THREE TOPICS IN EYE INJURY RESEARCH

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ABSTRACT

Eye injuries are a leading cause of monocular blindness, with approximately 2 million Americans sustaining an eye injury annually. Occupational eye injuries resulting in at least one missed day of work total nearly 28,000 each year. Eye injuries have many different etiologies, although most are “minor” injuries such as corneal abrasions and foreign bodies. Chemical-related eye injuries have not been described epidemiologically. The most widely advocated prevention method for eye injuries is protective eyewear, but evidence to support this is surprisingly absent. Furthermore, the use of eye protection among workers who have previously sustained an eye injury remains a question of interest to understand changes in prevention habits. Data from the emergency department of a free-standing eye hospital was used to address three research questions.

A descriptive study identified 640 consecutive cases of chemical eye injuries. Patterns of chemical eye injuries were observed to differ by gender, age, and by months of the year. Based on visual acuity data, chemicals did not generally threaten sight. Opportunities to prevent chemical eye injuries may exist by improving product labeling and design.

Patients of 201 occupational eye injuries were contacted to participate in a case-crossover study to evaluate transient risk factors. Eye protection was observed to reduce the incidence of eye injury (IRR 0.5, 95% CI 0.4 to 0.7), while risk factors included the use of tools (IRR 3.9, 95% CI 3.0 to 4.9), tool malfunction (IRR 2.6, 95% CI 1.5 to 4.5),
performing an unfamiliar task (IRR 1.8, 95% CI 1.6 to 2.1), being rushed (IRR 3.8, 95% CI 2.4 to 5.9), being distracted (IRR 12.7, 95% CI 6.9 to 23.2) working overtime (IRR 2.9, 95% CI 1.9 to 4.4), and feeling fatigued (IRR 3.1, 95% CI 1.8 to 5.4).

A follow-up study of 77 workers that sustained occupational eye injuries permitted the evaluation of eye protection habits before and after their eye injury. Overall, the use of eye protect increased following an eye injury, but appear to be limited to those who previously were not in the habit. Clinician’s could make use of opportunities to increase appropriate use of eye protection when treating eye injuries.

**Keywords:** eye injury, occupational, chemical, eye protection
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>v</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vi</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>THE EPIDEMIOLOGY OF CHEMICAL EYE INJURIES</td>
<td>15</td>
</tr>
<tr>
<td>A CASE-CROSSOVER STUDY OF RISK FACTORS FOR OCCUPATIONAL EYE INJURIES</td>
<td>42</td>
</tr>
<tr>
<td>CHANGES IN EYE PROTECTION HABITS FOLLOWING AN OCCUPATIONAL EYE INJURY</td>
<td>64</td>
</tr>
<tr>
<td>SUMMARY CONCLUSIONS</td>
<td>86</td>
</tr>
<tr>
<td>GENERAL LIST OF REFERENCES</td>
<td>89</td>
</tr>
<tr>
<td>APPENDIX</td>
<td></td>
</tr>
<tr>
<td>A  IRB APPROVAL</td>
<td>96</td>
</tr>
<tr>
<td>B  CASE-CROSSOVER STUDY QUESTIONNAIRE</td>
<td>102</td>
</tr>
<tr>
<td>C  FOLLOW-UP QUESTIONNAIRE</td>
<td>123</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Incidence rate of work-related eye injuries requiring at least two days from work among occupations with the highest rate of injury</td>
</tr>
<tr>
<td>THE EPIDEMIOLOGY OF CHEMICAL EYE INJURIES</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Specific injury and external cause codes that were used to identify patients with chemical eye injuries</td>
</tr>
<tr>
<td>2</td>
<td>Patient characteristics</td>
</tr>
<tr>
<td>3</td>
<td>Agents involved in chemical eye injuries</td>
</tr>
<tr>
<td>4</td>
<td>Subgroups of the most common chemical categories</td>
</tr>
<tr>
<td>5</td>
<td>Characteristics of patients and eyes injured due to mistaken product</td>
</tr>
<tr>
<td>A CASE-CROSSOVER STUDY OF RISK FACTORS FOR OCCUPATIONAL EYE INJURIES</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Demographic characteristics of 201 respondents with work-related eye injuries</td>
</tr>
<tr>
<td>2</td>
<td>All primary and secondary ICD 9 CM diagnoses among respondents</td>
</tr>
<tr>
<td>3</td>
<td>Associations of transient exposures to work-related eye injuries using incidence rate ratios</td>
</tr>
<tr>
<td>CHANGES IN EYE PROTECTION HABITS FOLLOWING AN OCCUPATIONAL EYE INJURY</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Demographic characteristics of respondents compared to non-respondents</td>
</tr>
<tr>
<td>2</td>
<td>All primary and secondary ICD 9 CM diagnoses among respondents</td>
</tr>
</tbody>
</table>
3 Comparison of the median work-time wearing eye protection before and after injury, stratified by protective eyewear use during injury .................................. 83

4 Likelihood and frequency of wearing eye protection since eye injury in general and when performing the same task as when the injury occurred .......... 84

5 Reasons given for not changing eye protection habits among those not more likely to wear eye protection following their eye injury ..................................................... 85
LIST OF FIGURES

Table Page

INTRODUCTION

1 Nonfatal Work-Related Eye Injuries Involving Days Away from Work, Private Sector All Industries 2003-2008 ................................................................. 8

THE EPIDEMIOLOGY OF CHEMICAL EYE INJURIES

1 The age distribution of patients with chemical eye injuries ........................................... 39
2 The month distribution of when chemical eye injuries occurred ............................... 40
3 The distribution of best potential visual acuity at entrance among chemically-injured eyes. ................................................................. 41

A CASE-CROSSOVER STUDY OF RISK FACTORS FOR OCCUPATIONAL EYE INJURIES

1 Exposure prevalence during the control and injury periods ................................. 63
INTRODUCTION

Incidence of Eye Injuries in the United States: Current, Historical, and Trends

Approximately 2 million Americans experienced an eye injury in the year 2001, at an estimated rate of 698 per 100,000 population (1). The World Health Organization (WHO) estimated the rate of eye injuries requiring medical attention was 1,000 per 100,000 population among industrialized nations in 1998 (2). In the last 30 years several estimates of the rate of eye injuries in the United States have been produced among varying selected subpopulations. While some publications are no longer considered current in their estimation of the actual rate of eye injuries, review of this literature can assist in the understanding of the progression of knowledge on the topic. The choice of study populations and injury definitions in previous incidence estimates produced a wide range collectively, making interpretation of an overall injury rate in the U.S. difficult. Inclusion or exclusion of other facial injuries (e.g., orbital floor fracture, wounds of the ocular adnexa) can hinder the comparability of studies. Whether the data were collected from medical records or via self-report also contributes to the variability among estimates. Thus, the real challenge in attempting to infer the burden of eye injuries in the U.S. over recent decades has been the lack of comparable literature. Estimates among subpopulations have limitations, but provide insight into eye care-seeking behavior as well as an indication of the burden of eye injury severity.
Eye Injuries Among Hospital Inpatients

Eye injuries requiring hospitalization are the most severe, but represent a small fraction of the total incidence. Primarily, these injuries tend to be open wounds of the eyeball (ICD-9-CM 870-871), contusion of the eyeball (921.3), and orbital blowout fracture (802.6-7) (3, 4). A study of acute hospital-treated eye injuries from five county hospitals in Wisconsin during 1979 estimated an overall incidence rate of 423 per 100,000 population, observing 11% of their cases among inpatients—some of which had other injuries contributing to their hospitalization (5). Compared to the overall incidence of eye injuries, those severe enough to be the primary cause of hospitalization are relatively rare; however, this fraction is not completely negligible. A Maryland-based study estimated the annual incidence of eye injuries requiring hospitalization (i.e., the hospitalization was directly related to the eye injury) to be 27.3 per 100,000 population for the period from 1979-1986 (4). Again considerable portion had other injuries which may have contributed to the decision to hospitalize. In the same study, when restricting to hospitalizations with eye injury as the principal diagnosis, the estimated incidence was limited to 13.2 per 100,000 population (4). A study using National Hospital Discharge Survey (NHDS) data echoed the Maryland results, estimating 29.1 eye injuries per 100,000 population for all diagnoses and 13.2 per 100,000 for primary diagnoses from 1984-1987 (3). More recent data suggests a declining rate of eye injuries resulting in hospitalization. Using NHDS data for the year 2001, the incidence of hospitalization was an estimated 18.0 per 100,000 population (converted to common units of 100,000 per population to compare with other studies) (1); reduced from 29.1 per 100,000 in the 1984-1987 study using the same data source. This reduction is consistent with the overall reduction of eye injuries during this
time period. The WHO, using an amalgamation of studies, estimates the incidence of hospitalization in industrialized countries at 13.0 per 100,000 population (2). Hospitalizations are the rarest category of treatment for eye injury and likely indicate a severe injury, however not necessarily all severe eye injuries require hospitalization. The reasons for hospitalization are varied and may be influenced by many factors, not limited to comorbid conditions or other concomitant injuries. Despite being of low incidence, the burden of these injuries is important given their physical and economic costs.

**Eye Injuries Treated in the Emergency Department and Other Outpatient Clinics**

Despite the name, the emergency department (ED) treats a wide ranging severity of injuries and illnesses. Intuitively, ED-treated eye injuries would seem to be more severe than other outpatient or private physician-managed injuries. However, EDs have increasingly becoming a point of care for non-urgent medical events due in part to individuals lacking access to care or private insurance, fragmentation of emergency medical services, and ambulance diversions (6). This is documented specifically for non-injury eye conditions among Medicaid beneficiaries, who may use ED services rather than primary care physicians (7). It is therefore not accurate to classify all injuries treated in the ED as more severe than those treated in other outpatient departments or private physician offices. In fact, the ED offers an opportunity to observe perhaps the full scope of severity among eye injuries.

Using data from the National Hospital Ambulatory Medical Care Survey (NHAMCS) and a including injuries to the orbit and surrounding soft tissue, Nash and Margo estimated the incidence of ED-treated ocular trauma at 447.1 per 100,000 popula-
tion in the year 1993 (7). More recently in 2001, the estimated incidence was 354 per 100,000 population using NHAMCS data limited to eye injuries to the globe only (1). Another study using data from the National Electronic Injury Surveillance System All Injury Program (NEISS-AIP) estimated the incidence of eye injury was 315 per 100,000 population (95% CI, 266-363) in 2000 (8). The discrepancy between estimates could be explained by the latter studies used a restrictive case definition that only included injuries to the “eyeball.” It could also be attributed to variability in the data, or temporal trends resulting in reduced injury incidence. Even with different definitions and data sources, ED-treated eye injuries tended to be minor, each study finding over 70% of injuries were diagnosed as superficial injury (e.g., corneal abrasion) or foreign body (7,8). While severe injuries are treated in the ED, it is evident that these are far-outnumbered by minor injuries. This finding reiterates that most eye injuries that are minor and not sight-threatening. It also demonstrates that there may be “misuse” of the ED for minor injuries which are non-urgent and could be managed in private physicians’ offices.

Estimates of eye injuries treated in other outpatient clinics are limited, likely a reflection that most ambulatory treatment is done via the ED. For the year 2001, McGwin et al. observed nearly 40% of eye injuries were managed by private physicians at an estimated rate of 270 per 100,000 population (1). Ambulatory injuries treated outside the ED represent a larger fraction of eye injuries than those requiring hospitalization, which is not surprising given the volume of minor eye injuries that are non-urgent. For the year 2001, the incidence was 54 per 100,000 population for eye injuries treated in outpatient clinics (1). There are no other incidence estimates for this type of care for eye injuries in
the literature—other studies do not differentiate between ED and other ambulatory care, or are restricted to hospitalizations.

**Self-reported Eye Injuries**

Self-reported data is another source for estimating eye injury incidence that has notable strengths and limitations as compared to administrative data. It may capture injuries where medical care was not sought, which may occur for a variety of reasons. These injuries, presumably minor in severity, could still be painful and limit activities. Although validation of self-reported data is not always possible, data of this nature is useful in understanding causes of eye injuries as determined directly from the patient. Self-reported data can also have the advantage of investigating factors of injuries when medical care is not sought because of limited access to care or fear of lost employment. Among residents in six New England states, the self-reported incidence of an eye injury for the year 1985 was 975 per 100,000 adults (9). The estimated average annual incidence in a multiracial urban environment in Baltimore was 260 per 100,000 population for the years 1986 to 1988, indicating a large difference (10). It is unclear if the differences were due to high variability of the self-reported data, or due to differences in location and population characteristics. More recent studies using self-reported data are unavailable, which is likely due to the wider collection and availability of administrative data, and the difficulty of primary data collection.
**Trends in Eye Injuries**

Considering the eye injury incidence estimates for the last 30 years, it is difficult to determine whether the incidence actually declined over time, or if improved data collection and availability account for the observed reductions. A decline of 25% in the incidence in hospitalizations for eye injuries was observed for the period from 1979-1986 in Maryland (4). The authors suggest the observed reduction may be explained by the fact that some conditions, such as contusions and hyphemas, were no longer indicated for hospitalization; a change that occurred during this period (4). Pooled data from three sources for the period from 1992 to 2001 estimated the rate of eye injuries declined by approximately 4.2% each year (11). The authors postulate that the reduction in eye injuries during this time can be at least partially attributed to improvements in occupational safety, thereby reducing work-related eye injuries, or the increase in passive leisurely activities (11). Furthermore, these findings suggest that the prevention of eye injuries is possible and continued effort to reduce the rate of eye injuries is important.

**The Incidence of Eye Injuries Among Subpopulations**

The incidence of eye injuries may be influenced by categories of injuries or by subpopulations. For example, among U.S. military personnel the incidence of ambulatory eye injury was 983 per 100,000 active duty men and women, 237 per 100,000 for hospitalizations, during the year 1998 (12). Both estimates are considerably higher than estimates among the general population, suggesting the risk of eye injury among military personnel may be different than the general population.

Other occupations experience increased incidence of eye injury as well. Occupational eye injuries are estimated to represent approximately 20% all eye injuries
However, other studies have estimated this proportion to range from 8% to 70% of eye injuries (15). Eye injuries are more common in certain occupations, particularly installation, maintenance, and repair as well as construction and extraction (Table 1) (16).

Table 1. Incidence rate of work-related eye injuries requiring at least two days from work among occupations with the highest rate of injury.

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Incidence Rate*</th>
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<tbody>
<tr>
<td>Welders, cutters, solderers, and brazers</td>
<td>48.1</td>
</tr>
<tr>
<td>Bus and truck mechanics and diesel engine specialists</td>
<td>22.8</td>
</tr>
<tr>
<td>Plumbers, pipefitters, and steamfitters</td>
<td>18.8</td>
</tr>
<tr>
<td>Automotive service technicians and mechanics</td>
<td>16.8</td>
</tr>
<tr>
<td>Heating, air conditioning, and refrigeration mechanics and installers</td>
<td>15.6</td>
</tr>
<tr>
<td>Painters, construction and maintenance</td>
<td>15.0</td>
</tr>
<tr>
<td>Construction laborers</td>
<td>12.1</td>
</tr>
</tbody>
</table>


The Bureau of Labor Statistics estimated there were 27,450 work-related eye injuries requiring days away from work in 2008, an estimate that has declined from previous years (Figure 1) (16-21). A study of all nonfatal work-related eye injuries treated in EDs nationwide estimated the rate was 210 per 100,000 full-time workers (22). Workers’ compensation claims from several states have been used to assess the impact of ocular trauma on workers, and have produced largely different rates of injury per 100,000 workers—Rhode Island, 329 (23), West Virginia, 537 (24), and Kentucky, 62.9 (25). This may be attributed to the States’ administration of the workers’ compensation system, or the type of industry in that state. The workplace offers opportunities for research and intervention that may not be possible among “domestic” eye injuries.
Figure 1. The total number and incidence rate of nonfatal work-related eye injuries per 10,000 full time workers

Etiology of Eye Injuries

In general, the most commonly treated types of eye injuries are corneal abrasions and extraocular (i.e., corneal or conjunctival) foreign bodies (1,5,7,8,11,26,27) that are most often not sight-threatening (2,13,26,28). Foreign bodies and corneal abrasions often are associated with one another, but may also be distinct types of eye injuries occurring independently. Other types of eye injuries include orbital floor fractures, open wounds of ocular adnexa, superficial injury of the eye and adnexa, burn confined to the eye and adnexa, and injuries to the optic or oculomotor nerves. Some subpopulations experience different types and severity of eye injuries. Among ocular trauma in an urban population, the most common types of injury observed were from assaults, and were predominately...
subconjunctival hemorrhage (24.6%) and orbital contusion (22.8%) (29). Military personnel, however, mostly experience corneal abrasions and lacerations (26.7%), many due to guns or explosive handling related to training (16.9%) (30). It is important to consider the etiology of eye injury among different subpopulations in addition to the general population.

The major mechanisms of eye injuries include foreign body, striking or being struck by an object, assault, fall, and motor vehicle collision (MVC) (1,3-5,7,8,11). Other mechanisms include thermal and chemical burns, cutting/piercing objects, machinery, and electrical current (11). The mechanism varies widely by age. Sports-related injuries are prominent among children; accidental blows and falls among the youngest children (4,31,32). Falls are a common mechanism in older adults (4). Assaults and MVCs play a larger role in urban populations (29).

There is a variety of agents which cause eye injuries. Several case reports and small studies have reported on specific agents as they pertain to eye injuries such as fireworks (33,34), guns—including air guns and firearms (35,36), paintballs (37), nail guns (38), bungee cords (39), motor vehicle collisions (40)—including air bag deployment (41-44)—and lawnmowers (45). Case reports make understanding the impact of agents from an epidemiological perspective difficult to comprehend. However, these studies illustrate potential sources of serious eye injury as well as are informative for clinicians. Needed is a greater understanding of how agents contribute to the overall burden of eye injuries. One such study used data from the NEISS, which collects data nationally on injuries associated with consumer products, indicated welding equipment (5.47%), household cleaners (4.82%), basketball equipment (3.42%), workshop equipment (3.31%),
saws (2.95%) and adhesives (2.91%) are common products associated with eye injuries (27). Another limitation to understanding the agents involved in eye injuries is the lack of sufficient exposure data. Case-based studies only indicate exposure to agents among injuries, but do not quantify the level of exposure or report on exposure to the agent when injuries do not occur, all of which may vary among age, gender, race, socioeconomic status, occupation, or other yet unknown factors.

The primary short-coming within the eye injury literature is the lack of cohort or case-control studies to quantify risk factors for eye injuries. Among the retrospective studies that have been conducted, many of the findings regarding potential risk factors of eye injury are consistent. The effect of gender on eye injuries is most notably that males are injured with greater frequency than females (1,3-5,7,9-11,13,26-28). Although eye injuries are observed among every age group, certain ages have experienced different rates of injury. Persons aged between 20 and 40 years tend to be the most often injured (1,5,7,9-11,13,26-28). The effect of age and/or sex on certain types of eye injuries may differ than the overall pattern for eye injuries. Among hospitalizations for eye injuries, the age distribution is bimodal, with peak incidence among those 20-40 years and among older adults aged 80 years and above (3). As with the majority of injuries, males experience the majority of work-related eye injuries (22,24,46). Based on a case-crossover study among Taiwanese workers, other risk factors of eye injuries included performing an unfamiliar task, operating faulty tools or equipment, and being distracted (47).
Prevention of Eye Injuries

According to the Occupational Safety and Health Administration (OSHA), an estimated 90% of eye injuries in the workplace are preventable through the use of proper protective eyewear (48). This often-cited figure is often used in conjunctions with the evidence that most eye injuries are minor. Thus suggesting that minor injuries occur in the absence of proper protective eyewear or that minor injuries are more preventable than severe injury. However, interventions to prevent eye injuries, including various methods of promoting the use of protective eyewear, have been under-evaluated for quantitative risk reduction (49). Although personal protective equipment (PPE) have been required to be provided by employers when reasonably appropriate since the Occupational Safety and Health Act in 1971, approximately 30,000 work-related eye injuries require time away from work each year, not including smaller businesses or the self-employed (16). This suggests prevention of work-related eye injuries is more complex than simply making eye protection available.

Lack or improper use of protective eyewear is often observed among medically-treated work-related eye injuries. In Australia, where occupational standards are comparable to that of the U.S., injured individuals reported using correct protective eyewear while performing tasks such as welding and grinding/drilling 24% and 18% of the time, respectively (50). Another case-control study conducted in Hong Kong reported a protective association of workers wearing safety glasses (51). A study using the case-crossover design from Taiwan estimated that protective eyewear could reduce the number of eye injuries among workers by 60% (47). Similarly, a study in Taiwan observed 80.6% of workers with eye injuries failed to wear eye protection at work; 69.4% of non-injured,
matched controls did not wear any type of eye protection (52). No comparable studies have been published in the United States, where government regulations are different, presumably more stringent, than the countries of origin of the previous studies. For example, Taiwan does not require eye protection to be worn at work (47) and safety and health in the construction industry in China is poorly monitored (51).

Studies have demonstrated that a history of previous work-related injury is predictive of a subsequent work-related injury. Among union carpenters, workers’ compensation claims for eye injuries were 1.6 times as likely among individuals with a previous claim as individuals without a claim (53). This observation is true for other work-related injuries, not just eye injuries. In a cohort of Brazilian steelworks, previous injuries were found to be associated with increased rate of injury (54). Multiple work-related injuries among farmers have also been reported (55). With regards to eye injuries, where eye protection is generally available and easy to implement, understanding the factors that contribute to multiple injuries among the same worker may lead to improved prevention.

A large proportion of eye injuries occur outside of the workplace; however, the use of protective eye among adults and children engaging in activities with potential for eye injury is low (56,57). Understanding barriers to use of appropriate protective eyewear or the failure of eyewear to prevent injury are important questions that remain unanswered. Eye injury prevention should be a priority area of research going forward. As such, the U.S. Department of Health and Human Services included prevention of occupational eye injuries, and increasing eye protection use in and around the home as objectives in Healthy People 2010 (Objectives 28-8 and 28-9) (58).
Implications for Current Research

This dissertation combines three novel topics which will advance the epidemiological literature of eye injury. The first topic is an epidemiologic description of the distribution of chemical eye injuries among patients presenting to the emergency department. Chemical eye injuries in the U.S have not been studied in detail, with the literature being primarily case reports. A retrospective medical record review was conducted using four years of records from the Alabama’s only eye hospital. The principal aim of the study was to describe chemicals that are most often implicated among this type of injury. A secondary aim of the study was to investigate cases of chemical eye injuries occurring from the use of an improper product, such as mistakenly using cyanoacrylate glue instead of eye drops.

The second topic measured the associations of transient risk factors and occupational eye injuries using the case-crossover study design. Among the risk factors investigated were: use of protective eyewear, use of tools, being rushed, working overtime, being distracted, feeling ill, being fatigued, and sleep duration. Many of these risk factors have yet to be evaluated with respect to eye injuries, and the primary aim of this study was to do so. Investigation of specific risk factors among work-related injuries may help elucidate challenges to prevention of eye injury by protective eyewear alone. That is, although 90% of work-related eye injuries are thought preventable through protective eyewear, other risk factors may be important than whether or not eye protection was available to the worker.

The final topic presented herein is a quantitative assessment of how an injury event affects future protective health behaviors. Participants in an earlier occupational
eye study were administered a follow-up questionnaire a year after their injury to compare their current use of eye protection to that before their injury. The aim of this study was to evaluate to what extent workers modify their behavior after an eye injury. The results of this study will provide insight into other areas of injury prevention and lead to a greater understanding of how injury events affect health behavior.
THE EPIDEMIOLOGY OF CHEMICAL EYE INJURIES

by

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Format adapted for dissertation
Abstract

**Purpose:** To describe the epidemiology and identify categories of agents involved in chemical eye injuries.

**Methods:** Retrospective case series of consecutive cases of chemical eye injury presenting to the emergency department at a large eye hospital. Six-hundred and thirty-three patients presented to the emergency department between January 1, 2006 and December 31, 2009 for treatment of 640 chemical eye injuries. Information was collected via medical record review and chemical agents were classified into logical categories based on the patient-reported intended use of the product. Demographic measures, month of service, work-related status, and visual acuity at presentation were described overall and by chemical agent category.

**Results:** Males were more often observed than females (58.4% vs. 41.6%). The mean age across all categories was 33.6 years. More injuries were observed in warmer months. The mean visual acuity for all available injured eyes was 0.17 logarithm of the minimum angle of resolution (20/30 Snellen). The most common categories of chemical agents were cleaning agents, personal care products, and automotive chemicals. Thirty-nine cases were observed as having misidentified a product which led to injury.

**Conclusion:** Patterns of eye trauma resulting from chemicals differ by gender, across age groups, and during different months of the year. In most cases, chemical eye injuries do not threaten sight. Improvements in product labeling and design could represent an avenue to prevent some chemical eye injuries.
Introduction

Chemical eye injuries, including chemical conjunctivitis and chemical burns, are the result of exposure to caustic or corrosive substances such as acidic or alkaline agents. Generally, this type of injury results from exposure to the active ingredients in products such as cleaners and detergents, damaging the ocular surface epithelium, cornea, or anterior segment.\(^1\) Other chemicals, such as cyanoacrylate glue, may result in injuries to the eyelids and lashes or conjunctivitis.\(^2\) Most chemical eye injuries do not result in permanent visual impairment, but the outcome is highly dependent on the agent as well as the treatment.\(^3\)

The incidence of burns to the eye has been reported to be 10.7 per 100,000 population\(^5\) and such burns represent an estimated 10% of ocular trauma treated in emergency departments.\(^4\) Though estimates vary, chemicals seem to represent a greater proportion of injuries than thermal burns.\(^6\)-\(^11\) Descriptive studies in the United Kingdom and Germany indicate chemical eye injuries mostly affect males aged 16-25 years.\(^3,6\)-\(^11\) Common agents include solvents/paints, detergents, antipersonnel sprays, adhesives, bleach, automotive battery acid, plaster, and ammonia;\(^3,6\)-\(^11,12\) alkali agents tend to result in more severe injuries than acid or other agents.\(^13\) However, culture and geography influence the types of chemicals used in and around the home, for cleaning or cosmetic application. National regulations may too impact which chemicals are available to consumers and use in commercial or industrial settings.

To date information regarding the most common specific products responsible for chemical eye injuries is not available. In fact, there has been no descriptive study of chemical eye injuries in the United States general population. This deficiency could be
due to the difficulties in collecting accurate data. Existing data sources such as the National Electronic Injury Surveillance System (NEISS) and American Association of Poison Control Centers (AAPCC) do not contain product specific information or represent a selected patient population. Primary data from medical records, like that collected in the current study, is an appropriate method to describe the patterns and clinical characteristics (e.g., visual acuity) of such injuries when direct patient interview is not available. Although this type of data collection is much costlier with respect to time and resources than secondary data sources, having information on the specific chemical agents implicated in eye injuries will enhance prevention efforts and identify areas for additional study.

**Methods**

This study is a descriptive case series. The study base consisted of all patients regardless of age seeking care at the Callahan Eye Foundation Hospital (CEFH) emergency department (ED) for eye injuries involving exposure to chemicals between January 1, 2006 and December 31, 2009. The CEFH ED serves patients primarily from Jefferson and surrounding counties in the state of Alabama, but as the only free-standing, 24-hour 7 day a week eye emergency room in the state, patients occasionally travel from more remote areas for treatment. The CEFH ED evaluates approximately 350 patients per month, of which approximately 30% of these are seeking care for eye injury. The study protocol was approved by the institutional review board.

Eligible patients (hereafter “cases”) were initially identified using International Classification of Diseases, Clinical Modification version 9 (ICD-9-CM) diagnostic codes
and codes for the external causes of injury (E code) suggestive of chemical injury (Table 1). Multiple visits for the same injury were not included and were identified by visits given a supplementary V code (V67) indicating a follow-up examination. However, individuals presenting for a separate chemical injury were included; that is a visit to the ED that contained the specified ICD-9-CM codes but lacked the V67 code (5 individuals representing 12 cases). Ophthalmologists’ notes were then reviewed to confirm chemical injuries and thermal burns or other injuries were excluded. Information regarding the demographics of injured cases, date of injury, and visual acuity of injured eyes was collected from medical records and examined overall and by chemical agent category. Distance visual acuity was taken on the injured eye during the visit to the ED. If patients had multiple visual acuity measurements, the best measure was used be it with spectacle correction, or with the pinhole occluder.

Chemical agents were grouped into logical categories describing the intended use of the agent based on the context in which the patient described it during the injury. Information to elucidate more specific details such as chemical manufacturer was not uniformly available and thus broad categories was the extent of detail in this study. Agents were classified as “unknown” if the chemical was not identified in the medical record. This generally occurred if that patient did not know or did not divulge the information. Some chemicals were identified, but could not be classified if the intended use was not clear. Determination of mistaken product identification was possible only in instances wherein the patient provided the information to the ED staff. For example, the medical records would include notes by nurses or attending ophthalmologists that the patient
stated using Super Glue™ by mistake instead of eye drops. Key words such as “patient thought was...” or “patient mistook as...” were used to identify such cases.

To test the reliability of the case identification by ICD-9-CM codes, a validation study was conducted wherein the ophthalmologist’s notes for all CEFH ED records for the period of September 1, 2008 through August 31, 2009 were reviewed to determine the presence of chemical injuries. There was almost perfect agreement between the chemical injuries identified on the basis of ophthalmologist notes and the ICD-9-CM code-based approach for identifying chemical eye injuries ($\kappa=0.86$, $p < .0001$).

**Results**

Over the study period there were 19,995 visits to the CEFH emergency department of which 640 (3.2%) cases of chemical eye injury were identified among 633 patients included in the final analysis. The characteristics of cases presenting with chemical eye injuries is summarized in Table 2. There were more males than females (58.4% vs. 41.6%). The racial-ethnic distribution of cases was: 59.8% Caucasian, 33.6% African American, 2.8% Hispanic, and 3.7% other races. Right and left eyes were injured a similar proportion of the time, 33.8% and 32.2% respectively. Both eyes were injured in 27.2% of cases, and for a small number of cases (6.4%) it was not possible to determine which eye was injured based on the attending ophthalmologist’s notes. Approximately one-quarter (25.2%) of the injuries were known to be work-related, though a determination of whether the injury was work-related could not be made for nearly half (47.8%) of all cases.
The mean age ± standard deviation of cases was 33.6 ± 18.7 years. The age distribution of the cases is shown in Figure 1, indicating a nearly normal distribution with a peak between ages 41-45 years. Although most patients observed were between 21-50 years of age, children between ages 0 and 5 years were a notable exception. The month of injury distribution of cases demonstrates a seasonal effect with more injuries occurring in warmer months (Figure 2). Thursday and Friday were the days of the week in which chemical eye injuries were most often treated, 16.6% and 16.7% of all injuries respectively, with the fewest injuries treated on Saturday (11.9%). The visual acuity for 69 (9.0%) eyes could not be measured. Of those, 59 (85.5%) were children too young to measure, 5 (7.2%) had light perception only, 4 (5.8%) were uncooperative, and 1 (1.4%) had no light perception. The mean visual acuity ± standard deviation of 704 injured eyes that were measurable upon presentation to the ED (excluding 41 cases whose injured eye was unknown) was 0.17 ± 0.32 logarithm of the minimum angle of resolution (logMAR), ranging from -0.125 to 3.00 logMAR (20/15 to 20/20,000 Snellen) (Figure 3).

The most common category of chemicals was household cleaning agents, accounting for 183 injuries (28.6%) (Table 3), followed by personal care products with 88 injuries (13.8%) and automotive chemicals with 84 injuries (13.1%). Males were most often injured by automotive chemicals, unknown agents, paint/paint thinner, building/construction supplies, defense spray, refrigerants, toys/entertainment, and other/unclassified. Females were most often injured by personal care products and medications. The mean age by product category deviated from the overall mean only among agents in the toys/entertainment category, which had a mean of age of 8.0 years. More specific classifications of the three most-common chemical categories are summarized in
Table 4. The leading agents were bleach from the household cleaning agents category, hair products from the personal care products category, and battery acid from the automotive chemical category. Thirty-nine injuries (6.1% overall) resulted from the use of a non-ophthalmic solution instilled directly into the eye because of misidentification of the product. As summarized in Table 5, these injuries occurred most often among slightly older patients, females, and involved glues/adhesives or medications.

**Discussion**

The current study is the largest epidemiological investigation of chemical eye injuries to be conducted and the only to examine patients identified from a U.S. facility. Among all eye injuries, males are known to be injured more often than females, although it has been shown to vary by circumstance of the injury. For example, injury type has been shown to have a sex effect, such that foreign body injuries are more common among males while being “struck accidentally by object or person” is more common among females. Among injuries related to consumer products, sex differences have been observed for different products. Compared to other studies, the sex distribution in the current study was more equal between males and females (58.4% male) than previously observed (75% - 83% male). However, the sex distribution is not the same across agent categories, possibly reflecting differential patterns in the use of products by gender. This finding is consistent with McGwin et al. (2006) who observed eye injuries from chemicals and compounds were more common among females (19.5%) than males (10.6%).
Seasonal relationships in the incidence of eye injuries have not previously been reported. General trauma admissions are correlated with increase in temperature, thus implying injuries are more likely in warmer months.\textsuperscript{15} This observation was true across all categories, however some categories were observed almost exclusively in warmer months, such as swimming pool chemicals and refrigerants, suggesting a seasonally dependant exposure. Another potential explanation is changes in protective eyewear behaviors as a function of temperature. The use of protective eyewear may be less likely in warmer months because of fogging-up or discomfort.

The age distribution observed in the current study is similar to previous reports regarding ocular trauma\textsuperscript{14,8} as well as chemical injuries specifically.\textsuperscript{9,10} However, a notable departure from this distribution is the number of injuries among children aged < 6 years. Only the toys/entertainment category\textsuperscript{1} appear limited to children, but does not explain all 58 cases in the fewer than 6 years age group. Most of these injuries (48.3\%) were the result of exposure to cleaning agents, followed by glues/adhesives (17.2\%). Household cleaning agents previously have been shown to be leading causes of injury from consumer products among this age group,\textsuperscript{16} and particularly eye injuries.\textsuperscript{17}

Cleaning agents were, in fact, the most common category of chemical observed among all age groups. McGwin et al. (2006) identified household cleaners as the second most-common consumer product associated with eye injury.\textsuperscript{12} The present study was able to determine that among cleaning agents, bleach was the most common single agent. It is unclear from this study whether bleach represents a greater inherent danger to the eye than other agents, or if the ubiquity of bleach in products exposes a larger number of people than any other agent. Alkaline agents are known to cause extensive damage to eye

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\textsuperscript{1} All agents in this category were chemicals related to “glow stick” devices.
tissue due to their ability to rapidly penetrate the layers of the eye, whereas acid injuries tend to be more superficial.\textsuperscript{1,18-20} Wagoner (1997) concluded that alkali agents were commonly used in household cleaners resulting in more eye injuries, but failed to mention bleach.\textsuperscript{1} Furthermore, since bleach is a common ingredient among cleaning agents designed for a range of applications from household to commercial-grade cleaners, the perception that it is not harmful may result in less vigilance and lower use of protective eyewear as compared to other agents.

The second most common agent was personal care products. Chemicals within this category are unique, in that they are intended for application around the eyes, increasing the likelihood of eye contact. Agents within this category, such as hair products, may have a perception of being benign among those using them and protective eyewear may be perceived as unnecessary or use may be impractical.

Among the various chemicals comprising the automotive chemical category, battery acid was the most common specific agent. Eye injuries occurring from automotive batteries have previously been described.\textsuperscript{21} Explosions, improper handling or failure to wear proper protective eyewear may result in exposure to the acid within automotive batteries.

Visual acuity measured during ED presentation indicates most injuries are not sight-threatening, as most cases presented below 0.30 logMAR (20/40 Snellen). Cases wherein defense spray was the implicated agent category showed an overall poorer visual acuity than other categories, indicating potential visual impairment from the product. However, follow-up data on visual acuity was not available and therefore it is unclear whether changes in acuity occurred over time. Defense sprays containing oleoresin capsi-
cum (i.e., pepper spray) are not considered harmful to corneal tissues, and in most circumstances do not negatively impact visual acuity.\textsuperscript{22,23} However, conflicting reports suggest permanent visual acuity damage may occur over time without proper treatment.\textsuperscript{24,25}

A small number of injuries resulted from intentional exposure to a product not designed for the intended use (e.g., nail glue mistaken for eye drops). The two main products involved in this type of injury were nail glue/SuperGlue\textsuperscript{TM} (cyanoacrylate) and ear medications. As numerous case reports have previously stated, similar product design is often responsible for this confusion.\textsuperscript{26-35} Also observed were situations in which contact lens cleaner, not meant for direct instillation, was mistaken for eye drops, such as rewetting drops or saline solution. This does not appear to be previously reported. Although painful, these injuries are not likely to have any long-term consequences. Changes in the product design or increasing the visibility of warnings on the labels of contact lens solutions may prevent some of these injuries. However, despite concern in the ophthalmology community for over 30 years, it is unclear how much progress has been made to prevent injuries resulting from misidentified products as the rate of this injury is unknown. Given the results of the current study, this type of injury does still occur.

The use of chemicals, especially extremely caustic solutions such as ammonia, have been documented in assaults,\textsuperscript{36} and often result in eye injuries.\textsuperscript{10,11,37} Determining whether injuries were related to assaults was difficult given the retrospective nature of the study. Assault injuries related to chemicals were not common in the current study, with only 2 cases which involved defense spray. However, the circumstances of all injuries, notably the remaining 3 of the 5 total injuries involving defense spray, were unclear from medical records and cannot be definitively attributed to assault. Other injuries in this
study may have resulted from assault but they could not be classified in this category if law enforcement were not involved, or if the patient was not forthcoming to the care providers about the nature of the injury.

The results of this study must be interpreted in light of several strengths and limitations. This study represents the largest collection of chemical eye injuries to date, thereby decreasing the likelihood of spurious patterns of demographic or chemical agent characteristics. Although studies were published from Europe and Africa, the descriptive epidemiology of chemical eye injuries had previously remained unknown in the U.S. By including injuries of all severity presenting to an emergency department within an ophthalmic hospital, the current study provides a description of more common injuries which collectively are a greater public health burden. However, the use of a single ophthalmologic emergency department may introduce selection bias if eye injuries seen in this setting are limited to only the more or less severe than injuries compared to those treated in other settings (e.g., physician’s offices, or general emergency departments). The CEFH emergency department treats patients with a varying degree of severity, including both minor ambulatory patients using it as a convenient clinic for non-urgent conditions as well as severe injuries referred from surrounding clinics. For this reason selection bias could be present should patients presenting for chemical injuries not be representative of the base population. Based on zip code information, cases of chemical eye injuries matched the geographic distribution for all other presentations to the ED, therefore patients with chemical eye injuries were not more likely to travel greater distances for treatment than other conditions. Due to the lack of previous literature on the topic, and the opportunity to observe a large number of cases, the choice of the emergency depart-
ment is an appropriate setting to provide a foundation for investigating chemical eye inju-
ries. Consistent with the case series design, the results presented herein are limited to cha-
racteristics of cases and agents involved in chemical eye injuries, and do not provide de-
tailed information regarding the risk factors of chemical eye injury since exposures in a
“non-injured” control group were not used for comparison. The circumstances were not
always apparent for every injury, and were based on the patients’ accounts relayed to
healthcare providers. Thus, determination of the agent categories based on this informa-
tion could lead to misclassification. However, this is likely to be random and not
represent a bias toward classification into any specific category. Additionally, failure to
identify assault injuries or injuries due to mistaken identity of a product are possible, re-
sulting in an under estimation of the true occurrence. Finally, the presence or absence of
protective eyewear at the time of injury was not commonly available from medical
records. It is therefore not possible to identify to what extent protective eyewear can pre-
vent or mitigate chemical eye injuries.

Patterns of eye trauma resulting from chemicals differ by gender, across age
groups, and during different months of the year. Though uncommon, injuries resulting
from cyanoacrylate glue and certain types of contact lens products represent an opportu-
nity to prevent injury by alterations in the product labeling or design. Future studies may
include case-control or cross-sectional studies to quantify the exposure-injury relation-
ship among chemical eye injuries, which is not possible in the case series design. Under-
standing the role of protective eyewear in prevention of injuries from chemicals would be
beneficial to improve prevention efforts. In general, increasing awareness of chemical
eye injuries in the general public as well as improving product warning labels effectiveness could assist in prevention.
Acknowledgments

This work was supported by the EyeSight Foundation of Alabama and Research to Prevent Blindness, Inc.
References


Table 1. Specific injury and external cause codes that were used to identify patients with chemical eye injuries.

<table>
<thead>
<tr>
<th>Code</th>
<th>Disease or Injury, or External Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>940</td>
<td>Burn confined to eye and adnexa</td>
</tr>
<tr>
<td>940.0</td>
<td>Chemical burn of eyelids and periocular area</td>
</tr>
<tr>
<td>940.1</td>
<td>Other burns of eyelids and periocular area</td>
</tr>
<tr>
<td>940.2</td>
<td>Alkaline chemical burn of cornea and conjunctival sac</td>
</tr>
<tr>
<td>940.3</td>
<td>Acid chemical burn of cornea and conjunctival sac</td>
</tr>
<tr>
<td>940.4</td>
<td>Other burn of cornea and conjunctival sac</td>
</tr>
<tr>
<td>940.5</td>
<td>Burn with resulting rupture and destruction of eyeball</td>
</tr>
<tr>
<td>940.9</td>
<td>Unspecified burn of eye and adnexa</td>
</tr>
<tr>
<td>989</td>
<td>Toxic effect of other substances, chiefly nonmedicinal as to source</td>
</tr>
<tr>
<td>989.0</td>
<td>Hydrocyanic acid and cyanides (Excludes gas and fumes)</td>
</tr>
<tr>
<td>989.1</td>
<td>Strychnine and salts</td>
</tr>
<tr>
<td>989.2</td>
<td>Chlorinated hydrocarbons (Excludes chlorinated hydrocarbon solvents)</td>
</tr>
<tr>
<td>989.3</td>
<td>Organophosphate and carbamate</td>
</tr>
<tr>
<td>989.4</td>
<td>Other pesticides, not elsewhere classified</td>
</tr>
<tr>
<td>989.6</td>
<td>Soaps and detergents</td>
</tr>
<tr>
<td>989.8</td>
<td>Other substances, chiefly nonmedicinal as to source</td>
</tr>
<tr>
<td>989.9</td>
<td>Unspecified substance, chiefly nonmedicinal as to source</td>
</tr>
<tr>
<td>976</td>
<td>Poisoning by agents primarily affecting skin and mucous membrane, ophthalmological, otorhinolaryngological, and dental drugs</td>
</tr>
<tr>
<td>976.2</td>
<td>Local astringents and local detergents</td>
</tr>
<tr>
<td>976.4</td>
<td>Keratolytics, keratoplastics, other hair treatment drugs and preparations</td>
</tr>
<tr>
<td>976.5</td>
<td>Eye anti-infectives and other eye drugs</td>
</tr>
<tr>
<td>976.6</td>
<td>Anti-infectives and other drugs and preparations for ear, nose, and throat</td>
</tr>
<tr>
<td>976.9</td>
<td>Unspecified agent primarily affecting skin and mucous membrane</td>
</tr>
<tr>
<td>E924</td>
<td>Accident caused by hot substance or object, caustic or corrosive material, and steam</td>
</tr>
<tr>
<td>E924.1</td>
<td>Caustic and corrosive substances</td>
</tr>
<tr>
<td>E924.9</td>
<td>Unspecified</td>
</tr>
<tr>
<td>E858</td>
<td>Accidental poisoning by other drugs</td>
</tr>
<tr>
<td>E858.7</td>
<td>Agents primarily affecting skin and mucous membrane, ophthalmological, otorhinolaryngological, and dental drugs</td>
</tr>
<tr>
<td>E858.8</td>
<td>Other specified drugs</td>
</tr>
<tr>
<td>E858.9</td>
<td>Unspecified drugs</td>
</tr>
</tbody>
</table>
Table 2. Patient characteristics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>374 (58.4)</td>
</tr>
<tr>
<td>Female</td>
<td>266 (41.6)</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>383 (59.8)</td>
</tr>
<tr>
<td>African American</td>
<td>215 (33.6)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>18 (2.8)</td>
</tr>
<tr>
<td>Other</td>
<td>24 (3.7)</td>
</tr>
<tr>
<td><strong>Injured eye(s)</strong></td>
<td></td>
</tr>
<tr>
<td>Right eye</td>
<td>217 (33.9)</td>
</tr>
<tr>
<td>Left eye</td>
<td>208 (32.5)</td>
</tr>
<tr>
<td>Both eyes</td>
<td>174 (27.2)</td>
</tr>
<tr>
<td>Unknown/unclear</td>
<td>41 (6.4)</td>
</tr>
<tr>
<td><strong>Work-related injury</strong></td>
<td></td>
</tr>
<tr>
<td>Work-related</td>
<td>161 (25.2)</td>
</tr>
<tr>
<td>Not work-related</td>
<td>173 (27.0)</td>
</tr>
<tr>
<td>Unknown</td>
<td>306 (47.8)</td>
</tr>
</tbody>
</table>
Table 3. Agents involved in chemical eye injuries (VA=visual acuity).

<table>
<thead>
<tr>
<th>Category of Agent</th>
<th>Frequency</th>
<th>Percent</th>
<th>Male (%)</th>
<th>Mean Age</th>
<th>Mean VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household cleaning agents</td>
<td>183</td>
<td>28.6</td>
<td>105 (57)</td>
<td>32.8</td>
<td>0.19</td>
</tr>
<tr>
<td>Personal care products</td>
<td>88</td>
<td>13.8</td>
<td>22 (25)</td>
<td>32.3</td>
<td>0.23</td>
</tr>
<tr>
<td>Automotive chemicals</td>
<td>84</td>
<td>13.1</td>
<td>69 (82)</td>
<td>34.3</td>
<td>0.15</td>
</tr>
<tr>
<td>Glues/adhesives</td>
<td>54</td>
<td>8.4</td>
<td>23 (43)</td>
<td>28.0</td>
<td>0.15</td>
</tr>
<tr>
<td>Medications</td>
<td>41</td>
<td>6.4</td>
<td>15 (37)</td>
<td>40.2</td>
<td>0.15</td>
</tr>
<tr>
<td>Unknown agent</td>
<td>31</td>
<td>4.8</td>
<td>22 (71)</td>
<td>38.9</td>
<td>0.12</td>
</tr>
<tr>
<td>Paint/paint thinner</td>
<td>30</td>
<td>4.7</td>
<td>28 (93)</td>
<td>37.4</td>
<td>0.10</td>
</tr>
<tr>
<td>Pesticides</td>
<td>29</td>
<td>4.5</td>
<td>15 (52)</td>
<td>40.2</td>
<td>0.12</td>
</tr>
<tr>
<td>Building/construction supplies</td>
<td>16</td>
<td>2.5</td>
<td>16 (100)</td>
<td>30.4</td>
<td>0.24</td>
</tr>
<tr>
<td>Swimming pool chemicals</td>
<td>13</td>
<td>2.0</td>
<td>7 (54)</td>
<td>33.8</td>
<td>0.23</td>
</tr>
<tr>
<td>Deodorizers</td>
<td>7</td>
<td>1.1</td>
<td>3 (43)</td>
<td>26.0</td>
<td>0.12</td>
</tr>
<tr>
<td>Defense spray</td>
<td>5</td>
<td>0.8</td>
<td>4 (80)</td>
<td>27.4</td>
<td>0.58</td>
</tr>
<tr>
<td>Foods</td>
<td>5</td>
<td>0.8</td>
<td>3 (60)</td>
<td>27.0</td>
<td>0.02</td>
</tr>
<tr>
<td>Refrigerants</td>
<td>5</td>
<td>0.8</td>
<td>4 (80)</td>
<td>38.2</td>
<td>0.03</td>
</tr>
<tr>
<td>Plants</td>
<td>3</td>
<td>0.5</td>
<td>2 (67)</td>
<td>37.3</td>
<td>0.10</td>
</tr>
<tr>
<td>Toys/entertainment</td>
<td>3</td>
<td>0.5</td>
<td>3 (100)</td>
<td>8.0</td>
<td>0.00</td>
</tr>
<tr>
<td>Ink</td>
<td>2</td>
<td>0.3</td>
<td>1 (50)</td>
<td>22.0</td>
<td>0.00</td>
</tr>
<tr>
<td>Body fluids</td>
<td>1</td>
<td>0.2</td>
<td>0 (0)</td>
<td>40.0</td>
<td>0.00</td>
</tr>
<tr>
<td>Other/unclassified</td>
<td>40</td>
<td>6.3</td>
<td>32 (80)</td>
<td>33.8</td>
<td>0.11</td>
</tr>
</tbody>
</table>
Table 4. Subgroups of the most common chemical categories.

<table>
<thead>
<tr>
<th>Household Cleaning Agents</th>
<th>Personal Care Products</th>
<th>Automotive Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subgroup</strong></td>
<td><strong>N</strong></td>
<td><strong>Subgroup</strong></td>
</tr>
<tr>
<td>Bleach</td>
<td>50</td>
<td>Hair products</td>
</tr>
<tr>
<td>All purpose/household</td>
<td>18</td>
<td>Contact lens solution</td>
</tr>
<tr>
<td>Disinfectant</td>
<td>13</td>
<td>Soap/cleanser</td>
</tr>
<tr>
<td>Laundry detergent</td>
<td>12</td>
<td>Lotion/make-up</td>
</tr>
<tr>
<td>Drain cleaner</td>
<td>11</td>
<td>Nail products</td>
</tr>
<tr>
<td>Automotive cleaner</td>
<td>9</td>
<td>Perfume/cologne</td>
</tr>
<tr>
<td>Industrial/commercial</td>
<td>8</td>
<td>Shampoo</td>
</tr>
<tr>
<td>Ammonia</td>
<td>7</td>
<td>Deodorant</td>
</tr>
<tr>
<td>Degreaser</td>
<td>7</td>
<td>Hand sanitizer</td>
</tr>
<tr>
<td>Dishwashing soap</td>
<td>6</td>
<td>Other products</td>
</tr>
<tr>
<td>Metal cleaner/polish</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Floor/carpet cleaner</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Glass cleaner</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Oven cleaner</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Furniture cleaner/polish</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Other/unknown cleaner</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>

- Battery acid: 34
- Brake/transmission/hydraulic fluid: 21
- Gasoline/fuel: 16
- Engine coolant: 5
- Airbag deployment: 2
- Body compound: 2
- Tire sealant: 2
- Windshield fluid/Def-icer: 2
Table 5. Characteristics of patients and eyes injured due to mistaken product.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>25 (64.1)</td>
</tr>
<tr>
<td>Male</td>
<td>14 (35.9)</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>32 (82.1)</td>
</tr>
<tr>
<td>African American</td>
<td>5 (12.8)</td>
</tr>
<tr>
<td>Other</td>
<td>2 ( 5.1)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
</tr>
<tr>
<td>0-15</td>
<td>6 (15.4)</td>
</tr>
<tr>
<td>16-25</td>
<td>5 (12.8)</td>
</tr>
<tr>
<td>26-35</td>
<td>5 (12.8)</td>
</tr>
<tr>
<td>36-45</td>
<td>4 (10.3)</td>
</tr>
<tr>
<td>46-55</td>
<td>6 (15.4)</td>
</tr>
<tr>
<td>56-65</td>
<td>9 (23.1)</td>
</tr>
<tr>
<td>66+</td>
<td>4 (10.3)</td>
</tr>
<tr>
<td><strong>Agent Category</strong></td>
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</tr>
<tr>
<td>Household cleaning agents</td>
<td>3 ( 7.7)</td>
</tr>
<tr>
<td>Glues/adhesives</td>
<td>10 (25.6)</td>
</tr>
<tr>
<td>Medications</td>
<td>17 (43.6)</td>
</tr>
<tr>
<td>Personal care products</td>
<td>8 (20.5)</td>
</tr>
<tr>
<td>Other/unclassified</td>
<td>1 ( 2.6)</td>
</tr>
<tr>
<td><strong>Visual Acuity (eyes)</strong></td>
<td></td>
</tr>
<tr>
<td>20/40 or better</td>
<td>35 (74.5)</td>
</tr>
<tr>
<td>20/50 – 20/100</td>
<td>3 ( 6.4)</td>
</tr>
<tr>
<td>20/120 – 20/200</td>
<td>1 ( 2.1)</td>
</tr>
<tr>
<td>19/200 – 5/200</td>
<td>2 ( 4.3)</td>
</tr>
<tr>
<td>Unable to obtain</td>
<td>6 (12.8)</td>
</tr>
</tbody>
</table>
Figure 1. The age distribution of patients with chemical eye injuries.
Figure 2. The month distribution of when chemical eye injuries occurred.
Figure 3. The distribution of best potential visual acuity at entrance among chemically-injured eyes.
A CASE-CROSSOVER STUDY OF RISK FACTORS FOR OCCUPATIONAL EYE INJURIES

by

JUSTIN BLACKBURN, EMILY B. LEVITAN, PAUL MACLENNAN, CYNTHIA OWSLEY, GERALD MCGWIN, JR

In preparation for *Ophthalmology*

Format adapted for dissertation
Abstract

**Purpose:** To study transient risk factors for occupational eye injuries using a novel study design.

**Design:** Case-crossover study.

**Methods:** Patients treated for work-related eye injuries were recruited from the emergency department at a free-standing eye hospital in Alabama. A mail or phone questionnaire was administered to collect information regarding risk factors at the time of eye injury and at specific time periods prior to injury.

**Main Outcome Measures:** Incidence rate ratios (IRRs) were used to measure the relationship between each risk factor and injury occurrence.

**Results:** Protective eyewear reduced the risk of occupational eye injury by 50% (IRR 0.5, 95% CI 0.4 to 0.7). Other statistically significant risk factors were: use of tools (IRR 3.9, 95% CI 3.0 to 4.9), tool malfunction (IRR 2.6, 95% CI 1.5 to 4.5), performing an unfamiliar task (IRR 1.8, 95% CI 1.6 to 2.1), being rushed (IRR 3.8, 95% CI 2.4 to 5.9), working overtime (IRR 2.9, 95% CI 1.9 to 4.4), and feeling fatigued (IRR 3.1, 95% CI 1.8 to 5.4).

**Conclusions:** Although use of protective eyewear can significantly reduce the risk of an eye injury, other factors are important contributors. Identification of potentially modifiable transient risk factors can be used to prevent occupational eye injuries.
Eye injuries represent a leading cause of monocular blindness, and interventions to prevent them including the proper use of protective eyewear, have been under-evaluated. The Occupational Safety and Health Act of 1970 created the Occupational Safety and Health Administration (OSHA) which sets the standards under which employers in the United States are required to provide personal protective equipment for employees (29 U.S.C. §655-657; 29 C.F.R. §1910.133). Yet an estimated 280,000 non-fatal work-related eye injuries were treated in emergency departments nationwide in 1999. In 2008, the Bureau of Labor Statistics (BLS) estimated there were 27,450 work-related eye injuries requiring two or more days away from work at a rate of 2.9 injuries per 10,000 full-time workers. Most eye injuries are minor and do not result in missed work days; however, such injuries are painful and require medical intervention.

Epidemiologic research regarding the etiology of occupational eye injuries is limited. Young males experience the majority of work-related eye injuries. Metalworkers have the highest rate of missed work due to eye injury of any specific occupational group, getting injured at 16-times the national average rate. Other occupations within the agriculture, construction, and manufacturing fields have also been shown to have high rates of eye injuries. Specific risk factors of work-related eye injury have been identified as performing an unfamiliar task, operating faulty tools or equipment, and being distracted. Protective eyewear has been associated with a 60% reduced odds of injury among workers in Taiwan.

To date, no study among U.S. workers has examined transient risk factors for occupational eye injuries, including the role of protective eyewear. Thus, the current case-crossover study seeks to measure this relationship with incidence rate ratios (IRRs) as a
measure of relative risk via the usual frequency approach,⁸ which has been demonstrated to be an efficient method of analyzing case-crossover data.⁹

**Methods**

The study protocol was approved by the Institutional Review Board at the University of Alabama at Birmingham.

*Study Design*

The case-crossover design is similar to a matched case-control study, wherein an individual with the disease of interest (“case”) is matched with a person free of disease (“control”) based upon a set of criteria that may be relevant to the exposure. However, in the case-crossover study, a single individual is self-matched at two defined points in time: the control period and the hazard period. Depending on the analysis, the case-crossover design can also resemble a retrospective cohort study with stratification on the individual and time-varying exposure. Akin to a washout period, the control period must be defined sufficiently prior to the outcome (i.e., eye injury) to ensure exposures experienced during this time do not have a lingering effect that could specifically contribute to the injury. The hazard period is then defined with a close proximity to the injury, such that any exposures could alter the individual’s risk. Case-crossover studies avoid between-subject confounding among fixed effects such as age, gender, experience, and training since exposure information is collected from the same individual.⁹ Only exposures which are intermittent, known as transient risk factors, and acute events can be evaluated using the case-crossover design.
Because many occupations feature routines that are relatively static from day-to-day, the case-crossover design is well-suited to evaluate associations with occupational injuries, in which an injury represents a deviation from the norm. As such, case-crossover studies have been employed to study several types of injuries among different occupations \(^7,^{10-14}\) and the expanded use in occupational injury has been advocated.\(^{15}\)

**Study Population**

Patients 19 years of age and older seeking care at the Callahan Eye Foundation Hospital (CEFH) emergency department for eye injuries sustained during work-related activities from August 2008 through September 2010 were eligible for inclusion in the study. The CEFH serves patients primarily in Jefferson County, Alabama but is also the only 24-hour eye emergency room in the state. The emergency department at the CEFH evaluates approximately 400 patients per month, of which approximately 36% are for injury.

**Data Collection**

On a daily basis, medical records from the previous day were reviewed in order to identify injury-related emergency department (ED) visits. Eye injuries were broadly defined as any condition resulting from trauma to the eye or ocular adnexa. Identification of such injuries was determined in part through the interpretation of the treating ophthalmologist’s notes as well as the billing diagnoses. This included *ICD-9-CM* codes 802.6 and 802.7 (orbital floor fractures); 870.0 to 870.9 (open wounds of the ocular adnexa); 871.0 to 871.9 (open wounds of the eyeball); 918.0 to 918.9 (superficial wound of the eye.
and adnexa); 921.0 to 921.9 (contusion of the eye and adnexa); 930.0 to 930.9 (foreign body on the external eye); 940.0 to 940.9 (burn confined to the eye and adnexa); 941.02 to 941.52 (burn involving the eye with other parts of the face, head, and neck); 950.0 to 950.9 (injury to the optic nerve and pathways); and 951.0, 951.1, and 951.3 (injury to the oculomotor, trochlear, and abducens nerves). In some situations, other diagnoses were included if other information from the ophthalmologist’s notes indicated a injury was likely, such as keratitis (370), as well as other disorders of the eye (379), conjunctiva (372), or iris and ciliary body (364).

The determination of whether the injury potentially occurred in a work setting was made by reviewing the ophthalmologists’ and nurses’ notes and/or whether workman’s compensation was filed. Questionnaires were mailed the next business day following patients’ visit to the CEFH to all individuals meeting age requirements for which the injury was clearly work-related as well as to those for whom the injury occurred at work was unclear. It was made clear in the letter that participation should be limited to injuries sustained while working. The questionnaire consisted of 85 questions and took approximately 20 minutes to complete. Included with the questionnaire was a consent form that detailed the purpose of the study as well as risks and benefits of participating. Participants received a $20 gift card as compensation for their time. To maximize response rate, patients who did not return the questionnaire via the mail were called a maximum of 10 times, which served as a reminder to complete the questionnaire or to answer any questions regarding the questionnaire content. Individuals also had the opportunity to have the questionnaire administered over the phone at that time, or at a more convenient time.

With the exception of injury diagnoses, all data presented were collected from the ques-
tionnaire. Occupations were classified based on the BLS Occupational Classification System. Individuals with multiple injuries during the study period were eligible for participation for each injury, which was treated as distinct.

Statistical Analysis

The statistical analysis followed standard methods for case-crossover studies including both the pair-matched interval and the usual frequency approaches. Data for the pair-matched analysis were derived from exposure information collected during the hazard period, defined as up to 10 minutes prior to the injury, and during the control period, defined as the 10 minute window at the same time of day as the injury but on the previous work-day. Conditional logistic regression was used to estimate odds ratios (ORs) and 95% confidence intervals (95% CI).

The usual frequency approach follows the method for stratified analyses using the Mantel-Haenszel estimator for person-time data wherein the individual subjects are the stratifying variables. Exposure information for analysis was identical for the hazard period, and the amount of person-time exposed and not exposed during the prior work-month was estimated from the reported usual frequency of exposure. Incident rate ratios (IRRs) of the observed frequency of exposure during the hazard period were compared to the usual exposure frequency. In general, the usual frequency approach has been shown to have greater statistical efficiency in the analysis of case-crossover data when the effect of within-person confounding is negligible, which results in less variance.
**Results**

During the study period, 3,447 eye injuries were treated in the emergency department, of which 2,723 (79%) were among patients aged under 19 years or were not work-related. Among the remaining 724 injuries potentially eligible for participation, 46 (6%) refused and 477 (66%) did not respond to either mail or phone calls, thus their eligibility was unknown. A total of 201 eligible injuries (28%), among 198 patients, participated in the study. Assuming all 477 non-responding injuries were eligible and simply refused to participate, comparisons yielded statistically significant differences between the sex and racial/ethnicity of respondents and non-respondents. Respondents were more likely to be female (15.4% vs. 9.8%, p=0.02) than non-respondents. The racial distribution was such that Caucasians (79.1% vs. 68.2%) were more likely to respond, while African Americans (16.9% vs. 19.8%) and other racial groups (4.0% vs. 12.0%) were less likely to respond (p=0.003).

The mean age among the respondents was 38.0 years and most were between 25-45 years (58.2%) (Table 1). One hundred and seventeen respondents were male (84.6%). More respondents were Caucasian (79.1%) than African-American (16.9%) and other races (4.0%). The most often observed Major Occupational Group (BLS) was Precision Production, Craft, and Repair, representing 56.2% of all injuries. Respondents tended to have been working at their current job between 1 and 5 years (48.3%) at the time of their injury. The largest number of participants worked in companies with 11-50 employees (34.3%) and the smallest number were self-employed (12.4%) Among respondents whose employer conducted safety meetings, the most common frequency was monthly (23.9%), and 22.9% replied they never had safety meetings. Approximately half of those injured
had experienced a prior work-related injury (44.8%), 48.3% of whom had previously experienced an eye injury at work. Figure 1 presents the frequency of the measured exposures during the hazard and control periods. It is important to note that due to the matched nature of the study design these frequencies do not represent measures of relative risk. Use of tools represented the most common exposure, both in the case and control periods with 80% of the study population using a tool in the case period and 65% during the control period.

The diagnoses of respondents are shown in Table 2. Foreign body and superficial injuries (i.e., corneal abrasions) were the most common among respondent diagnoses, accounting for a combined 53% of all injuries.

Measures of association between transient risk factors and work-related eye injury are shown in Table 3. Protective eyewear was observed to have a protective IRR of 0.5 (95% CI 0.4, 0.7). The largest effect was observed for being distracted, which was associated with an over 12-fold increase in the incidence rate of injury (95% CI 6.9, 23.2). Use of tools, tool malfunction, being rushed, working overtime, and feeling fatigued were observed to have statistically significant IRRs of 2.6 or greater. Although lesser in magnitude than other observed risk factors, performing an unfamiliar task was associated with an 80% increased incidence rate of injury of (95% CI 1.6, 2.1). In all, the IRRs indicated statistically significant associations for all but one exposure tested, but significant ORs were observed only for the use of tools. No other exposures were significantly associated when evaluated using the pair-matched approach. Furthermore, distraction had an infinite OR as there were no control periods wherein workers reported being distracted.
Discussion

Although scientific literature offers scant evidence regarding modifiable risk factors of occupational eye injuries, they are generally assumed to be highly preventable. Surprisingly, it is largely unknown to what extent protective eyewear can reduce the rate of eye injuries among workers. Among workers with eye injuries, proper use of appropriate safety equipment is relatively infrequent, considering the OSHA standards requiring use of eye protection.\textsuperscript{16,17} Still, the BLS estimates as many as 60\% of workers with eye injuries in the U.S. fail to wear proper eye protection.\textsuperscript{18} The current study observed a reduction in the incidence rate of eye injury by 50\% among workers wearing eye protection compared to those not. Although the corresponding unadjusted OR was not statistically significant, the magnitude was comparable. Both findings are consistent with the results from a Taiwanese study, which indicated a 60\% reduced odds of eye injury associated with the use of eye protection devices.\textsuperscript{7}

The use of tools was the most consistent exposure observed, with similar associations as measured both by the IRR and OR; both of which were statistically significant. Chen et al.\textsuperscript{7} did not directly evaluate this exposure, but reported “unskilled” operation of tools or equipment as a risk factor with a 48-fold increase in the odds of injury. Similarly, performing an “unusual task,” which was defined as a task that was performed on less than 1 day per work-week, was also associated with increased risk of eye injury. McGwin et al.\textsuperscript{19} has observed this association among general occupational injuries, and has been observed in studies of occupational hand injuries\textsuperscript{10,13,20} as well as by Chen et al.\textsuperscript{7} for occupational eye injuries. Working overtime also was observed to have a nearly 3-fold increase in eye injury risk. Although it has not previously been evaluated with respect to
eye injuries, shift length and hours worked per week have been implicated as risk factors in other types of occupational injuries, including those among healthcare workers\textsuperscript{11,21,22} and manufacturing occupations.\textsuperscript{14} Epidemiologic evidence continues to support the notion that extended working hours per week can increase injury among some occupations. In this study, in which respondents were primarily working in fields requiring a high degree of manual dexterity, it is unclear the specific mechanism by which overtime work increases injury risk. However, taken with the observed association of fatigue and eye injury, working overtime may be a marker of fatigue, which is the underlying risk factor.

Features of the work environment may not be the only risk factor of injury. Risk factors related to the worker, such as being distracted, rushed, or fatigued which have been shown as increasing the risk of occupational injuries,\textsuperscript{10,13,19} including eye injuries.\textsuperscript{7} Being distracted represented a strong risk factor in the current study, increasing the risk of injury 12-fold. Although fatigue was shown to affect injury risk, the associations with sleep duration were not statistically significant. Questions about sleep duration were intuitive, but required quantification of the number of hours of sleep the night prior to injury whereas fatigue was a binary response. The question structure for sleep could be more vulnerable to recall bias such that remembering hours of sleep in the specified hazard period could be more difficult than the usual sleep, as the injury could be a marker to better remember sleep deficit. If respondents were unable to recall an actual sleep deficiency in the hazard period, they may self-impute their normal sleep time. Such a response would bias the association of sleep and injury toward the null. The effects of sleep duration increasing the risk of occupational injury are well documented.\textsuperscript{11,21-28} However, evaluating the role of sleepiness or sleep duration in observational studies, including the
case-crossover design, have proven challenging. Self-reported sleep information has limitations, as subjects may overestimate their actual sleep duration. Thus, evidence would suggest an association between sleep duration and risk of eye injuries, but it is unclear if such a relationship exists and could not be measured by the current. Further studies could focus on sleep duration with more detailed methods to measure the exposure to better evaluate this association.

Two approaches to analyzing case-crossover data are presented in this study. The improved statistical efficiency of the usual frequency approach is an advantage because of the larger amount of exposure data. Recall bias due to fading memory is likely to be less of an impact with this method of data collection, as it does not require exposure information from a precise timeframe not tied to any event. For instance, it may be easier for a respondent to quantify their use of protective eyewear over a month rather than at a given moment a few days in the past. However, within-person confounding is impractical to assess when using the usual frequency approach due to the awkward line of questions that would be required (e.g., “In the past month, how often did you wear eye protection while you were distracted at work?”). Although, the pair-matched interval approach is more amenable to control for this type of information bias, the lack of sufficient sample size did not allow for it to be controlled for in this analysis.

The results of this study must be interpreted in light of some limitations. Case-crossover studies have the advantage of controlling for time-invariant confounding within subjects, such as age, sex, race, occupation, and socioeconomic status. Although respondents “self-selected” themselves for inclusion into the study (questionnaires were sent to patients with eye injuries that may not have been work-related), it is unlikely individuals
would have completed the questionnaire for injuries not work-related because the question-naire and accompanying letter stated the intentions of the study clearly. All data was gathered from self-reported responses among patients of confirmed eye injuries, but the exposure information could not be validated; any means of doing so through contacting co-workers or employers would be unethical, as it could result in risks to the respondents’ employment.

Two types of misclassification bias have been identified as limitations of case-crossover studies. First, poor recollection as memory fades over time could result in misreporting of exposure information that might be differential between the control period and hazard period. As previously stated, the usual frequency approach would minimize this effect, by giving a larger control window, rather than a single point not tied to an event. If underreporting of exposure during the control period occurred due to recall, the results would be biased away from the null. Steps to minimize recall bias included sending questionnaires the business day following the injury as well as providing open-ended response questions early in the questionnaire. Studies have been able to validate responses within four days of the event. 13,32 Moeller et al. 32 has also demonstrated recall bias was not a threat to validity in their case-crossover study of triggers of attacks of Ménière’s disease, where individuals were aware of their disease and the potential risk factors for attack. If respondents reported exposures during the hazard period that were not directly involved in the injury, this could bias results away from the null. However, questions were structured so as the respondent was asked about exposures that were within a short period (not more than 10 minutes) surrounding their injury. Thus by minimizing the length of the hazard periods, which were assumed to be relatively discrete points
in time, this attempted to limit the influence of multiple exposures unrelated to the eye injury.

**Conclusion**

Prevention of occupational eye injuries should first be accomplished by improving the proper use of protective eyewear, which has been shown to reduce the risk of injury. Reasons for not wearing eye protection have been studied elsewhere and were beyond the scope of this study. Other prevention strategies should incorporate the risk factors identified herein, including better understanding their presence in the workplace. Educating employers and employees about the risk factors as well as the consequences of eye injuries is also important.
References


4. Forrest KYZ, Cali JM. Epidemiology of lifetime work-related eye injuries in the U.S. population associated with one or more lost days of work. *Ophthalmic Epidemiol.* 2009;16(3):156-162.


Table 1. Demographic characteristics of 201 respondents with work-related eye injuries.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
</tr>
<tr>
<td>&lt; 25 years</td>
<td>32 (15.9)</td>
</tr>
<tr>
<td>25 – 45 years</td>
<td>117 (58.2)</td>
</tr>
<tr>
<td>46 – 65 years</td>
<td>49 (24.4)</td>
</tr>
<tr>
<td>≥ 66 years</td>
<td>3 (1.5)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>170 (84.6)</td>
</tr>
<tr>
<td>Female</td>
<td>31 (15.4)</td>
</tr>
<tr>
<td><strong>Race/ethnicity</strong></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>159 (79.1)</td>
</tr>
<tr>
<td>African American</td>
<td>34 (16.9)</td>
</tr>
<tr>
<td>Other</td>
<td>8 (4.0)</td>
</tr>
<tr>
<td><strong>Number of jobs</strong></td>
<td></td>
</tr>
<tr>
<td>Single job</td>
<td>184 (91.5)</td>
</tr>
<tr>
<td>Multiple</td>
<td>17 (8.5)</td>
</tr>
<tr>
<td><strong>Major Occupational Group</strong></td>
<td></td>
</tr>
<tr>
<td>Precision Production, Craft, &amp; Repair</td>
<td>113 (56.2)</td>
</tr>
<tr>
<td>Machine Operators, Assemblers, &amp; Inspectors</td>
<td>33 (16.4)</td>
</tr>
<tr>
<td>Service, Except Private Household</td>
<td>17 (8.5)</td>
</tr>
<tr>
<td>Handlers, Equipment Cleaners, Helpers, &amp; Laborers</td>
<td>15 (7.5)</td>
</tr>
<tr>
<td>Professional, Technical &amp; Related</td>
<td>11 (5.4)</td>
</tr>
<tr>
<td>Others</td>
<td>12 (6.0)</td>
</tr>
<tr>
<td><strong>Job experience</strong></td>
<td></td>
</tr>
<tr>
<td>&lt; 1 year</td>
<td>33 (16.4)</td>
</tr>
<tr>
<td>1 – 5 years</td>
<td>97 (48.3)</td>
</tr>
<tr>
<td>&gt; 5 years</td>
<td>71 (35.3)</td>
</tr>
<tr>
<td><strong>Scale of employment</strong></td>
<td></td>
</tr>
<tr>
<td>Self-employed</td>
<td>25 (12.4)</td>
</tr>
<tr>
<td>2-10 workers</td>
<td>47 (23.4)</td>
</tr>
<tr>
<td>11-50 workers</td>
<td>69 (34.3)</td>
</tr>
<tr>
<td>&gt; 51 workers</td>
<td>57 (28.4)</td>
</tr>
<tr>
<td>Unknown</td>
<td>3 (1.5)</td>
</tr>
<tr>
<td><strong>Frequency of employer-conducted safety meetings</strong></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>46 (22.9)</td>
</tr>
<tr>
<td>Every day</td>
<td>20 (9.9)</td>
</tr>
<tr>
<td>Weekly</td>
<td>39 (19.4)</td>
</tr>
<tr>
<td>Monthly</td>
<td>48 (23.9)</td>
</tr>
<tr>
<td>Yearly</td>
<td>31 (15.4)</td>
</tr>
<tr>
<td>Other</td>
<td>5 (2.5)</td>
</tr>
<tr>
<td>Don’t know / Refused to answer</td>
<td>12 (6.0)</td>
</tr>
<tr>
<td><strong>Prior work-related injury</strong></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>112 (55.7)</td>
</tr>
<tr>
<td>Any</td>
<td>89 (44.3)</td>
</tr>
<tr>
<td>Injury to the eye (among those injured)</td>
<td>43 (48.3)</td>
</tr>
</tbody>
</table>

*For those with multiple occupations, the job with the most hours reported was used.
Table 2. All primary and secondary ICD 9 CM diagnoses among respondents.

<table>
<thead>
<tr>
<th>ICD9CM Code</th>
<th>Description</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>930</td>
<td>Foreign body on external eye</td>
<td>90 (33.3)</td>
</tr>
<tr>
<td>918</td>
<td>Superficial injury of eye and adnexa</td>
<td>53 (19.6)</td>
</tr>
<tr>
<td>370</td>
<td>Keratitis</td>
<td>28 (10.4)</td>
</tr>
<tr>
<td>940</td>
<td>Burn confined to eye and adnexa</td>
<td>19 ( 7.0)</td>
</tr>
<tr>
<td>921</td>
<td>Contusion of eye and adnexa</td>
<td>16 ( 5.9)</td>
</tr>
<tr>
<td>379</td>
<td>Other disorders of eye</td>
<td>14 ( 5.2)</td>
</tr>
<tr>
<td>372</td>
<td>Disorders of conjunctiva</td>
<td>9 ( 3.3)</td>
</tr>
<tr>
<td>364</td>
<td>Disorders of iris and ciliary body</td>
<td>8 ( 3.0)</td>
</tr>
<tr>
<td>871</td>
<td>Open wound of eyeball</td>
<td>8 ( 3.0)</td>
</tr>
<tr>
<td>371</td>
<td>Corneal opacity and other disorders of cornea</td>
<td>4 ( 1.5)</td>
</tr>
<tr>
<td>870</td>
<td>Open wound of ocular adnexa</td>
<td>3 ( 1.1)</td>
</tr>
<tr>
<td>Other</td>
<td>All other diagnoses codes</td>
<td>18 ( 6.7)</td>
</tr>
</tbody>
</table>
Table 3. Associations of transient exposures to work-related eye injuries using incidence rate ratios (IRRs) and odds ratios (ORs).

<table>
<thead>
<tr>
<th>Exposure</th>
<th>IRR</th>
<th>p</th>
<th>OR</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of protective eyewear (N=200)</td>
<td>0.5 (0.4, 0.7)</td>
<td>&lt;0.001</td>
<td>0.6 (0.3, 1.4)</td>
<td>0.244</td>
</tr>
<tr>
<td>Use of tools, machines, other work material (N=196)</td>
<td>3.9 (3.0, 4.9)</td>
<td>&lt;0.001</td>
<td>3.0 (1.7, 5.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Use of a malfunctioning tool (N=192)</td>
<td>2.6 (1.5, 4.5)</td>
<td>&lt;0.001</td>
<td>6.0 (0.7, 49.8)</td>
<td>0.10</td>
</tr>
<tr>
<td>Performing an unfamiliar task (N=196) †</td>
<td>1.8 (1.6, 2.1)</td>
<td>&lt;0.001</td>
<td>6.0 (0.7, 49.8)</td>
<td>0.10</td>
</tr>
<tr>
<td>Feeling distracted (N=194)</td>
<td>12.7 (6.9, 23.2)</td>
<td>&lt;0.001</td>
<td>inf.</td>
<td>0.002</td>
</tr>
<tr>
<td>Being rushed (N=199)</td>
<td>3.8 (2.4, 5.9)</td>
<td>&lt;0.001</td>
<td>2.8 (0.9, 8.6)</td>
<td>0.08</td>
</tr>
<tr>
<td>Working overtime (N=194)</td>
<td>2.9 (1.9, 4.4)</td>
<td>&lt;0.001</td>
<td>3.0 (0.9, 9.3)</td>
<td>0.06</td>
</tr>
<tr>
<td>Feeling sick (N=190)</td>
<td>1.6 (0.6, 4.2)</td>
<td>0.30</td>
<td>1.5 (0.3, 9.0)</td>
<td>0.66</td>
</tr>
<tr>
<td>Fatigue (N=194)</td>
<td>3.1 (1.8, 5.4)</td>
<td>&lt;0.001</td>
<td>1.0 (0.3, 3.5)</td>
<td>1.00</td>
</tr>
<tr>
<td>Inadequate sleep (≤6 hrs) (N=174) †</td>
<td>--</td>
<td>--</td>
<td>1.5 (0.6, 3.7)</td>
<td>0.28</td>
</tr>
<tr>
<td>Excessive sleep (≥8 hrs) (N=174) †</td>
<td>--</td>
<td>--</td>
<td>1.3 (0.3, 4.7)</td>
<td>0.74</td>
</tr>
</tbody>
</table>

†Exposure information did not permit calculation of unusual task ORs, or sleep duration IRRs.
Figure 1. Exposure prevalence during the control and injury periods.
CHANGES IN EYE PROTECTION HABITS FOLLOWING AN OCCUPATIONAL EYE INJURY

by

JUSTIN BLACKBURN, EMILY B. LEVITAN, PAUL MACLENNAN, CYNTHIA OWSLEY, GERALD MCGWIN, JR

In preparation for *Accident Analysis and Prevention*

Format adapted for dissertation
Abstract

Objective: To evaluate whether workers modify their eye protection behavior following an occupational eye injury.

Methods: Patients treated for a work-related eye injury were questioned regarding the use of protective eyewear for the work-month prior to their eye injury and again for a work-month period 6-12 months later.

Results: Overall, workers reported an increase in the proportion of work-time spent using eye protection from a median of 20% to 100% (p<0.001). The effect appeared to be primarily driven by whether eye protection was used at the time of eye injury. Most respondents (66%) indicated they were more likely to use eye protection since their injury.

Conclusions: Workers not using eye protection while sustaining an occupational eye injury are more likely to use eye protection in the future. A variety of factors related to the individual or employer may influence this change. Even as many workers may change behavior on their own, clinician’s could make use of the teachable moment when treated occupational eye injuries to encourage increasing use or more appropriate forms of eye protection.
1. Introduction

Eye injuries affect approximately 2 million Americans annually (McGwin, Xie and Owsley, 2005). An estimated 280,000 non-fatal work-related eye injuries are treated each year in emergency rooms nationwide (Xiang et al., 2005). Nearly 28,000 eye injuries will result in two or more days of missed work each year according to the Bureau of Labor Statistics (BLS, 2009). Preventing eye injuries, particularly occupational, remains an area in need of further research as interventions, including the use of protective eyewear, have been under-evaluated (Lipscomb, 2000). To date, only limited evidence suggests that protective eyewear is successful in preventing occupational eye injuries (Chen et al., 2009); however a link between the absence of protected eyewear and occupational eye injuries requiring medical attention has been shown (Fong and Taouk, 1995; Ho et al., 2008). Despite this, occupational eye injuries and lost work time due to injuries are considered to be highly preventable through the use of eye protection (Lombardi, 2000; OSHA, 1991).

The evidence that injury is a risk factor for subsequent injury is equivocal (Hamilton et al., 2011), but occupational eye injuries tend to reoccur among individuals and may be highly dependent on type of occupation. Previous eye injury has been found predictive of subsequent eye injury among steelworkers (Schoemaker et al., 2000), carpenters (Lipscomb et al., 1999), military personnel (Ward and Gorie, 1991), and workers in general (de la Hunty and Sprivulis, 1994).

The extent with which an injury event can trigger a change in behavior has not been well-established, and no evidence currently exists with respect to occupational eye injuries. A better understanding of the factors which influence safety-related behavior
change (or fail to incite change) in light of an eye injury can be used to improve eye injury prevention efforts. For example, physician contact following injury may be an opportunity to capitalize on the “teachable moment” concept. This has been advocated for physicians to encourage several health behaviors such as tobacco cessation, seatbelt and helmet use, dangerous driving, binge drinking, and reducing violence (Cummings et al, 2006; Ekeh et al, 2008; Gittelman et al, 2008; Horn et al, 2007; Johnston et al, 2002; Mangus et al, 2004; Neuner et al, 2009).

This study evaluated whether an eye injury is a compelling event to change a person’s habits with respect to wearing eye protection. A cohort of patients with medically-treated occupational eye injuries were asked to quantify their eye protection habits prior to, at the time of, and a period from six to twelve months following, an eye injury.

2. Methods

2.1 Study Population

The study base for this cohort study was patients at least 19 years of age and older seeking care at the Callahan Eye Foundation Hospital (CEFH) emergency department for eye injuries sustained during work-related activities from August 2008 through September 2010. The CEFH serves patients primarily in Jefferson County, Alabama but is the only 24-hour eye emergency room in the state. The CEFH emergency department evaluates approximately 400 patients per month, of which 36% are for injury. Between August 2008 and September 2010, a total of 198 patients completed a questionnaire following 201 work-related eye injuries and were re-contacted between September 2009 and December 2010.
2.2 Data Collection

Study participants were identified through daily review of medical records from the previous day in order to determine injury-related emergency department (ED) visits resulting from occupational activities. Eye injuries were broadly defined as any condition resulting from trauma to the eye or ocular adnexa. Identification of such injuries was determined in part through the interpretation of the treating ophthalmologist’s notes as well as the billing diagnoses. This included ICD-9-CM codes 802.6 and 802.7 (orbital floor fractures); 870.0 to 870.9 (open wounds of the ocular adnexa); 871.0 to 871.9 (open wounds of the eyeball); 918.0 to 918.9 (superficial wound of the eye and adnexa); 921.0 to 921.9 (contusion of the eye and adnexa); 930.0 to 930.9 (foreign body on the external eye); 940.0 to 940.9 (burn confined to the eye and adnexa); 941.02 to 941.52 (burn involving the eye with other parts of the face, head, and neck); 950.0 to 950.9 (injury to the optic nerve and pathways); and 951.0, 951.1, and 951.3 (injury to the oculomotor, trochlear, and abducens nerves). In some situations, other diagnoses were included if other information from the ophthalmologist’s notes indicated a injury was likely, such as keratitis (370), as well as other disorders of the eye (379), conjunctiva (372), or iris and ciliary body (364).

The determination of work status during the time of the injury was made by reviewing the ophthalmologists’ and nurses’ notes, whether workman’s compensation was filed, and by contacting the patient directly. A brief, 20-minute questionnaire was mailed to all patients meeting age requirements for which the injury was clearly work-related or if unknown whether the injury occurred at work or not. Demographic data, including occupational characteristics, was collected at baseline from the patient’s responses. Occupa-
tion was classified based on the Bureau of Labor Statistics (BLS) Occupational Classification System.

Approximately six months to one year following their injury, responding patients were contacted again by telephone and asked a brief set of questions covering current eye protection habits, likelihood of eye protection use given the previous injury, current use of eye protection during similar tasks as to when their eye injury occurred, and changes to employer requirements regarding protective eyewear. The period between questioning varied based on the ability to re-contact the initial respondents. Participants reporting no change or less likely to use eye protection since their eye injury were asked to describe why their behavior has not changed.

2.3 Statistical Analysis

For each individual, the usual frequency of eye protection was calculated as the proportion of time using eye protection while at work. The numerator was the amount of time using eye protection over the past work-month (in minutes), derived from questions asking the frequency and duration of use (i.e., “On how many days did you wear eye protection,” and “When you wore eye protection, for how long did you wear it?”). The denominator was the total minutes worked in the previous month. This proportion was calculated for the period during the work-month prior to injury and the work-month 6-12 months after injury. To account for data which were skewed towards proportions of 0 and 100%, the Wilcoxon signed rank test was used to test the null hypothesis that an eye injury did not change the usual frequency of eye protection use. If respondents changed jobs or were no longer employed, they were excluded from analysis.
3. Results

During the enrollment period between August 2008 and September 2010, an attempt was made to contact patients with 1,101 potentially work-related eye injuries, identified through the ED. Of those, 377 (34%) were confirmed to not be work-related, leaving 724 eye injuries of which 46 refused (6%), 477 (66%) could not be contacted, and 201 (28%) responded. Among 201 responses to the initial questionnaire, a total of 77 (38.3%) responded to the second questionnaire (hereafter “respondents”) and had information on eye protection use prior to their eye injury as well as in the period after their eye injury. An additional 23 (11.4%) respondents were successfully re-contacted, but were unemployed or had switched jobs and thus were excluded. Age, sex, and race/ethnicity comparisons between 77 respondents and 124 non-respondents were similar, with the exception that African Americans were underrepresented (p=0.0144) (Table 1). The most common age group was 25-45 years (59.7%), most respondents were male (80.5%) and Caucasian (89.6%). Precision production, craft, and repair were the most commonly represented Major Occupational Group using the BLS system (54.5%). Most respondents were at their job between 1-5 years (44.2%) with a scale of employment of either 11-50 (29.9%) or > 51 employees (29.9%). Over half of respondents (52%) indicated they were wearing eye protection at the time of their eye injury. The most common injuries observed among respondents were corneal foreign body (26.7%) and corneal abrasion (23.7%) (Table 2).

The median proportion of work-time spent wearing protection among respondents prior to their injury was 20% (Table 3). In the period after their eye injury, the frequency of eye protection use increased to a median of 100% of work-time (p<0.0001). This
change was modified by whether or not eye protection was recorded as being worn at the
time of eye injury. Those wearing eye protection at the time of eye injury reported nearly
universal use, with a median proportion of 100%. There was no change in the median
among this group. Respondents stating they were not wearing eye protection during their
eye injury were not likely to usually wear eye protection during work, with a median pro-
portion of work time at 0%. The proportion of work-time using eye protection among this
group increased to 3%, which was statistically significant (p<0.0001).

Overall, respondents self-reported they were more likely to wear eye protection
following their injury (66.2%), while 32.5% indicated no change in their eye protection
habits (Table 4). Most respondents indicated they currently “always” use eye protection
when performing a task similar to that by which they were performing when they sus-
tained their eye injury (Table 4). A stronger likelihood of always wearing eye protection
for a similar task was observed among those who were using eye protection during their
eye injury (87.5%) versus those who were not (56.8%). Regardless of eye protection sta-
tus at time of injury, 25 respondents indicated they did not make any changes and 1 res-
pondent less likely to wear eye protection since eye injury, the primary reason given was
they were in the already in habit of wearing them (69.2%), followed by no perceived
need for eye protection (19.2%) (Table 5). Employer-initiated eye protection policy
change to introduce eye protection requirements or increase enforcement of existing re-
quirements was reported by 25 respondents (32.4%) occurring in the time since their in-
jury (not shown). Employer policy change was not different for respondents based on
their use during their eye injury.
4. Discussion

The experience of an eye injury appears to provide an impetus to produce changes in the use of eye protection that persists for months after the injury. The precise reasons for this change require additional investigation, as maintaining eye protection habits may be related to a variety of factors including the work environment or the individual themselves. Specific factors such as employer policy, worker age, and comfort/fit of protective eyewear have previously been identified as relating to eye protection use (Lombardi et al., 2009). Several other factors may influence the use of eye protection such as fear of irreversible vision loss, pain, temporary disability, costs associated with treatment, and attitudes towards the perceived need for eye protection.

Eye injuries, despite being mostly minor, are costly in terms of healthcare expenses, missed workdays, and potential disability (Islam et al., 2000; Welch et al., 2001). Although this study finds that an eye injury may lead to increases in the use of eye protection among some workers, it does not diminish the need for primary prevention. Rather, the results are only generalizable to workers able to return to work following an eye injury, and thus given “a second chance” to prevent a more serious eye injury. Additional opportunities to encourage more appropriate or correct use of eye protection could exist in the clinical setting through counseling and education following an eye injury. While an increase in the use of protective eyewear was observed among those not wearing eyewear during their injury, the rate of use among this group still remained relatively low. It is presumed that ophthalmologists treating patients in the emergency department do provide some form of counseling or encouragement to wear eye protection in the future by utilizing the “teachable moment,” but a structured intervention was not in place during the
study period. Such an intervention may be able to capitalize on the willingness to change following and injury that was observed in this study and result in greater and more appropriate use of eye protection.

Few prospective studies have investigated behavior changes following an injury. Seat belt use following a motor vehicle collision was shown to increase from 54% to 85% a year following the crash (Passman et al., 2001). Among children hospitalized for a bicycle related injury, only modest gains in helmet use were observed after discharge, with 75% continuing to ride without protective headwear (Nakayma, Pasieka, & Gardner, 1990). With respect to eye injuries, evidence from cross-sectional studies have shown that previous eye injury is predictive of current use of protective eyewear among squash and women’s lacrosse players (Eime et al., 2005; Waicus and Smith, 2002). Despite the differences that may exist in to the readiness to change behavior among these populations previously studied, the effects are consistent with the findings of this study.

Of note was the high proportion of respondents wearing eye protection at the time of their injury. The BLS has previously reported that 60% of occupational eye injuries occur among workers not using eye protection (BLS, 1999). Approximately half of the participants in this study (including those responding only to the first questionnaire) self-reported wearing eye protection during their injury. This group of respondents did not indicate a decline in use of eye protection after their injury, despite ineffectiveness in preventing their eye injury. Thus, the motivation to wear eye protection was seemingly not diminished as behaviors were maintained. However, it is unclear from the collected information whether or not the most appropriate eye protection was being used, and whether improper use may have contributed to injury. Nor is it clear to what extent eye
protection may have mitigated the severity of eye injury. Not only should primary prevention efforts aim to promote universal use of eye protection, but should focus on educating individuals about appropriate types of protective eyewear. Although the findings of this study suggests individuals are likely to improve their overall use of eye protection following an eye injury with no intervention, utilizing clinician-based counseling to promote not only use, but the appropriate use, of protective eyewear could be effective.

In an occupational setting, the behavior changes with respect to protective eyewear are not only strictly at the worker’s own volition. Among workers in this study, approximately one-third of respondents indicated their employer had initiated policy changes since their eye injury. Employer policy has previously been identified as an effective means to prevent occupational eye injuries (Lipscomb, 2000; Lombardi, 2009). Opportunities to encourage employers to improve eye injury prevention exist prior to an eye injury by addressing the associated human capital and economic costs, as well as presenting known modifiable risk factors.

The results of this study must be interpreted in light of some limitations. A quarter of the responses obtained were unemployed or had changed jobs and were excluded. In one case, this was directly related to the eye injury, which had prevented the respondent from returning to work. Therefore the results should only be interpreted for injured workers that were able to return to work. In addition to those responses that were excluded, half of the cohort was lost to follow-up before answering the second questionnaire. As a potential source of selection bias, differences between respondents and non-respondents were not observed among age or gender. However, if African Americans, who were underrepresented, are less likely to modify their behavior following an injury, the results
could be biased upward. There is evidence to suggest African Americans may be less likely to wear eye protection at work (Forrest, Cali, and Cavill, 2008), but nothing among the limited studies of behavioral changes following injury suggests a differential effect by race or ethnicity (Eime et al., 2005; Passman et al., 2001; Waicus and Smith, 2002). The extent with which the contact with respondents during the initial survey following their eye injury influenced their behavior is not clear, but cannot be ignored. Respondents were informed after the initial questionnaire that they would be contacted again, but the nature of the follow-up questions were not specified and no educational information was presented to respondents. Questions were designed only to collect objective responses to questions about eye protection habits. Similarly, the extent with which respondents experienced interventions directed toward improving eye protection use, whether as part of worksite or other exogenous sources, was unknown and could have influenced the results. It is possible that staff treating the patients gave some form of counseling on eye protection, but no standard or structured intervention is currently in place at the CEFH. Self-report data could be subject to recall bias or overestimation, as has been shown in a previous study of occupational exposures (Eime et al., 2005), but it is not known how it may affect reporting of eye protection. As respondents were compared to their own baseline use, it is unlikely that either recall or overestimation would be differential between the pre-injury and post-injury periods for a given individual.

This study highlights the changes workers undergo in their safety behavior habits following an eye injury. The results may suggest a readiness to change safety behaviors by workers previously not using eye protection. It is clear that prevention should occur before any eye injury occurs, but clinicians can build upon the teachable moment of an
eye injury to encourage the use of eye protection, or educate on appropriate types protection given the nature of the worker’s occupation. Understanding specific factors which drive the observed increase in eye protection use following an eye injury can enhance primary prevention efforts. Employer policy and perceived need of eye protection appear to be important factors. Although beyond the scope of the current study, future research should investigate the extent with which a worker with an eye injury can influence the eye protection habits of non-injured co-workers.
References


Occupational Safety & Health Administration (OSHA). Eye protection in the workplace. Fact Sheet No. OSHA 93-03. 1993.


Table 1. Demographic characteristics of respondents compared to non-respondents.

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Respondents N = 77</th>
<th>Non-respondents N = 124</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td>0.3890</td>
</tr>
<tr>
<td>&lt; 25 years</td>
<td>10 (13.0)</td>
<td>22 (17.7)</td>
<td></td>
</tr>
<tr>
<td>25 – 45 years</td>
<td>46 (59.7)</td>
<td>71 (57.3)</td>
<td></td>
</tr>
<tr>
<td>46 – 65 years</td>
<td>21 (27.3)</td>
<td>19 (22.6)</td>
<td></td>
</tr>
<tr>
<td>≥ 66 years</td>
<td>0 ( 0.0)</td>
<td>3 ( 2.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td>0.2094</td>
</tr>
<tr>
<td>Male</td>
<td>62 (80.5)</td>
<td>108 (87.1)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>15 (19.5)</td>
<td>16 (12.9)</td>
<td></td>
</tr>
<tr>
<td><strong>Race/Ethnicity</strong></td>
<td></td>
<td></td>
<td>0.0144</td>
</tr>
<tr>
<td>Caucasian</td>
<td>69 (89.6)</td>
<td>90 (72.6)</td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>6 ( 7.8)</td>
<td>28 (22.6)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>2 ( 2.6)</td>
<td>6 ( 4.8)</td>
<td></td>
</tr>
<tr>
<td><strong>Major Occupational Groupa</strong></td>
<td></td>
<td></td>
<td>0.0545</td>
</tr>
<tr>
<td>Precision Production, Craft,</td>
<td>42 (54.5)</td>
<td>71 (57.3)</td>
<td></td>
</tr>
<tr>
<td>&amp; Repair</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine Operators, Assemblers,</td>
<td>9 (11.7)</td>
<td>24 (19.4)</td>
<td></td>
</tr>
<tr>
<td>&amp; Inspectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service, Except Private</td>
<td>4 ( 5.2)</td>
<td>13 (10.5)</td>
<td></td>
</tr>
<tr>
<td>Household</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handlers, Equipment Cleaners,</td>
<td>7 ( 9.1)</td>
<td>8 ( 6.4)</td>
<td></td>
</tr>
<tr>
<td>Helpers, &amp; Laborers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional, Technical &amp;</td>
<td>7 ( 9.1)</td>
<td>4 ( 3.2)</td>
<td></td>
</tr>
<tr>
<td>Related</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>8 (10.4)</td>
<td>4 ( 3.2)</td>
<td></td>
</tr>
<tr>
<td><strong>Job experience</strong></td>
<td></td>
<td></td>
<td>0.6315</td>
</tr>
<tr>
<td>&lt; 1 year</td>
<td>13 (16.9)</td>
<td>20 (16.1)</td>
<td></td>
</tr>
<tr>
<td>1 – 5 years</td>
<td>34 (44.2)</td>
<td>63 (50.8)</td>
<td></td>
</tr>
<tr>
<td>&gt; 5 years</td>
<td>30 (38.9)</td>
<td>41 (33.1)</td>
<td></td>
</tr>
<tr>
<td><strong>Scale of employment</strong></td>
<td></td>
<td></td>
<td>0.8637</td>
</tr>
<tr>
<td>Self-employed</td>
<td>11 (14.3)</td>
<td>14 (11.3)</td>
<td></td>
</tr>
<tr>
<td>2-10 workers</td>
<td>19 (24.6)</td>
<td>28 (22.6)</td>
<td></td>
</tr>
<tr>
<td>11-50 workers</td>
<td>23 (29.9)</td>
<td>46 (37.1)</td>
<td></td>
</tr>
<tr>
<td>&gt; 51 workers</td>
<td>23 (29.9)</td>
<td>34 (27.4)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>1 ( 1.3)</td>
<td>2 ( 1.6)</td>
<td></td>
</tr>
<tr>
<td><strong>Used eye protection during</strong></td>
<td></td>
<td></td>
<td>0.6235</td>
</tr>
<tr>
<td>eye injury</td>
<td>40 (52.0)</td>
<td>60 (48.4)</td>
<td></td>
</tr>
</tbody>
</table>

aFor those with multiple occupations, the job with the most hours worked was used.
Table 2. All primary and secondary ICD 9 CM diagnoses among respondents.

<table>
<thead>
<tr>
<th>ICD9CM Code</th>
<th>Description</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>930</td>
<td>Foreign body on external eye</td>
<td>27 (26.7)</td>
</tr>
<tr>
<td>918</td>
<td>Superficial injury of eye and adnexa</td>
<td>24 (23.7)</td>
</tr>
<tr>
<td>370</td>
<td>Keratitis</td>
<td>13 (12.9)</td>
</tr>
<tr>
<td>379</td>
<td>Other disorders of eye</td>
<td>8 ( 7.9)</td>
</tr>
<tr>
<td>940</td>
<td>Burn confined to eye and adnexa</td>
<td>7 ( 6.9)</td>
</tr>
<tr>
<td>372</td>
<td>Disorders of conjunctiva</td>
<td>5 ( 5.0)</td>
</tr>
<tr>
<td>921</td>
<td>Contusion of eye and adnexa</td>
<td>5 ( 5.0)</td>
</tr>
<tr>
<td>871</td>
<td>Open wound of eyeball</td>
<td>2 ( 2.0)</td>
</tr>
<tr>
<td>Other</td>
<td>All other diagnoses codes</td>
<td>10 ( 9.9)</td>
</tr>
</tbody>
</table>
Table 3. Comparison of the median work-time wearing eye protection before and after injury, stratified by protective eyewear use during injury.

<table>
<thead>
<tr>
<th></th>
<th>Median use, prior to injury (%)</th>
<th>Median use, after injury (%)</th>
<th>Median difference (%)</th>
<th>p&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wearing during injury (N=40)</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>0.2314</td>
</tr>
<tr>
<td>Not wearing during injury (N=37)</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Total (N=77)</td>
<td>20</td>
<td>100</td>
<td>0</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

<sup>b</sup>Wilcoxon signed rank test.
Table 4. Likelihood and frequency of wearing eye protection since eye injury in general and when performing the same task as when the injury occurred.

<table>
<thead>
<tr>
<th>Eye protection use</th>
<th>Not wearing during injury N = 37 (%)</th>
<th>Wearing during injury N = 40 (%)</th>
<th>Total N = 77 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At work, since injury:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More likely</td>
<td>27 (73.0)</td>
<td>24 (60.0)</td>
<td>51 (66.2)</td>
</tr>
<tr>
<td>No change in likelihood</td>
<td>9 (24.3)</td>
<td>16 (40.0)</td>
<td>25 (32.5)</td>
</tr>
<tr>
<td>Less likely</td>
<td>1 ( 2.7)</td>
<td>0 ( 0.0)</td>
<td>1 ( 1.3)</td>
</tr>
<tr>
<td>When performing same task as when injured:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always</td>
<td>21 (56.8)</td>
<td>35 (87.5)</td>
<td>56 (72.7)</td>
</tr>
<tr>
<td>Most of the time</td>
<td>0 ( 0.0)</td>
<td>1 ( 2.5)</td>
<td>1 ( 1.3)</td>
</tr>
<tr>
<td>Some of the time</td>
<td>5 (13.5)</td>
<td>1 ( 2.5)</td>
<td>6 ( 7.8)</td>
</tr>
<tr>
<td>Never</td>
<td>9 (24.3)</td>
<td>1 ( 2.5)</td>
<td>10 (13.0)</td>
</tr>
<tr>
<td>Have not performed task since</td>
<td>2 ( 5.4)</td>
<td>2 ( 5.6)</td>
<td>4 ( 5.2)</td>
</tr>
</tbody>
</table>
Table 5. Reasons given for not changing eye protection habits among those not more likely to wear protective eyewear following their eye injury.

<table>
<thead>
<tr>
<th>Reason</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Already in the habit of wearing</td>
<td>18 (69.2)</td>
</tr>
<tr>
<td>No perceived need</td>
<td>5 (19.2)</td>
</tr>
<tr>
<td>Interferes with job</td>
<td>2 (7.7)</td>
</tr>
<tr>
<td>Does not like wearing</td>
<td>1 (3.9)</td>
</tr>
</tbody>
</table>
SUMMARY CONCLUSIONS

Eye injuries affect nearly 2 million Americans annually, and represent an important cause of blindness, missed days of work, and healthcare expenditures. The incidence of eye injuries is currently declining, which may be attributed to improvements in eye protection usage rates as well as Americans increasingly partaking in more passive leisurely activities. To continue to reduce the burden of eye injuries, further eye injury research to describe different etiologies, identify modifiable risk factors, and to evaluate aspects of eye protection use are warranted. This dissertation has sought to address each of the aforementioned aspects of eye injury research.

Thorough epidemiologic descriptions of chemical eye injuries are lacking from the scientific literature, with only case reports existing from the U.S. Of people with chemical eye injuries, little is known regarding the age and sex distributions as well as types of agents involved. However, chemical eye injuries have been identified as leading types of eye injuries among occupational eye injuries and eye injuries from consumer products. Therefore, a case series of chemical eye injuries was conducted spanning four years of emergency department records from a free-standing eye hospital, in what is the largest collection of information on chemical eye injuries to date. The findings indicated that cleaning agents, those containing bleach in particular, are the most common agent among chemical eye injuries. Demographic information of patients sustaining chemical eye injuries was found to have different patterns depending on the type of agent, as categorized logically by the intended use. For example, personal care products were the second-leading category of agent observed, and occurred most often among middle-aged women. A similar number of eye injuries were observed as a result of automotive chemi-
cal contact, but affected predominately middle-aged men. Most chemical eye injuries were not sight-threatening, as determined by the visual acuity of patients upon entrance to the emergency department. A subset of chemical eye injuries appeared to be the result of mistakenly identifying a product, the most common examples being use of cyanoacrylate glue (SuperGlue™), ear medication, and contact lens cleaner. These injuries may be directly related to product design, as the packaging is similar to various ophthalmic solutions, or insufficient labeling.

Protective eyewear has long been advocated as a way to prevent eye injuries. The Occupational Safety and Health Administration has estimated that 90% of eye injuries can be prevented by eye protection. However, observational studies have been surprisingly absent from the epidemiological literature until recently, while no study based in the U.S. has evaluated the association. Furthermore, identification of additional risk factors may elucidate other ways to reduce the occurrence of occupational eye injuries. Using a relatively recent epidemiological study design, the case-crossover study, patients with occupational eye injuries treated in the emergency department of a free-standing eye hospital were asked questions regarding transient exposures prior to and during their eye injury. The case-crossover study design is unique in that cases of eye injuries were matched to themselves during prior work days to eliminate the need of a non-injured control group. Protective eyewear was indeed observed to reduce the incidence of eye injuries (IRR 0.5, 95% CI 0.4 to 0.7), while other risk factors include: use of tools (IRR 3.9, 95% CI 3.0 to 4.9), tool malfunction (IRR 2.6, 95% CI 1.5 to 4.5), performing an unfamiliar task (IRR 1.8, 95% CI 1.6 to 2.1), being rushed (IRR 3.8, 95% CI 2.4 to 5.9), working overtime (IRR 2.9, 95% CI 1.9 to 4.4), and feeling fatigued (IRR 3.1, 95% CI 1.8 to 5.4).
Thus, while eye protection can significantly reduce occupational eye injuries, a more comprehensive prevention approach to address other risk factors should be considered.

It may seem as though after an eye injury occurs, the opportunity for prevention has passed. However, in the case of occupational eye injuries workers are often exposed to the same hazards following an eye injury as they were before the eye injury. Understanding to what extent a worker alters their behavior with respect to eye protection after sustaining an eye injury can improve upon prevention efforts. A cohort of workers treated for occupational eye injuries were asked at separate intervals to quantify their use of eye protection prior to and following their eye injury. Workers were observed to respond to an occupational eye injury by increasing the use of eye protection up to six to 12 months after the eye injury. However, this effect seemed to occur most among workers who did not wear eye protection during their eye injury, while those who did maintain the same habits. Newly implemented employer policies regarding the use of eye protection appeared to factor into this increase. To build upon the observed, a structured intervention by clinicians treating occupational eye injuries could be used to improve the appropriate use of eye protection.
GENERAL LIST OF REFERENCES


46. Forrest KYZ, Cali JM. Epidemiology of lifetime work-related eye injuries in the U.S. population associated with one or more lost days of work. Ophthalmic Epidemiol. 2009 Jun;16(3):156-162.


APPENDIX A
IRB APPROVAL
Form 4: IRB Approval Form
Identification and Certification of Research
Projects Involving Human Subjects

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federal Assurance with the Office for Human Research Protections (OHRP). The Assurance number is FWA00005960 and it expires on October 26, 2010. The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56 and ICH GCP Guidelines.

Principal Investigator: BLACKBURN, JUSTIN L.
Co-Investigator(s):
Protocol Number: X09090808
Protocol Title: Chemical Eye Injuries

The IRB reviewed and approved the above named project on 8-31-10. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received EXPEDITED review.
IRB Approval Date: 8-31-10

Date IRB Approval Issued: 8-31-10

HIPAA Waiver Approved?: Yes
Marilyn Doss, M.A.
Vice Chair of the Institutional Review Board for Human Use (IRB)

Investigators please note:
The IRB approved consent form used in the study must contain the IRB approval date and expiration date.

IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one year anniversary of the IRB approval date.

Any modifications in the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.

Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.
UAB IRB Approval of Waiver of Informed Consent and/or Waiver of Patient Authorization

Approval of Waiver of Informed Consent to Participate in Research. The IRB reviewed the proposed research and granted the request for waiver of informed consent to participate in research, based on the following findings:
1. The research involves no more than minimal risk to the subjects.
2. The research cannot practically be carried out without the waiver.
3. The waiver will not adversely affect the rights and welfare of the subjects.
4. When appropriate, the subjects will be provided with additional pertinent information after participation.

Check one: [ ] Waiver of Authorization (below)
[ ] Waiver of Authorization not applicable

Approval of Waiver of Patient Authorization to Use PHI in Research. The IRB reviewed the proposed research and granted the request for waiver of patient authorization to use PHI in research, based on the following findings:
1. The use/disclosure of PHI involves no more than minimal risk to the privacy of individuals
   i. There is an adequate plan to protect the identifiers from improper use and disclosure
   ii. There is an adequate plan to destroy the identifiers at the earliest opportunity consistent with conduct of the research, unless there is a health or research justification for retaining the identifiers or such retention that is otherwise required by law.
   iii. There is an assurance that the PHI will not be reused or disclosed to any other person or entity, except as required by law, for authorized oversight of the research study, or for other research for which the use or disclosure of PHI would be permitted.
2. The research cannot practically be conducted without the waiver or alteration.
3. The research cannot practically be conducted without access to and use of the PHI.

---OR---

Full Review
The IRB reviewed the proposed research at a convened meeting at which a majority of the IRB was present, including one member who is not affiliated with any entity conducting or sponsoring the research, and not related to any person who is affiliated with any of such entities. The waiver of authorization was approved by the majority of the IRB members present at the meeting.

Date of Meeting

Signature of Chair, Vice-Chair or Designee

Date

Expedited Review
The IRB used an expedited review procedure because the research involves no more than minimal risk to the privacy of the individuals who are the subject of the PHI for which use or disclosure is being sought. The review and approval of the waiver of authorization were carried out by the Chair of the IRB, or by one of the Vice-Chairs of the IRB as designated by the Chair of the IRB.

Date 8-31-10

Signature of Chair, Vice-Chair or Designee

Date 8-31-10
Form 4: IRB Approval Form
Identification and Certification of Research
Projects Involving Human Subjects

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federalwide Assurance with the Office for Human Research Protections (OHRR). The Assurance number is FWA0005960 and it expires on October 26, 2010. The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56.

Principal Investigator: MCGWIN, GERALD
Co-Investigator(s): OWSELEY, CYNTHIA
                     YEE, JEFFREY L
Protocol Number:    X070917009
Protocol Title:     Protective Eyewear and Work-Related Eye Injury: A Case-Crossover Study

The IRB reviewed and approved the above named project on 9.24.10. The review was conducted in accordance with UAB’s Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received EXPEDITED review.

IRB Approval Date: 9.24.10
Date IRB Approval Issued: 9.24.10

Partial HiPAA Waiver Approved?: Yes

Marilyn Doss, M.A.
Vice Chair of the Institutional Review Board for Human Use (IRB)

Investigators please note:

The IRB approved consent form used in the study must contain the IRB approval date and expiration date.

IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one year anniversary of the IRB approval date.

Any modifications in the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.

Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.
UAB IRB Approval of Partial Waiver of HIPAA Authorization to Use PHI in Screening for Research

Patient Authorization: Approval of Partial HIPAA Waiver to Use PHI in Screening for Research. The IRB reviewed the proposed research and granted the request for a “partial HIPAA waiver,” to allow the proposed use of protected health information (PHI) in screening for research, based on the following findings:

1. The nondisclosure of PHI to screen candidates for research involves no more than minimal risk to the privacy of individuals
   a. There is an adequate plan to protect the identifiers from improper use and disclosure.
   b. There is an adequate plan to destroy the identifiers at the earliest opportunity consistent with conduct of the research, unless there is a health or research justification for retaining the identifiers or such retention is otherwise required by law.
   c. The PHI will not be reused or disclosed to any other person or entity, except as required by law, for authorized oversight of the research study, or for other research for which the use or disclosure of PHI would be permitted.
2. The screening cannot practically be conducted without the waiver or alteration.
3. The screening cannot practically be conducted without access to and use of the PHI.

OR

Full Review
The IRB reviewed the proposed research at a convened meeting at which a majority of the IRB was present, including one member who is not affiliated with any entity conducting or sponsoring the research, and not related to any person who is affiliated with any such entities. The partial waiver of authorization for screening was approved by the majority of the IRB members present at the meeting.

Date of Meeting

Signature of Chair, Vice-Chair or Designee

Date

Expedited Review
The IRB used an expedited review procedure because the research involves no more than minimal risk to the privacy of the individuals who are the subject of the PHI for which use or disclosure is being sought. The review and approval of the partial waiver of authorization for screening was carried out by the Chair of the IRB, or by one of the Vice-Chairs of the IRB as designated by the Chair of the IRB.

9.24.10
Date of Expedited Review

Signature of Chair, Vice-Chair or Designee

9.24.10
Date
101

Project Revision/Amendment Form

(please type: In MS Word, highlight the shaded, underlined box and replace with your text; double check checkboxes to check/uncheck.)

- Federal regulations require IRB approval before implementing proposed changes.
- Change means any change, in content or form, to the protocol, consent form, or any supportive materials (such as the Investigator's Brochure, questionnaires, surveys, advertisements, etc.)
- Complete this form and attach the changed research documents.

Today's Date: 8/12/2009

1. Contact Information
Principal Investigator's Name: Gerald Mcgwin Jr BlazerID: mcgwin E-mail: mcgwin@uab.edu
Contact Person's Name: Angela Marsh McKinney BlazerID: ammarsh E-mail: ammarsh@uab.edu
Telephone: 325-8637 Fax: 325-8697 Campus Address: 609EFP

2. Protocol Identification
Protocol Title: Protective Eyewear and Work-Related Eye Injury: A Case-Crossover Study
IRB Protocol Number: X070917009

Current Status of Project (check only one):
- Currently in Progress (Number of participants entered: 107)
- Study has not yet begun (No participants entered)
- Closed to participant enrollment (remains active)—
  Number of participants on therapy/intervention:
- Number of participants in long-term follow-up only:
- Closed to participant enrollment (data analysis only)—
  Total number of participants enrolled:

This submission changes the status of this study in the following manner (check all that apply):
- Protocol Revision
- Protocol Amendment
- Study Closed to participant entry
- Study Closure
- Other, (specify)

3. Reason for change
Briefly describe, and explain the reason for, the change. If normal, healthy controls are included, describe in detail how this change will affect those participants.
Include a copy of the protocol and any other documents affected by this change (e.g., consent form, questionnaires) with all the changes highlighted.

We are adding Justin Blackburn as study personnel. He will be assisting the study coordinator with various aspects of the study. Justin has completed IRB training. See attached IRB training report.

4. Does this change revolve or add a genetic or storage of samples component?
Yes ☐ No ☒
If yes, please see the Guidebook to assist you in revising or preparing your submission, or call the IRB office at 934-7789.

5. Does the change affect subject participation (e.g., procedures, risks, costs, location of services, etc.)?
Yes ☐ No ☒
If yes, Fiscal Approval Process (FAP)-designated units complete a FAP submission and send to fap@uab.edu. For more on the UAB FAP, see www.uab.edu/ohr.

6. Does the change affect the consent document(s)?
Yes ☐ No ☒
If yes, briefly discuss the changes.
Include the revised consent document with the changes highlighted.
Will any participants need to be reconsented as a result of the changes?
Yes ☒ No ☐
If yes, when will participants be reconsented?

Signature of Principal Investigator

Date 2/4/09
APPENDIX B

CASE-CROSSOVER STUDY QUESTIONNAIRE
Occupational Eye Injury Survey

We appreciate your cooperation with our research study on work-related eye injuries. Please answer the questions to the best of your ability. Instructions for answering the questions appear below.

- Answer by checking the appropriate box: x Yes □ No
- OR by putting numbers in the box: 250
- Some questions have follow-up questions. After answering a question, proceed to the next question unless otherwise directed:

  □ No ↘ Go to question 26, below
  □ Yes ↑

- After completing the survey, please put it in the enclosed self-addressed envelope and place it in the mail.

- You will receive your $20 gift card once we have your completed survey.
Occupational Eye Injury Survey

1. What is your date of birth?
   
   Month / Day / Year

2. Which of the following would you say best represents your racial or ethnic group? [Mark only one]
   
   □......White
   □......Black
   □......Hispanic
   □......Asian
   □......American Indian
   □......Other: __________________________

3. What is the highest grade or year in school you completed? [Mark only one]
   
   □......Eighth grade or less
   □......Some high school
   □......High school or GED
   □......Some college or trade school
   □......College or higher

4. How tall are you?
   
   _______ (feet, inches)

5. How much do you weigh?
   
   _______ (lbs)

This section contains eight questions related to your job(s). We are interested in all of your jobs, even if you are self-employed. If you have more than one job, please provide responses for each job in the table on the next page.

6. How many jobs do you have, including both PART-TIME and FULL-TIME?
   
   _____ Jobs
## Occupational Eye Injury Survey

<table>
<thead>
<tr>
<th>7. Where do you work/who is your employer?</th>
<th>8. What is your job title?</th>
<th>9. How long have you worked there? [In years or months]</th>
<th>10. What is the total number of employees?</th>
<th>11. What is your normal work schedule [how many hours do you work each day]?</th>
<th>12. How often does your employer provide safety training and conduct safety meetings? [Mark only one]</th>
<th>13. Did you receive pre-employment training about the use of eye protection?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Employees</td>
<td>MON: Never</td>
<td>Never</td>
<td>□ Yes</td>
</tr>
<tr>
<td>Job #1</td>
<td></td>
<td></td>
<td>Employees</td>
<td>TUES: Every day</td>
<td>Yes</td>
<td>□ No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Employees</td>
<td>WED: Weekly</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Employees</td>
<td>THUR: Monthly</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>FRI: Yearly</td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td>Employees</td>
<td>SAT: Other</td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td>Employees</td>
<td>SUN:</td>
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<td></td>
</tr>
<tr>
<td>Job #2 (if applicable)</td>
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<td></td>
<td>Employees</td>
<td>MON: Never</td>
<td>Never</td>
<td>□ Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Employees</td>
<td>TUES: Every day</td>
<td>Yes</td>
<td>□ No</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>Employees</td>
<td>WED: Weekly</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>Employees</td>
<td>THUR: Monthly</td>
<td></td>
<td></td>
</tr>
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<td>Employees</td>
<td>FRI: Yearly</td>
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<td></td>
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<td>SAT: Other</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>Employees</td>
<td>SUN:</td>
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<tr>
<td>Job #3 (if applicable)</td>
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<td>TUES: Every day</td>
<td>Yes</td>
<td>□ No</td>
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<td>Employees</td>
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<td></td>
<td>Employees</td>
<td>SUN:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Occupational Eye Injury Survey

This section contains four questions related to any injuries you might have had PRIOR to your most recent eye injury.

14. Prior to your most recent injury, have you ever had ANOTHER injury at work that required medical attention?

   □ No  Go to question 18, on the next page

   □ Yes

15. Date of Injury (if more than one injury, list the MOST RECENT first).

   □ Yes

   □ No

16. Was this injury to your eye?

   □ Yes

   □ No

17. Were you wearing eye protection when this injury occurred?

   □ Yes

   □ No
Occupational Eye Injury Survey

The next section asks questions about your most recent eye injury, the one you went to the Eye Foundation Hospital for. Please read every question carefully, as some questions have similar structure but might be asking you about different things.

18. On the day of your injury, what time did you start work?

   : AM / PM

19. What time did the injury occur?

   : AM / PM

The next four questions are related to what you were doing at the time of your injury. Please be as specific as possible.

20. At the time of your eye injury, what specific task were you doing?

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

21. At approximately the SAME TIME on the DAY BEFORE your injury, were you doing the same task? (If you did not work the day before, answer with your last workday in mind.)

   □ Yes
   □ No

22. In past month, how frequently have you performed this task? [Mark only one]

   □ Every workday
   □ Most days (3-4 days/work week)
   □ Some days (1-2 days/work week)
   □ A few days (<1 day/work week)
   □ This was the only time I performed this task
Occupational Eye Injury Survey

23. In the past month, when you did perform this task, how much time did you spend doing it? [Mark only one]
   - 10 minutes or less
   - 10-20 minutes
   - 30 minutes to 1 hour
   - 1 to 5 hours
   - Greater than 6 hours

*The next five questions will ask about your use of eye protection at work.*

24. At the time of your eye injury, were you wearing eye protection?
   - No
   - Yes
   → Go to question 26, below

25. What type of eye protection were you wearing? [Check all that apply.]
   - Spectacles
   - Goggles
   - Face shields
   - Welding helmet
   - Prescription eyeglasses
   - Other: ______________________________

26. At approximately the SAME TIME as your injury but on the DAY BEFORE, were you wearing eye protection? (If you did not work the day before, answer with your last workday in mind)
   - Yes
   - No

27. In the month prior to your injury, on how many days did you wear eye protection at work? [Mark only one]
   - Every workday
   - Most days (3-4 days/work week)
   - Some days (1-2 days/work week)
   - A few days (<1 day/work week)
   - Never
   → Go to question 30, on the next page
Occupational Eye Injury Survey

28. In the past month, when you wore eye protection, for how long did you wear it? [Mark only one]
   - 10 minutes or less
   - 10-20 minutes
   - 30 minutes to 1 hour
   - 1 to 5 hours
   - Greater than 6 hours
   - Other: ____________

The next six questions are related to your sleeping habits and how often you feel fatigued at work.

29. On the day or night BEFORE your injury, how many hours of sleep did you get?
   _______ hours

30. On an average work-night in the past month, how much sleep would you normally get?
   _______ hours

31. At the time of your injury, did you feel fatigued?
   - Yes
   - No

32. At approximately the SAME TIME as your injury but on the DAY BEFORE, did you feel fatigued? (If you did not work the day before, answer with your last workday in mind)
   - Yes
   - No

33. In the past month, how often have you felt fatigued while at work? [Mark only one]
   - Everyday worked
   - Most days (3-4 days/work week)
   - Some days (1-2 days/work week)
   - A few days (<1 day/work week)
   - Never → Go to question 35, on the next page
Occupational Eye Injury Survey

34. In the past month, when you felt fatigued at work, how long did it last? [Mark only one]
   - 10 minutes or less
   - 10-20 minutes
   - 30 minutes to 1 hour
   - 1 to 5 hours
   - Greater than 6 hours

The following ten questions ask about YOUR use of tools, machines, or other work materials and whether any of these have malfunctioned.

35. At the time of your injury, were you using any tools, machines, or other work materials?
   - Yes
   - No
   Go to question 39, on the next page

36. What tools, machines, or other work materials were you using? Please be as specific as possible.

   __________________________________________
   __________________________________________

37. Did any of these tool(s), machine(s) or other work material(s) malfunction at the time of your injury?
   - Yes
   - No
   Go to question 39, on the next page

38. If you were using MORE THAN ONE tool, machine or other work material, which malfunctioned at the time of your injury?

   __________________________________________
   __________________________________________
39. At approximately the **SAME TIME** as your injury, but on the day **BEFORE**, were you using any tools, machines, or other work materials? *(If you did not work the day before, answer with your last workday in mind)*

   - [ ] Yes
   - [ ] No ➔ **Go to question 41, below**

40. On the day **BEFORE** your injury, did this tool, machine or other work material malfunction?

   - [ ] Yes
   - [ ] No

41. In the past month, how frequently have you used any tools, machines or other work materials? *[Mark only one]*

   - [ ] Everyday worked
   - [ ] Most days (3-4 days/work week)
   - [ ] Some days (1-2 days/work week)
   - [ ] A few days (<1 day/work week)
   - [ ] Never ➔ **Go to question 45, on the next page**

42. In the past month, when you have used tools, machines or other work materials, how much time did you spend using it/them? *[Mark only one]*

   - [ ] 10 minutes or less
   - [ ] 10-20 minutes
   - [ ] 30 minutes to 1 hour
   - [ ] 1 to 5 hours
   - [ ] Greater than 6 hours

43. In the past month, when you were using any tool, machine, or work material, how frequently did it malfunction? *[Mark only one]*

   - [ ] Everyday worked
   - [ ] Most days (3-4 days/work week)
   - [ ] Some days (1-2 days/work week)
   - [ ] A few days (<1 day/work week)
   - [ ] Never ➔ **Go to question 45, on the next page**
Occupational Eye Injury Survey

44. In the past month, when any tool, machine or work material malfunctioned, for how long did it malfunction? [Mark only one]

- [ ] 10 minutes or less
- [ ] 10-20 minutes
- [ ] 30 minutes to 1 hour
- [ ] 1 to 5 hours
- [ ] Greater than 6 hours

The next ten questions ask about SOMEONE ELSE’s use of tools, machines, or other work materials and whether any of these have malfunctioned.

45. At the time of your injury, was ANYONE ELSE using a tool, machine, or other work material that contributed to YOUR eye injury?

- [ ] Yes
- [ ] No

Go to question 49, on the next page

46. What tools, machines, or other work materials were THEY using that contributed to YOUR eye injury?

__________________________________________________________________________

__________________________________________________________________________

47. Did any of these tools, machines, or other work materials malfunction at the time of your injury?

- [ ] Yes
- [ ] No

48. Were any of these tools, machines, or other work materials used improperly at the time of your injury?

- [ ] Yes
- [ ] No
Occupational Eye Injury Survey

49. At approximately the **SAME TIME** as your injury, but on the day **BEFORE**, was anyone around you using a tool, machine, or other work material? (If you did not work the day before, answer with your last workday in mind)

   - Yes
   - No → Go to question 51, below

50. At approximately the **SAME TIME** as your injury, but on the day **BEFORE** your injury, did anyone’s tool, machine, or other work material malfunction?

   - Yes
   - No

51. In the past month, how frequently have you been around anyone using a tool, machine, or other work material? **[Mark only one]**

   - Everyday worked
   - Most days (3-4 days/work week)
   - Some days (1-2 days/work week)
   - A few days (<1 day/work week)
   - Never → Go to question 53, below

52. In the past month, when you were around anyone using a tool, machine, or other work material how much time were you around them? **[Mark only one]**

   - 10 minutes or less
   - 10-20 minutes
   - 30 minutes to 1 hour
   - 1 to 5 hours
   - Greater than 6 hours

53. In the past month, how frequently have you been around anyone when a tool, machine, or other work material malfunctioned? **[Mark only one]**

   - Everyday worked
   - Most days (3-4 days/work week)
   - Some days (1-2 days/work week)
   - A few days (<1 day/work week)
   - Never → Go to question 55, on the next page
Occupational Eye Injury Survey

54. In the past month, when this tool, machine, or other work material malfunctioned, for how long did it malfunction? [Mark only one]

- 10 minutes or less
- 10-20 minutes
- 30 minutes to 1 hour
- 1 to 5 hours
- Greater than 6 hours

The next four questions relate to whether or not you have felt distracted at work.

55. At the time of your injury, did you feel distracted?

- Yes
- No

56. At approximately the SAME TIME as your injury but on the day BEFORE, did you feel distracted? (If you did not work the day before, answer with your last workday in mind)

- Yes
- No

57. In the past month, how often have you felt distracted while at work? [Mark only one]

- Everyday worked
- Most days (3-4 days/work week)
- Some days (1-2 days/work week)
- A few days (<1 day/work week)
- Never

Go to question 59, on the next page

58. In the past month, when you felt distracted at work, how long did it last?

- 10 minutes or less
- 10-20 minutes
- 30 minutes to 1 hour
- 1 to 5 hours
- Greater than 6 hours
Occupational Eye Injury Survey

The next four questions relate to whether you work overtime.

59. At the time of your injury, were you working overtime?
   □ Yes
   □ No

60. At approximately the SAME TIME as your injury but on the day BEFORE, were you working overtime? (If you did not work the day before, answer with your last workday in mind)
   □ Yes
   □ No

61. In the past month, how frequently have you worked overtime? [Mark only one]
   □ Everyday worked
   □ Most days (3-4 days/week)
   □ Some days (1-2 days/week)
   □ A few days (<1 day/week)
   □ Never
      Go to question 63. below

62. In the month prior to your injury, when you worked overtime, how long did you work? [Mark only one]
   □ 10 minutes or less
   □ 10-20 minutes
   □ 30 minutes to 1 hour
   □ 1 to 5 hours
   □ Greater than 6 hours

The next four questions relate to whether you feel rushed at work.

63. At the time of your injury, did you feel rushed?
   □ Yes
   □ No
Occupational Eye Injury Survey

64. At approximately the **SAME TIME** as your injury but on the **DAY BEFORE**, did you feel rushed? (If you did not work the day before, answer with your last workday in mind)

   [ ] Yes
   [ ] No

65. In the past month, how frequently have you felt rushed while at work? **[Mark only one]**

   [ ] Everyday worked
   [ ] Most days (3-4 days/work week)
   [ ] Some days (1-2 days/work week)
   [ ] A few days (<1 day/work week)
   [ ] Never ➔ Go to question 67, below

66. In the past month, when you felt rushed, how long did it last? **[Mark only one]**

   [ ] 10 minutes or less
   [ ] 10-20 minutes
   [ ] 30 minutes to 1 hour
   [ ] 1 to 5 hours
   [ ] Greater than 6 hours

---

The next four questions relate to whether you have felt sick at work.

67. At the time of your injury, did you feel sick?

   [ ] Yes
   [ ] No

68. At approximately the **SAME TIME** as your injury but on the **DAY BEFORE**, did you feel sick? (If you did not work the day before, answer with your last workday in mind)

   [ ] Yes
   [ ] No
Occupational Eye Injury Survey

69. In the past month, how frequently have you felt sick while at work? [Mark only one]

- Everyday worked
- Most days (3-4 days/week)
- Some days (1-2 days/week)
- A few days (<1 day/week)
- Never → Go to question 71, on the next page

70. In the past month, when you felt sick, how long did it last? [Mark only one]

- 10 minutes or less
- 10-20 minutes
- 30 minutes to 1 hour
- 1 to 5 hours
- Greater than 6 hours
### Occupational Eye Injury Survey

This section will ask questions related to your medication use. Please provide as detailed information as possible.

71. **On the day of your injury, were you taking any medications, including prescription and over-the-counter medications, vitamins or supplements?**

   - [ ] No  
   - [ ] Yes

   *Go to question 73, on the page 19*

72. **What medication(s) did you take?** [Please provide information on all medications.]

<table>
<thead>
<tr>
<th>A. Name of Medication</th>
<th>B. Did you take this medication the day before your injury?</th>
<th>C. Over the past month, how frequently did you take this medication?</th>
</tr>
</thead>
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<td>[ ] Yes</td>
<td>[Mark only one] Everyday worked</td>
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### Occupational Eye Injury Survey

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</table>
Occupational Eye Injury Survey

The next eight questions relate to your consumption of alcoholic beverages.

73. Do you **ever** drink alcoholic beverages?

   □ Yes
   □ No → Go to question 81, on the next page

74. On the day of your injury, did you drink any alcoholic beverages?

   □ Yes
   □ No → Go to question 76, below

75. On the day of your injury, how many drinks of any type of alcoholic beverage did you drink? One drink means a 12 oz. beer, a 5 oz. glass of wine, or 1.5 oz. of liquor.

   Number of Drinks

76. On the day **before** your injury, did you drink any alcoholic beverages?

   □ Yes
   □ No → Go to question 78, below

77. On the day **before** your injury, how many drinks of any type of alcoholic beverage did you drink?

   Number of Drinks

78. In the past month, did you consume any alcoholic beverages?

   □ Yes
   □ No → Go to question 81, on the next page
Occupational Eye Injury Survey

79. In the past month, on average how frequently have you had at least one alcoholic beverage on workdays or days prior to workdays? [Mark only one]
   - Everyday worked
   - Most days (3-4 days/work week)
   - Some days (1-2 days/work week)
   - A few days (<1 day/work week)

80. In the past month, when you drank alcoholic beverages, how many drinks of any type did you consume?
   [ ] Drinks

81. Do you think your injury could have been prevented?
   - [ ] Yes
   - [ ] No → Go to question 83, below

82. How do you think your injury could have been prevented?
   _____________________________________________________
   _____________________________________________________
   _____________________________________________________

83. Do you feel that eye protection makes your work more difficult?
   - [ ] Yes
   - [ ] No → Go to question 85, below

84. How does eye protection make your work more difficult?
   _____________________________________________________
   _____________________________________________________
   _____________________________________________________
Occupational Eye Injury Survey

85. Is there anything else that you think is important that happened to cause your injury?


86. That was the last question. Thank you very much for your time and help. We would like to follow-up with you in 1 year from now with a brief survey about your eye protection since your initial eye injury. May we contact you in 1 year?

☐ Yes, you may contact me in 1 year for follow-up survey.

☐ No

Thank you for your participation. Please use the self-addressed envelope to mail the survey back to the UAB Department of Ophthalmology.
APPENDIX C

FOLLOW-UP QUESTIONNAIRE
Hello, my name is ____________, and I'm calling from the Department of Ophthalmology at the University of Alabama at Birmingham.

May I please speak to _______________________________?

1. Yes
2. No
3. Does not reside at this location

You completed a survey regarding the use of eye protection and work-related eye injuries for us on ___ month/year of completed survey ___. We would like to ask you a few questions as a follow-up to that survey. I will only need a moment of your time.

Your participation in this survey is voluntary and does not affect your treatment at the Callahan Eye Foundation Hospital. Your responses will be kept confidential and will not be included in your hospital medical chart. If you would like to get more information on this study you can contact Dr. Gerald McGwin at 205-325-8294. Should you have questions about your rights as a research participant, you may contact Sheila Moore, Director of the Office of the UAB Institutional Review Board for Human Use at 1-800-822-8616.
1. How many jobs do you have, including both part-time and full-time?
   ______ Jobs

2. Are you still currently employed at _____insert job(s) from prior questionnaire_____?
   1. Yes
   2. No
   8. _____DK/NS
   9. _____REF

3. What is your normal work schedule? (INTERVIEWER: Please fill in hours worked for all jobs)

<table>
<thead>
<tr>
<th>JOB 1</th>
<th>JOB 2</th>
<th>JOB 3</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

4. In the past month, on how many days did you wear eye protection at work?
   1. Every workday
   2. Most days (3-4 days/work week)
   3. Some days (1-2 days/work week)
   4. A few days (<1 day/work week)
   5. Never .................................................. Skip to Q6, below
   8. _____DK/NS
   9. _____REF
5. In the past month, when you wore eye protection, for how long did you wear it?

   1. . . . .10 minutes or less
   2. . . . .10-20 minutes
   3. . . . .30 minutes to 1 hour
   4. . . . .1 to 5 hours
   5. . . . .Greater than 6 hours
   6. . . . .Other: __________
   8. . . . .DK/NS
   9. . . . .REF

6. Whenever you __insert task from prior questionnaire____, how often do you wear eye protection?

   1. . . . .Always
   2. . . . .Most of the time
   3. . . . .Some of the time
   4. . . . .Never
   8. . . . .DK/NS
   9. . . . .REF

7. Since your eye injury, would you say that you are...

   1. . . . .More likely to wear eye protection at work...Skip to Q8, below
   2. . . . .Less likely to wear eye protection at work
   3. . . . .No change in eye protection habits
   8. . . . .DK/NS
   9. . . . .REF

8. Why have your eye protection habits not changed following your injury?

   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
9. Has your employer made any changes to their policies regarding the use of eye protection since the time of your eye injury?

1.....Yes
2.....No..................................................................SKIP TO Q11
8.....DK/NS
9.....REF

10. Briefly describe those changes.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

11. Have you received medical treatment for any eye injuries since your injury on __insert injury date from prior questionnaire___?

1.....Yes
2.....No..................................................................SKIP TO END
8.....DK/NS
9.....REF

12. Were you wearing eye protection at the time of this injury?

1.....Yes
2.....No
8.....DK/NS
9.....REF