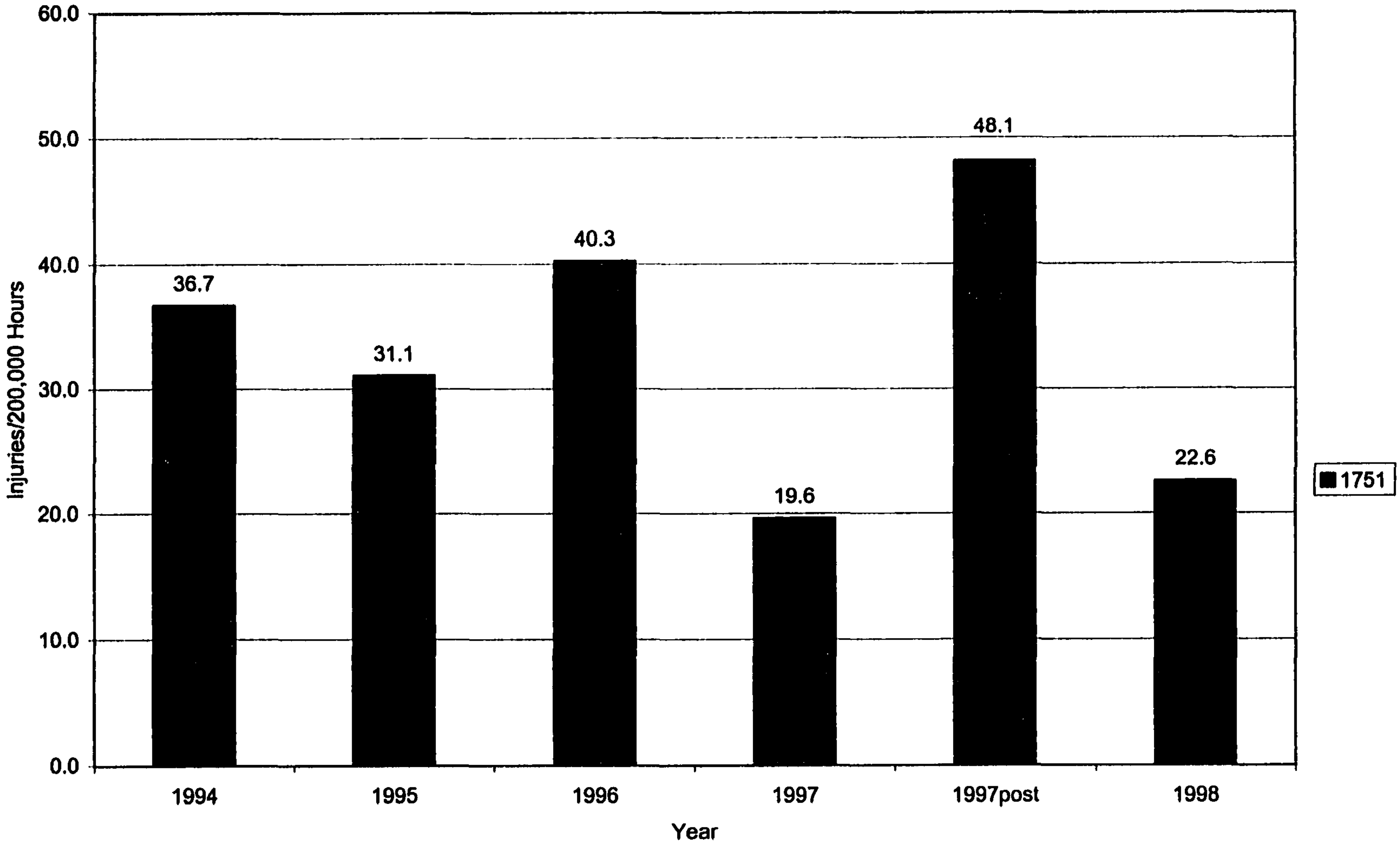
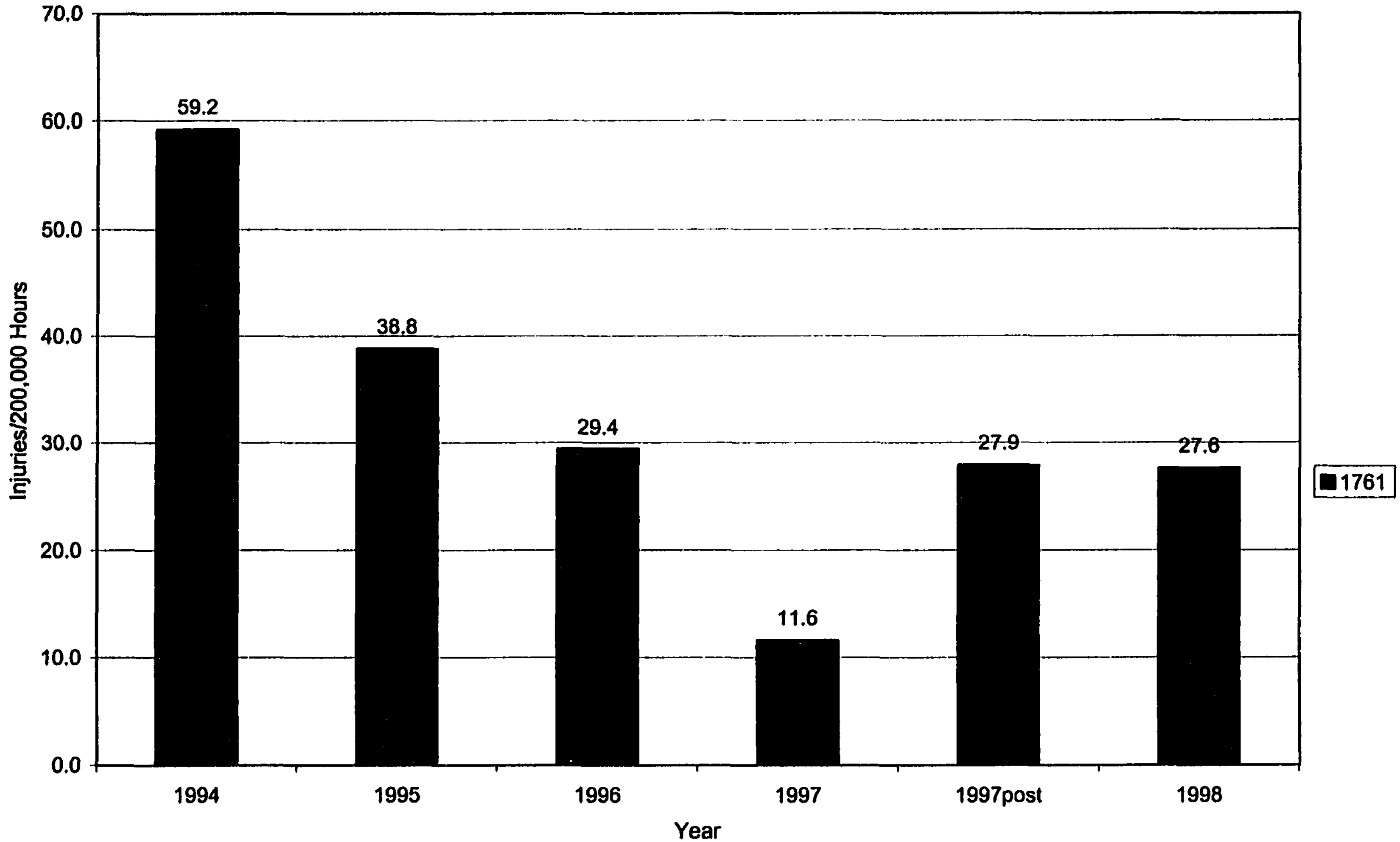
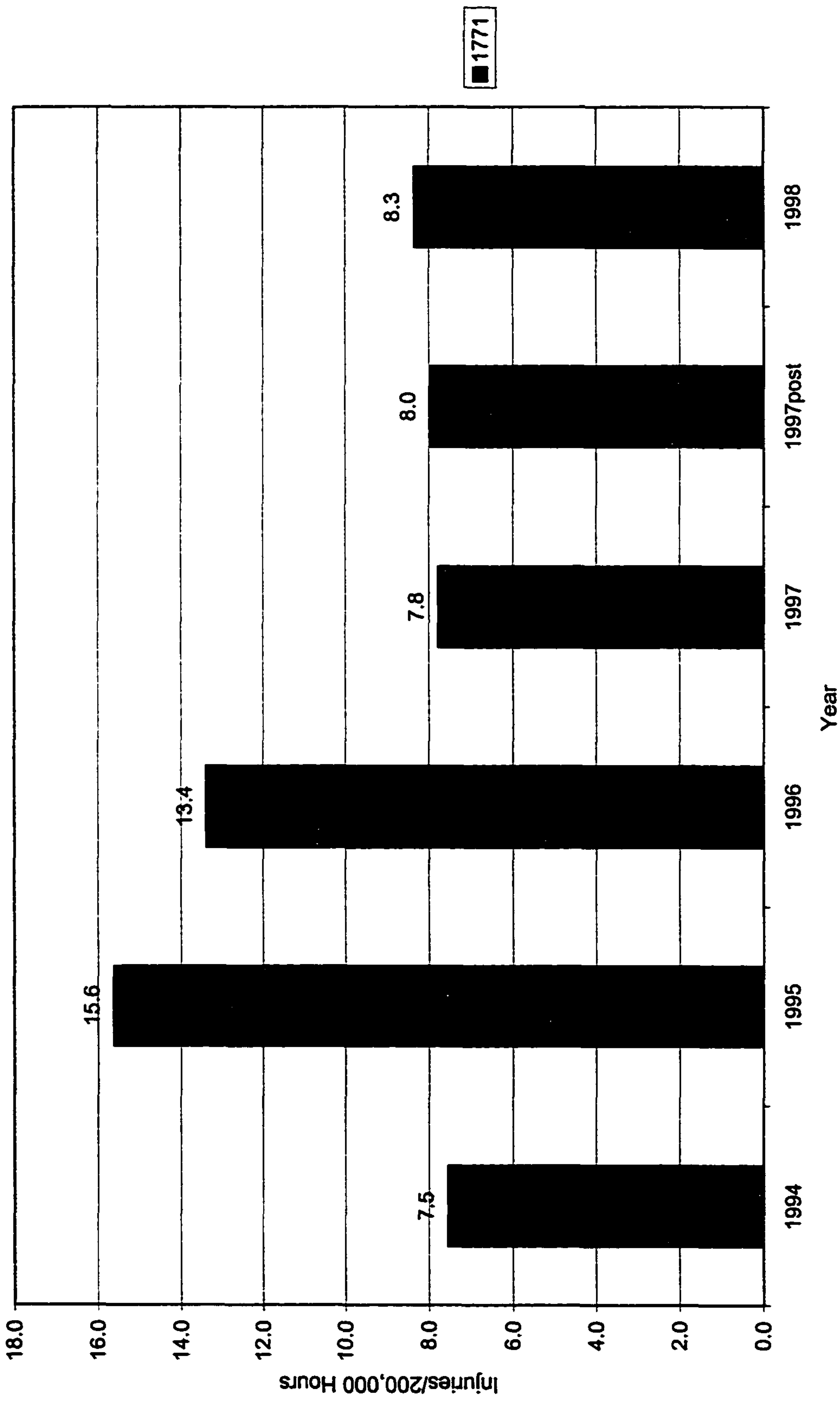


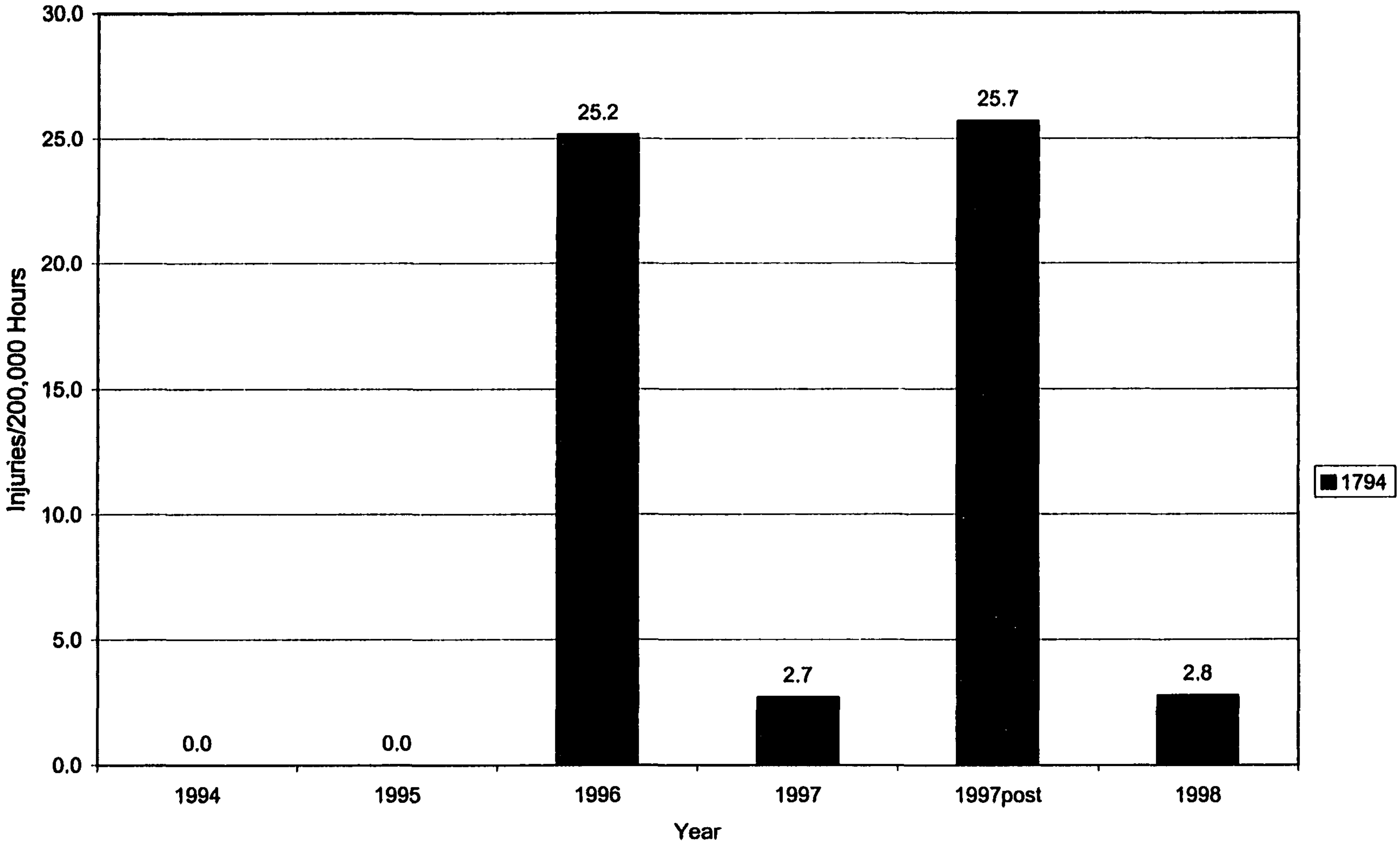
Injury Incidence Rates among Companies Specializing in Carpentry, 1994 - 1998



Injury Incidence Rates among Companies Specializing in Roofing, Siding, and Sheetmetal Work, 1994 - 1998

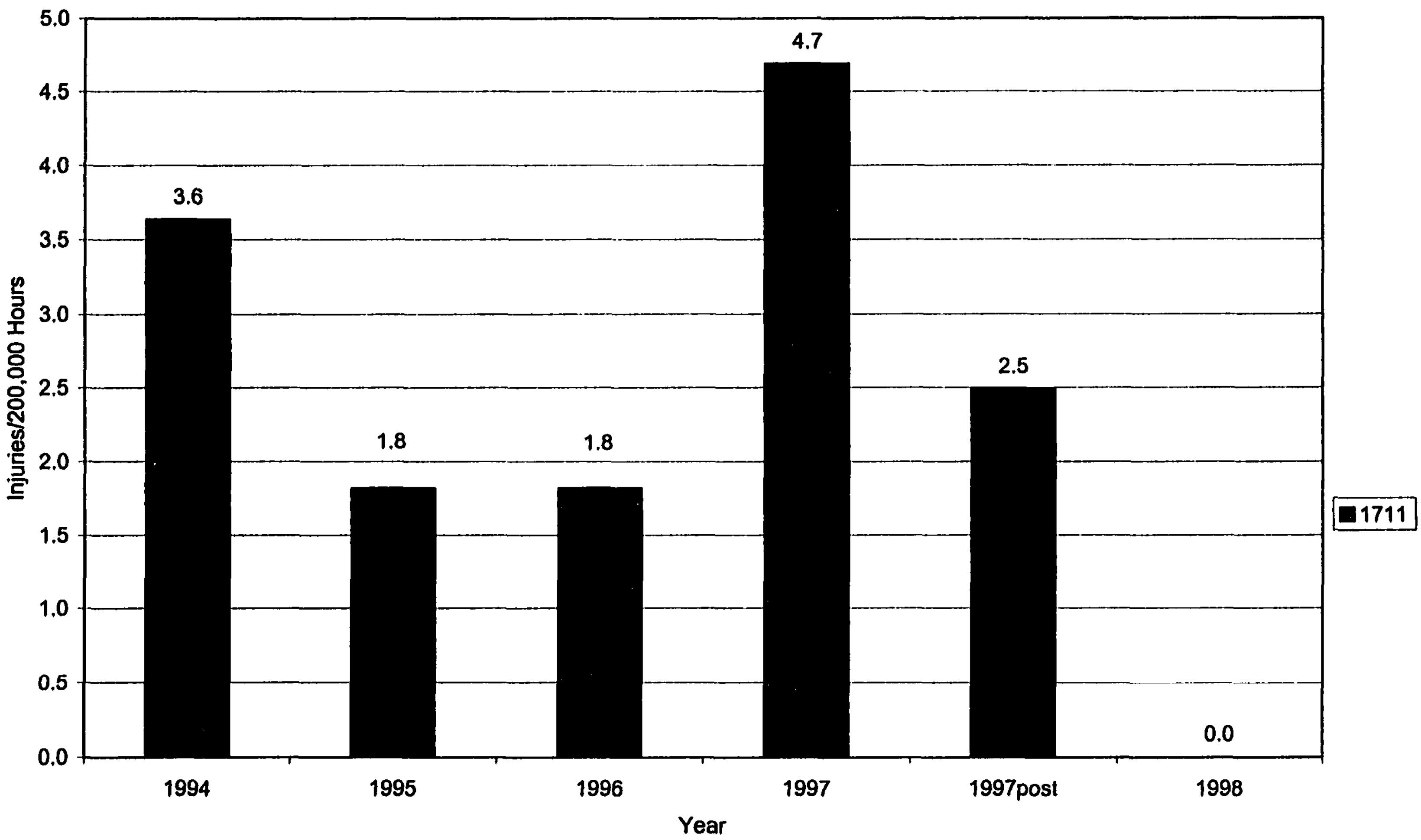


Injury Incidence Rates among Companies Specializing in Concrete Work, 1994 - 1998

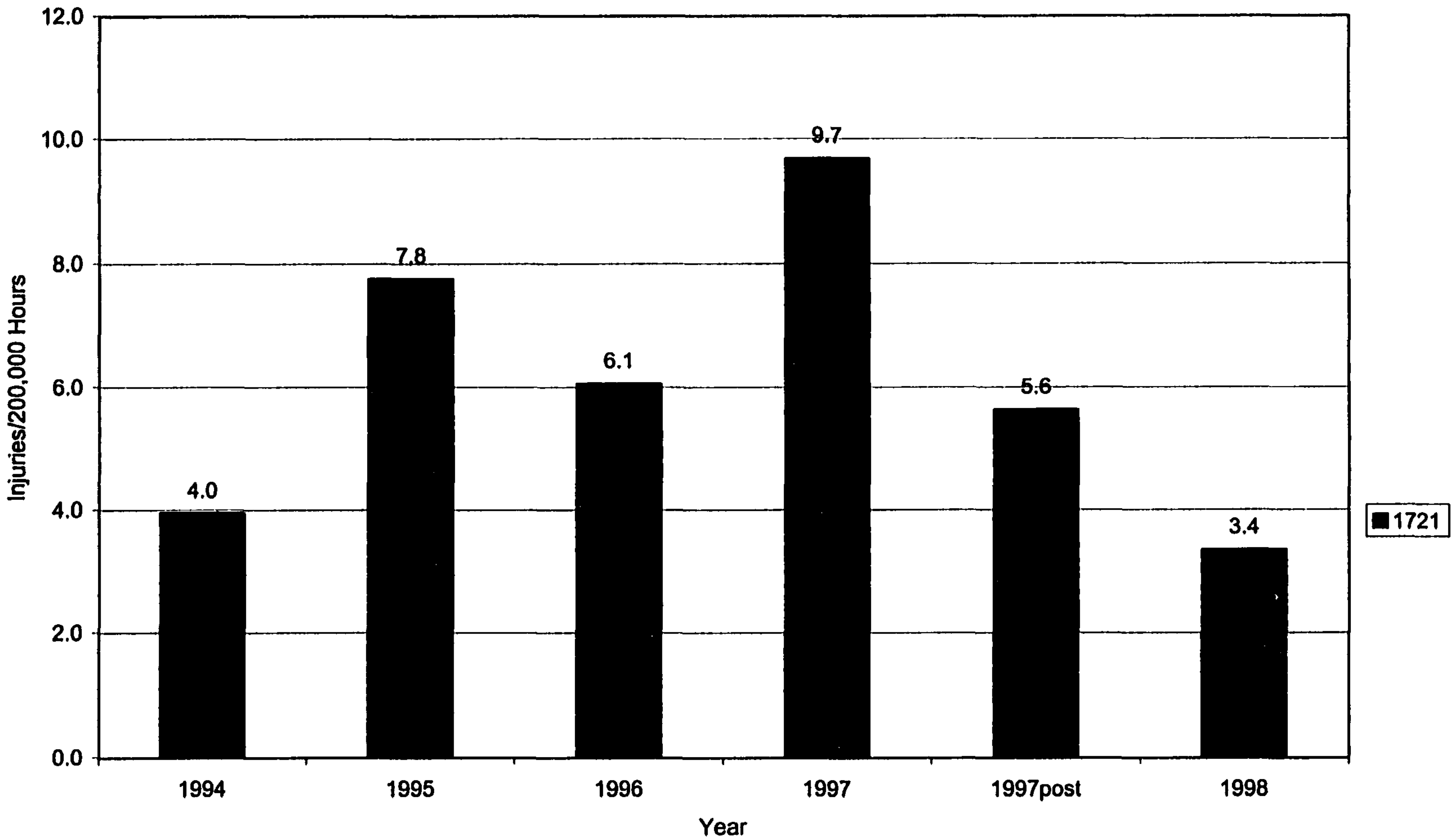


Injury Incidence Rates among Companies Specializing in Excavation Work, 1994 - 1998

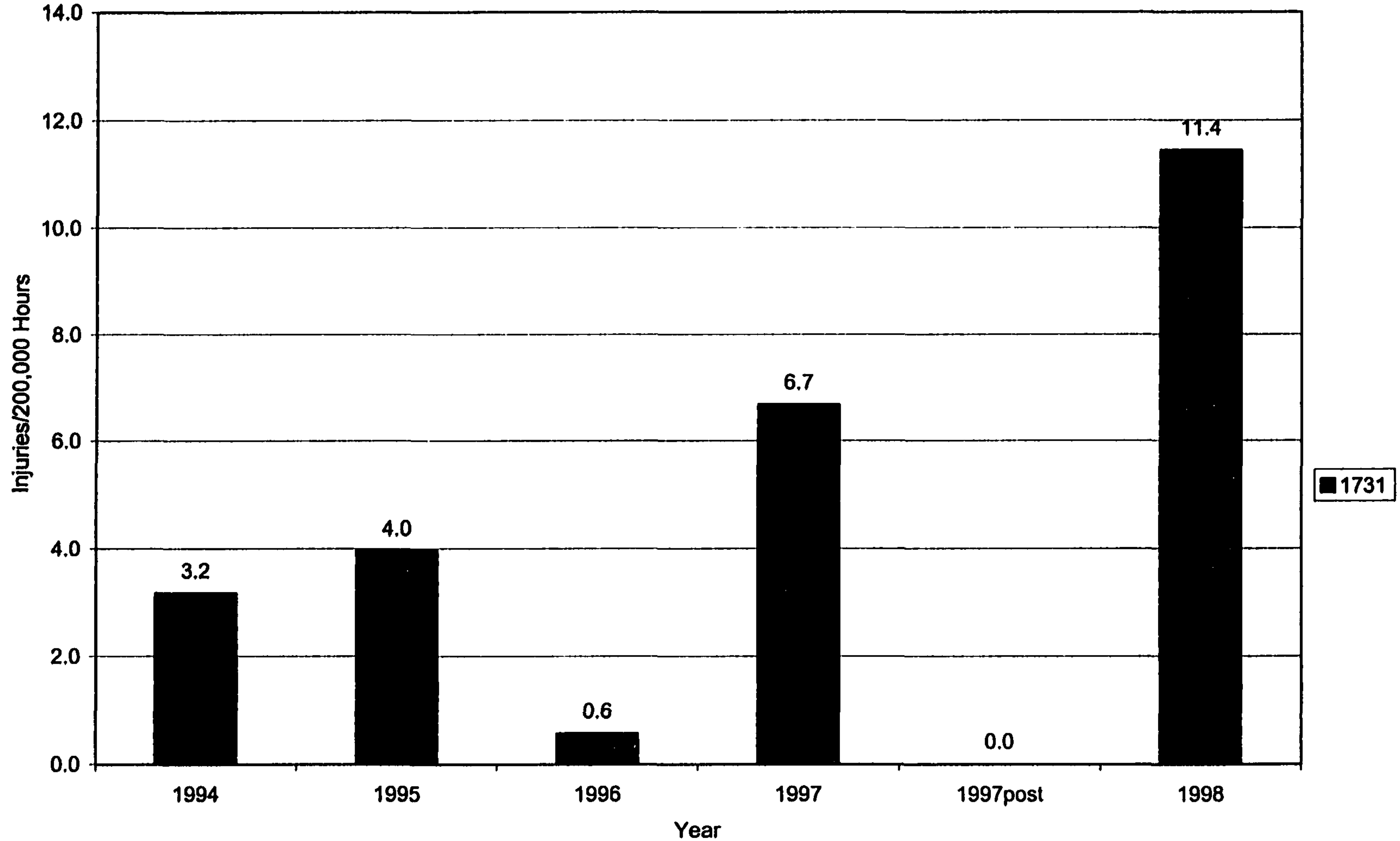
APPENDIX B



Lost Work Day Injury Incidence Rates among Companies Specializing in Plumbing, Heating,and Air Conditioning, 1994 - 1998



Lost Work Day Injury Incidence Rates among Companies Specializing in Painting and Paper Hanging, 1994 - 1998



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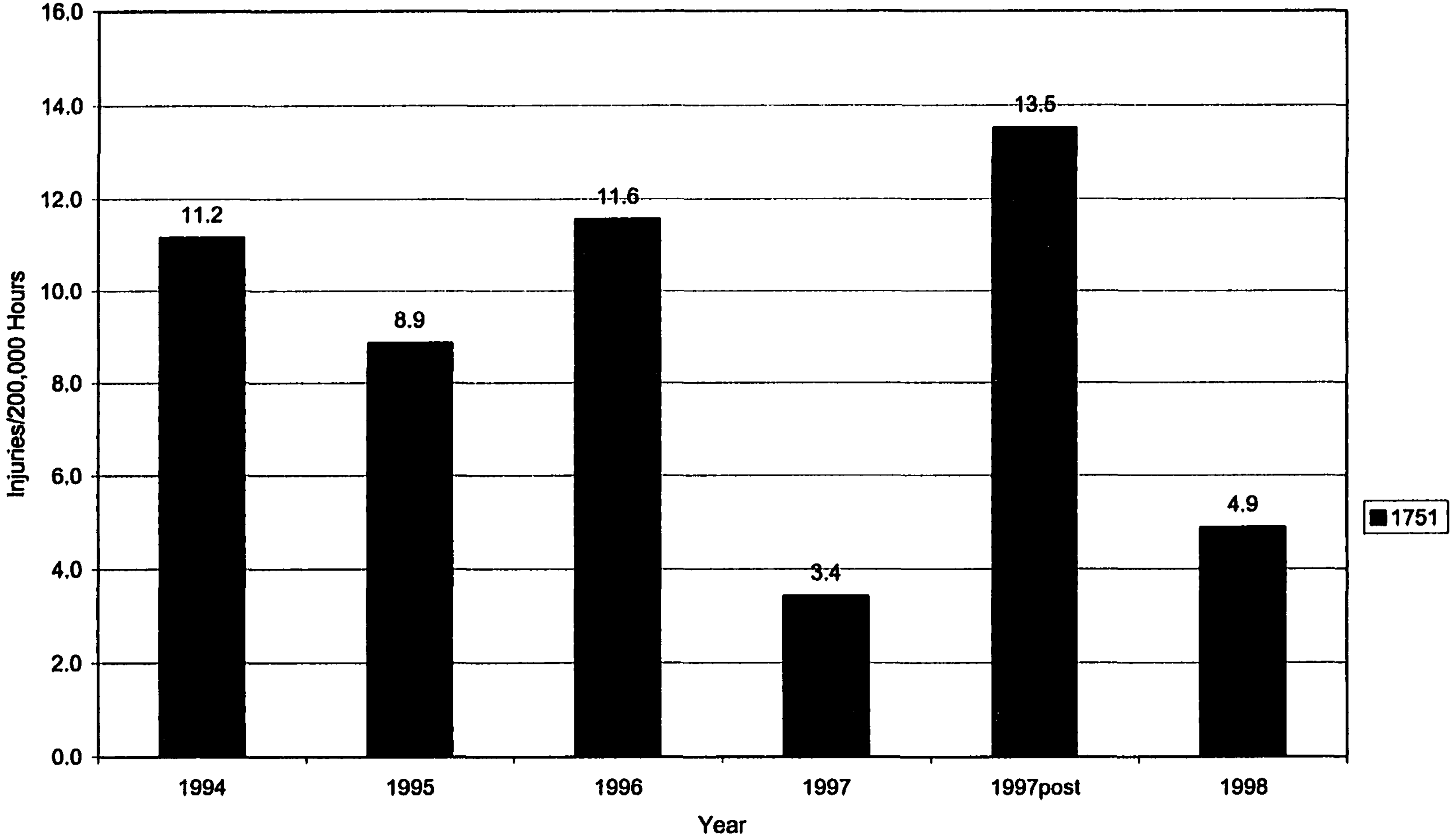

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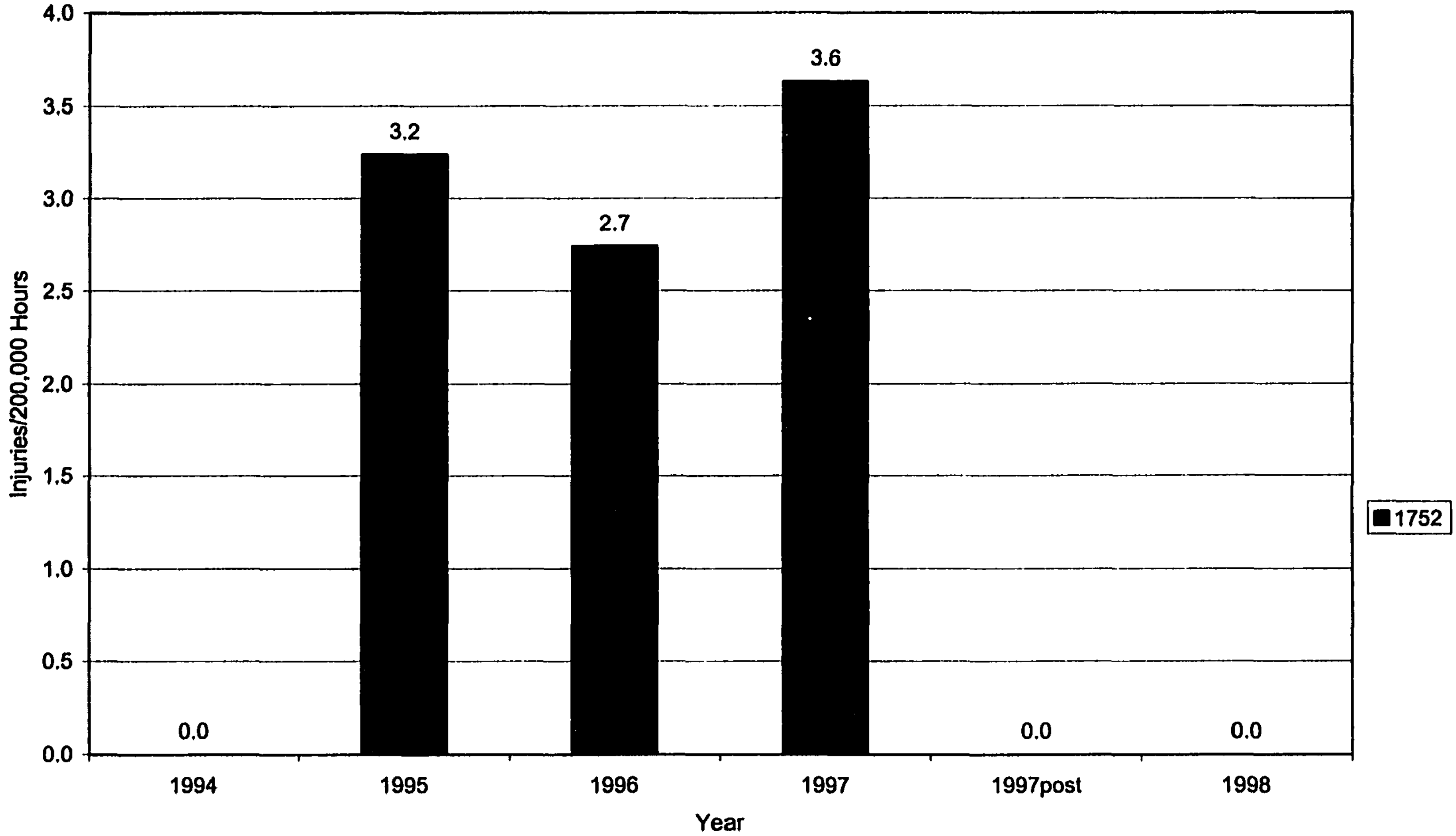

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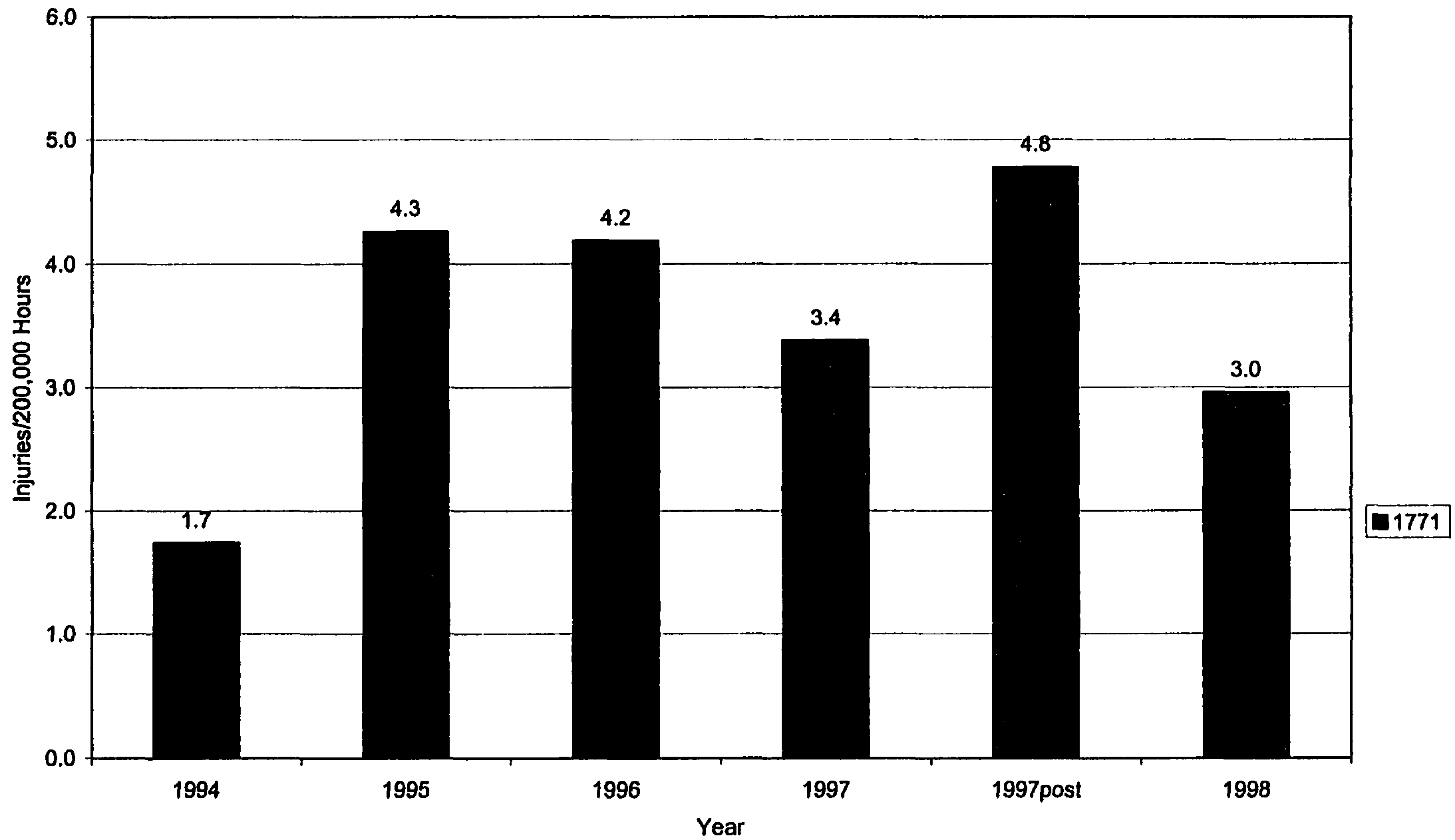

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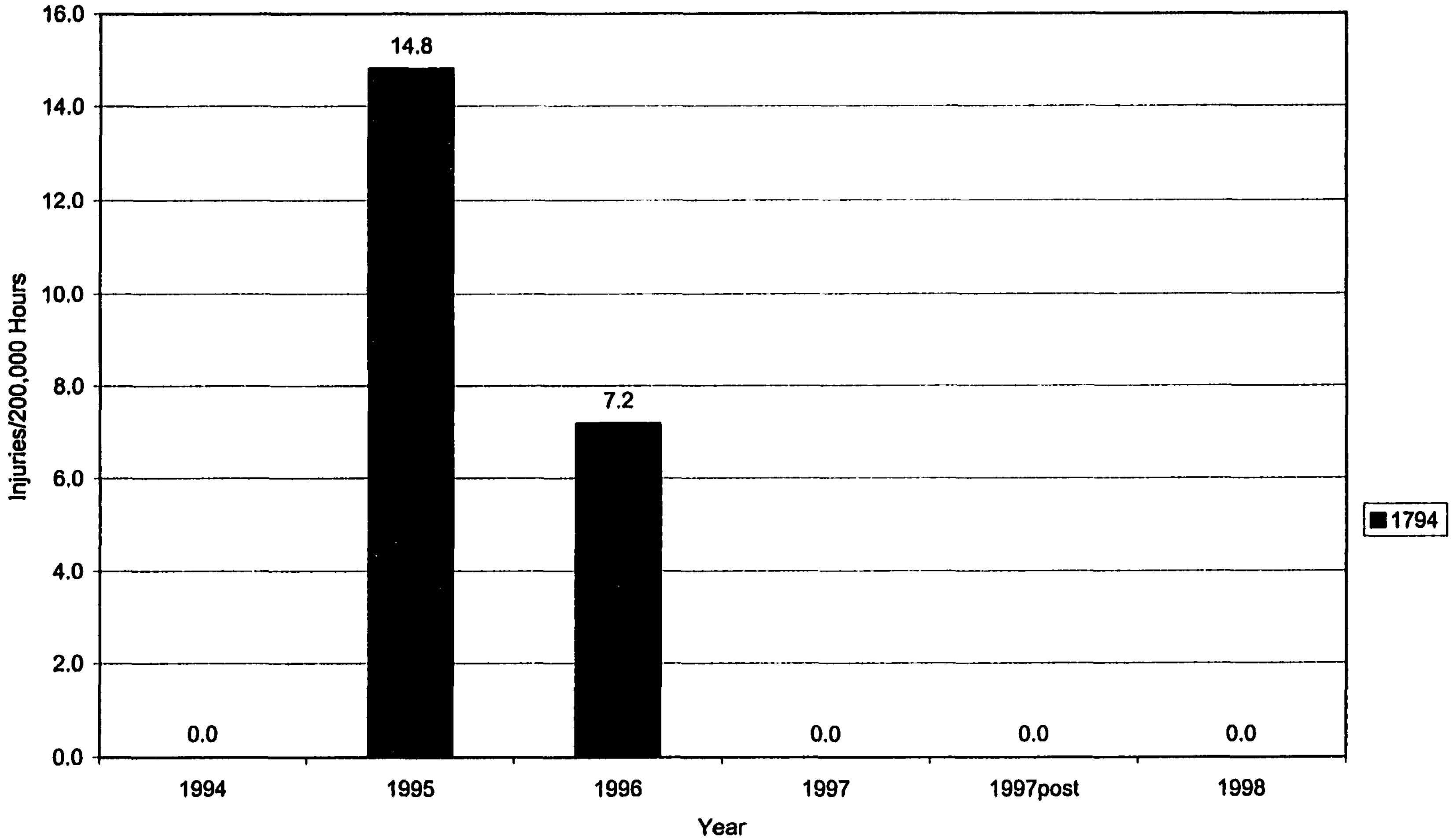
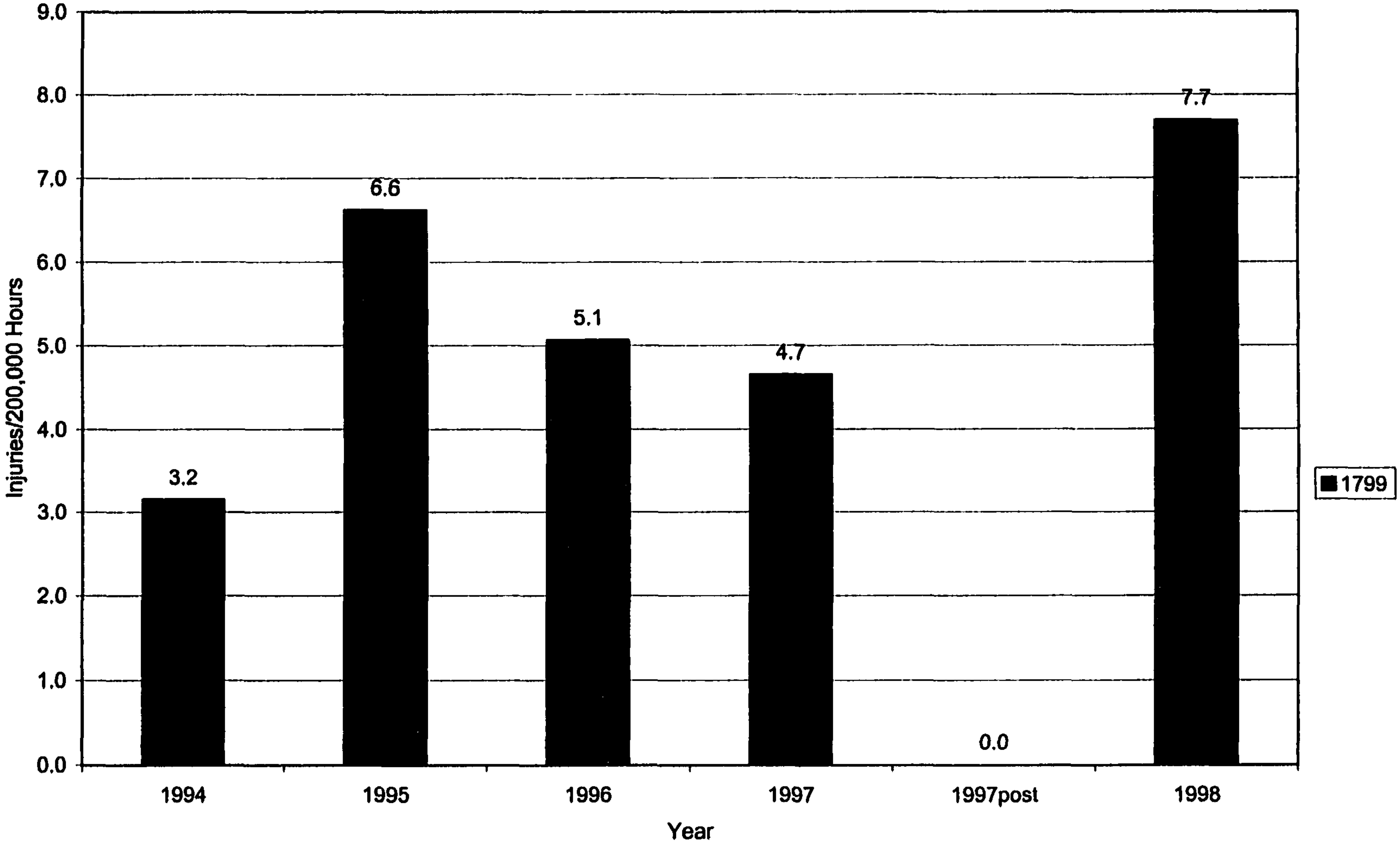
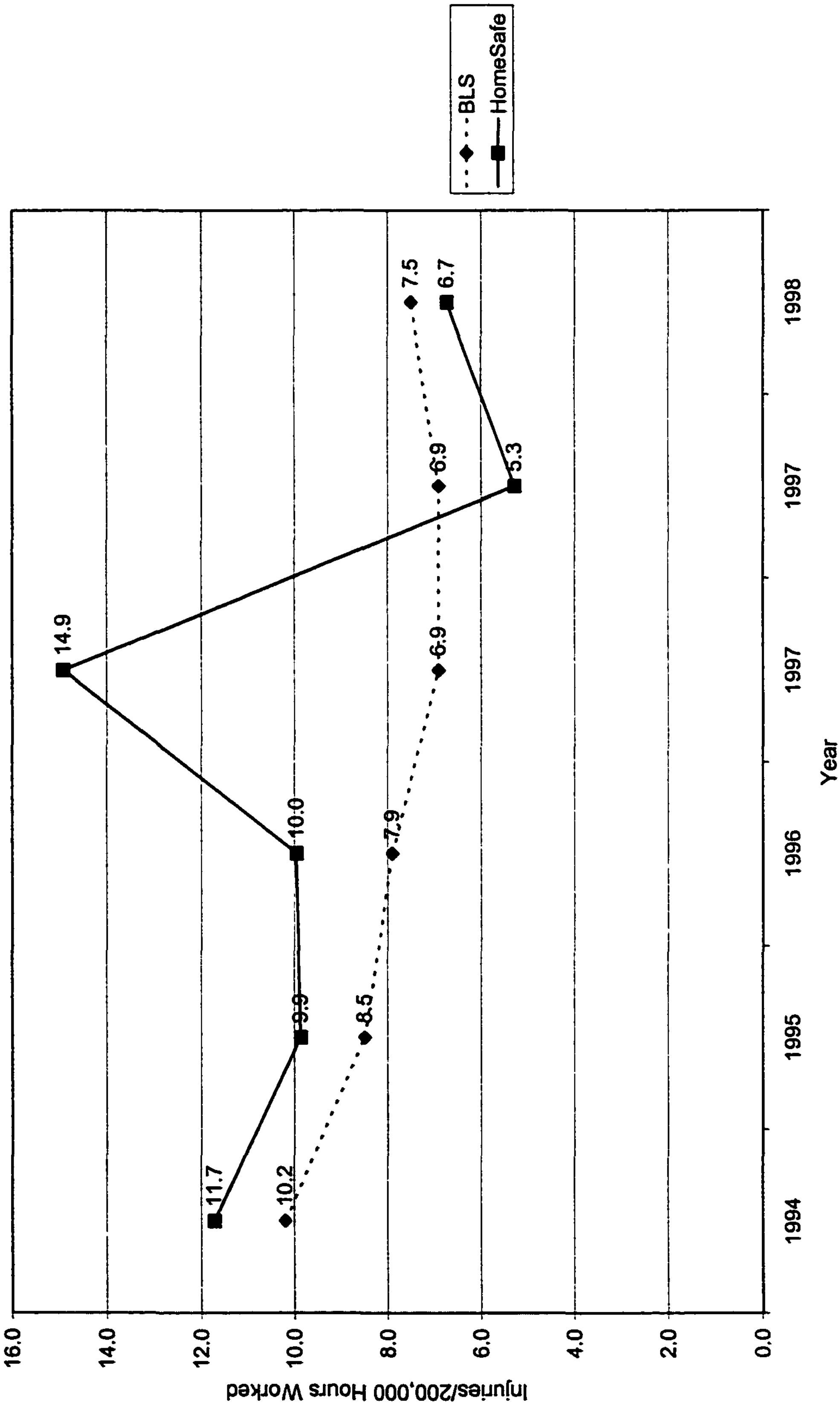


Lost Work Day Injury Incidence Rates among Companies Specializing in Excavation Work, 1994 - 1998

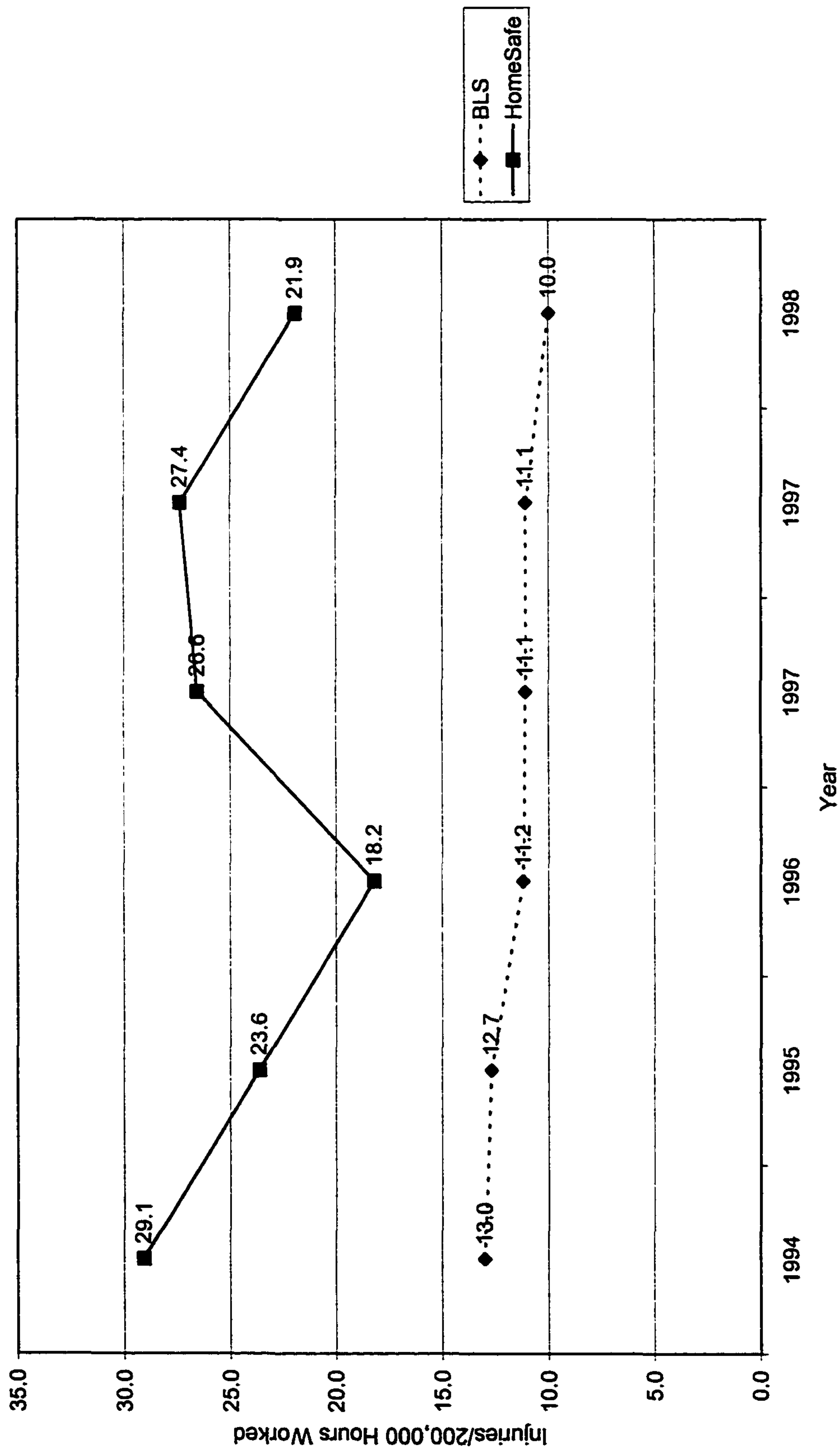


Lost Work Day Injury Incidence Rates among Miscellaneous Special Trade Contractors, 1994 - 1998

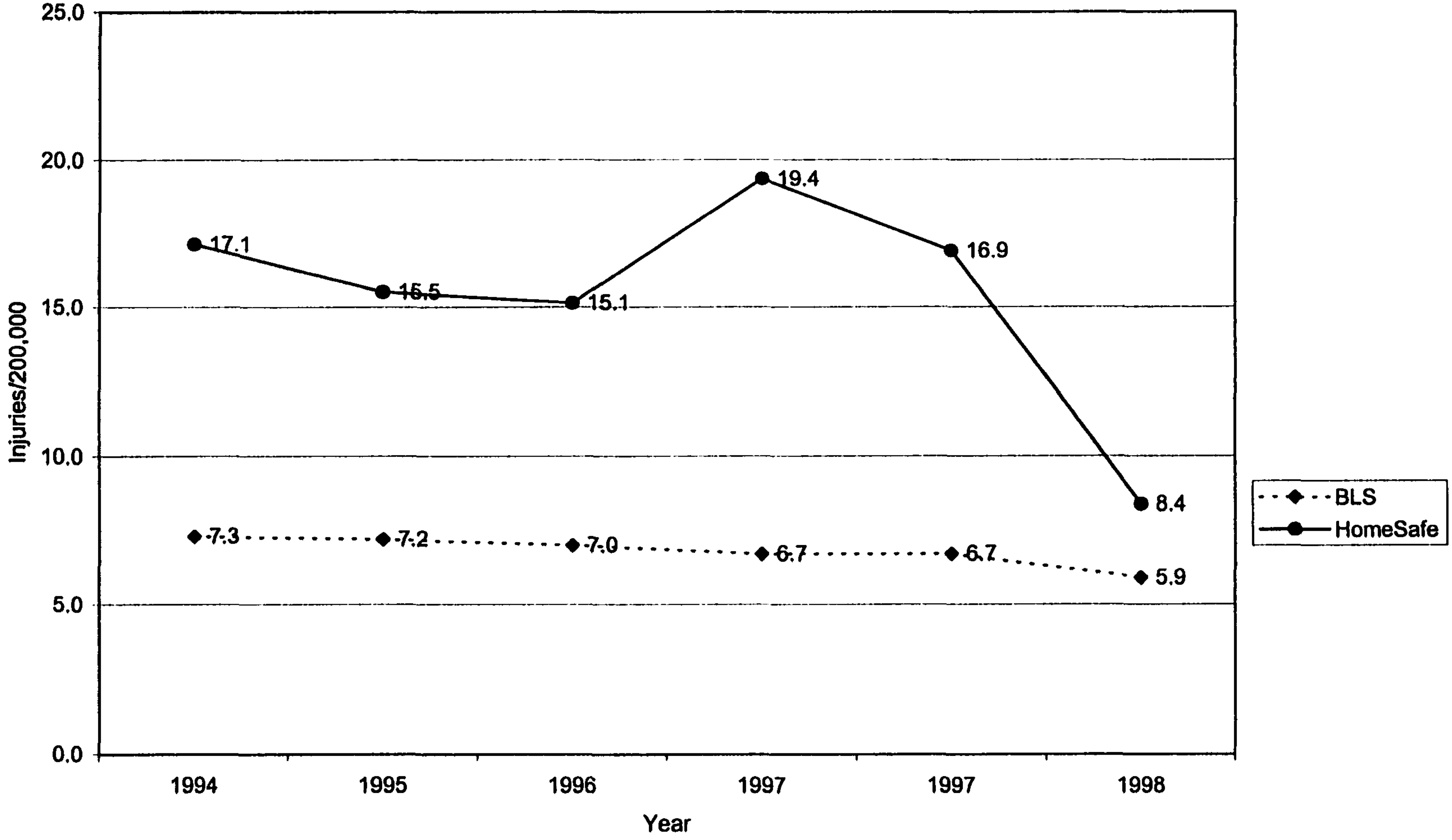
APPENDIX C



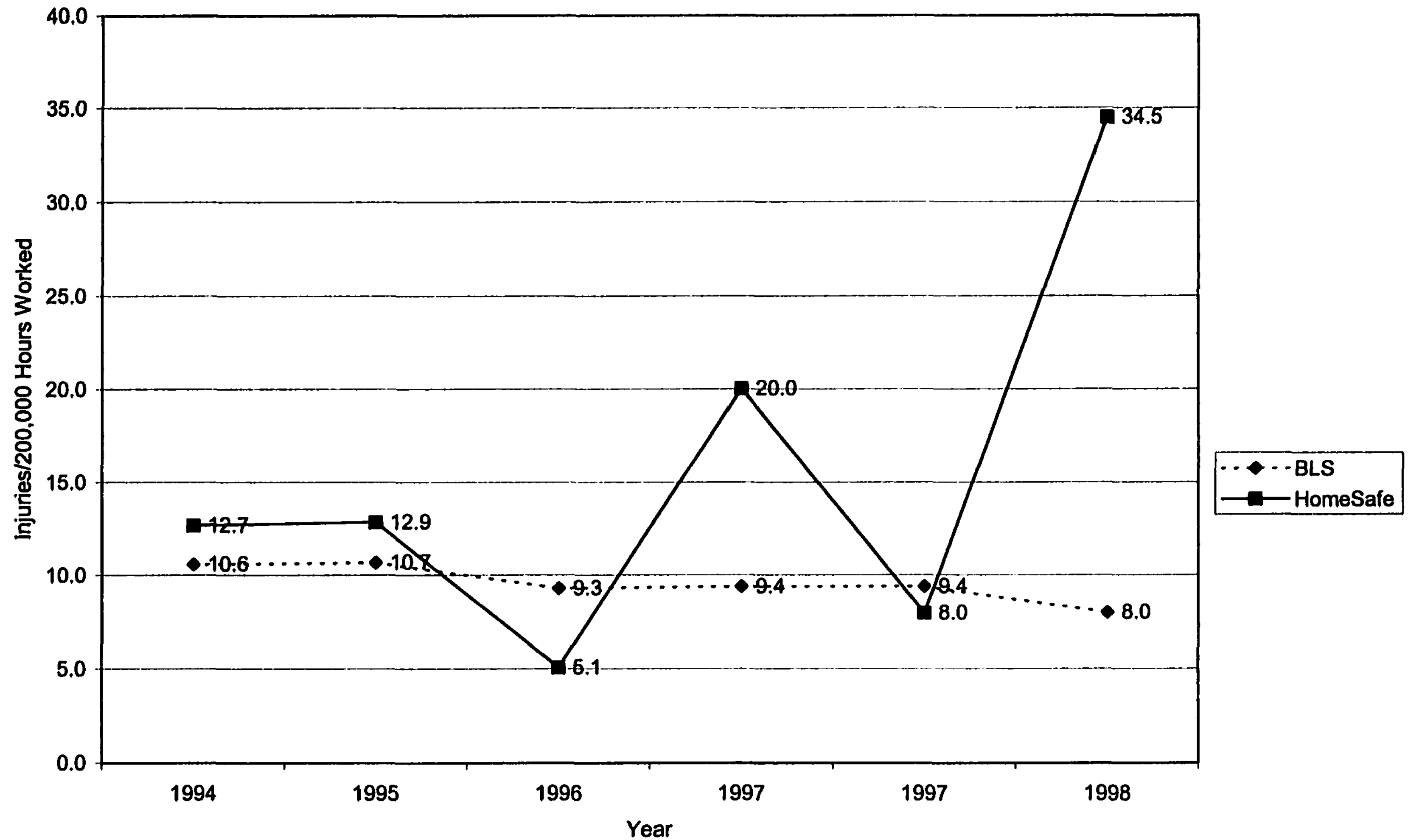
Injury Incidence Rates among Residential Builders 1994 - 1998: BLS versus HomeSafe



Injury Incidence Rates among Plumbing, Heating, and Air Conditioning Companies
1994 - 1998: BLS versus HomeSafe



Injury Incidence Rates among Painting and Paper Hanging Companies 1994 - 1998:
BLS versus HomeSafe



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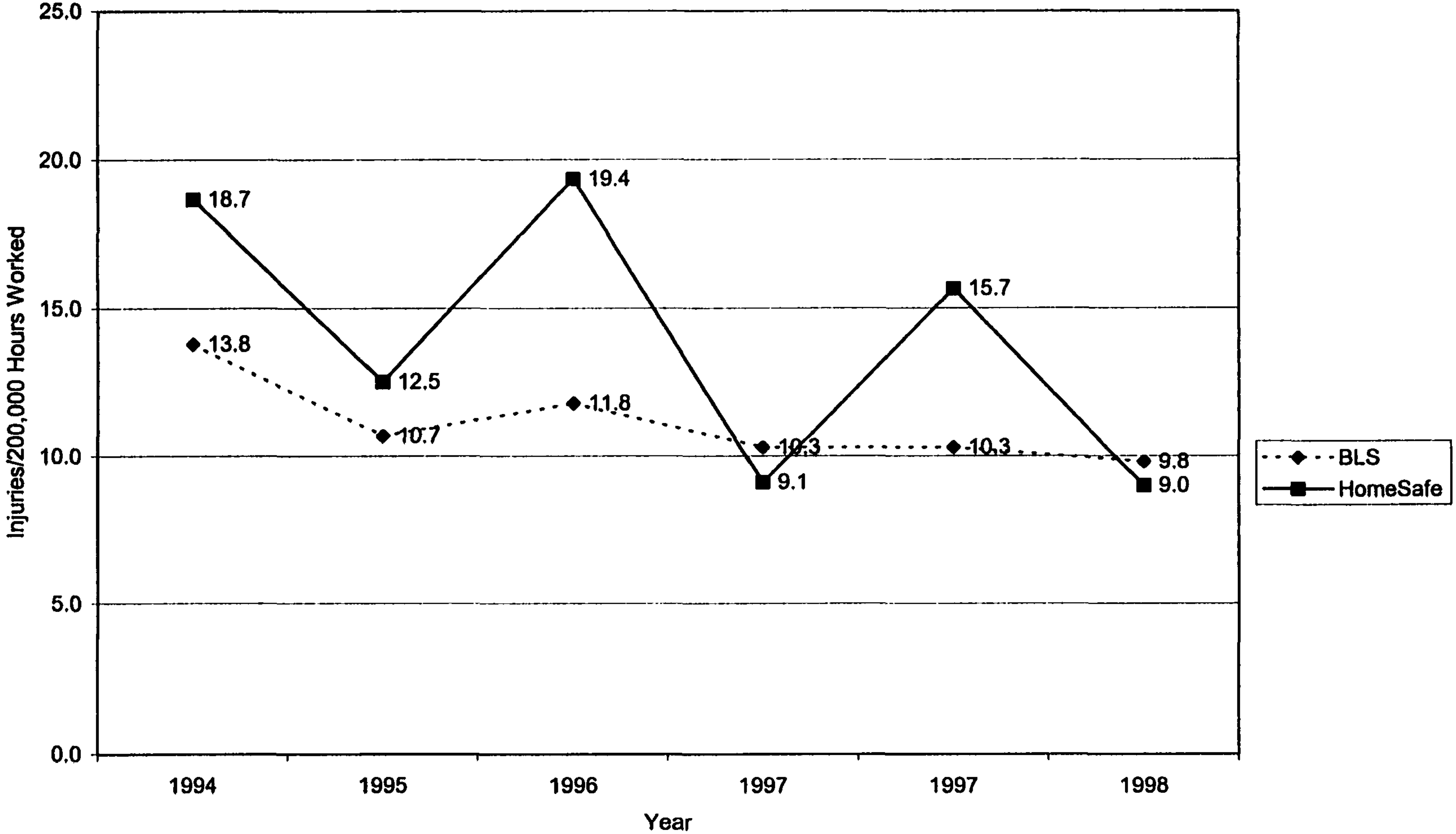
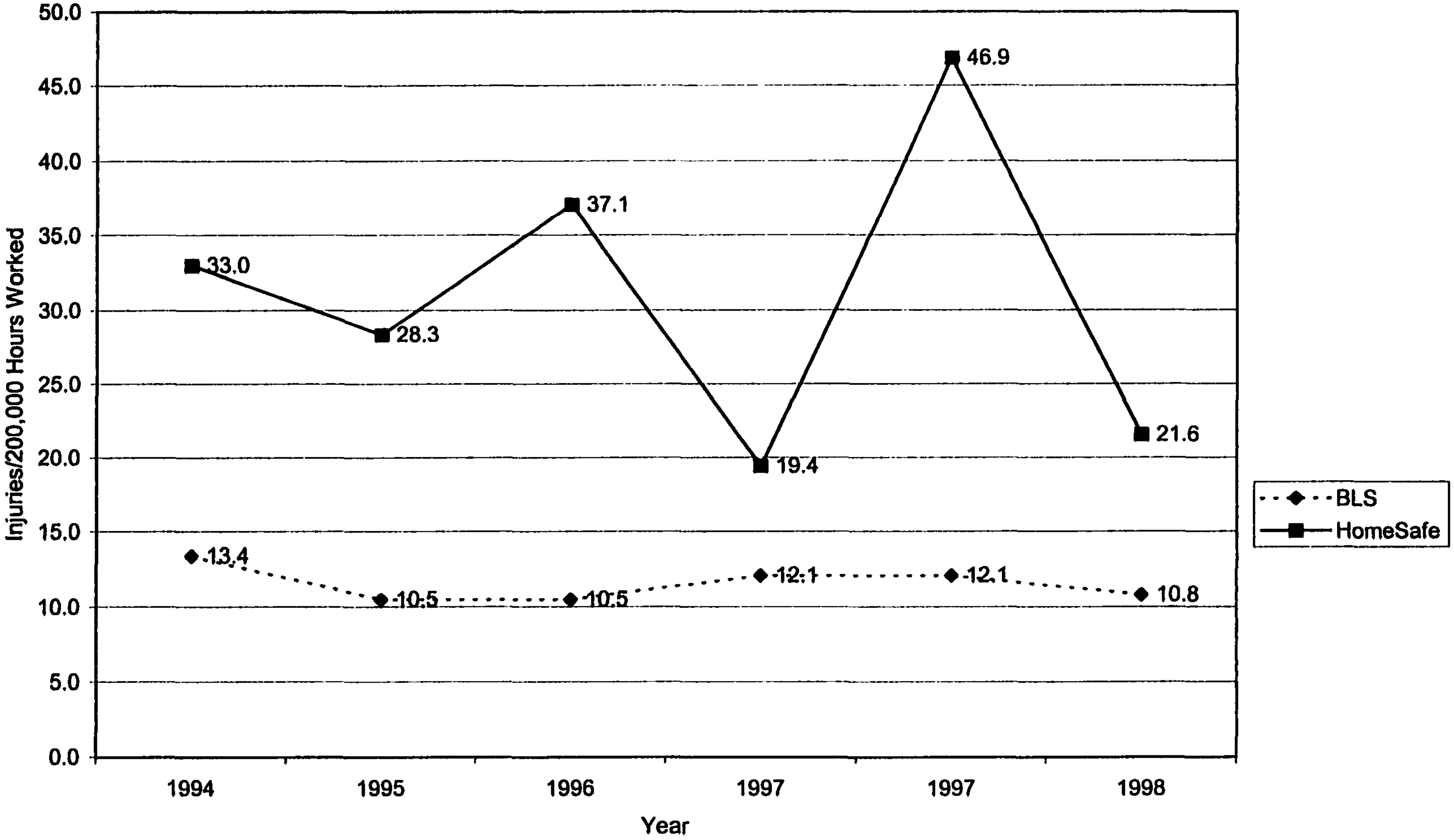


Injury Incidence Rates Among Masonry, Stonework, and Plastering Companies
1994 - 1998: BLS versus HomeSafe



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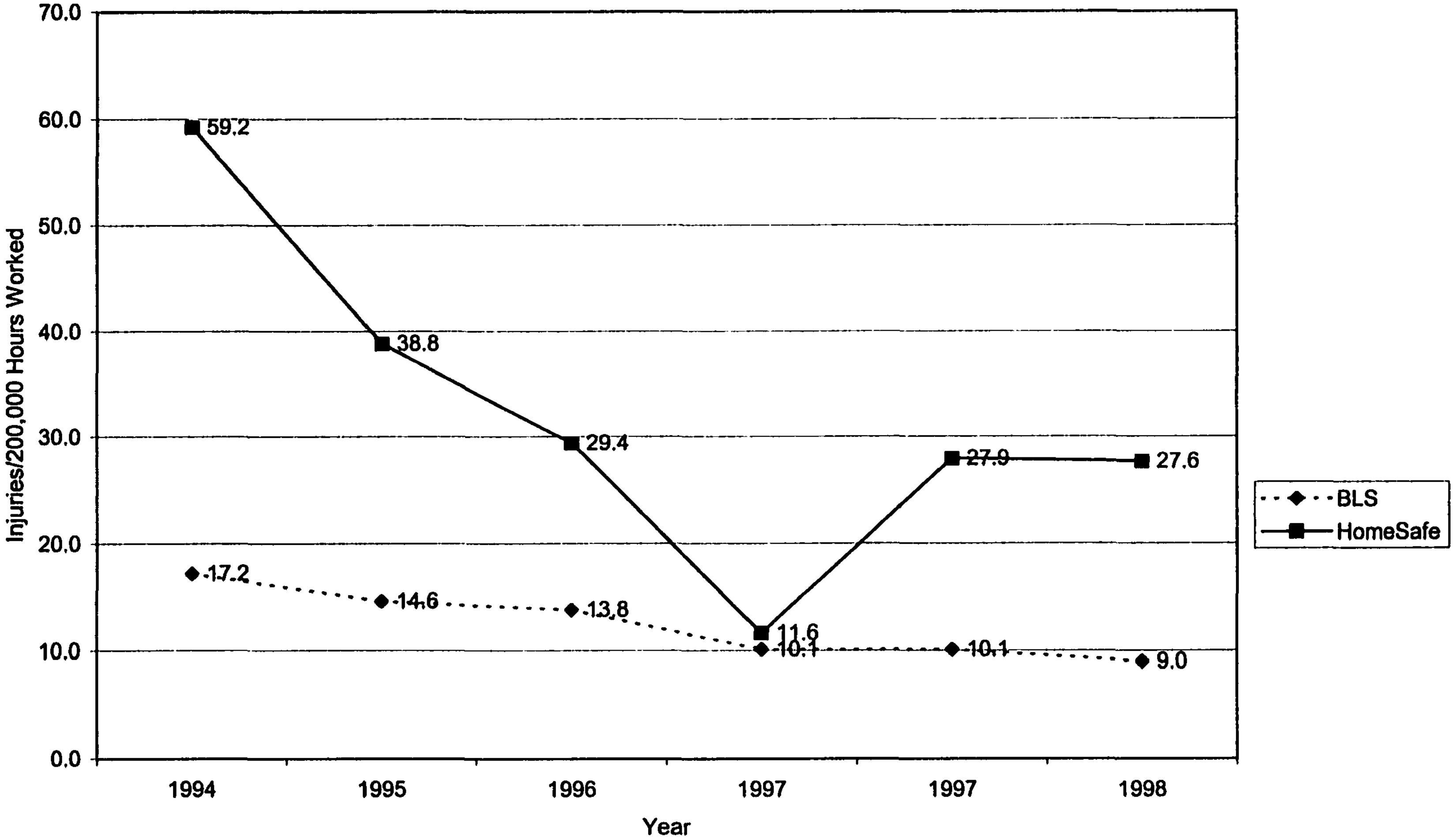
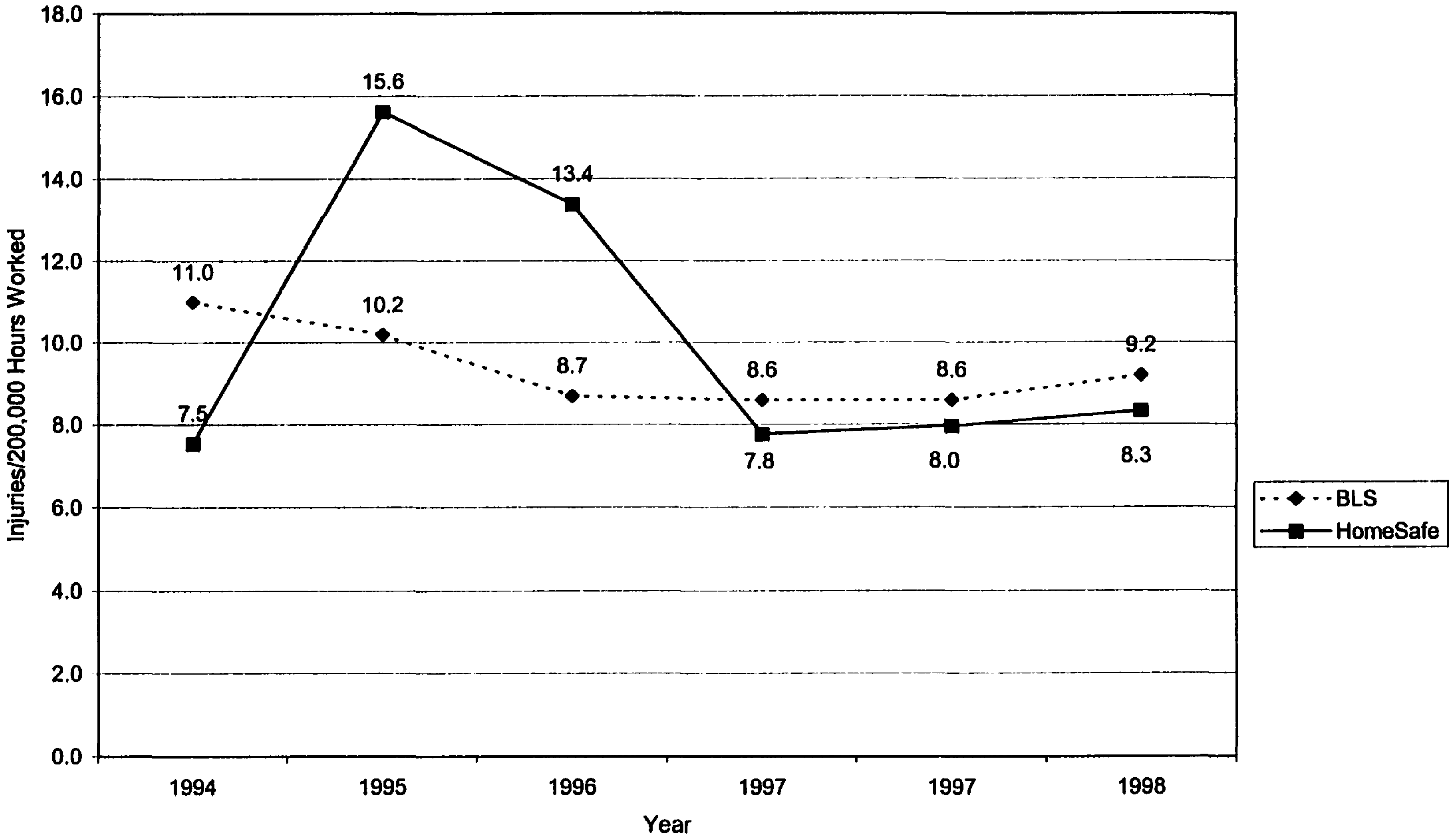


Injury Incidence Rates among Roofing, Siding, and Sheetmetal Work Companies
1994 - 1998: BLS versus HomeSafe



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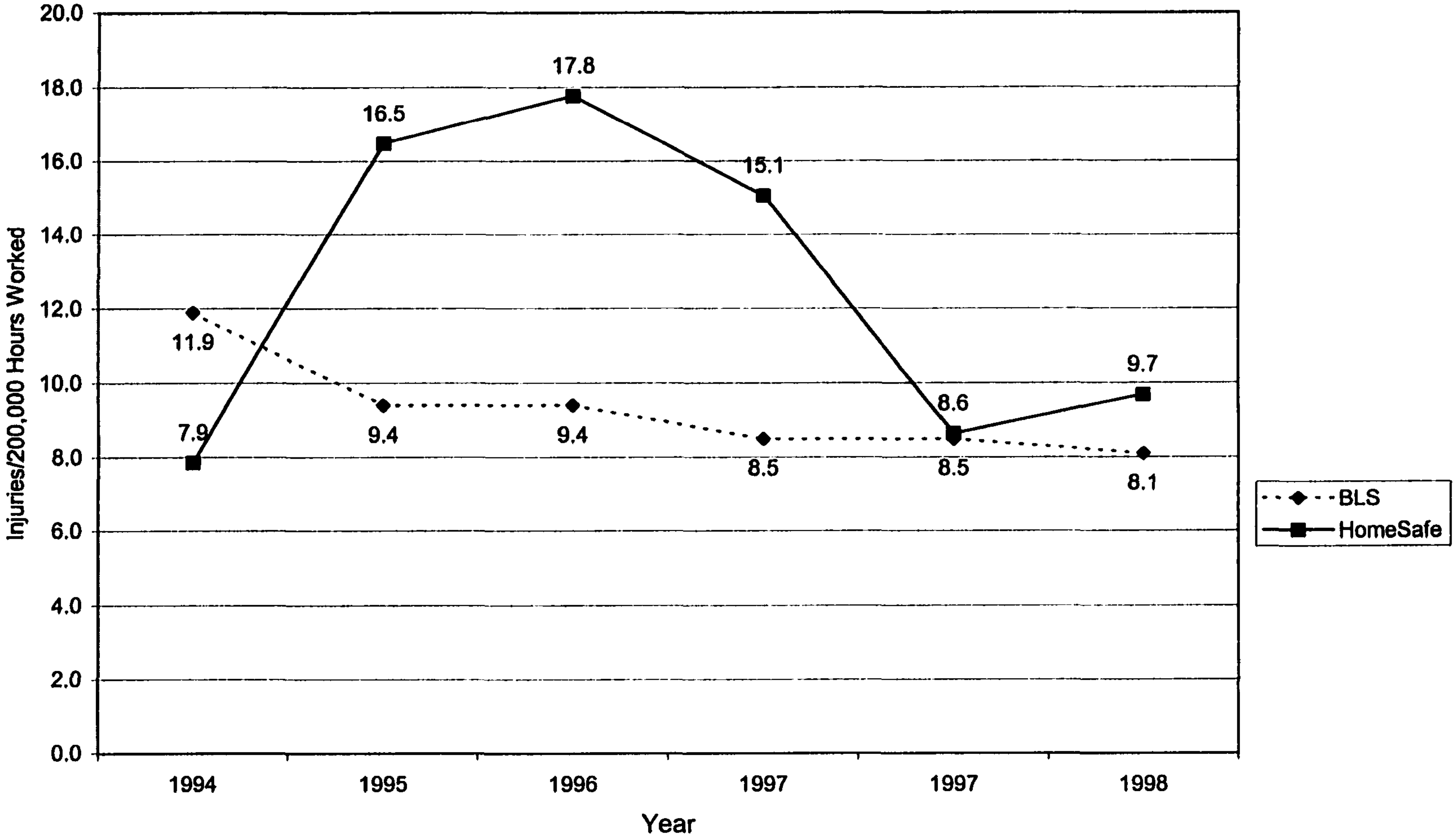
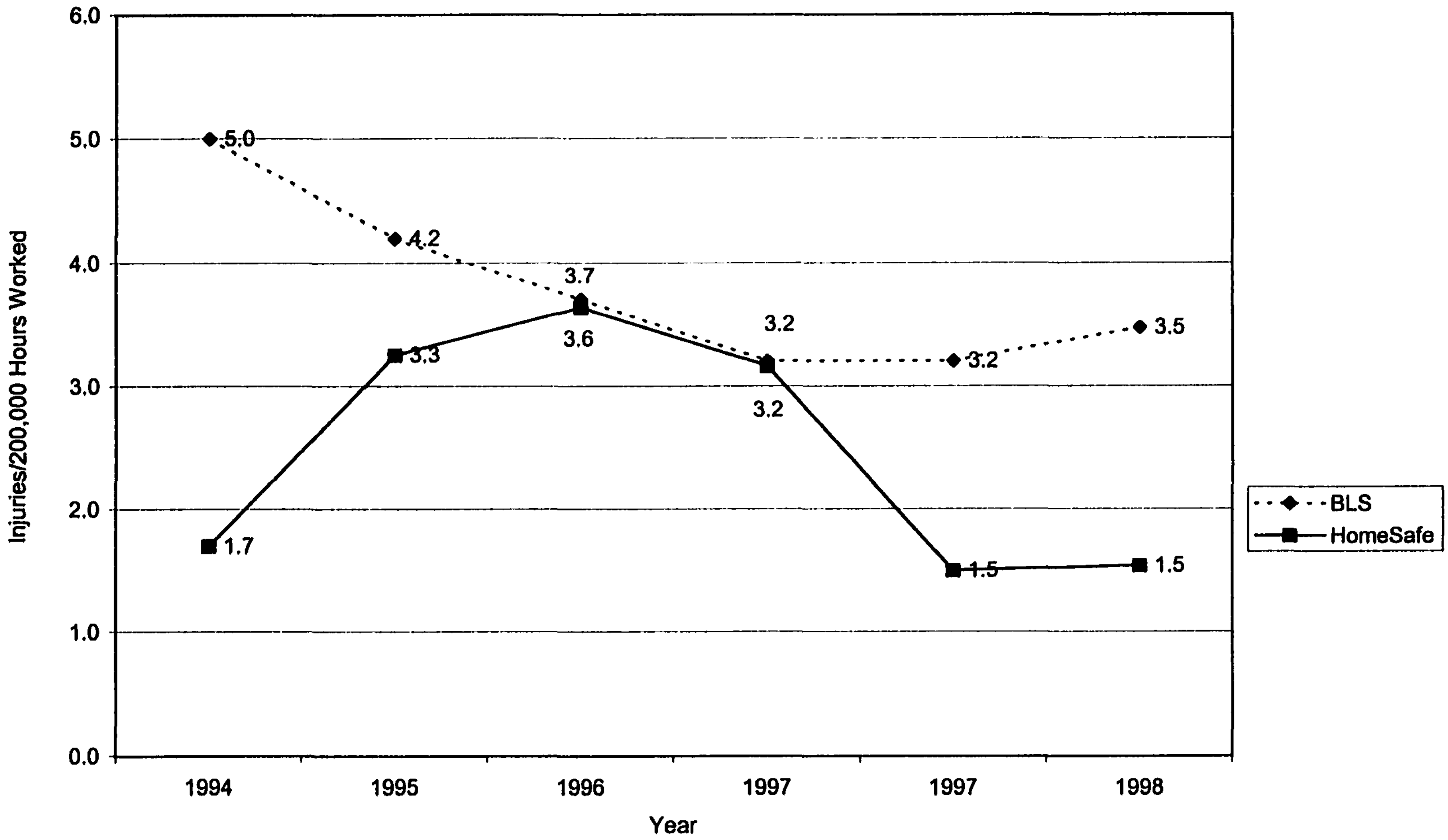
BLS versus HomeSafe

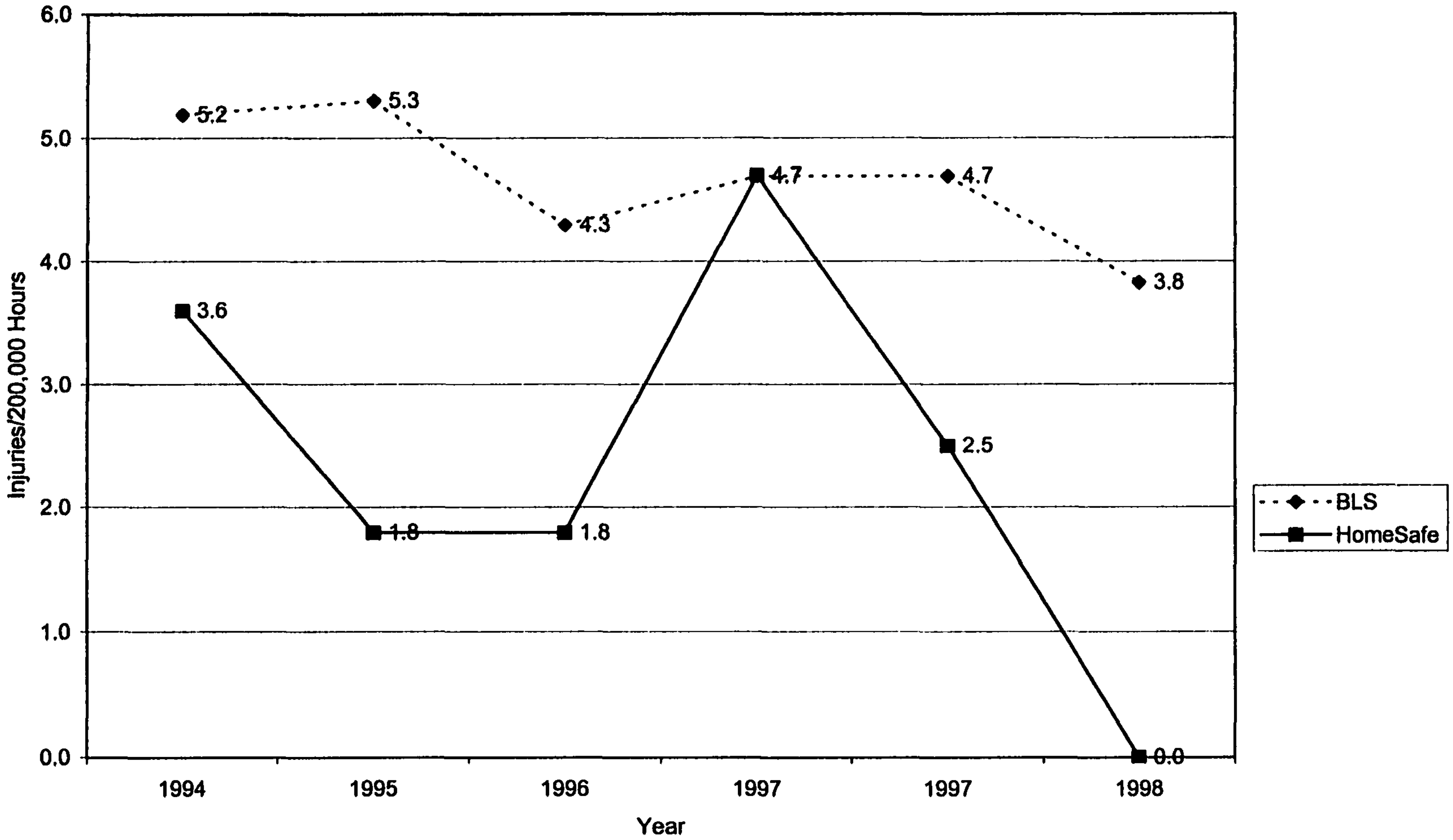


Injury Incidence Rates among Miscellaneous Special Trade Contractors 1994 - 1998:
BLS versus HomeSafe

APPENDIX D



Lost Work Day Injury Incidence Rates among Residential Builders 1994 - 1998:
BLS versus HomeSafe



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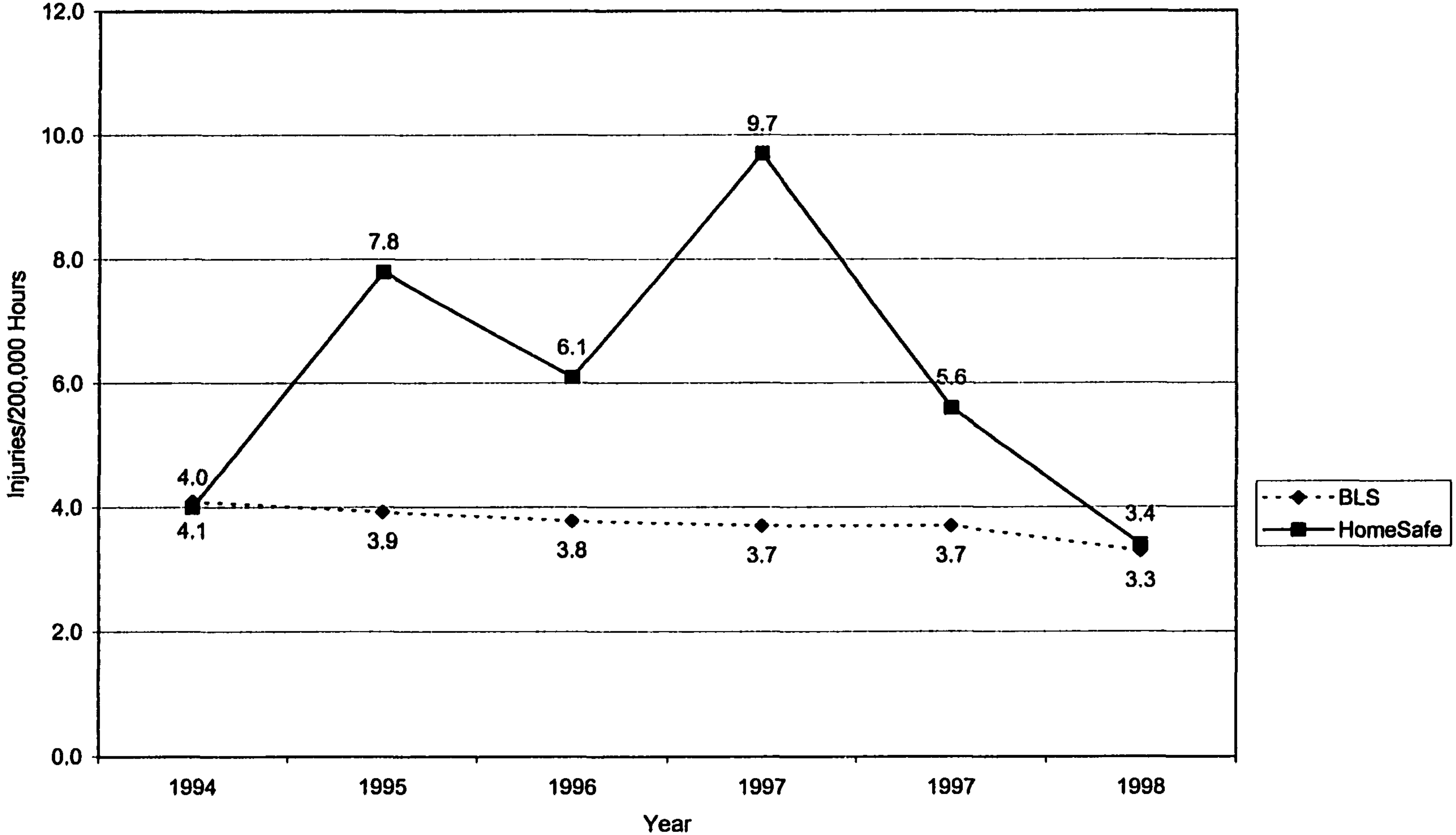

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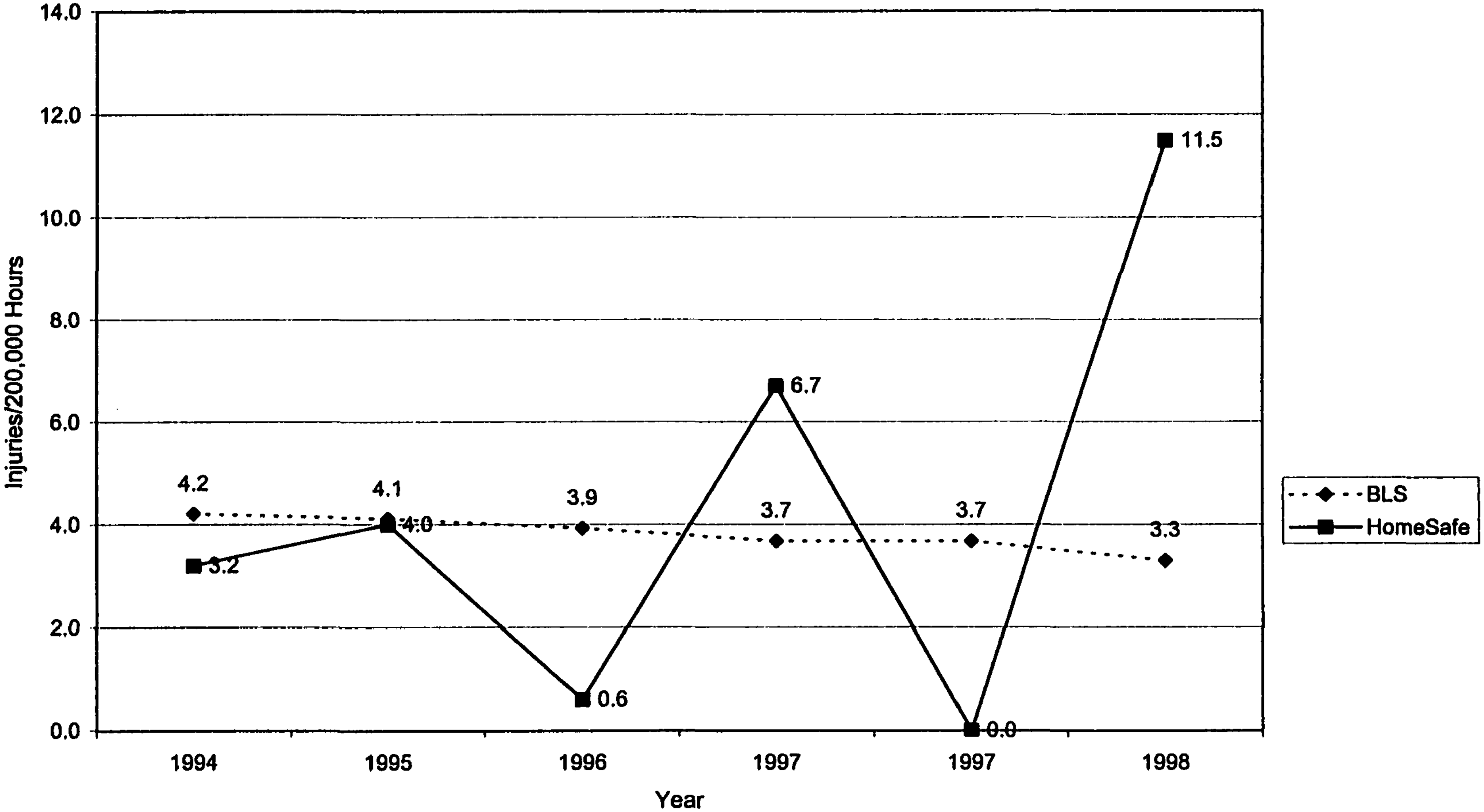
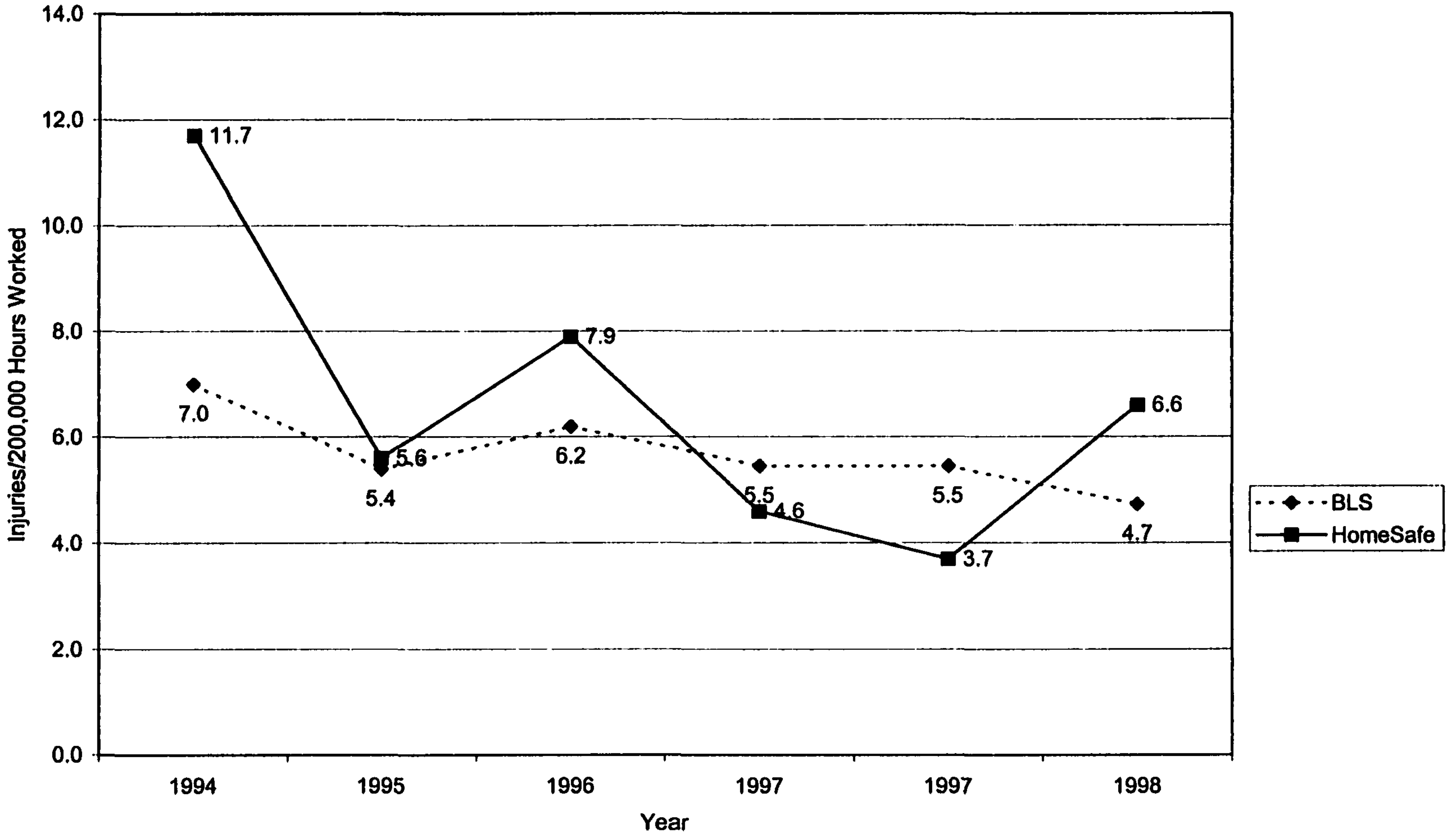
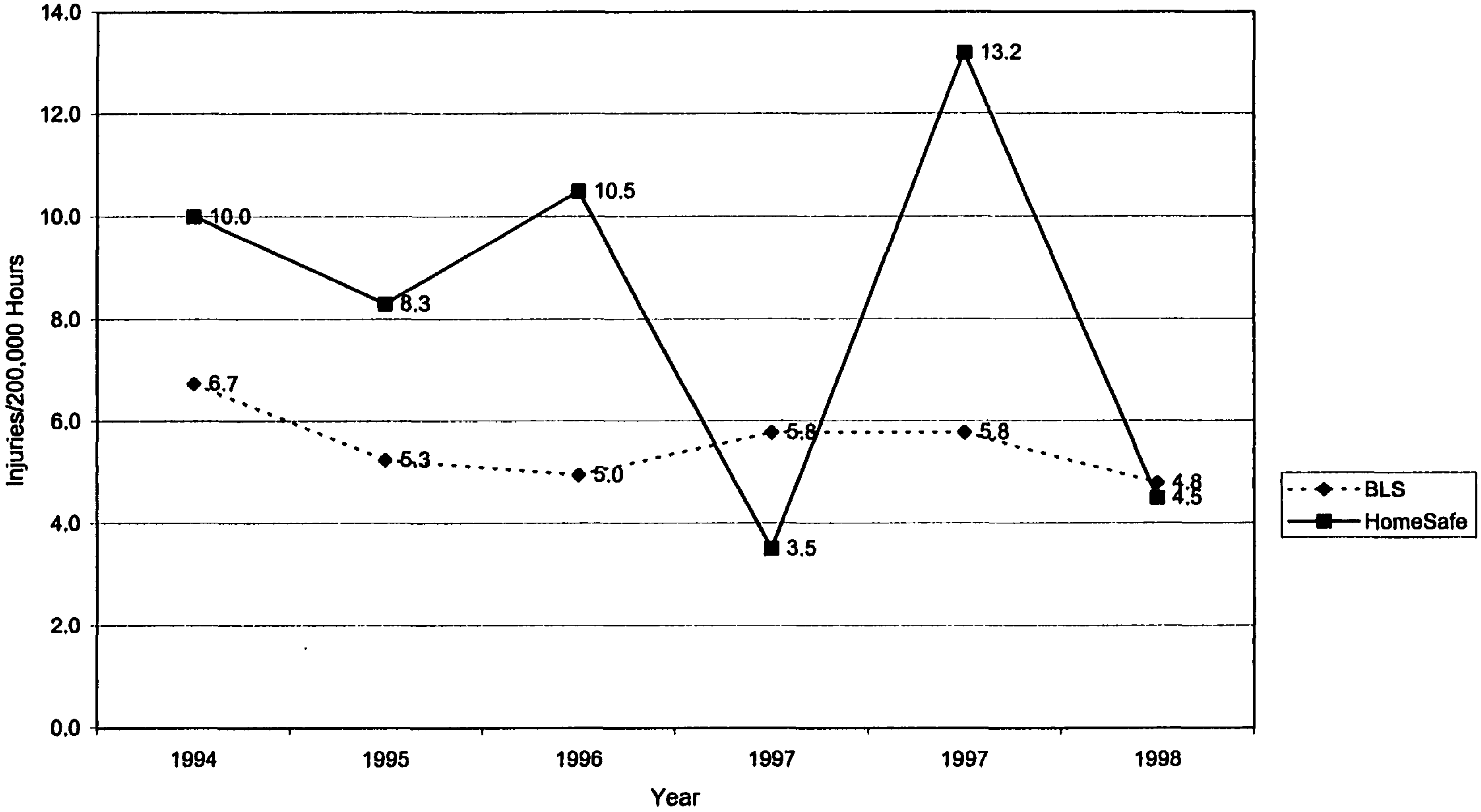


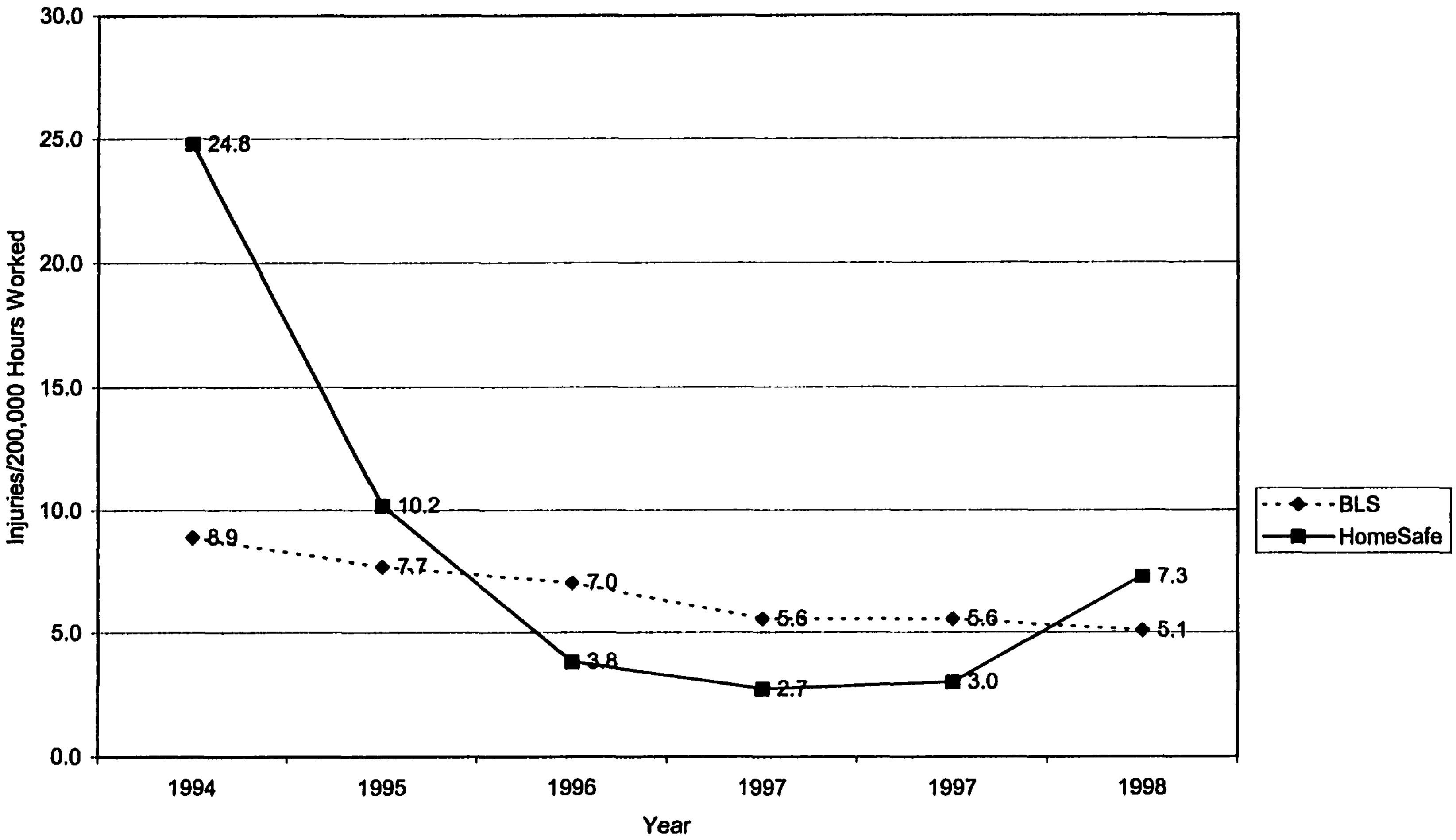
Lost Work Day Injury Incidence Rates among Companies Specializing in Electrical Work
1994 - 1998: BLS versus HomeSafe



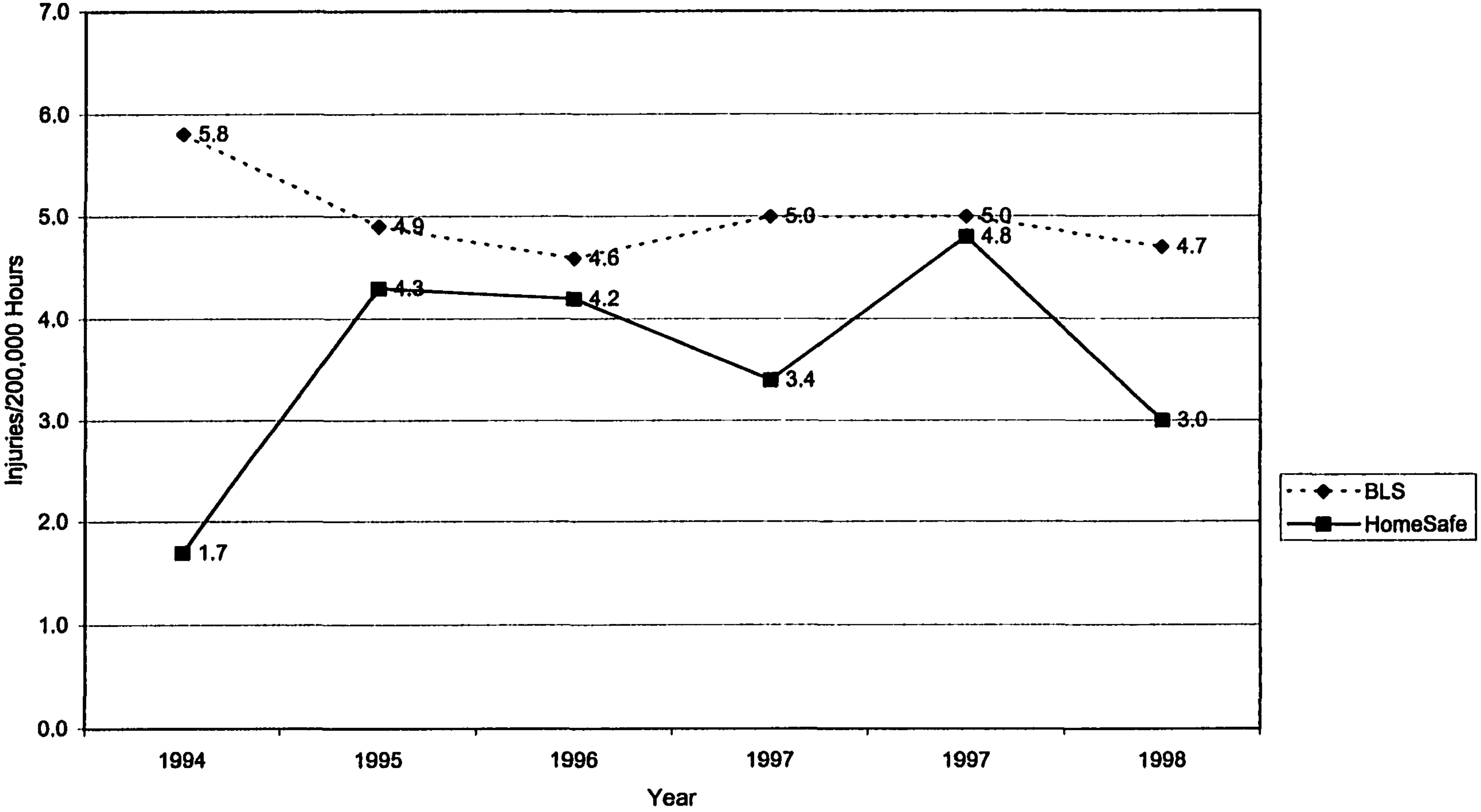
Lost Work Day Injury Incidence Rates among Companies Specializing in Masonry, Stonework and Plastering 1994 - 1998: BLS versus HomeSafe



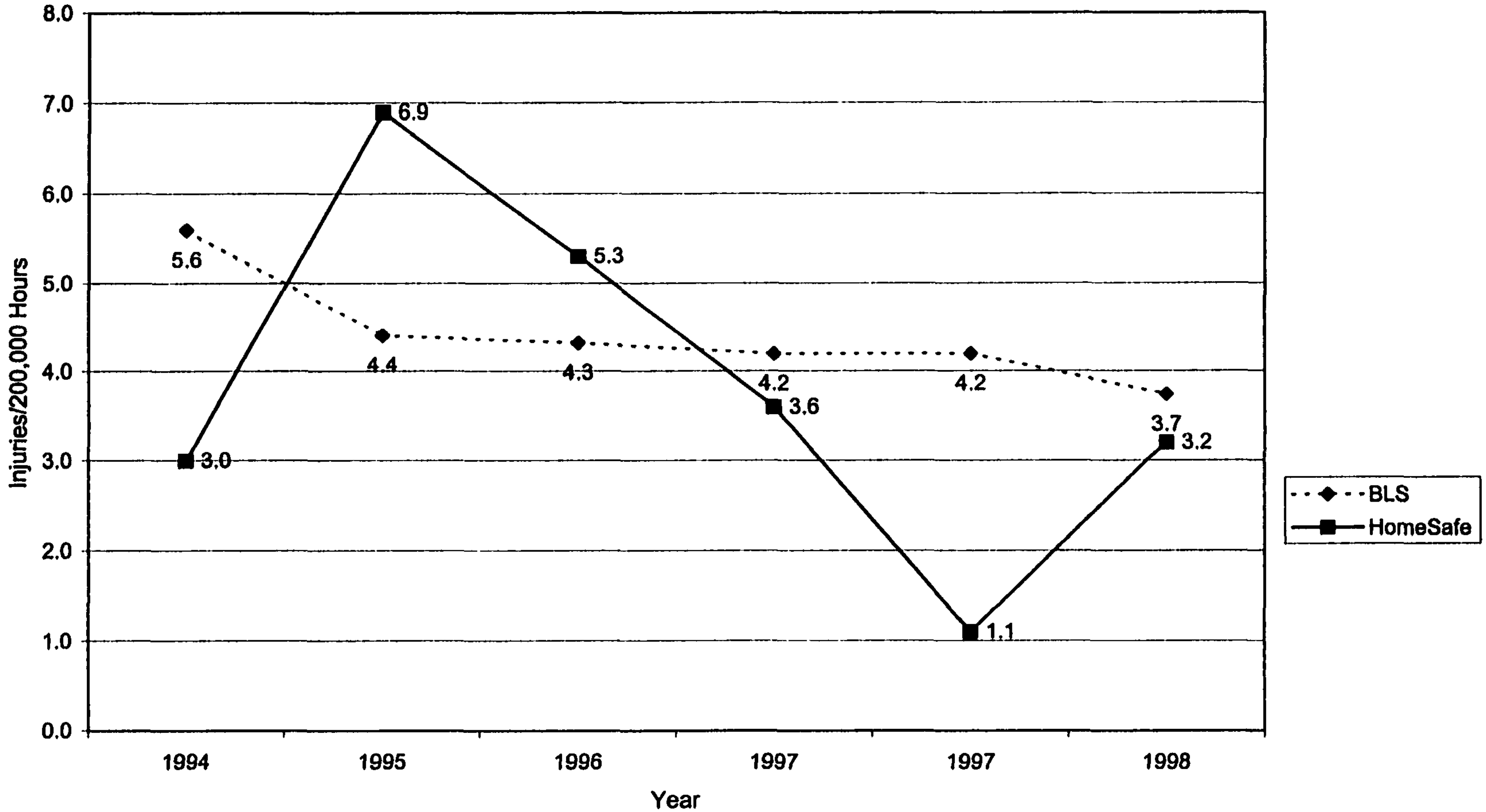
Lost Work Day Injury Incidence Rates among Companies Specializing in Carpentry and Floor Work 1994 - 1998: BLS versus HomeSafe



Lost Work Day Injury Incidence Rates among Companies Specializing in Roofing, Siding, and Sheetmetal 1994 - 1998: BLS versus HomeSafe



Lost Work Day Injury Incidence Rates among Companies Specializing in Concrete Work
1994 - 1998: BLS versus HomeSafe



Lost Work Day Injury Incidence Rates among Miscellaneous Special Trade Contractors
1994 - 1998: BLS versus HomeSafe

PART THREE

THE EFFECTIVENESS OF THE HOMESAFE PILOT PROGRAM IN REDUCING INJURY RATES AMONG RESIDENTIAL CONSTRUCTION WORKERS, 1994–1998

INTRODUCTION

Injury rates among construction workers are among the nation's highest[1]. In Colorado, construction workers seem to be at particular risk, with 174 construction workers killed between 1984 and 1993, seven residential construction workers in the Denver-metropolitan region killed in a single year in 1991, and injury rates among construction workers among the highest in the country[2,3]. To address this issue, the HomeSafe Pilot Program was designed and implemented through a partnership between OSHA Region VIII (OSHA) and the Home Builders Association of Metropolitan Denver (HBA).

The HomeSafe Program

The HomeSafe Program was the product of a collaborative effort between the HBA and OSHA. Following the deaths of seven residential construction workers in 1991, OSHA and the HBA developed the program to address the specific hazards and safety challenges faced by the residential construction industry. The final product took four years to develop and was completed in 1996. The HBA and OSHA developed the HomeSafe Program based on available injury data in the field of residential construction and packaged it to be easy to understand and practical to use.

The HomeSafe Pilot Program consisted of a three-hour safety training and program orientation class, the "Guide to Safe Work Practices for Home Builders:

HomeSafe 10 Point List" booklet, and access to optional OSHA Training Institute-approved 10-hour Construction Courses, tailored to the particular needs of residential construction workers. In return for participation in the HomeSafe Program, companies received focused inspections on the contents of the ten points in the HomeSafe booklet from OSHA compliance officers, thus limiting citations for non-serious violations. In addition, if a HomeSafe company was cited, it was eligible to receive the maximum penalty reductions available. Participating companies also were eligible for the Colorado Cost Containment Program, which reduces workers' compensation premiums by 5%, and for an additional 5% reduction in workers' compensation premiums through a major carrier in the Denver Metropolitan area.

As with Colorado construction workers at large, the residential construction workers participating in the HomeSafe Pilot program experienced higher pre-intervention non-fatal injury rates than those typically reported by the BLS, with the exception of concrete workers and single family homebuilders[4]. Fatality rates before and after the HomeSafe intervention were much lower than those previously reported in Colorado and the Nation, with only two fatalities reported during the five years of the study. Participating companies typically were small, with ten or fewer employees, worked primarily in residential construction, and represented a variety of trade groups.

There is limited research demonstrating the utility of safety training for the reduction of injury rates in construction. Kinn et al. (2000) found that safety orientation was associated with a 77% reduction in injuries among plumbers and pipefitters[5]. They also found that of those workers injured, 38% did not receive any health and safety training or orientation[5]. McKenzie et al. (1985) reported that a safety orientation program reduced the rate of repetitive motion injuries from 2.2/200,000 hours worked to 0.53/200,000 hours worked[6].

Characteristics of the residential construction industry (a transitional workforce employed by small businesses with sporadic work patterns, short term employment opportunities, and isolated job sites) present significant challenges for health and safety interventions and associated research projects[7,8]. In an effort to overcome these challenges and provide a comprehensive and effective intervention program, the creators of the HomeSafe Pilot program integrated engineering, behavioral, and administrative interventions into its design and addressed ten fundamental countermeasures for injury control[9].

Engineering Controls

Engineering controls include such interventions as ergonomic redesign of the workplace, job activities, or tools[10,11,12]. For example, in the Guide to Safe Work Practices for Home Builders: HomeSafe – 10 Point List[13], section three addresses the use of scaffolding. Engineering controls include instructions on the proper erection of job-built wood, tubular welded, and pump jack scaffolding. Section five provides instructions on the use of ground fault circuit interrupters, electrical extension cords, and junction boxes.

Behavior Modifications

Behavior modification includes education on, training on and reinforcement of safe work practices, including the use of proper equipment and tools related to the performance of specific job duties[14,12,15]. The HomeSafe program used a variety of approaches to education and training. All member companies were required to participate in a three-hour orientation, during which they received training on the ten points and how to integrate them into their safety programs or how to use them if they did not have a safety program. They also agreed to on-site safety audits performed by the HBA safety and health committee audit team, which occurred throughout the project period.

HomeSafe also provided written information to participating companies to reinforce the training and to hand out to employees in the form of the HomeSafe booklet, "Guide to Safe Work Practices for Home Builders: HomeSafe 10 point list." The booklet specifically depicts residential construction workers and their everyday hazards in an attempt to increase its perceived relevance among workers. The HomeSafe booklet provided concise, simple guidelines for the safe use of equipment and correct types and uses of personal protective equipment. The booklet was available in English and in Spanish. In addition, it provided cartoon depictions of common hazards and solutions to augment the textual information. The booklet was designed to be small enough for a worker to place in a toolbox or pocket for easy reference.

Finally, the HBA offered OSHA Training Institute-approved ten hour construction courses, safety training classes tailored to the homebuilding industry, throughout the year, providing up to date safety information provided by experienced safety personnel and OSHA Compliance Officers.

Administrative Controls

Administrative controls include company safety and health policies, procedures, and programs[16,12,17]. HomeSafe creators believed that the safety behavior of employees would be affected by the value placed on safety by management. In fact, the benefit of any intervention program will be impacted if the supervisors and managers are not committed to its success[18]. Therefore, the HomeSafe program mandated that member companies maintained a written safety policy aimed at fostering a culture of safe and healthy working conditions. The policies must have been written clearly and in plain language, explained to all employees, and available to all employees and subcontractors. The HomeSafe booklet provides two sample safety policy statements for companies to use in addition to the safety information the booklet that can be included in a safety program.

Countermeasures

Injury control strategies typically have consisted of education, enforcement and engineering. However, Haddon (1995), suggested a more comprehensive approach to injury prevention, describing ten countermeasures available for reducing the occurrence and severity of injuries[9]. To discuss injury prevention and control, however, we first must define injury. Haddon includes injuries in his definition of energy damage processes: those processes "involved when energy is transferred in such ways and amounts, and at such rates, that inanimate and animate structures are damaged"[9].

Among residential construction workers, a vast majority of the injuries will be considered unintentional. Waller (1985) defines unintentional injuries as events in which (1) injury occurs over a brief period of time, usually seconds or minutes; 2) the harmful outcome was not sought; and 3) the injury resulted from either physical energy in the environment (including kinetic, chemical, thermal, electrical, or ionizing radiation) or from external blocking of the normal body mechanisms for using these sources of energy[19]. Both Waller and Haddon emphasize the role of physical energy in injury events in order to help distinguish injuries from sudden illness events, such as heart attacks or strokes.

The ten injury countermeasures defined by Haddon include: prevent the initial accumulation of the energy form; reduce the amount of energy accumulated; prevent the release of the energy form; change the rate or spatial distribution of energy release; separate the energy from susceptible structures, in either space or time; separate the energy from susceptible structures using a material barrier; modify the surfaces or structures with which people come in contact; strengthen the structures, living or non living that may be susceptible to the energy transfer; increase the speed with which damage is detected and evaluated, and further damage is prevented; and implement all measures which assist in the return of the living or non living structure to pre-event status or stabilization of the structure in functionally altered state.

Examples of these countermeasures are found throughout the HomeSafe Program. To prevent the accumulation of the energy form, the HomeSafe Booklet provides guidelines for the use of electrical power, including information about grounding, cord repair, and circuit overload. To address the second strategy, reducing the amount of energy accumulated, the HomeSafe booklet outlines the maximum allowable slopes for excavations less than 20'. For the prevention of the release of the energy form, the booklet gives information on modifying the roof environment with slide guards to prevent falls. Changing the rate or spatial distribution of energy release is addressed also through the reduction of slopes during trenching/excavating to reduce the chance or magnitude of cave-ins. Ladders must be positioned at least 10' from overhead electrical power lines in order to separate the energy from susceptible structures, in either space or time, strategy number five. An example of the sixth strategy is that open-sided floors and holes must be protected by the use of guardrails or covers, thus separating the energy from susceptible structures using a material barrier. HomeSafe recommends the modification of surfaces and structures with which people come in contact in the Access/Housekeeping section of the booklet. They recommend all surfaces and pathways be kept free of debris and other obstructions. HomeSafe addresses strategy number eight, strengthening the structures, living or non-living, that may be susceptible to the energy transfer through their recommendations for job-built scaffolding. Strategies nine and ten refer to the emergency response to an injury event and the treatment of the injured. The HomeSafe program emphasizes the importance of safety programs, which contain emergency response protocols and strategies, non-emergent medical care information and protocols, and documentation requirements for injuries to be used in future loss prevention planning.

By providing safety training that was accessible and, in effect, portable, involving management in the program, and addressing hazards specific to residential construction, the HBA hoped to significantly reduce the occurrence and severity of injuries among residential construction workers in the Denver-Metropolitan region. Previous studies have indicated a potential effect of HomeSafe[20,4]. However, they do not account for the potentially confounding effect of time on the decrease in injury rates. They acknowledge the necessity of confirming their results with further analysis that controls for the effect of time on decreasing injury rates. The purpose of this paper is to evaluate the effectiveness of the HomeSafe Project in reducing both overall and severe injuries among residential construction workers, during the years 1994 – 1998.

METHODS

Injury Data Collection

Members of HomeSafe submitted the following information to the local Home Builders Association (HBA): OSHA 200 logs, first reports of injury and worker's compensation loss runs for calendar years 1994 - 1998. Those companies with fewer than ten employees filled out forms similar to the OSHA 200 forms provided by HomeSafe staff. The HBA forwarded this information, assigning each company a four-digit code, to the HomeSafe research staff. Injuries were cross-referenced between all three data sources for accuracy, and incomplete or incompatible reports were excluded. Illnesses were not included in the analysis, and those reports also were excluded.

The above information was coded for number of injuries per year, mechanism of injury, body part injured, nature of injury, cost of injury, number of workdays lost, and severity. A graduate student in epidemiology coded the data using an abbreviated version the American National Standards Institute's (ANSI) coding method for describing injuries by mechanism, nature, and bodypart of injury. The version was consistent with the one utilized by the two primary workers' compensation carriers used by the HomeSafe participants. Codes were cross-referenced with the codes supplied on the workers compensation loss runs for accuracy. Routine comparisons of the injury information showed high agreement between the workers compensation codes and the codes assigned by the student. The cost of injury and the number of days lost were entered as continuous variables. Severity was coded as a dichotomous variable and defined as an injury that results in at least one lost workday. The day of injury was not included as a lost workday.

Population Denominator

Each company was required to submit the total person hours worked for each year of the study. These were used as the denominator for the rate calculations. Any company who did not submit total hours was not included in the rate analysis. Rates for each year and then all years were calculated using the following formula:

$$\frac{\#\ injuries}{man\ \ hours\ \ worked} \times 200{,}000\, hours$$

All injury events were included in the calculations and the time accumulated in the denominator included the total hours worked per year for each employee and did not cease with the first injury occurrence. Most employees will return to work following an injury and will be at risk of injury again, hence their continuous inclusion in the denominator. Pre-HomeSafe was defined as January 1, 1994 through the company's compliance training date. Post-HomeSafe was defined as the company's compliance training date through December 31, 1998.

Statistical Analysis

The study involves the comparison of pre-intervention injury incidence rates (1994 – 1997) and post-intervention injury incidence rates (1997 – 1998). Overall injury incidence rates were compared, as were lost workday injury incidence rates. Injury incidence rates for all injuries and for lost workday injuries were calculated for each calendar year for each participating company and for the pre and post intervention years. Injury incidence rates also were calculated for each trade group, based on the Standard Industrial Classification codes. Further descriptions of injuries by the mechanism, nature and body part injured among the trades and the group as a whole can be found elsewhere[4,20].

Prior analysis indicated a significant difference in overall injury incidence rates pre-HomeSafe (17.4/200,000 hours) and post-HomeSafe (14.7/200,000 hours worked). A significant decrease in lost work day injury incidence rates also was reported (5.8 pre-HomeSafe to 3.4 post-HomeSafe), as was a decrease in lost work day injuries associated with medical cost (3.8/200,000 to 2.2/200,000).

Among trade groups, residential homebuilders and masonry and other stonework companies experienced what appeared to be sharp decline in injury rates for the two years post-HomeSafe, companies specializing in floor work and floor laying experienced steady increases in injury rates until HomeSafe intervention and then experienced a decrease, and a number of other trades had significantly lower overall and lost work day injury rates post-HomeSafe. That these differences were due to HomeSafe is difficult to assert because we did not control for the effect annual decreases in injury incidence rates occurring across occupations nationally.

To control for this potential confounder and to compare the pre- and post-intervention rates, the quasi-likelihood, over-dispersed Poisson regression analysis was used. Poisson regression models allow the regression parameters to be interpreted as the log of the relative risk, adjusted for other covariates in the model[21]. In this study, annual trends in injury incidence rates were adjusted for by the model to evaluate the relative risk of injury during the pre-intervention period as compared to the post-intervention period. In other words, if injury incidence rates were decreasing before the intervention, the regression model would only indicate a protective effect of the intervention if a post-intervention decrease in incidence rates was greater than the pre-intervention trend.

The outcome variable was the injury rate for each year of the study and was coded as a continuous variable to account for annual trend. HomeSafe intervention was coded as an indicator variable, 0 for pre-HomeSafe and 1 for post-HomeSafe. A general model was created, as well as a model for each trade group, for both lost workday and overall injuries. When the analysis was limited by trade group and/or lost workday injury, the data became more spare and convergence harder to achieve. Scale parameters were adjusted on all models to control for over-dispersion, based on the null model's Pearson chi-square ($p < 0.0001$ for all models, indicating extra-variation). Descriptive statistics and the poisson regression analyses were done using SAS [SAS Version 8.0][22].

RESULTS

Data from ninety-seven companies was included in the analysis. Company trade was identified by Standard Industrial Classification (SIC) code and those trades are outlined below in Table I. Companies ranged in size from sole proprietorships to over 100 employees, though most companies had under 50 employees. Among those employees injured, 98% were men and 2% were women. They ranged in age from 17 to 70, with most in their late twenties to late thirties, and ranged from 0 years to 37 years of experience, with most employees possessing one to six years of experience. Companies reported a total of 23, 620, 963 hours worked during 1994 – 1998.

Table I: Residential Construction Trade Group and SIC

Trade	SIC
Landscaping	0781
Single Family Home Builders	1521
Plumbing, Heating, Air Conditioning	1711
Painting and Paper Hanging	1721
Electrical Work	1731
Masonry and Other Stonework	1741
Plastering, Drywall, and Insulation	1742
Carpentry	1751
Floor Laying and Floor Work	1752
Roofing, Siding, and Sheetmetal Work	1761
Concrete Work	1771
Excavation Work	1794
Miscellaneous Special Trade Contractors	1799

Overall Injuries

The overall rates by year are outlined graphically in Figure 1. It is difficult to see a downward trend in injury incidence rates merely by observing the data.

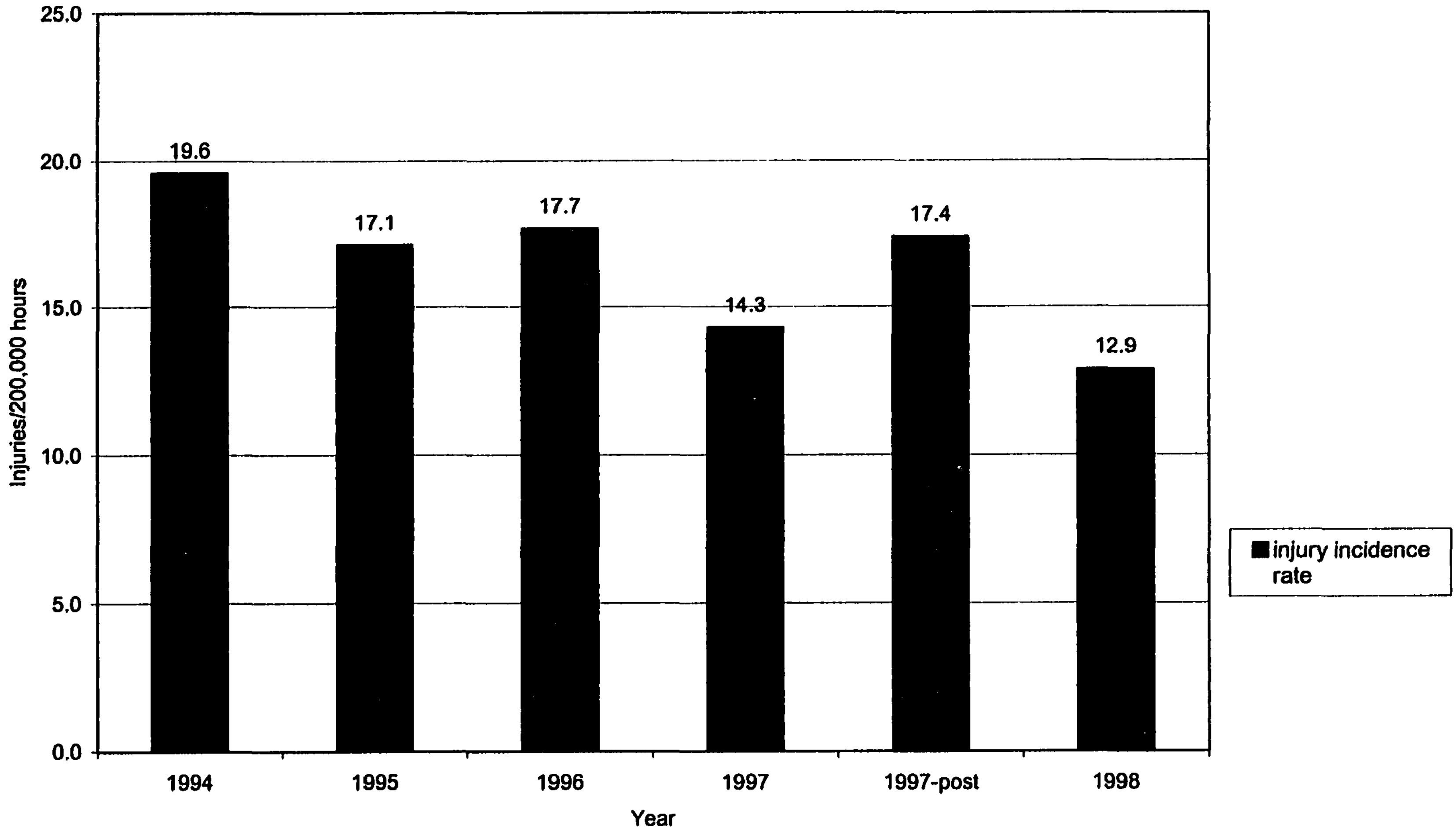


Figure 1
Injury Incidence Rates among HomeSafe Partners, 1994 - 1998

The Poisson regression results in Table II, however, show no decrease in overall injury incidence rates following the HomeSafe intervention (RR = 0.97, 95% CI = 0.5, 2.0). Interestingly, the results also indicate no significant time trend was associated with the decrease in injury rates. This supports graphical evidence that does not show consistent decreases in incidence rates over the years 1994 – 1998[4]. Among the trades, the relative risk of injury prior to HomeSafe intervention is greater among single family home builders, companies specializing in painting and paper hanging, floor laying and floor work, and excavation work, and miscellaneous special trade contractors. With the exception of floor work companies, confidence intervals all contain one. For all trades, confidence intervals are consistently skewed towards an effect. In addition, companies specializing in floor laying and floor work had a relative risk of injury pre-HomeSafe of 5.66 (95% CI = 1.0, 32.1), a significant p-value (p = 0.0503), and this is the only trade group with a significant effect of annual trend. This group of companies had increasing rates prior to HomeSafe and decreasing rates following HomeSafe.

Table II: Results of Poisson Regression Models for Adjusted Rates of Overall Injuries: Effect of Intervention Period Adjusting for Year.

Trade	β	SE(β)	P	RR	95% Confidence Interval
Overall					
Year	-0.1015	0.1141	0.3736		
Intervention	-0.0356	0.3615	0.9215	0.97	0.5, 2.0
0781	*	*	*	*	*
1521					
Year	0.0501	0.3473	0.8854		
Intervention	0.6507	1.0892	0.5502	1.92	0.2, 16.2
1711					
Year	-0.0502	0.4317	0.9075		
Intervention	-0.2782	1.2737	0.8271	0.76	0.1, 9.2
1721					
Year	-0.0383	0.4035	0.9244		
Intervention	0.0680	1.2630	0.9570	1.07	0.1, 12.7
1731					
Year	0.1076	0.2461	0.6620		
Intervention	-0.2062	0.8174	0.8008	0.81	0.2, 4.0
1741	*	*	*	*	*
1742					
Year	-0.0937	0.3771	0.8038		
Intervention	-0.1145	1.2001	0.9240	0.89	0.1, 9.4
1751					
Year	-0.1743	0.2835	0.5388		
Intervention	-0.2559	0.8833	0.7720	0.77	0.1, 4.4
1752					
Year	0.7556	0.3053	0.0133		
Intervention	1.7329	0.8853	0.0503	5.66	1.0, 32.1
1761					
Year	-0.4054	0.2806	0.1486		
Intervention	-1.2811	1.0994	0.2439	0.28	0.03, 2.4
1771					
Year	-0.0182	0.2220	0.9345		
Intervention	-0.2011	0.6677	0.7633	0.82	0.2, 3.0
1794					
Year	0.0000	0.0154	0.9983		
Intervention	1.6900	1.7190	0.3256	5.42	0.2, 157.5
1799					
Year	0.2110	0.2084	0.3113		
Intervention	1.2174	0.9300	0.1905	3.38	0.6, 20.9

Lost Work Day Injuries

The Poisson model for lost workday injury essentially mimics the overall model (Table III). No statistically significant results emerged from the data, either overall or by trade group (overall model: RR = 1.0, 95% CI = 0.5, 2.3). This is consistent with the graphical representation of lost workday injury rates: a downward trend is visible from 1994 –1998, with no obvious change following HomeSafe intervention (Figure 2). However, annual trend was not a significant contribution to the overall model, or among any trades except among roofing, siding and sheetmetal companies. These companies had a relative risk of injury of 1.73 pre-HomeSafe as compared to Post-HomeSafe and demonstrated a significant decrease in rates following HomeSafe[4]. Three other trade groups experienced a significant decrease in lost workday injury incidence rates following HomeSafe: single family homebuilders, masonry and other stonework companies, and plastering, drywall and insulation companies[4]. Carpentry companies, plumbing, heating, and air conditioning companies, floor laying and floor work companies, and excavation companies all experienced lower, though not statistically significant, rates following HomeSafe[4]. For all these trades, the confidence intervals surrounding the relative risk of injury pre-HomeSafe included one, though are consistently skewed toward a protective effect of the intervention.

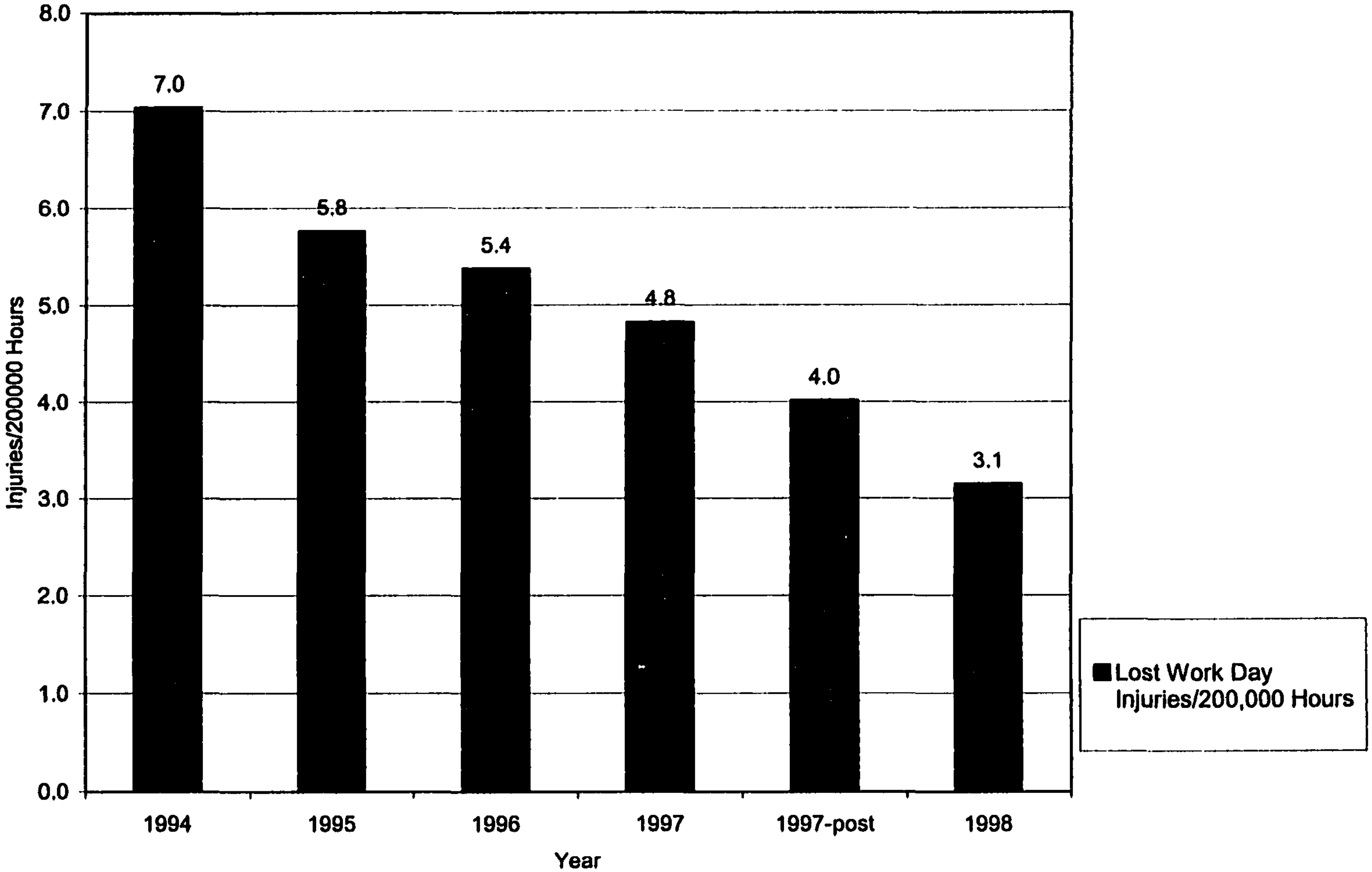


Figure 2
Lost Work Day Injury Incidence Rates among HomeSafe Partners, 1994 - 1998

Table III: Results of Poisson Regression Models for Adjusted Rates of Lost Work Day Injuries: Effect of Intervention Period Adjusted for Year.

Trade	β	SE(β)	p	RR	95% Confidence Interval
Overall					
Year	-0.1337	0.1261	0.2890		
Intervention	0.0213	0.4078	0.9583	1.02	0.5, 2.3
0781	*	*		*	*
1521					
Year	0.2128	0.6109	0.7277		
Intervention	0.9221	1.8386	0.6160	2.52	0.1, 92.4
1711					
Year	0.0458	0.7894	0.9538		
Intervention	0.5810	2.3192	0.8022	1.79	0.02, 168.4
1721					
Year	0.1637	0.4218	0.6979		
Intervention	0.6035	1.2973	0.6418	1.83	0.1, 23.3
1731					
Year	0.1188	0.3954	0.7638		
Intervention	0.4102	1.5215	0.7874	1.51	0.1, 29.7
1741	*	*	*	*	*
1742					
Year	-0.2335	0.2323	0.3149		
Intervention	-0.0798	0.7979	0.9203	0.92	0.2, 4.4
1751					
Year	-0.1671	0.2762	0.5452		
Intervention	-0.3960	0.8397	0.6372	0.67	0.1, 3.5
1752	*	*	*	*	*
1761					
Year	-0.7325	0.3699	0.0477		
Intervention	0.5477	1.0079	0.5869	1.73	0.2, 12.5
1771					
Year	0.1207	0.2643	0.6479		
Intervention	-0.1345	0.7315	0.8541	0.87	0.2, 3.7
1794	*	*	*	*	*
1799					
Year	-0.0008	0.1761	0.9962		
Intervention	1.0202	0.8242	0.2158	2.77	0.6, 14.0

*no convergence or insufficient data to model

DISCUSSION

Poisson regression analysis often has been used to evaluate injury rates. The use of the Poisson model to evaluate program effectiveness through the analysis of incidence rates was successfully employed by Kuhn et al. (1994) in their evaluation of a community based injury prevention program aimed at reducing injuries among urban children[21,23]. They assert the value of this method is its ability to quantify time trends and therefore describe and evaluate the effect of temporal variation. This method can explain outcomes due to the effect time versus the effect of the intervention. They also recommend this form of analysis over time series analysis because it is well suited to the analysis of rare events and the effect estimates are more precise.

The results of the analysis in this study yielded inconclusive information about the effect of the HomeSafe Pilot Project on injury incidence rates. An effect of HomeSafe on all trades combined was not apparent in this model, though previous analyses of rates have demonstrated a difference between pre- and post-HomeSafe incidence rates[20]. The primary purpose of the poisson regression was to control for the effect of antecedent time trend on decreasing injury incidence rates. In fact, time appeared to have a limited effect on the rates, and only contributed significantly to the models for floor laying and floor work companies and roofing, siding, and sheetmetal companies. This is consistent with the graphical representation of incidence rates over time reported in earlier studies[4,20]. Of interest was the lack of a significant effect of secular trend in the overall lost workday injury model, as the graphical analysis showed a consistent decline in rates from 1994 – 1998.

The effect of HomeSafe was more apparent in the trade specific analyses. Floor laying and floor work companies demonstrated a significant effect of the intervention, with the probability of sustaining an injury over five times as high prior to the HomeSafe intervention. Employees of companies specializing in building single family homes, excavation, and miscellaneous special trade contractors also appeared to have a greater probability of sustaining an injury prior to the intervention. Prior analysis also demonstrated a significant decrease in injury incidence rates among single family homebuilders and miscellaneous special trade contractors[4]. As previously reported, companies specializing in floor work did not experience a significant decrease in injury incidence rate but a trend of increasing injury rates reversed following HomeSafe and rates began to decrease[4].

Severe injuries among trades also were reduced following HomeSafe. Employees of companies specializing in roofing, siding and sheetmetal work appeared to have a greater probability of injury before the intervention (RR = 1.73, 95% CI = 0.2, 12.5), as did single family home builders, plumbing, heating, and air conditioning companies, painting and paper hanging companies, electrical companies, and miscellaneous special trade contractors. These effects were not statistically significant but, although they contained one, the confidence intervals around the relative risks were skewed enough to suggest an effect of the intervention may have been present, especially in the absence of an effect of time. Additionally, roofing, siding, and sheetmetal companies and single family homebuilders also experienced a significant decrease in injury incidence rates in previous analyses[4].

One possible explanation for the lack of a statistically significant effect in this model is the lack of power in the study. The lack of an effect, the width of the confidence intervals, and the magnitude of the standard error suggest that insufficient sample size and breadth among the trade groups may have prevented the detection of an effect. Post hoc power estimates, based on the number of injured and the total number of employees pre- and post-HomeSafe, using Epi Info 2000 revealed adequate power (≥ 80.0%) only for analysis of all trades and for one individual trade group, single family homebuilders[24]. Power was adequate (≥ 80.0%) for lost workday injury calculations for all trades but not for any single trade group. Among the trade groups, the likelihood of finding a 'true' effect was less than 60%, and in some cases, power was as low as 5%. That the confidence intervals seemed to indicate an intervention effect in the absence of sufficient data strengthens the argument for the positive contributions of HomeSafe to injury reduction.

The study had other limitations in the research methodology that are germane. The study itself was limited to a twelve to twenty-four month follow up period. This limited period may not have provided adequate time for intervention effects to be seen.

In addition, the number of companies who submitted data for the period post-HomeSafe was significantly reduced. The trade specific analyses, therefore, may reflect an inadequate representation of tradesmen. In over 50% of trade groups, the number of participating companies in a trade group was less than five. Our study evaluated the injury rates by company, not by individual. In essence, then, we evaluated each company, which do not represent injuries among workers at large.

A number of threats to internal validity were evident. The HomeSafe participants were not randomly selected, they were recruited by the Home Builder's Association. As described previously, a number of incentives were used to recruit these companies, which introduces the potential for self-selection bias. If companies joined the program for the benefits and did not implement the program, we would expect to see a bias toward the null hypothesis, or bias toward no effect.

In addition, study must contend with information bias. Non-differential misclassification of exposure almost certainly occurred. Exposure to HomeSafe intervention was determined by company participation and was dated according to company compliance training, not employee participation. Some employees may have been exposed to HomeSafe prior to the intervention start date through companies who participated in the development of HomeSafe. Even the exclusion of those companies could not rule out this exposure secondary to the lack of individual data and the frequency with which employees changed employers. Following the intervention, all injured employees were considered 'exposed' because of the employer. However, some companies may not have implemented the program, or the employee may have never been exposed to the program. Again, this would bias our results toward the null. Without adequate individual measurement of the exposure, the effects of the program are difficult to assess.

The primary confounding variable we assessed was time. When this variable was controlled, no new effects emerged. However, without more detailed company and individual information, we may have encountered an as yet undetermined confounder.

The lack of a comparison group also makes inferences about the success of the program difficult. Efforts to recruit a control group were unsuccessful and comparisons with BLS data are inadequate[4]. While we know our participants experienced a decrease in rates following HomeSafe, we do not have information about the experiences of other residential construction companies in Colorado. For example, HomeSafe partners could have been experiencing a greater decrease in injury rates than other companies in the region.

There are other explanations for the inconclusive effects of this intervention, including both behavioral explanations and program limitations. First, the design and approach of the HomeSafe Pilot Program had a number of significant limitations. Though the design of HomeSafe accounted for injury control countermeasures and administrative, behavioral, and education-based interventions, there was no evaluation of the level of readiness for change among this population. Research in the psychological and communication sciences has demonstrated the importance of directing prevention activities at the level of awareness and motivation to change of the individual, group, or community[25,26]. Individuals who designed and implemented HomeSafe (business owners, managers, and superintendents) may have had a different view of or motivation for introducing interventions designed to bring about a change in safety behavior than the tradesmen, apprentices and laborers.

Models of behavior change, including continuum models (such as the health belief model, the theory of planned behavior, and social cognitive theory) and stage based models (such as the precaution adoption process model, the community readiness model, and the transtheoretical model), all address the various stages or processes of change and their effect on the ability of an individual or a group to change[25,27,26, 28,29, 30]. Though most often used to address health behaviors (smoking, preventive care, obesity), their constructs are salient here. These models also address the limitations of global behavior change campaigns aimed at either the prevention or change of a specific behavior. A global program or campaign is not matched to individuals belonging to different categories or stages of behavior change and may not be able to elicit the desired changes in the target audience[31]. For example, the transtheoretical model of behavior change describes the stages through which people move as they change personal behaviors[25,32]. In the first stage, precontemplation, the individual does not recognize there is a problem and is not ready to change a behavior. In fact, individuals in this stage may avoid reading, talking, or thinking about their high risk behaviors[32]. The precaution adoption process model describes the initial stages of behavior change as points at which individuals are not aware of a health issue or are aware of but not engaged by it (stages one and two)[30]. According to Velicer et al. (1998), most intervention programs are not designed for individuals in these stages and are more appropriate for individuals who have a plan to change a behavior and are ready to take action[32]. Thus, providing information to an individual with a plan for action about ways to modify a task may be met with more interest and enthusiasm than to an individual who has not yet recognized the potential dangers of a behavior. The HomeSafe Pilot Program provided the information about and methods for avoiding specific hazards on construction sites, however, if participants were not willing to make a change or even recognize the hazards, this information could not help them. Among those individuals who do respond to the campaign and change their high-risk behavior, the challenge of maintaining that behavior begins. The maintenance stage in the transtheoretical model and stage seven in the precaution adoption model emphasize prevention of a return to the risky or problematic behavior and the maintenance of new behaviors over time[25,30].

Behavior maintenance is critical for the success of an intervention program. Follow up trainings such as tailgate talks, annual orientations for all employees, and topic specific courses are all ways in which safety behaviors can be maintained. HomeSafe attempted to provide on-going trainings through the ten-hour courses. However, those who attended the courses often were superintendents, safety managers, or supervisors who may or may not have been able to pass the information on to their employees. In addition, employees who received information second-hand or in an abbreviated form may have passed judgement about the relevance or benefits of a new safety behavior without complete information.

Behavior maintenance also is affected by the individual's satisfaction with the outcome[33]. Social cognitive theorists assert that motivation to take action and change a behavior is difficult to sustain over time if the work environment and supervisory staff confound the change with, for example, increased demands for productivity[28]. For example, extra time may be required to erect safe and stable scaffolding. If this is perceived as interfering with the completion of the job, the worker's satisfaction with the outcome (increased safety but decreased productivity) and the demands of management (increased productivity) will discourage the continued use of this method of scaffold construction.

A crucial element in behavior change is the cost-benefit analysis most individuals undertake as they are faced with the prospect of a behavior change. The theory of planned behavior can be used to identify an individual's beliefs about and evaluation of the costs and benefits of behavior and to establish the weights of those costs and benefits in the decision making process[27,34]. This theory emphasizes the importance of the relation between the strength of the belief that a behavior will produce a certain outcome and the evaluative judgements (costs and benefits) of the behavior. For example, HomeSafe may emphasize behavioral practices to reduce lacerations. Workers must decide whether they think that changing their behaviors will produce that outcome and how that outcome interacts with the benefits (fewer cuts, fewer visits to the doctor) and costs (increased time, learning something new) of the behavior. Similarly, the transtheoretical model uses the 'decisional balance construct'[35]. Two measures, 'pros' and 'cons', are used by the individual to assess the importance of the benefits of the change versus the costs. For example, an individual in the precontemplation stage examining the safety benefits of protective eyewear may see the hassle and discomfort of wearing ill-fitting safety glasses in the heat of summer as far outweighing the possible risk of an eye injury. As an individual moves through the stages of change, he or she may be able to weight the pros of behavior change more heavily than the cons, therefore tipping the scales in favor of the change. This decision making process is related to the body of literature that exists on risk perception, of particular relevance here.

The challenge of risk perception is that, while intervention programs often are designed based on objective assessments of risk, the individual's assessment of risk is almost entirely subjective, is influenced by individual factors, and varies between individuals and groups[36]. The precaution adoption process model discusses individuals' perception of personal vulnerability as crucial in determining their transition from considering a response to taking action[31]. Holmes and Gifford (1997) assert that risk perception may be different among employees and employers, that risk appraisal is affected by personal characteristics, and that judgements about risk are affected by the method by which information is presented[37]. The HomeSafe program trained managers, supervisors, and safety personnel, who perceived their employees were at risk.

If the employees to whom the information was disseminated did not perceive that the same level of risk existed with a particular hazard, their ability to change would be affected. In addition, individual and group dynamics interact with safety behavior[37]. This may provide another explanation for why interventions primarily directed at individual behavior change and technical intervention might be unsuccessful. Sociocultural factors within an organization or professional culture shape the way that risk is evaluated in the workplace, and these social contexts vary by position within the workplace (employer versus employee)[37].

Risk taking behaviors result from an interaction between perceived risk, perceived benefit, and risk acceptance, and this interaction is influenced by such characteristics as familiarity, control, catastrophic potential, and level of knowledge, in addition to the individual's belief about the efficacy of an action to prevent an injury event[28,38]. For example, does guarding power tools really prevent cutting or piercing injuries. This interaction is central to injury prevention. Not only may workers underestimate their risk of injury based on task familiarity and personal control, they may assign their own definitions of injury severity to different types of injury, based on personal criteria and needs. For example, prior results revealed that cuts, punctures and scrapes, though heavily targeted by the HomeSafe program, remained a major cause of overall injury[4,20]. These injuries, however, rarely resulted in lost work time. Therefore, the risk of incurring such an injury may not be perceived as outweighing the convenience of blocking open the guard on a Skil™ saw to facilitate cutting wood, especially as this practice is familiar and perhaps under the individual's control. Severe injuries caused by falls, however, were significantly lower following HomeSafe intervention, which were based on the 1995 revision of 29CFR part 1926 subpart M, and the OSHA directive STD 3.1 published in December 1995 (OSHA's fall protection standard)[39]. Falls typically result in lost work time and more severe injuries. In an industry where work patterns are sporadic, lost work time may mean lost wages, and disability may mean loss of livelihood, these injuries are viewed differently. The catastrophic potential associated with a severe injury caused by a fall may increase the perceived personal risk of fall and outweigh the perceived comfort and time benefits of avoiding fall protection or failing to put up slide guards.

Finally, employers must assess the injury risk of employees from a cost-benefit perspective. An employer's assessment of employee risk may vary as a function of the relation between company size and perceived risk. For example, the pre-HomeSafe injury incidence rate of 17.4 injuries per 200,000 hours worked may sound significant to a larger company, for whom 200,000 person hours worked is reasonable. However, a company with ten employees could convert that to a rate of 1.7 injuries per 20,000 hours worked, a rate the employer may perceive as very low. Although the two rates are the same, the employer may perceive his risk as lower merely because the number is smaller. Among HomeSafe companies, 40.0% of which had ten or fewer employees, this rate includes minor medical injuries requiring no more than first aid on the site. An employer with a history of few or no serious injuries may be willing to risk the injury, based on a cost benefit analysis of safety training versus injury cost. The risk of a lost work time injury would seem even more remote. For the above example, the company would have a lost workday injury rate of 0.6 / 20,000 hours worked. To train ten employees for fifteen minutes a week at a tailgate training would result in 125 hours of time away from the job site over a year's time at an approximate cost of $1,831.00 (average prevailing wage estimate for all trades represented in HomeSafe)[40]. In a highly competitive market, small companies must bid the least amount of time at the lowest price to compete, and may not be able to absorb this kind of 'lost' time. Paradoxically, it is often the smaller companies that experience the higher rates of injury[5,41].

In addition, though the HomeSafe Pilot Program was designed to address the industry characteristics that interfere with health and safety education and training, problems with information dissemination remained. The HomeSafe program had no mechanism to ensure dissemination among the workers. Information was provided to company representatives with the understanding that they would then train their employees. There were companies who did just that. Anecdotal and case studies demonstrated the program's effectiveness as reflected by a decrease in workers compensation claims following HomeSafe intervention. However, these companies were exceptionally invested in HomeSafe, participated in safety committee members, and trained their employees using HomeSafe methods. There were companies who sent safety personnel, superintendents, managers, and owners to the three-hour training, received booklets, stickers, and posters, and when contacted one to two years later, had no memory of HomeSafe or enrolling in HomeSafe. Employees need access to committed supervisors, managers, and safety personnel for ongoing safety training, problem solving, and hazard assessment in order to continue their behavior change and personal investment in safety[18].

Additionally, workers in residential construction often switch employers based on work load and experience sporadic work patterns, thus limiting their exposure to health and safety information. Ringen et al. (1995) reported that many hazardous exposures in the construction industry are due to poor access to information[7]. Kinn et al. (2000) reported that 58% of injured workers in their study did not have appropriate safety education and training[5]. Companies often subcontract trade specialties and may not train those subcontractors using the HomeSafe model, or may not provide health and safety training secondary to economic impracticality and the time constraints of short term assignments[5]. The likelihood that each employee received the information is small. In addition, small companies may not have the resources to hire, or recognize the benefits of hiring, a safety professional to design, disseminate, and monitor a safety program. Among HomeSafe participants, safety professionals or other employees who were assigned these tasks had a high rate of turn over. When contact people established by the company on enrollment in HomeSafe were contacted one to two years later, many of them had left for other employment opportunities and the new contact people had limited knowledge of HomeSafe and were implementing the program on a limited basis, if at all. In those cases where the contact had no knowledge of the program, and they were not implementing the program, they usually requested to be removed from the project and were excluded from the analysis.

There were significant limitations in record keeping that also impacted the program's effectiveness and evaluation. There was no mechanism in place to record which HomeSafe participants attended the optional ten hour safety courses that were available, therefore, there was no way to potentially target companies who were not attending with reminder notices or phone calls.

Inadequate record keeping also was a problem in the program evaluation. Because there were no records, we could not more closely examine companies who may have been more invested in the program as defined by attendance at these classes. A method of evaluating the degree of a company's investment or participation in the program would provide more information about the effects of company interaction with the program on injury rates.

Conclusions and Recommendations for Further Research

Evidence, both graphical and statistical, appears to indicate the HomeSafe Program had at least some effect on injury rates. Optimism regarding its effectiveness is warranted, based on the presence of declining injury incidence rates, especially injury rates for severe injuries. As previously reported, severe injury rates for the three leading causes of injury were significantly lower following HomeSafe, and both overall and severe injury rates were lower for HomeSafe participants following the HomeSafe intervention[20]. Methodologic problems with the HomeSafe Program indicate the need for more carefully crafted interventions with evaluation plans integrated into the program from the start. As this study has demonstrated, post-hoc applications of epidemiologic methods cannot compensate for limitations in intervention programs. Emphasis on the dissemination of information to the workers, methods for monitoring the extent of the dissemination, and therefore the exposure, and methods for obtaining a control group would have improved the validity of the findings of this study, as would access to information at an individual, not company, level. These recommendations should be coupled with interventions that are based on sound data regarding the experiences of workers in this industry and the community or social culture surrounding on-the-job injuries. The specific characteristics of the residential construction industry indicate the need for more research into the hazards, perceptions, and behaviors of workers in this industry. Finally, additional follow up and increased recruitment of companies into the program would increase the probability of detecting an effect of HomeSafe.

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