Use of Alcohol as a Risk Factor for Bicycling Injury

Guohua Li, MD, DrPH
Susan P. Baker, MPH
John E. Smialek, MD
Carl A. Soderstrom, MD

Context  Bicycling is one of the leading causes of recreational injuries. Elevated blood alcohol concentrations (BACs) are found in about one third of fatally injured bicyclists aged 15 years or older.

Objective  To assess the relative risk of fatal and serious bicycling injury according to BAC.

Design  Matched case-control study.

Setting and Subjects  Bicyclists aged 15 years or older who were fatally or seriously injured while riding a bicycle during the day in Maryland in 1985-1997 (cases, n = 124) and bicyclists aged 15 years or older who were interviewed and given a breath test for estimated BAC during roadside surveys that took place in June 1996 through May 1998 at the same site, time of day, day of week, and month of year in which a case bicyclist was injured (controls, n = 342).

Main Outcome Measure  Odds ratio of bicycling injury according to estimated BAC.

Results  An estimated positive BAC (≥0.02 g/dL) was detected in 12.9% of the case bicyclists (23.5% of the 34 fatally injured and 8.9% of the 90 seriously injured) compared with 2.9% of the control bicyclists (P<.001). Relative to an estimated BAC of less than 0.02 g/dL, the adjusted odds ratio of bicycling injury was 5.6 (95% confidence interval [CI], 2.2-14.0) for a BAC of 0.02 g/dL or higher and was 20.2 (95% CI, 4.2-96.3) for a BAC of 0.08 g/dL or higher. Rates of helmet use at the time of injury or interview were 5% and 35%, respectively, for those with and without a positive BAC (P = .007).

Conclusion  Alcohol use while bicycle riding is associated with a substantially increased risk of fatal or serious injury.

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METHODS

Definitions  Case bicyclists were those who, while riding a bicycle, were injured fatally or so severely that they required hospitalization, as identified from the records of the Office of the Chief Medical Examiner (OCME) of Maryland and the trauma registry of the University of Maryland Medical Center. At OCME, alcohol testing is routinely performed using the head-space gas chromatography method. Medical examiner cases eligible for this study were bicyclists who were fatally injured in Maryland during 1985 through 1997, excluding those who were injured at night (9 PM to 5 AM), those whose BACs were not measured, and those who survived 6 hours or longer after injury.

The University of Maryland Medical Center maintains a trauma registry database of all people admitted to the hospital for injuries, but only those with a BAC of 0.02 g/dL or higher were included in this study.

Author Affiliations: Department of Emergency Medicine, Johns Hopkins University School of Medicine and Center for Injury Research and Policy, Johns Hopkins University School of Hygiene and Public Health (Dr Li and Ms Baker), Office of the Chief Medical Examiner of Maryland (Dr Smialek), and Division of Trauma Surgery, the R Adams Cowley Shock Trauma Center, University of Maryland Medical Center (Dr Soderstrom), Baltimore.

Corresponding Author and Reprints: Guohua Li, MD, DrPH, Department of Emergency Medicine, Johns Hopkins University School of Medicine, 1830 E Monument St, Suite 6-100, Baltimore, MD 21205 (e-mail: ghl@jhmi.edu).
ALCOHOL AND BICYCLING INJURY

Table 1. Selected Characteristics of Cases and Controls

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%) of Cases (n = 124)</th>
<th>No. (%) of Controls (n = 342)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>104 (83.9)</td>
<td>280 (81.9)</td>
<td>.62</td>
</tr>
<tr>
<td>Women</td>
<td>20 (16.1)</td>
<td>62 (18.1)</td>
<td></td>
</tr>
<tr>
<td><strong>Age, y†</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-19</td>
<td>29 (23.4)</td>
<td>58 (17.0)</td>
<td></td>
</tr>
<tr>
<td>20-29</td>
<td>31 (25.0)</td>
<td>81 (23.7)</td>
<td></td>
</tr>
<tr>
<td>30-39</td>
<td>26 (21.0)</td>
<td>101 (29.5)</td>
<td>.31</td>
</tr>
<tr>
<td>40-49</td>
<td>21 (16.9)</td>
<td>61 (17.8)</td>
<td></td>
</tr>
<tr>
<td>50-59</td>
<td>10 (8.1)</td>
<td>30 (8.8)</td>
<td></td>
</tr>
<tr>
<td>≥60</td>
<td>7 (5.6)</td>
<td>11 (3.2)</td>
<td></td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>91 (73.4)</td>
<td>230 (67.3)</td>
<td>.28</td>
</tr>
<tr>
<td>Black</td>
<td>28 (22.6)</td>
<td>102 (29.6)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>5 (4.0)</td>
<td>10 (2.9)</td>
<td></td>
</tr>
<tr>
<td><strong>Marital status‡</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never married</td>
<td>59 (61.5)</td>
<td>187 (54.7)</td>
<td>.16</td>
</tr>
<tr>
<td>Married</td>
<td>31 (32.3)</td>
<td>110 (32.2)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>6 (6.3)</td>
<td>45 (13.2)</td>
<td></td>
</tr>
<tr>
<td><strong>Estimated blood alcohol</strong></td>
<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>concentration, g/dL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;0.02</td>
<td>108 (87.1)</td>
<td>332 (97.1)</td>
<td></td>
</tr>
<tr>
<td>0.02-0.07</td>
<td>3 (2.4)</td>
<td>7 (2.0)</td>
<td></td>
</tr>
<tr>
<td>≥0.08</td>
<td>13 (10.5)</td>
<td>3 (0.9)</td>
<td></td>
</tr>
</tbody>
</table>

*P value indicates the significance of differences in percentage distribution between cases and controls based on χ2 tests. Percentages may not add up to 100 due to rounding.
†The mean (SD) age was 32.6 (14.5) years for the cases and 33.6 (13.1) years for the controls (P = .49).
‡Excludes 28 cases with unknown marital status.

tabase for all patients admitted to the R Adams Cowley Shock Trauma Center.11 BAC testing using gas-liquid chromatography is performed on admission for more than 95% of the patients.12 Eligible cases were injured bicyclists admitted to the trauma center between 1990 and 1997, exclusive of those who were younger than 15 years, injured at night, or without BACs measured within 6 hours of injury.

For each case bicyclist, up to 4 controls were selected at random from passing-by bicyclists who were 15 years or older at the site where the case bicyclist was injured and at the same time of day (within 2 hours), day of week, and month of year as the injury.

Data Collection

Data for case bicyclists were ascertained from medical records. A trained research assistant reviewed the records for all cases and abstracted the required information. Data for control bicyclists came from roadside interviews and tests of breath alcohol using the hand-held device, Alco Sensor III (Intoximeters Inc, St Louis, Mo).13 Trained field workers arrived at each study site 2 hours before the index time (ie, the time of day at which the case bicyclist was injured) and asked passing bicyclists to voluntarily give a brief anonymous interview and, at the end of the interview, a breath sample for alcohol test. At each site, field workers stayed until the lack of estimated BAC information was unavailable. Data collection on a total of 106 control bicyclists was completed for 34 of the 39 fatal cases eligible for fieldwork.

An additional 233 injured bicyclists were identified for the years 1990 to 1997 from the trauma registry database maintained by the University of Maryland Medical Center. Of these, 11 were excluded from the study due to being underage (<15 years), 36 due to the lack of estimated BAC information, 52 due to being injured at night, and 64 due to missing information on the time and/or locality of the injury event. For the remaining 90 nonfatal cases, a total of 236 control bicyclists were interviewed and tested for alcohol. Overall, there were 124 case bicyclists and 342 control bicyclists available for data analysis.

RESULTS

During 1985 through 1997, the OCME recorded a total of 133 bicyclist fatalities. Excluded from the study were 40 bicyclists who died at age 14 years or younger, 42 who were injured at night, and 12 for whom valid estimated BAC information was unavailable. Data collection on a total of 106 control bicyclists was completed for 34 of the 39 fatal cases eligible for fieldwork.

An additional 233 injured bicyclists were identified for the years 1990 to 1997 from the trauma registry database maintained by the University of Maryland Medical Center. Of these, 11 were excluded from the study due to being underage (<15 years), 36 due to the lack of estimated BAC information, 52 due to being injured at night, and 64 due to missing information on the time and/or locality of the injury event. For the remaining 90 nonfatal cases, a total of 236 control bicyclists were interviewed and tested for alcohol. Overall, there were 124 case bicyclists and 342 control bicyclists available for data analysis.

Characteristics of Cases and Controls

The demographic characteristics of the cases and controls were similar (TABLE 1). Overall, 82% of the study subjects were men; 69%, white; and 56%, never married with a mean age of 33.4 years. Alcohol was detected in 23.5% of the 34 fatal cases, 8.9% of the 90 nonfatal cases, and 2.9% of the controls (P < .001), yielding a crude odds ratio (OR) of 5.3 (95% confidence interval [CI], 2.1-13.1; matched analysis).

Statistical Analysis

Data were analyzed using SAS software.14 Statistical significance at the bivariate level was assessed based on χ2 tests or Fisher exact tests where appropriate for categorical variables, and t tests for continuous variables. The relative risk of bicycling injury in relation to alcohol use was estimated through conditional logistic regression modeling with consideration of the matched case-control design. Helmet use was not included in the multivariate analysis because not wearing a helmet has been recognized as an intermediate factor in the pathway of alcohol use and bicycling injury.7,15
For those who tested positive for alcohol, the mean estimated BAC was 0.18 g/dL for the cases and 0.07 g/dL for the controls.

### Adjusted Risk of Bicycling Injury

With adjustment for age, sex, and race, the OR of bicycling injury relative to an estimated BAC of less than 0.02 g/dL was 3.6 (95% CI, 2.2-14.0) for riders with an estimated BAC of 0.02 g/dL or higher and was 20.2 (95% CI, 4.2-96.3) for riders with an estimated BAC of 0.08 g/dL. (Table 2).

The risk of bicycling injury associated with a positive BAC was much greater for fatal injury than for nonfatal injury (Table 2).

To assess the potential bias resulting from the different time periods that cases were injured and controls were interviewed, analysis was performed separately for cases occurring between 1985 and 1993 and cases occurring between 1994 and 1997. Odd ratios related to BACs appeared to be consistent between the 2 time periods (Table 3).

### Estimated BAC and Helmet Use

Among the 78 cases whose helmet use status was known, 8% (1/12) of those with an estimated BAC of 0.02 g/dL or higher were wearing a helmet at the time of injury compared with 38% (25/66) of those with an estimated BAC of less than 0.02 g/dL. (P = .09). Sensitivity analyses based on 2 assumptions regarding cases with unknown helmet use status (ie, either all were wearing or all were not wearing helmets) revealed that the rate of helmet use at the time of injury ranged from 6% to 31% for those with an estimated BAC of 0.02 g/dL or higher and from 23% to 62% for those with an estimated BAC of less than 0.02 g/dL. None of the 10 control bicyclists with an estimated BAC of 0.02 g/dL or higher was wearing a helmet at the time of interview vs 34% (114/332) of their counterparts with an estimated BAC of less than 0.02 g/dL. (P = .03). Overall, bicyclists with an estimated BAC of less than 0.02 g/dL were 7 times as likely as those with an estimated BAC of 0.02 g/dL or higher to be wearing a helmet (35% vs 5%, respectively; P = .007).

### COMMENT

Although alcohol has been implicated in many types of injuries, few controlled epidemiologic studies have examined the role of alcohol in these injuries. Our study expands the knowledge base of alcohol as an etiologic factor in causing trauma. The risk of bicycling injury increases significantly with BACs. In particular, alcohol at levels of 0.08 g/dL and higher may subject bicyclists to a 20-fold heightened risk of fatal or serious injury.

There are 2 main pathways linking alcohol to injury. First, the excess risk of injury for drinking bicyclists may be caused by the deleterious effects of alcohol on psychomotor skills, cognitive functions, and safety behaviors, ie, a reduction in the rider’s ability to maintain balance, negotiate traffic, and perceive and respond to situational hazards. Second, the increased risk of injury for alcohol-impaired bicyclists may result from a host of risk-taking behaviors that correlate with alcohol use and expose the subjects to more dangerous circumstances, such as riding at excessive speed, on highways, at night, or under adverse weather conditions. Our study shows that bicyclists with a positive BAC are less likely than other bicyclists to be wearing a safety helmet. Although this disparity in helmet use represents a plausible explanation for the heightened injury risk for bicyclists who consume alcohol, it is unclear to what extent the dismal rate of helmet use among BAC-positive riders is due to alcohol-induced impairment in cognitive functions and safety behaviors. It is possible that people who ride bicycles after consuming alcohol may simply be less likely than other bicyclists to own a safety helmet or to opt to wear it when available. A recent study found that 30% of injured bicyclists with a positive BAC have a history of alcohol-impaired driving.

It is noteworthy that this study did not take into account alcohol use by motorists, who are involved in 90% of all fatal bicycling injuries and 30% of all bicycling injuries requiring hospitalization. Other limitations of this study include potential selection bias and reduced external validity. Information for control bicyclists was collected only from those who stopped in response to our verbal invitation for participation. If bicyclists who had been drinking were less likely than those who had not been drinking to stop in response to our invitation to be interviewed, the ORs of bicycling injury related to alcohol use reported in this study would be somewhat overestimated.

Individually matching cases and controls on index site and time has probably enhanced the internal validity of our findings. However, the rigorous de-

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**Table 2. Bicycling Injury by Estimated Blood Alcohol Concentration (BAC) From Multivariate Conditional Logistic Regression Models**

<table>
<thead>
<tr>
<th>BAC, g/dL</th>
<th>Nonfatal Injury</th>
<th>Fatal Injury</th>
<th>Fatal or Nonfatal</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥0.02</td>
<td>2.9 (0.9-8.8)</td>
<td>21.9 (2.7-179.4)</td>
<td>5.6 (2.2-14.0)</td>
</tr>
<tr>
<td>≥0.08</td>
<td>10.1 (1.8-55.6)</td>
<td>. . .</td>
<td>20.2 (4.2-96.3)</td>
</tr>
</tbody>
</table>

* Odds ratios are relative to BAC<0.02 g/dL and are adjusted for age, sex, and race. Ellipses indicate that data are not estimatable because none of the controls had a BAC ≥0.08 g/dL.

<table>
<thead>
<tr>
<th>BAC, g/dL</th>
<th>1985 and 1993*</th>
<th>1994 and 1997†</th>
<th>All Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥0.02 vs &lt;0.02</td>
<td>5.2 (1.7-15.2)</td>
<td>5.6 (1.1-30.0)</td>
<td>5.3 (2.1-13.1)</td>
</tr>
<tr>
<td>≥0.08 vs &lt;0.08</td>
<td>17.3 (1.5-141.9)</td>
<td>11.7 (1.3-103.5)</td>
<td>14.6 (3.2-65.9)</td>
</tr>
</tbody>
</table>

*For injuries occurring between 1985 and 1993, the number of cases is 102 with 285 controls.
†For injuries occurring between 1994 and 1997, the number of cases is 22 with 57 controls.

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sign proved to be labor-intensive and detrimental to the study power and generalizability. Out of safety concerns for field workers in collecting data for control bicyclists, matching on site and time excluded from analysis bicyclists who were injured at night. Previous studies3,7 indicate that about 56% of fatal bicycling injuries occur between 7 PM and 6 AM and indicate that bicyclists who are injured at night are more likely than those who are injured during the day to have been drinking and to have become intoxicated. Given the reduced visibility and increased demand of psychomotor skills for bicyclists at night, it is conceivable that the risk of bicycling injury attributable to alcohol use is actually greater than reported in this study.

**Author Contributions:** Dr Li participated in the study conception and design, acquisition of data, analysis and interpretation of data, and drafting of the manuscript; provided critical review of the manuscript for important intellectual content, statistical expertise, and administrative, technical, or material support; obtained funding; and conducted supervision of the study. Ms Baker participated in analysis and interpretation of the study data; provided critical revision of the manuscript for important intellectual content; and obtained funding for the study. Dr Sniezek participated in acquisition of study data; provided critical revision of the manuscript for important intellectual content and statistical expertise.

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