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The Prevalence of Eye Injury in the United States, Estimates from a Meta-Analysis

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\textbf{ABSTRACT}

\textbf{Purpose:} The burden of vision impairment and blindness is typically focused on the most common causes of these conditions, namely cataract, macular degeneration, glaucoma, and diabetic retinopathy. However, the burden of less common but more preventable causes such as eye injury has not been quantified. The goal of this study is to estimate the prevalence of eye injury and eye injury-associated vision impairment and blindness in the United States.

\textbf{Methods:} A systematic review was conducted to identify peer-reviewed population-based studies reporting the prevalence of eye injury. The relevant qualitative and quantitative results were extracted from these studies and the latter pooled using a random-effects model. The model results were then applied to the United States population counts to estimate the number of individuals impacted by eye injury.

\textbf{Results:} A total of 20 population-based studies met the inclusion criteria for the study. The pooled prevalences of eye injury and eye injury-associated vision impairment and blindness were 7.5 per 100, 4.4 per 1000 and 5.1 per 1000, respectively. These estimates suggest that an estimated 24 million persons in the United States have ever suffered an eye injury, of whom 1.5 million are visually impaired and 1.7 million and 147,000 are partially blind or totally blind, respectively.

\textbf{Conclusions:} Eye injury is an important contributor to the burden of vision impairment and blindness in the United States. Prevention efforts should be enhanced to reduce the incidence of these largely preventable events and as should effective therapies to minimize the visual consequences of those currently affected.

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\textbf{KEYWORDS}
Eye injury; vision impairment; blindness

\section*{Introduction}

Vision impairment and blindness are important causes of disability in the United States.\textsuperscript{1,2} Additionally, recent research suggests that vision impairment and blindness are increasing and will continue to do so, owing to changes in demographics and increases in the prevalence of risk factors that lead to these conditions (e.g., diabetes).\textsuperscript{1,3} Beyond the health-care costs associated with these conditions, the increase in vision impairment and blindness are of additional concern given the repercussions of these conditions including depression, decreased quality of life, social isolation and mortality, among others.\textsuperscript{3} It is therefore important to understand the underlying causes of vision impairment and blindness such that preventive and therapeutic solutions can be developed. Research regarding the prevalence and causes of vision impairment and blindness in the United States has focused on adults and the leading causes of these conditions, namely cataract, macular degeneration, glaucoma, and diabetic retinopathy. With the exception of cataract, treatments for these conditions have largely focused on slowing the progression of the disease; the success of which is variable. The prevention of these eye diseases requires the identification of robust risk factors which, with minor exceptions, remain elusive.

Eye trauma has received little attention as a cause of vision impairment and blindness, despite being largely preventable with the proper use of eye protection. Despite an abundance of research regarding the epidemiology of eye injuries, few population-based studies in the United States provide a comprehensive depiction of their burden. The population-based studies that do exist are either based on injuries treated in specific settings such as emergency departments\textsuperscript{4,5} or that require hospitalization.\textsuperscript{6,7} Perhaps the most comprehensive estimate of the incidence of eye injury in the United States (7 per 1000 population) was reported by McGwin et al. and was based on injuries treated in emergency departments, hospitals, outpatient clinics and physician offices.\textsuperscript{8} However, this study, like
In order to fill this gap in the literature, the quantitative estimates for the prevalence of eye injury and eye injury-associated vision impairment and blindness in the United States using published estimates from published population-based studies.

**Methods**

**Identification and selection of studies**

A search of the literature in PubMed was conducted in August 2019 for all population-based studies reporting the prevalence of eye injury which were written in English, without restriction on the geographic location of the study. The identification of the relevant studies was facilitated by Wang et al. and Wong et al. who previously assembled population-based studies reporting the prevalence of eye trauma. Searches were completed by two qualified injury epidemiologist with search terms of: eye injury AND vision impairment, eye injury AND blindness, ocular trauma AND vision impairment, ocular trauma AND blindness, ocular trauma AND prevalence, and eye injury AND prevalence. Only those studies that were based on complete or statistical samples of well-defined populations were selected for inclusion. Studies based on data from individual hospitals or other health-care facilities were excluded unless it was explicitly stated that such institutions were the sole source of eye care in the region of interest. Studies published prior to 1990 were excluded. Additionally, studies focused on specific age groups (i.e., children or the elderly), hospitalized/admitted cases, injuries to specific areas of the eye (e.g., globe, cornea, retina, orbit), injuries due to specific causes (e.g., fireworks, blasts, sports, work-related, motor vehicle-related, war, natural disasters, chemicals), or a specific mechanism of injury (e.g., penetrating, blunt, burn) were excluded. This study used data from published sources; therefore, no institutional review board approval was necessary.

**Data extraction**

From each study, the following quantitative information was extracted: the total number of study participants, the number of study participants with a history of vision impairment or blindness, the number of participants whose injuries that resulted in vision impairment or blindness. Population age range and qualitative information including the geographic location, definition of eye injury, and definition of vision impairment was also extracted for each study. Both authors independently extracted the aforementioned information, and any inconsistencies were adjudicated following a mutual review of the item in question.

### Estimates of the prevalence of eye injury and eye injury-associated vision impairment

In order to obtain eye injury prevalence estimates for the United States, the quantitative estimates for the prevalence of eye injury, eye injury-associated vision impairment and blindness from each study were pooled using a random-effects statistical model. A random-effects normal-binomial model and a sandwich estimator were utilized as the intent of the analyses was to make inferences beyond the results of the included studies. This type of modeling has been shown to produce consistent estimates for rare events, even when not all distributional assumptions are met. Assessment of heterogeneity for the pooled estimates was not performed since this study estimated descriptive statistics and not measures of association. Risk of bias was not assessed as the majority of the domains (random sequence generation, allocation concealment, blinding of the participants and personnel, blinding of outcome assessment) in the Cochrane Collaboration tool do not apply to the type of studies, population-based descriptive epidemiology studies, included in this systematic review. To quantify the number of people in the United States who have sustained an eye injury, and who suffer from eye injury-associated vision impairment or blindness, the estimates from the random-effects models were applied to United States population estimates from the U.S. Census Bureau.

**Results**

**Study characteristics**

The systematic literature review identified 11,997 publications using the search terms specified in the methods with 6667 unique records (Figure 1). Of the 6667 records screened, 159 were selected for further assessment. In all, a total of 20, Table 1, studies that reported population-based estimates for the prevalence of eye injury were selected for inclusion in the analysis. The majority of studies were based on populations in Asian countries; five studies were conducted in United States and
Australian populations. The majority of studies were also limited to adults, though six studies included persons of all ages. Given the nature of the studies, all used self-report to identify participants who had ever sustained an eye injury, though the exact definition of “injury” varied across studies, with half of the studies specifying that only those injuries requiring medical treatment be considered.

Pooled estimates

The prevalence of eye injury ranged from a minimum of 1.6% to a maximum of 21.1%. The pooled estimate of the prevalence of eye injury was 7.5% (95% confidence interval [CI], 4.2% to 10.8%). Fourteen of the 20 studies either reported estimates for the prevalence of vision impairment or provided results that permitted such estimates to be calculated by the authors. It is worthy of note that the definitions of vision impairment were heterogeneous across the studies. The prevalence estimates ranged from a minimum of 0.9 per 1000 to 14.6 per 1000 with a pooled estimate of 4.5 per 1000 (95% CI 2.3 per 1000 to 6.7 per 1000).

Seven of the 20 studies reported the number of participants who were unilaterally and bilaterally blind, the prevalence of which was 5.1 per 1000 (95% CI 3.7 to 6.4) and 4.5 per 10,000 (95% CI 1.0 to 8.0).

Prevalence of eye injury, eye injury-associated vision impairment and blindness in the United States

According to the United States Census Bureau, in 2018 there were an estimated 327,167,434 persons in the United States. Applying the pooled estimates from above to that population, there are an estimated 24.5 million persons in the United States who have ever suffered an eye injury, of whom 1.5 million (6.1%) have experienced vision impairment and...
Table 1. Presented in Table is a summary of all studies included in the calculation of the pooled estimates for the prevalence of eye injury, eye injury-associated vision impairment, and blindness.

<table>
<thead>
<tr>
<th>Reference #</th>
<th>Publication Year</th>
<th>Location</th>
<th>Population Size</th>
<th>Age Range of Cohort</th>
<th>Injury Definition</th>
<th>Eye trauma validated with exam</th>
<th>Definition of Vision Impairment</th>
<th>Prevalence (per 1,000) of Vision Impairment</th>
<th>Definition of Blindness</th>
<th>Prevalence of Blindness (per 1000)</th>
<th>Prevalence of Bilateral Blindness (per 10000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>1990</td>
<td>Mud Creek Valley, Floyd County, Kentucky</td>
<td>1,136</td>
<td>40 and older</td>
<td>Eye injury found after population-based eye examination</td>
<td>Yes</td>
<td>BCVA &lt;20/60 and ≥20/400</td>
<td>4.4</td>
<td>BCVA worse than 20/400</td>
<td>13.2</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>1990</td>
<td>Kenya</td>
<td>13,803</td>
<td>0 to death</td>
<td>Eye injury found after population-based eye examination</td>
<td>Yes</td>
<td>BCVA &lt;20/400</td>
<td>8.5</td>
<td>BCVA worse than 3/60</td>
<td>7.3</td>
<td>5.7</td>
</tr>
<tr>
<td>10</td>
<td>1993</td>
<td>Baltimore</td>
<td>5,308</td>
<td>40 and older</td>
<td>Any eye injury</td>
<td>Yes</td>
<td>BCVA &lt;20/400</td>
<td>4.8</td>
<td>BCVA worse than 20/400</td>
<td>19.8</td>
<td>7.1</td>
</tr>
<tr>
<td>23</td>
<td>1999</td>
<td>Victoria, Australia</td>
<td>4,744</td>
<td>40 and older</td>
<td>Any eye injury requiring a doctor</td>
<td>Yes</td>
<td>BCVA between 6/12 and 6/60</td>
<td>7.3</td>
<td>Worse than 6/60</td>
<td>4.9</td>
<td>11.7</td>
</tr>
<tr>
<td>9</td>
<td>2000</td>
<td>Beaver Dam, Wisconsin</td>
<td>4,926</td>
<td>43 to 84</td>
<td>Any eye injury requiring a doctor</td>
<td>No</td>
<td>BCVA &lt;20/40</td>
<td>14.4</td>
<td>BCVA &lt;20/400</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>2000</td>
<td>Andhra Pradesh, India</td>
<td>2,522</td>
<td>0 to death</td>
<td>Any eye injury that caused enough discomfort for them to want treatment</td>
<td>Yes</td>
<td>BCVA between 6/12 and 6/60</td>
<td>16.4</td>
<td>BCVA less than 20/200</td>
<td>7.1</td>
<td>4.0</td>
</tr>
<tr>
<td>24</td>
<td>2004</td>
<td>Southern India</td>
<td>5,150</td>
<td>40 and older</td>
<td>Any eye injury</td>
<td>Yes</td>
<td>BCVA between 6/12 and 6/60</td>
<td>5.8</td>
<td>BCVA worse than 3/60</td>
<td>7.4</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>2006</td>
<td>Andhra Pradesh, India</td>
<td>7,771</td>
<td>0 to death</td>
<td>Any eye injury that caused enough discomfort for them to seek treatment</td>
<td>Yes</td>
<td>BCVA &lt;6/12 to 6/60</td>
<td>5.6</td>
<td>BCVA worse than 6/60</td>
<td>4.9</td>
<td>11.7</td>
</tr>
<tr>
<td>25</td>
<td>2008</td>
<td>Goro District, Ethiopia</td>
<td>1,027</td>
<td>1 to 64</td>
<td>Any eye injury</td>
<td>Yes</td>
<td>BCVA &lt;6/12 to 6/60</td>
<td>16.4</td>
<td>BCVA less than 6/60</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>2008</td>
<td>Delhi, India</td>
<td>6,704</td>
<td>0 to death</td>
<td>Any eye injury requiring medical care</td>
<td>Yes</td>
<td>BCVA &lt;20/60</td>
<td>1.3</td>
<td>BCVA less than 20/200</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>2009</td>
<td>Singapore</td>
<td>3,264</td>
<td>40 to 79</td>
<td>Any eye injury requiring a doctor</td>
<td>Yes</td>
<td>BCVA &lt;6/12 to 6/60</td>
<td>16.4</td>
<td>BCVA less than 6/60</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>2010</td>
<td>Kumejima Island, Japan</td>
<td>3,762</td>
<td>40 and older</td>
<td>Eye injury found after population-based eye examination</td>
<td>Yes</td>
<td>BCVA &lt;20/60</td>
<td>1.1</td>
<td>BCVA worse than 20/400</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>2011</td>
<td>Fiji</td>
<td>1,381</td>
<td>40 and older</td>
<td>Any eye injury</td>
<td>Yes</td>
<td>BCVA &lt;6/12 to 6/60</td>
<td>20.6</td>
<td>BCVA less than 6/60</td>
<td>7.0</td>
<td>14.5</td>
</tr>
<tr>
<td>30</td>
<td>2011</td>
<td>Singapore</td>
<td>3,400</td>
<td>40 to 80</td>
<td>Any eye injury requiring medical attention</td>
<td>Yes</td>
<td>BCVA logMAR 0.3 to 1.0</td>
<td>5.1</td>
<td>BCVA worse than 1.0</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>2012</td>
<td>Daxing and Haidian Districts, China</td>
<td>4,439</td>
<td>40 and older</td>
<td>Any eye injury</td>
<td>Yes</td>
<td>BCVA &lt;20/60</td>
<td>1.6</td>
<td>BCVA worse than 20/400</td>
<td>0.7</td>
<td>0.0</td>
</tr>
</tbody>
</table>
1.7 million (6.9%) are partially and approximately 147,000 (0.6%) are totally blind as a consequence.

**Discussion**

Pooled estimates from this study indicate the prevalence of eye injury is 7.5% with 4.5 and 5.1 per 1000 persons have vision impairment and unilateral blindness, respectively, due to injury. These estimates indicate 1.5 million persons in the US have vision impairment and 1.7 million have unilateral blindness. Past work has estimated the current and projected prevalence of vision impairment and blindness due to any cause, specifically among older adults.\(^1\)–\(^3\) These studies have reported consistent estimates for the prevalence of vision impairment or low vision (i.e., <20/40) and blindness (i.e., <20/200) of approximately 2.0–3.0\% and 0.7%-0.8\%, respectively; these estimates are projected to double by the year 2050. A cause of the increase in the prevalence of vision impairment and blindness is population growth and an aging population.\(^15\),\(^16\) These studies have focused on the more common, age-related causes of vision impairment and blindness. And thus, from these studies it possible to understand the current and projected burden of eye diseases such as cataract, glaucoma, macular degeneration, and diabetic retinopathy, the burden of other eye conditions is less discernable. The results of the current study suggest that vision impairment and blindness attributable to eye injury represent approximately 15–20\% of the cases of vision impairment and 5-10\% of the cases of blindness in the United States. According to estimates of the causes of vision impairment in the United States, the burden imposed by eye injury may be equivalent to that of chronic eye conditions.\(^1\) But unlike those conditions, the majority of eye injuries are considered preventable with the use of appropriate protective eyewear.\(^4\)–\(^8\) This is in contrast to most chronic eye diseases for which well-established risk factors remain elusive, as do effective treatments. Additionally, eye injuries occur among younger age groups more than chronic eye diseases\(^17\); therefore, any associated vision impairment and blindness impose a longer burden on the individual and society. Thus, efforts to improve the use of eye protection, specifically during high-risk activities such as certain sports, jobs, and household tasks, may have a greater impact on reducing the burden of vision impairment and blindness than prevention and treatment efforts for other, more common eye diseases.

The prevalence estimates calculated in this study were derived from studies conducted in populations largely outside of the United States. Only three
studies were from the United States, all over two decades old. The remaining studies were conducted in Asian, African, or Oceania populations; there were no studies from South America or Europe. Though the studies span over three decades certain aspects of the study designs are consistent. Most of the studies were conducted among adults (i.e., 40 and older), which is not surprising given the underlying nature of the original studies. Additionally, nearly all of the studies limited the definition of eye injury to those self-reported events requiring medical treatment and which was validated with a clinical exam. Finally, the definitions of visual impairment and blindness were largely consistent. Given this homogeneity, it is perhaps not surprising that, with certain exceptions, the prevalence of eye injury reported in these studies was largely consistent and supports the validity of the pooled estimates.

The approach of pooling the results from an international collection of studies has been previously used by the Eye Diseases Prevalence Research Group to estimate the prevalence of visual impairment in the United States. As with the current analysis, that study pooled a diversity of prevalence estimates and then applied those estimates to the United States population. The validity of this approach rests upon several assumptions. One such assumption is that the diversity of prevalence estimates from the pooled studies reflects the random variation and/or systematic variation as a function of underlying demographic and behavioral risk factors. While random variation would inherently be taken into account in the pooling of the estimates, systematic variation is less problematic if the prevalence of demographic and behavioral risk in the United States is similar to that in populations represented by the pooled studies. Additionally, if access to and quality of eye care varies, the prevalence of subsequent visual impairment and blindness will be less generalizable from these studies to the United States. These differences are difficult to assess though it would be reasonable to conclude that differences in occupational and recreational activities, which are frequent settings for eye injury, exist between the study populations and the United States. Though, whether the prevalence derived from the mostly Asian countries is an over- or underestimate for the true prevalence in United States is open to conjecture. From the observed results, the prevalences reported in two of the United States studies and one of the Australian studies are much higher than those reported in Asian populations.

The studies included in the current analysis were largely among adult populations, though the pooled estimates were applied to the entire United States population. The assumption underlying this approach is that the eye injury prevalence among children and young adults is similar to that of adults. Based upon the results from the studies that did include all age populations, this is a reasonable assumption and reflects what is known about the epidemiology of eye injury, i.e., the incidence is highest among children and young adults and is rarely fatal.

In conclusion, the results of this study suggest that eye injury is an important contributor to the burden of vision impairment and blindness in the United States. Given the epidemiology of eye injury, for those who suffer the adverse visual consequences of eye injury, the impact is longstanding. Prevention efforts should be enhanced to reduce the incidence of these largely preventable events and as should effective therapies to minimize the visual consequences of those currently affected.

Disclosure statement
None of the authors have any proprietary interests or conflicts of interest related to this submission.

Submission statement
This work has not been published elsewhere nor will it be submitted to another journal while under consideration by Ophthalmic Epidemiology. There are no prior publications, posts, or submissions with any overlapping information.

References


