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From 1992 through 2001, the overall estimated rate of eye injury ranged from 8.2 to 13.0 per 1000 population. During this period the incidence of eye injury significantly declined overall, in persons aged 39 years and younger, in both genders, and in the black and white populations (all \( P < 0.05 \)).

Conclusions. From 1992 through 2002, the incidence of eye injury in the United States declined overall, in persons aged 39 and younger, in both genders, and in both racial groups. Certain segments of the population, however, continued to be at high risk (i.e., males and persons aged 39 and younger) of eye injury and represent those groups toward whom prevention resources should be directed. (Invest Ophthalmol Vis Sci. 2006;47:521–527) DOI:10.1167/iovs.05-0909

Each year, approximately 2 million eye injuries occur in the United States, of which, more than 40 thousand result in permanent visual impairment.1,2 Prior studies in which the incidence of eye injury has been examined have produced varied results, in part because of study design differences. For example, when considering eye injuries requiring hospital admission, rates have ranged from 8 to 57 per 100,000.3,4 However, when study populations are broadened to include eye injuries treated at inpatient or outpatient facilities, estimates range from 8 to 1,140 per 100,000.5,6,7,8,9,10 Despite their heterogeneity of results, these studies provide important information regarding the burden of eye injury. However, they have all been limited to a single year or narrow time frame making it difficult to determine trends in injury rates over time.

To date, only one study has presented data concerning trends in the rate of eye injury in the United States. Tielsch et al.5 reported an increase in the incidence of eye injuries necessitating hospital admission in Maryland from 1979 to 1986. Information regarding recent trends does not presently exist. Moreover, no study has presented trends in the incidence of eye injury with data from all 50 of the United States and the District of Columbia. From a public health and injury prevention perspective, current information on these trends is needed to develop effective plans for disseminating eye injury prevention materials to the public and to earmark adequate funding for these initiatives. Herein, we report the national trends in the incidence of eye injury over a recent 10-year period.

Methods

Data Sources

The data for this study were derived from patient visits to office-based physician practices (National Ambulatory Medical Care Survey [NAMCS]), hospital outpatient clinics and emergency departments (National Hospital Ambulatory Medical Care Survey [NHAMCS]), and inpatient hospital wards (National Hospital Discharge Survey [NHDS]) during the period 1992 to 2001. The sampling used by the NAMCS, NHAMCS, and NHDS is designed to produce data that accurately represent the healthcare experience of the U.S. population. These data sources are relied on to provide national and regional estimates of disease prevalence and healthcare utilization in addition to serving as a valuable research resource. Thus, it can be expected that the results of the present study reflect accurate population-based estimates for eye injury in the United States for the period of the study.

National Ambulatory Medical Care Survey.

The NAMCS is a national survey of visits to office-based physicians conducted by the National Center for Health Statistics (NCHS).11 The NAMCS utilizes a multistage probability design involving probability samples of primary sampling units (PSUs), physician practices within the PSUs, and patient visits within the identified physician practices. The PSUs consist of discrete geographic areas covering the 50 states and the District of Columbia. The physician practices are selected from a probability sample of the American Medical Association (AMA) and American Osteopathic Association (AOA) rosters and must meet the following criteria. The practice is office-based as defined by the AMA and AOA, is predominantly involved inpatient care activities, and is not federally funded. The specialties of anesthesiology, pathology, and radiology are excluded. Finally, a sample of patient visits is selected from the identified physician practices.

The NAMCS data collection, performed by physicians with the aid of their staff, compiles information about a patient’s smoking habits, reason for visitation, expected source of payment, the physicians diagnosis, and the types of diagnostic and therapeutic services rendered. Other variables included are the medications ordered, administered, or provided during office visits including information on the medication code, generic name and code, brand name, entry status, prescription status, federal controlled substance status, composition status, and related ingredient codes. Moreover, information regarding the physicians specialization and geographic location, patient demographic information such as age, sex, race, and ethnicity, is also collected. Trained NCHS staff performs the data collection of items requiring medical coding, such as screening and surgical procedures, medication, and diagnoses. Each NAMCS record contains a weighting factor that enables creation of national estimates from the sampled data.
National Hospital Ambulatory Medical Care Survey. The NHAMCS is a national survey, also conducted by the NCHS, hospital outpatient and emergency department visits in the 50 states and the District of Columbia. The NHAMCS uses a four-stage probability design composed of samples of PSUs, of the hospitals within the PSUs, the clinics and emergency service areas within the hospital's outpatient and emergency departments, and the patient visits within the selected clinics and emergency service areas. As with the NAMCS, PSUs consist of discrete geographic areas covering all 50 states and the District of Columbia. Hospitals are sampled from those listed on the SMG Hospital Market Data Base. NHAMCS selects hospitals with an average length of stay that is less than 30 days for all patients or hospitals that specialize in adult or pediatric general medicine or surgery. Health maintenance organizations are included in the sampling. Within each hospital, either all outpatient clinics and emergency service areas are selected or a sample of such units is chosen. Clinics are included if ambulatory medical care was provided under both the supervision of a physician and the auspices of the hospital. An emergency department is included if it is staffed 24 hours a day. Finally, the basic sampling unit for the NHAMCS is the patient visit. These visits are systematically selected over a randomly assigned 4-week reporting period. A visit is defined as a direct, personal exchange between either a patient and a physician or a staff member acting under a physician's direction, for the purpose of seeking care and rendering health services.

Primarily administered by the hospital staff, the NHAMCS collects information about patient age, race, sex, visitation reason, in addition to the physician's diagnoses, the cause of injury, surgical procedures, medication therapy, and expected source of payment. As with the NAMCS, diagnoses, surgical procedures, and medications were coded centrally by trained NCHS staff. Each NHAMCS record contains a weighting factor that enables creation of national estimates from the sampled data.

National Hospital Discharge Survey. The NHDS collects information on discharges from noninstitutional hospitals located in the 50 states and the District of Columbia. The NHDS uses a three-stage design involving probability samples of PSUs, hospitals within the PSUs, and discharges within selected hospitals. Similar to the NAMCS, the hospitals are sampled from those listed on the SMG Hospital Market Data Base and the PSUs comprise discrete geographic areas covering the 50 states and the District of Columbia. Only hospitals with an average length of stay for all patients that is less than 30 days or those whose specialty is adult or pediatric general medicine or surgery are included in the survey. Health maintenance organizations are included in the sampling. Discharges are selected by systematic random sampling.

The NHDS employs either a manual or automatic data collection procedure. The manual system of data abstraction, used by approximately 50% of the responding hospitals, involves the collection of information from hospital records by their own medical records staff or by the U.S. Bureau of the Census for the NCHS. The completed forms are then forwarded to NCHS for coding and editing. The automated method is used by the other 41% of responding hospitals and involves the NCHS purchasing computerized data files. NCHS acquires files containing machine-readable medical record data, from which, records are systematically sampled by NCHS. Regardless of the collection procedure, abstracted data include information regarding the patients age, sex, race, marital status, diagnoses, and surgical or nonsurgical procedures that were rendered. Each NHDS record contains a weighting factor that enables creation of national estimates from the sampled data.

The Institutional Review Board for Human Use at the University of Alabama Birmingham approved the study protocol. This study adhered to the tenets of the Declaration of Helsinki, and, for the purposes of the present study, informed consent was not an issue, because the authors did not collect the data for the explicit purposes of this study. The data used in this study were devoid of any personal identifiers.

Study Population

Within each data source, patient visits associated with eye injuries were identified by using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes. The specific ICD-9-CM codes used included: 802.6 and 802.7 (orbital floor fractures); 870.0 to 870.9 (open wounds of the ocular adnexa); 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); 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 face, head, and neck); 950.0 to 950.9 (injury to optic nerve and pathways); and 951.0, 951.1, and 951.3 (injury to oculomotor, trochlear, and abducens nerve, respectively). The NAMCS and NHAMCS provide up to three diagnosis codes, whereas the NHDS provides up to seven. All available diagnoses codes within each data source were used to identify eye injury-related patient visits. Compared with prior work using these same data sources, acute eye injuries as well as those being seen for follow-up care were selected, because information necessary to separate acute and non-acute eye injuries was not available across all years.

Variable Selection and Definition

Most of the variables in the NAMCS, NHAMCS, and NHDS overlap and use the same coding systems thus facilitating the pooling of records from each source. There is also a high degree of consistency from year to year within each data source. For the purposes of this study, demographic (gender and race) and injury-specific (type, cause) variables were selected. Injury type (diagnosis) is classified as described earlier. Cause of injury is coded using the ICD-9-CM External Cause of Injury codes or E-codes. Information on the cause of injury was available from only the NAMCS and NHAMCS data sets.

Statistical Analysis

All analyses were conducted after applying the appropriate record weights. For each year (1992–2001), eye injury incidence rates were calculated both overall and according to gender and race, using denominators obtained from the U.S. Bureau of the Census. As everyone in the population was theoretically at risk for eye injury, this denominator is appropriate. Frequency distributions were created for injury type and cause. Poisson regression was used to calculate the trend in the rate of eye injury over the study period.

RESULTS

From 1992 to 2001, the most frequent type of eye injury was superficial injury of the eye and adnexa (41.6%) followed by foreign body on the external eye (25.4%), contusion of the eye and adnexa (16.0%), and open wounds in the ocular adnexa and eyeball (10.1%; Fig. 1). Orbital floor fracture (1.3%) and nerve injury (0.5%) were the least common types of injury. The most common specific cause of eye injury was foreign body (41.7%) followed by striking or being struck by an object (19.4%), fight or assault (6.8%), fall (5.9%), vehicle related (4.0%), and cutting/piercing objects (3.1%; Fig. 2). When miscellaneous causes of eye injury were combined to form the category “other” (e.g., burns, machinery, electric current), it became the third most common cause of eye injury.

From 1992 to 2001, there were approximately 3 million eye injuries annually. During this time, the overall estimated rate of eye injury ranged from 8.2 to 13.0 per 1000 representing a decline of approximately 4.2% per year (P < 0.0001; Fig. 3). Eye injury rates also declined for persons aged less than 19 years (7.0% per year, P < 0.0001) and persons aged 20 to 39 years (3.8% per year, P = 0.0022; Fig. 4); for those aged 40 and older, the eye injury rate remained relatively constant. Males had higher rates of eye injury during all study years and more
year-to-year variation than females (Fig. 5). Both genders had a significant decline in eye injury rates (males: 5.0% per year, \( P = 0.0001 \); females: 2.7% per year, \( P = 0.0051 \)). The larger absolute rate change in males compared with females indicates the gender rate difference progressively decreased during the study period. Figure 6 demonstrates that whites had higher eye injury rates than did blacks from 1992 through 1995 after which the rate of eye injury in both groups converged but showed considerable year-to-year variation. Overall, the rate of eye injury for both races declined during the study (whites: 4.5% per year, \( P < 0.0001 \); blacks 2.5% per year, \( P = 0.0342 \)). Figures 7 and 8 portray yearly eye injury rates according to treatment setting. Overall, eye injury rates were highest for private physician offices (NAMCS) followed by emergency departments (NHAMCS-ED), hospital outpatient clinics (NHAMCS-OP), and hospital inpatient facilities (NHDS). Overall, there was a decline in private physician office visits (5.2% per year, \( P < 0.0001 \)), emergency department visits (3.5% per year, \( P = 0.0031 \)), and hospital inpatient visits (4.4%, \( P < 0.0001 \)), whereas hospital outpatient visits had no clear trend.

The rates for all types of eye injuries declined over the 10-year study period generally, though only superficial injuries, contusions, and foreign bodies experienced statistically significant declines. Trends for specific causes of eye injury were not computed, given the lack of completeness of the data (i.e., cause information is not available in the NHDS).

**DISCUSSION**

Several explanations may account for the decreased rate of eye injury during the study period. Given that roughly 50% of eye injuries are caused by activities involving contact sports or physical confrontations, improvements in safety equipment and reduction in violence may have contributed to the decline. Additionally, increased awareness and use of protective eyewear among workers in industries and sports that involve eye hazards could have played a role. Further studies are needed to identify the specific factors contributing to the observed trends.
injuries occur on the job, changes in the workplace may, in part, reveal the cause of decline. The introduction of the Occupational Health and Safety Act of 1970 focused considerable attention on preventing all types of injury in the workplace and probably initiated the decline in the rate of eye injury, even though its efficacy has occasionally been questioned. In addition, the net loss of more than 600,000 jobs that carry a high-risk of eye injury (e.g., mining and manufacturing) during the 1990s is likely to have further contributed to the overall decline and the larger decline in males than in females. Recent changes in how Americans spend their leisure time may also reveal reasons for the decreasing rate of eye injury. For example, Americans during the past 10 years, especially teens and young adults, have increasingly spent more time in passive leisure activities (e.g., television, radio, video games, and consumer internet), in which eye injury is presumed to be infrequent, and less time in physical leisure activities (e.g., sports), in which eye injury is presumed to be more frequent. In addition to contributing to the overall decline, this may account for the selective decline among the age groups (i.e., only persons aged 39 years and younger experienced a decline in the rate of eye injury) as these persons are at highest risk for eye injury and comprise most persons experiencing these changes in leisure activities.

Aside from visual impairment, eye injury is known to cause significant morbidity in terms of pain, psychosocial stress, and economic burden. For example, the social morbidity resulting from eye injury–related facial disfigurement frequently causes undue psychosocial stress and the cost of work-related eye injury is estimated at 1 to 3 billion dollars annually.

**Figure 3.** Eye injury rate (per 1000) in the United States, according to year, 1992 to 2001.

**Figure 4.** Eye injury rate (per 1000) in the United States, by age, according to year, 1992 to 2001.
proper information and education, up to 90% of eye injuries and a significant amount of its burden are preventable.\textsuperscript{23} Herein, the results indicate the overall rate of eye injury has recently declined. However, certain segments of the population continue to be at high risk (e.g., males and persons aged 39 and younger) and are those to whom prevention resources should be directed.

The results of this study should be interpreted with regard to several strengths and limitations. The inclusion of data from a variety of treatment settings has enabled the construction of what is probably the most comprehensive assessment of eye injury rates in the United States to date. Moreover, the similarity of the sampling and data collection used by the NAMCS, NHAMCS, and NHDS facilitated the pooling of data from these sources. However, this study did not include eye injuries treated at certain settings (e.g., optometrist offices, Veterans Affairs hospitals, and facilities devoted to active duty military personnel) because these facilities were not included in the NAMCS sample. Regarding the exclusion of active duty military personnel, the eye injury rates are known to be much higher than those found in civilian populations. For example, from 1985 to 1994, the eye injury hospitalization rate for active duty U.S. Army personnel was 0.77 per 1000,\textsuperscript{24} whereas the rate reported herein ranged from 0.26 to 0.18 per 1000. When considering all ambulatory settings, the rate of eye injury for active duty U.S. Armed Forces members in 1998 was 9.83 per 1000, whereas the rate in the present study ranged from 3.93 to 7.08 per 1000.\textsuperscript{25} Although it may appear that the inclusion of these sources would significantly alter our results, the actual number of eye injuries in military personnel compared with

\begin{figure}[h]
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\includegraphics[width=\textwidth]{figure5.png}
\caption{Eye injury rate (per 1000) in the United States, by gender (solid line: males; dashed line: females), according to year, 1992 to 2001.}
\end{figure}

\begin{figure}[h]
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\includegraphics[width=\textwidth]{figure6.png}
\caption{Eye injury rate (per 1000 population) in the United States, by race (solid line: white; dashed line: black), according to year, 1992 to 2001.}
\end{figure}
the actual in civilian populations is so small the impact of excluding this source would be negligible. In contrast, it is difficult to estimate how many eye injuries are treated at optometrist offices and office-based practices not captured by the NAMCS. It is reasonable to surmise that a certain number of acute eye injuries were missed by the exclusion of optometrists, yet it is likely that very few were missed by the exclusion of certain office-based practices (e.g., anesthesiology, pathology, and radiology) as the treatment of acute eye injuries in these settings is not likely. Ultimately, the impact of excluding these settings is difficult to predict; however, overall, the injury rates reported herein are certainly conservative. Our use of ICD-9-CM codes to identify patients with eye injury, in a manner similar to other studies on this topic, helped prevent potential biases that may arise when using other sources such as patient self-report. Moreover, this facilitates comparison with prior studies. Although we were able to present data with respect to the etiology of eye injury, this information was only available from NAMCS and NHAMCS. Fortunately, these were the largest sources. Then again, the broad categories reflective of the ICD-9 E-code system do not provide an in-depth picture of the causes of eye injury. For example, the two most common injury mechanisms, foreign bodies and being struck against or by an object, fail to provide adequate information to ensure proper allocation of prevention resources. Population-based studies that provide detailed information on the specific causes of eye injuries are needed, to facilitate the development and targeting of appropriate injury prevention initiatives. The data sources used in this study did not have information on visual outcomes. Although visual impairment resulting from eye injury is infrequent, it increases with the severity of the injury. Thus, most injuries described in this study are unlikely to result in long-term visual impairment, although acute, short-term impairment might be expected for a larger proportion of

**Figure 7.** Eye injury rate (per 1000 population) in the United States, by treatment setting (solid line: private-physician; dashed line: emergency department), according to year, 1992 to 2001.

**Figure 8.** Eye injury rate (per 1000 population) in the United States, by patient group (solid line: outpatient; dashed line: inpatient), according to year, 1992 to 2001.
individuals. Finally, it is possible that when combining data from the NAMCS, NHAMCS, and NHDS we double counted cases of eye injury. This seems highly unlikely, although if it did occur it would be with such low frequency that its impact on the results of this study would be minimal.

We believe the comprehensive nature of this study has produced the most current and accurate picture of eye injury rates in the United States. The following conclusions are worth reviewing. In the United States, the incidence of eye injury is decreasing overall in persons aged 39 years and younger, in both gender and both racial groups. Persons aged 39 and younger and males are the individuals at greatest risk of eye injury although the gaps among genders and age groups are decreasing. Most eye injuries are treated in private physician’s offices. A foreign body is the most frequent cause of eye injury and superficial injury to the eye and adnexa is the most common type of injury. Finally, the distribution of prevention and monetary resources should be directed to those groups that remain at highest risk of eye injury (i.e., males and persons aged 39 and younger). In the future, research should continue to study the national longitudinal trends in eye injuries to update the current findings as well as trends in workplace- and leisure-related eye injuries.

References