BICYCLE USE AND HAZARD PATTERNS IN THE UNITED STATES

JUNE 1994

U.S. Consumer Product Safety Commission
Washington, D.C. 20207

U.S. CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, D.C. 20207

June 1994

Dear Bicycle Safety Professional:

Bicycle riding, both for recreation and commuting, is increasing in popularity across the United States. Bicycle riding is also a risky activity. Each year, bicycles are involved in about one million medically-attended injuries and almost 1,000 deaths. In fact, there are more injuries and deaths associated with bicycles than with almost any other single product under the U.S. Consumer Product Safety Commission's jurisdiction. The estimated cost to the nation for these bicycle-related injuries and deaths is approximately $8 billion annually. These statistics are staggering. Professionals like you are challenged with developing and implementing effective safety programs to address this serious problem.

Commission work on bicycle safety dates back to when its doors were first opened for business in 1973. The Commission's activities have included mandatory and voluntary standards to address equipment safety (bicycles and helmets) and consumer information programs to address the largest risk factor, rider skill and behavior.

The accompanying study is provided for your use in developing new bicycle safety programs or improving existing ones to help address issues with rider skill and behavior. This is the first national study of its kind to gather and evaluate information describing how bicycles are used and how they are involved in incidents. I hope that this CPSC study will become one of your most valuable tools in designing effective bicycle safety programs. By working together for bicycle safety, your organization and the CPSC can make bicycle riding safer.

Sincerely,

Ann Brown

Ann Brown
Chairman

Bicycle Use and Hazard Patterns in the United States

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Introduction

The purpose of this report is to present the results of a major national study of bicycle use and hazard patterns recently completed by the U.S. Consumer Product Safety Commission (CPSC). The study was developed as part of the CPSC's bicycle hazard project; the project was begun in 1990 to evaluate bicycle use and hazard patterns, and to assess alternative strategies for injury reduction.

The main impetus for the bicycle study was the large number of injuries and deaths involving bicycles every year and the serious lack of national data on bicycle use and hazard patterns. As described below, there are on the order of one million medically attended injuries and almost 1,000 deaths involving bicycles every year. However, despite the large number of injuries and deaths, there has never been a national study of bicycle use, or of injury and hazard patterns. Moreover, the studies that do exist have tended to focus on injuries and deaths in limited geographical areas, and have given little attention to the great majority of injuries that do not involve motor vehicles.

The bicycle study was designed to fill some of these gaps. It was a multi-disciplinary effort, using the expertise of an agency team of epidemiologists, economists, mechanical engineers, human factors specialists, and health scientists. The focus of the study was on two nationwide CPSC surveys, an injury survey and an exposure survey, that were planned in 1990 and conducted in 1991. The injury survey collected information on bicycle-related injuries reported through the CPSC's National Electronic Injury Surveillance System (NEISS), a stratified random sample of U.S. hospital emergency rooms. The exposure survey collected parallel information on the characteristics and use patterns of the general population of bicyclists in the U.S.

Each of the surveys provided important new information on bicycle use and hazard patterns. In addition, the combination of surveys enabled agency staff to conduct a formal risk analysis of the factors associated with bicycle injury risks. The staff also used the results of the two surveys, in conjunction with other available information, to conduct a human factors analysis of children's risk, an engineering analysis of mechanical hazard patterns, an evaluation of bicycle-related deaths, and an in-depth analysis of helmet use patterns.

This report is made up of eight parts. Part I presents a non-technical but detailed overview of the study's methodology, its major findings, and its implications for injury reduction strategies. It describes the major results of the study, and directs readers who are interested in the technical details of the study to the analyses in Parts II through VIII.

Parts II and III contain the descriptive results of the two CPSC surveys and the most important statistical analyses of the study. Part II describes the bicycle use patterns of the general population of bicyclists in the U.S. Part II also provides information on current helmet usage patterns, and includes a statistical analysis of the factors associated with helmet use. Part III presents a detailed description of bicycle injury and hazard patterns based on the survey of injuries treated in U.S. hospital emergency rooms. It also presents the bicycle risk analysis, which was conducted using the combined results of the injury and exposure surveys.

Parts IV and V contain the human factors and engineering assessments of the injury data. The human factors assessment focuses on children's risk patterns and the implications for bicycle training and the use of safety equipment. The engineering analysis evaluates the possible mechanical hazards reported in the injury survey.

Part VI presents an analysis of bicyclist deaths and fatality risk patterns. Information on bicycle-related deaths is compared with the results of the exposure survey to present a preliminary analysis of factors associated with the fatality risk. Parts VII and VIII complete the study with a description and analysis of the results of a complementary survey of adult bicyclists conducted by the Rodale Press in 1990. The Rodale Press survey did not include children, but it did gather information on a wide range of issues relevant to the behavior of adult bicyclists, much of which was directly comparable to the results of the CPSC exposure survey.

The CPSC compiled this report to facilitate improvements in bicycle safety by providing a sound empirical basis for the design and implementation of safety programs. Its purpose is to serve as a technical resource for individuals and organizations interested in promoting bicycle safety. It is especially intended for experienced bicycle safety practitioners, who need the latest information on bicycle use and hazard patterns to develop or improve their own safety programs, and for safety analysts who are interested in conducting further research on bicycle-related hazard patterns and injury reduction strategies.

Although the CPSC bicycle study focuses on bicycle injuries and rider safety, bicycles are also likely to play an increasingly important role in meeting the future transportation needs of Americans. Encouragement at the federal level has already been given through such legislation as the U.S. Intermodal Surface Transportation Efficiency Act of 1991. The report may also be of use to bicycle user groups interested in transportation and safety issues, and to transportation officials and state and local bicycle program coordinators interested in promoting a safe riding environment.

Contents

Part I.
An Overview of the Bicycle Study

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Background

Bicycle riding is one of the most popular recreational activities in the United States. The National Sporting Goods Association (1992) estimates that bicycle riding was the third leading U.S. recreational activity in 1991, after exercise walking and swimming. In addition, bicycle riding is an important means of transportation. The Bicycle Institute of America (1993) estimates that there were about 4.3 million Americans who regularly commuted to work in 1992.

Bicycle riding is also a risky activity, as indicated by the large numbers of injuries and deaths involving bicycles every year. According to the U.S. Consumer Product Safety Commission's (CPSC) National Electronic Injury Surveillance System (NEISS), an injury reporting system that consists of a statistical sample of the nation's hospital emergency rooms, there have been about one-half million nonfatal bicycle-related injuries treated in hospital emergency rooms every year since the early 1970s, when NEISS became operational. When other medically-attended injuries are counted, such as injuries treated in physicians' offices, there may be on the order of one million medically-attended injuries involving bicycles every year. In addition, there are as many as 1,000 bicycle-related fatalities annually. The estimated costs of these injuries and deaths to society are high -- approximately $8 billion annually -- and suggest that injury reduction strategies with even modest levels of effectiveness could prove to be cost-effective.

The CPSC has long had an interest in bicycle-related hazards and in promoting bicycle safety. The agency began development of a mandatory standard for bicycles as one of its first orders of business in 1973. The bicycle standard, which became effective in 1976,[1] set safety requirements for reflectors, wheels and tires, chains, pedals, braking and steering systems, and for structural components such as frames and forks. More recently, the Commission has provided a substantial amount of information on bicycle safety to the public and encourages all riders to use helmets.

[1] See, 16 CFR Part 1512, 41 Federal Register 4144-4154, January 28, 1976, and 16 CFR Part 1512, 43 Federal Register 60034-46, December 22, 1978.

Bicycle safety is also promoted by many other governmental and non-governmental organizations, and is of considerable interest to the health and safety research community. In 1991, Congress passed the Intermodal Surface Transportation Efficiency Act (ISTEA), an act that required all states and metropolitan planning organizations incorporate programs and facilities for bicyclists in their transportation plans. Also in 1991, the Department of Transportation's (DOT) Appropriations Act instructed DOT to develop a plan to promote bicycling and walking, and to enhance the safety of these transportation modes.

The interest of the health and safety community in bicycle safety is evidenced by the large number of professional publications in the safety and medical literature. For the most part, however, the published literature on bicycle hazards consists of injury analyses carried out at the level of the individual hospital or in limited geographical areas. While these studies provide valuable information about injury characteristics in various localities, there has never been a comprehensive national study of bicycle use and hazard patterns designed to quantify riding patterns and the rider and environmental factors associated with risk. Moreover, while injuries resulting from bicycle-motor vehicle collisions have been evaluated extensively (Cross and Fisher, 1977; Roland et al., 1979), little attention has been given to the analysis of bicycle-related hazard patterns which do not involve motor vehicles, but which do account for the great majority of injuries.

The CPSC bicycle project was intended to remedy some of these data deficiencies by evaluating bicycle use and hazard patterns on a national basis. The remainder of this report provides an overview of the methodology of the bicycle study, and the study findings.

Data and Methods

The CPSC conducted two nationwide bicycle surveys in 1991. The first, the "injury survey," was conducted by the CPSC's Directorate for Epidemiology (EP) during calendar year 1991 and gathered information on a sample of 463 bicycle-related (nonfatal) injuries reported through NEISS. NEISS injury reports were followed up with telephone interviews to collect information on the characteristics and use patterns of riders with injuries treated in hospital emergency rooms, the types of injuries suffered, and descriptions of the injury and hazard scenarios.

EP identified 41 incidents (i.e., injury accidents reported through NEISS) which might have involved mechanical failure or design problems. These incidents were assigned for on-site investigations. The Directorate for Engineering Sciences (ES) evaluated these incident investigations to determine if there were systematic mechanical hazards which might be addressed by revisions to the existing mandatory standard.

The second survey, the "exposure survey," was a national random-digit-dial telephone survey that collected information on the characteristics and use patterns of the general population of bicyclists. The survey was conducted by Abt Associates, Inc., under the direction of the Directorate for Economic Analysis (EC). It resulted in 1,254 completed interviews with bicyclists from around the nation.

These surveys provided nationally representative samples of injured bicyclists who were treated in hospital emergency rooms and of the general population of bicyclists. Because they gathered parallel information on injured and noninjured bicyclists, the agency staff were able to conduct a "risk analysis" by comparing the characteristics and use patterns of injured riders with those who were not injured. In effect, the exposure data were used as "control data" against which to compare the characteristics and use patterns of injured bicyclists. The aim of the risk analysis was to determine and quantify the rider and environmental factors associated with higher risk levels.

The Division of Human Factors (HF) reviewed the injury and exposure survey data bases in light of behavioral studies applicable to bicycle riding. HF also evaluated the literature on bicycle safety education and training, with emphasis on the developmental capabilities of children.

The CPSC does not collect information on all bicycle-related deaths. However, because deaths constitute an important bicycle hazard pattern, the study provides a brief description and analysis of information on bicyclist deaths obtained from the National Center for Health Statistics and from the National Highway Traffic Safety Administration's (NHTSA) Fatal Accident Reporting System.

To complement the analysis of bicycle use and risk patterns, the agency purchased data from a comprehensive 1990 survey of adult bicyclists commissioned by Rodale Press, the publishers of *Bicycling* magazine (Rodale Press, 1991). The Rodale Press survey was conducted by National Family Opinion, Inc., from its national consumer mail panel, and included interviews with over 3,200 adult bicyclists who were 18 years-of-age and older. Although the survey did not gather information on bicycle use by children, a major focus of the CPSC project, it did gather data on a wide range of topics relevant to an analysis of the risk and safety behavior of adult bicyclists. In many cases, its results were directly comparable to the results of the CPSC exposure survey. It also provided market data, such as plans for future purchases of bicycles and equipment, which were unavailable from other sources.

Characteristics of Riders and Injury Statistics

This section summarizes some of the important descriptive results from the 1991 injury and exposure surveys, including the characteristics and use patterns of riders, and injury statistics.

Rider Characteristics and Use Patterns

The results of the exposure survey are detailed in Part II. The exposure survey confirmed the popularity of bicycle riding in the U.S. There are about 67 million bicyclists who ride a total of about 15 billion hours annually. Most bicycle riding is for recreational purposes, but almost 9 percent of riders use their bicycles primarily for commuting to work or school.

Just over half of all bicyclists (52 percent) are males. In addition, a large proportion of bicyclists are young. About 22 percent are under the age of 10 years and 40 percent are under age 15. Young bicyclists ride more than the average for all bicyclists. Riders under age 15 reportedly ride about 300 hours per year, about 50 percent more than the average reported for riders age 15 and older.

Most bicyclists (64 percent) ride a substantial proportion of the time on neighborhood streets with low traffic volume, but sizable proportions also spend a lot of their riding time on sidewalks and playgrounds (29 percent), bike paths (17 percent), and unpaved roads (18 percent); smaller proportions ride on major thoroughfares with high traffic volume (7 percent) and on other unpaved surfaces or trails (11 percent).

Children under age 10 ride primarily on sidewalks, playgrounds, and neighborhood streets; riders over age 10 are more likely to be found on neighborhood streets, bike paths, or major thoroughfares. About 12 percent of bicyclists ride at least occasionally after dark. However, less than one-third of these nighttime riders use headlights or taillights.

There are about 96 million bicycles in existence, but only about 66 million (69 percent) were used in the year prior to the survey. Children's models (i.e., sidewalk or BMX/high rise) account for over one-fourth of the bicycles in use. Of the adult models (i.e., lightweight racing/touring, mountain, and middleweight/cruisers), the lightweight racing and touring bicycles are the most common and account for about one-third (34 percent) of the bicycles in use. Mountain bikes were first marketed in substantial numbers in the early 1980s, and now account for about 17 percent of the bicycles in use.[2]

The Rodale Press survey findings for adult bicyclists (age 18 and over) are described in Part VII of the study. They are generally consistent with the findings of the CPSC exposure survey. The majority of adult bicyclists (62 percent) rode most often on neighborhood streets. In addition, over half (57 percent) had access to community bike paths, and 28 percent had access to extra wide roads or bike lanes. Many bicyclists said that "having safer places to go riding" (35 percent) or "being able to ride to work" (14 percent) would encourage them to ride their bicycle more often.

About one-fifth of the Rodale Press survey respondents expected to purchase a new bicycle within 2 years. The mean expected outlay was $334, an 82 percent increase over the mean price paid ($183) by recent purchasers. The Rodale Press results also indicate that

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[2] The term mountain bike refers to the class of bicycles that includes city, all-terrain, or mountain bicycles.

mountain bicycles are increasing in market share. While 14 percent of recent purchasers said that they had bought a mountain bicycle, 44 percent of those planning a purchase expected to buy a mountain bicycle.

Characteristics of Victims, Injuries, and Injury Location

According to the analysis of the injury survey results, which are detailed in Part III of the study, there were an estimated 588,000 bicycle-related injuries treated in U.S. hospital emergency rooms in 1991. About 531,000 (90 percent) involved bicycle operators; the remainder involved primarily passengers and bystanders.

About 62 percent of the injured operators were male. Most were also children: about 37 percent of the injured operators were under age 10, and 71 percent were under age 15. Non-operators who were injured (i.e., primarily passengers and bystanders) were younger than injured operators; about 66 percent of the injured non-operators were under age 10.

Injured bicycle operators also tend to be younger than the general population of bicycle riders. Table 1 compares the ages of injured operators with those of the general rider population from the exposure survey. As can be seen, children between the ages of 5 and 14 are disproportionately involved in accidents resulting in injury. While 5-to-14 year-old bicyclists represent about 36 percent of riders, they account for about 68 percent of all emergency room treated injuries.

Table 1: Distributions of Riders by Age

Age (years)	Injured Operators (Percent)	All Riders (Percent)
≤ 4	3.1	3.8
5-9	33.6	17.7
10-14	34.7	18.6
15-24	10.9	16.3
25-44	13.4	32.7
45-64	3.1	9.5
≥ 65	1.1	1.4
Total	100.0	100.0

Source: 1991 CPSC Bicycle Injury and Exposure Surveys.

Almost one-third (30 percent) of all operator injuries involved the head or face; 27 percent of these head/face injuries involved potentially serious diagnoses, such as fractures, internal injuries, or concussions. Young children suffered a significantly higher proportion of head injuries than older victims; 50 percent of the injuries suffered by children under age 10 involved the head or face, compared with 19 percent for riders age 10 or older.

Less than 3 percent of injury victims were admitted for hospitalization. This is about the same rate of hospitalization (about 4 percent) for all product-related injuries reported through NEISS in 1991.

Just over half of the operator injuries (53 percent) happened on roadways (i.e., surfaces designed for use by motorized vehicles). About three-quarters of the roadway injuries occurred on neighborhood streets; the remainder were on major thoroughfares and unpaved roads. Riders age 25 and older were injured on highways or major thoroughfares more frequently than younger riders. Bicyclists under age 25 who were injured on roadways were more likely to be injured on neighborhood streets.

Another 12 percent of the operator injuries occurred on sidewalks and playgrounds; most involved children under age 10. About 5 percent of the incidents occurred on unpaved roads, 5 percent occurred on trails, and less than 1 percent occurred on bike paths.

Injury Hazard Patterns and Risk Factors

A major focus of the bicycle study was the evaluation of bicycle hazard patterns and the bicycle risk analysis. This section summarizes the results of these analyses, which are contained in Part III of the study. It also presents some complementary results from a risk analysis of the Rodale Press survey data base, which can be found in Part VIII.

Hazard Patterns and Contributing Factors.[3]

An estimated 15 percent of the injuries involved collisions with moving objects, such as motor vehicles, other bicycles, or animals. Another 13 percent involved collisions with non-moving objects, such as parked cars, traffic signs, or fences. Incidents involving collisions or near-collisions (i.e., swerving to avoid collisions) with moving motor vehicles accounted for only about 10 percent of the injuries.

About 11 percent of the incidents occurred while victims were performing stunts, such as jumping over ramps or speed bumps, or performing "wheelies." About 88 percent of the incidents that occurred while performing stunts involved children under age 15, and 80 percent involved male riders.

Respondents reported a number of factors that contributed to the incidents. Uneven riding surfaces (e.g., bumps, ruts, curbs) contributed to about 27 percent, slippery surfaces contributed to about 15 percent, and "going too fast" contributed to about 22 percent. Other miscellaneous reported factors included mechanical failure, rider inexperience, inattention,

[3] Unless otherwise noted, all injuries refer to injuries suffered by bicycle riders (i.e., bicycle operators rather than passengers or bystanders).

riding the wrong size bicycle, or riding at night without a light. The use of earphones or carrying young children in child carriers did not play a major role in injury scenarios.

Just over one-fifth of the injuries occurred under non-daylight conditions: about 5 percent were at night and 16 percent were at dawn or dusk. However, about 35 percent of the injuries on major thoroughfares occurred under non-daylight conditions. Less than 3 percent of the injuries occurred in rain or snow.

Risk Analysis and Risk Factors

Table 2 presents information on injury rates for various age groups. Based on the results of the injury and exposure surveys, there were about 8.8 bicycle-related injuries treated in hospital emergency rooms for every 1,000 riders in 1991. Riders 5-to-14 years of age have the highest injury rate with about 17 injuries per thousand riders. The injury rate for all riders age 15 and older is considerably lower than the child injury rate. However, when adjusted for hours of annual use, the injury rate for riders over age 64 is similar to the child injury rate. Although based on a small sample of older riders, riders over the age of 64 (who ride much less than children) have an adjusted injury rate comparable to that of riders in the 5-to-14 year-old age group.

Table 2: Bicycle Injury Rates, by Age Group

Victim Age (years)	Injuries per Thousand Riders	Injuries per Million Hours of Use
All Ages	8.8	37.2
≤ 4	7.3	25.3
5-9	16.9	57.0
10-14	16.7	55.4
15-24	5.9	29.4
25-44	3.6	18.1
45-64	2.9	22.0
≥ 65	7.2	61.0

Source: 1991 CPSC Bicycle Injury and Exposure Surveys

EP staff used a logistic regression model to determine and quantify the factors associated with the injury risk.[4] They estimated a general model which included riders from all age groups. In addition, they estimated two separate risk models, one for riders under age 15 ("children"), and one for riders 15 years of age and older ("adults"), because of the significant risk differential between these two groups.

[4] This statistical technique is used to determine the independent impact of each of several factors on the injury risk. It is useful when a number of factors simultaneously affect the injury risk.

The general model found a significantly higher risk for children under age 15. Holding all other factors constant, the risk for a child under age 15 was over 5 times the risk for an older rider. Most of the other results for the two age-specific models were similar to those in the general model.

In the children's model, higher risks were associated with certain riding surfaces, time of day, and population density. Children who rode during non-daylight hours, on streets, and who lived in areas with greater population density were more likely to be injured. The risk on streets was about 8 times the risk on bike paths, 3.4 times the risk on unpaved surfaces, and about 1.7 times the risk on sidewalks. Riding under non-daylight conditions (e.g., at night, dusk, or dawn) was about 3.6 times more risky than riding during the daytime. Rider gender had no statistically significant effect on the injury risk.

In the model for riders 15 years of age and older, risk was also affected by riding surface. As in the children's model, the adult risk was higher on paved roadways. The risk on neighborhood streets was about 7 times the risk on bike paths and about 9 times the risk on unpaved surfaces. Moreover, the risk on major thoroughfares, the highest risk riding surface, was about 2.5 times the risk on neighborhood streets. As in the children's model, risk was higher for riders who lived in areas with greater population density. However, there was no significant difference in risk between daylight and non-daylight hours. Nor did rider gender independently affect the injury risk.

In the Rodale Press survey of adult riders, about 9 percent of respondents reported that they had had accidents in which they had crashed or fallen off their bicycle within 12 months of the survey. These accidents may or may not have resulted in a medically-attended injury. An analysis of factors associated with this accident risk was highly consistent with the results of the EP risk analysis of riders 15 years of age and older. One especially noteworthy finding was that the accident risk rose for riders over age 64; the risk for riders over age 64 was significantly higher than for riders 25-to-64 years of age. (This finding was suggested in the EP risk analysis, but was not significant, probably because of the small sample of riders over age 64.) In addition, the accident risk was substantially higher on off-road trails (a type of riding surface not evaluated directly in the EP risk assessment) than on other riding surfaces.[5]

Human Factors Evaluation of Children's Risk

HF reviewed the bicycle injury data on children and the existing literature on safety education and training. This analysis, which can be found in Part IV, provides some explanation for the higher risks for children under age 15, based primarily on the cognitive immaturity of children. According to HF, bicycle riding is a complicated activity in which a lot

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[5] Riding on "unpaved roads" was combined with "other unpaved surfaces and trails" in the EP risk analysis.

of information is vying for the attention of children. Children often do not have the ability to filter all the information, or to filter it correctly.

According to available literature, children 5-to-14 years of age begin to test their skills and experience many physical and cognitive changes. They may push their bodies physically in ways that can lead to injury. In addition, boys tend to be more risk-taking than girls, as evidenced in many studies. These factors may help explain why 88 percent of those injured while performing stunts were under age 15, and why 80 percent involved boys.

The egocentric behavior of children (i.e., the inability to perceive other people's viewpoints) also helps explain their higher injury risk. It is not until around the age of 10 that children are able to consider the consequences of their actions. For example, children under age 10 may not consider their behavior unexpected when they suddenly turn in front of a car or dart out of a driveway, because that appears to them as the only way to go.

Evaluation of Mechanical Hazards

EP identified 41 incidents (i.e., injury accidents reported through NEISS) which might have involved mechanical failure or design problems. These cases represented about 13 percent of the operator injuries, and were all assigned for on-site investigations. ES evaluated the incident investigations to determine if there were systematic mechanical hazards which might be addressed by revisions or amendments to the existing mandatory standard. This analysis can be found in Part V.

The most frequently reported problems involved bicycle chains breaking or falling off, brakes failing, and various components such as handlebars and brake components coming loose. By mechanical component group, the 41 cases involved: brakes (15 cases); chains (13 cases); handlebars (6 cases); tires (2 cases); and gear cables, seats, spokes, handgrips, and pedals, with one case each.

Although the cause of these alleged mechanical failures could not be absolutely determined, ES concluded that poor bicycle maintenance and/or bicycle modifications were contributors in a minimum of 9 cases and possible contributors in an additional 11 cases. External conditions, such as slick road surfaces, were probable contributors in 4 cases. In addition, operator behavior and unfamiliarity with a bicycle were described as possible contributors in 12 cases.

Only 15 of the cases (representing an estimated 4 percent of emergency room treated injuries) reported component malfunctions without indicating other likely contributing factors. However, information was insufficient to determine if these incidents resulted from inherent mechanical failure not attributable to poor maintenance, ill-advised modifications, or other factors. ES concluded that there were no significant mechanical failure patterns that warranted amendment or revision to the mandatory bicycle standard.

Bicycle-Related Deaths

Information on bicycle-related deaths is available from two sources: the National Center for Health Statistics (NCHS) and NHTSA's Fatal Accident Reporting System (FARS). In Part III of the study, NCHS data on deaths are discussed and compared to data from the injury survey. The NCHS identified about 890 bicyclist deaths in 1989, the most recent year for which data from that source are available. About 90 percent of the deaths involved motor vehicles, compared to about 10 percent of the nonfatal injuries treated in hospital emergency rooms.

According to the NCHS data, bicycle injury victims who died tended to be older than those who were treated for nonfatal injuries in hospital emergency rooms. As shown in Table 3, about 63 percent of those who died were age 15 or older, and about 17 percent were age 45 or older. In contrast, about 29 percent of the nonfatal injury victims were age 15 or older, and only about 4 percent were age 45 or older. In addition, fatal accidents were more likely to involve males. About 85 percent of the fatality victims were male, in contrast to about 62 percent of the nonfatal injury victims.

Table 3: Age and Gender of Victims, by Percent of Deaths and Injuries

Age (years)	Deaths (NCHS, 1989) (Percent)	Injuries (NEISS, 1991) (Percent)
≤ 4	2.0	3.1
5-14	35.0	68.4
15-24	21.3	10.9
25-44	25.2	13.4
45-64	9.5	3.1
≥ 65	7.0	1.1
Total	100.0	100.0
Gender		
Female	14.7	37.7
Male	85.3	62.3
Total	100.0	100.0

Source: National Center for Health Statistics 1989, and the 1991 CPSC Bicycle Injury Survey

Fatal injuries also tended to involve a greater proportion of head injuries than did nonfatal injuries treated in hospital emergency rooms. While the injury survey indicated that 30 percent of emergency room treated injuries involved the head or face, Sacks et al. (1991) estimated that about 62 percent of all bicycle-related deaths involved head injury.

In Part VI of the study, bicycle-related deaths reported through NHTSA's Fatal Accident Reporting System (FARS) are evaluated in conjunction with data from the exposure survey. The FARS data are limited to deaths resulting from crashes with motor vehicles on public roadways (about 90 percent of deaths), but since data were available for 1991, the FARS data were directly comparable to data from the 1991 exposure survey. It was therefore possible to estimate comparative risk factors for various gender and age categories by comparing the distribution of the 1991 FARS deaths with estimates of riding exposure from the 1991 CPSC exposure survey.

This analysis revealed that the fatality risk for male bicyclists, adjusted for riding exposure, was almost five times the risk for female bicyclists. In addition, when adjusted for exposure, the fatality risk for 16-to-24 year-old bicyclists was about 2.1 times higher than for bicyclists under age 16. The relative risk of fatality was even higher for riders over the age of 44, and was highest for those over age 64. Riders over age 64 were about 3.2 times more likely to be involved in fatal accidents than 16-to-24 year-old riders, and about 6.6 times more likely to be involved in fatal accidents than riders under age 15.

Finally, riding after dark appears to contribute to the fatality risk. An estimated 23.5 percent of the deaths occurred between the hours of 9:00 p.m. and 5:59 a.m. Although daylight conditions vary during the year and by region, most of these deaths probably occurred after dark. Another 22.9 percent of the deaths occurred between 6:00 p.m. and 8:59 p.m., some of which probably occurred after dark. In contrast, only about 12.4 percent of riders from the exposure survey reported that they engage in nighttime riding at least some of the time. Nighttime riding therefore appears to be an important contributing factor in bicycle deaths.

Bicycle Helmet Findings

While recent studies show substantial safety benefits from helmet use, they also reveal that only a small proportion of riders actually use helmets. The exposure survey provides valuable insights into current helmet usage patterns and on the reasons why riders use or do not use helmets. This section summarizes the helmet usage patterns of bicyclists and the statistical analysis of factors associated with helmet use, which are detailed in Part II. It also describes the attempt in Part III to evaluate the impact of helmet use on the likelihood of head injury.

Descriptive Results

The exposure survey found that only 11.8 million (18 percent) of the entire population of about 67 million bicyclists wear helmets all or most of the time. Another 6 percent, representing about 4 million riders, reported that they wear helmets sometimes, but less than half of the time.

The proportion of children under age 15 who wear helmets all or most of the time was about 15 percent. HF reports (in Part IV) that the low usage rate for children may be partly related to peer pressure. Some studies show that children are not inclined to wear helmets if their social group disapproves of helmet use. However, helmet use in all age groups appears to be increasing. Just over half of the current users (53 percent) began wearing helmets in the last two years.[6]

Nearly all of the 9 million riders who always wear helmets described "safety" as an important reason for doing so. The "insistence of family members," was also important to about half of those who always wear helmets. Usage patterns for 6.8 million riders who wear helmets sometimes, but not all of the time, are apparently affected by risk perceptions. Many said that they usually wear helmets when in traffic (40 percent) and when on long rides (25 percent). Many also reported that they are less likely to wear helmets when riding only a short distance and when not riding in traffic.

Finally, when non-helmet users were asked why they do not wear helmets, nearly half (48 percent) reported that they had never considered wearing helmets, 21 percent said helmets were unnecessary, 19 percent said they did not wear helmets because they seldom ride in traffic, and 16 percent said they had not gotten around to wearing them.

Helmet Use Patterns

In an analysis of factors associated with helmet use, the exposure survey data revealed that the likelihood of helmet use increases with the amount of riding time. It is higher for those who ride on major thoroughfares and bike paths, and is lower for those who ride on neighborhood streets and on sidewalks and playgrounds. The relationship between age and helmet use is more complex, suggesting that helmet use increases with age for frequent riders and declines with age for infrequent riders. The results also suggest that children age 10 and under are more likely to wear helmets, relative to older riders, than can be otherwise explained by the general relationship between age and risk. The likely explanation is that enough parents of young children require their children to wear helmets so that helmet use patterns of children are distinguished from those of older bicyclists. Helmet use also increases substantially with higher household education levels.

These relationships are illustrated for individual riders in a table at page 53. For example, consider a male who rides 300 hours per year on neighborhood streets, and who has (or, for children, whose parents have) no more than a high school education. The expected likelihood of helmet use decreases from 9.9 percent for a 10 year-old rider to 6.8 percent for a 20 year-old rider. However, it rises again to 10.5 percent for a 40 year-old rider. In contrast, for a 30 year-old female who rides about 50 hours a year on neighborhood streets, the

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6 The Rodale Press findings for adults, described in Part VII, were similar. In 1990, only about 15 percent of adult bicyclists wore helmets all or some of the time. However, the results also suggested that helmet use was likely to increase substantially. About 10 percent of riders who did not own helmets said they planned to buy one within 2 years. If plans materialized, helmet usage rates would have increased to about 25 percent by 1992.

likelihood of helmet use rises from 5.4 percent if she has a high school education, to 16.4 percent if she has a college education. It rises further to 37.1 percent if she not only has a college education but also rides primarily on major thoroughfares.

The analysis of the Rodale Press survey data on helmet usage patterns (in Part VIII) came to similar conclusions. Helmet use increased with riding distances, and was higher for bicyclists who ride primarily on major thoroughfares and off-road trails. In addition, helmet use increased with household income, a variable not included in the analysis of helmet use patterns from the exposure survey.

Helmet Effectiveness

Since helmets are intended to reduce the likelihood of head injury, EP used injury survey data to examine the safety effects of helmet use by estimating the conditional probability of head injury given that a helmet was worn. As described in Part III, the results of this analysis were inconclusive, probably because the sample of helmet users was small (only about 12 percent of the injured riders were wearing a helmet at the time of accident), and possibly because no information was available on riders who avoided injuries or whose injuries were less severe because they were wearing helmets.

However, EP found evidence that helmets prevented or reduced the severity of some head injuries. Helmets were damaged in 16 of the injury cases, about one-third of the cases in which they were worn. In 11 of these cases (69 percent), the victim did not sustain a head injury. In addition, in all 16 cases, the victim expressed the opinion that the helmet prevented a head injury or made it less severe.

Conclusions and Implications for Injury Reduction

The bicycle study documented the large number of bicycle-related injuries and deaths that occur every year, and evaluated the use and hazard patterns of bicyclists in the United States. While the costs to society of bicycle-related injuries and deaths are enormous -- on the order of $8 billion annually -- the bicycle study does not indicate any simple or direct remedies to the hazards of bicycle riding.

Bicycle accidents result from a complex interaction of behavioral, environmental, and mechanical factors. Efforts to reduce injuries must therefore be based on long term strategies which systematically address risk factors on a number of fronts at the same time. The behavioral factors leading to injuries, for example, might be addressed by training, or by strategies that make riders aware of safe riding practices and the consequences of unsafe riding practices. Environmental factors might be addressed by improving road design, or by promoting the development of bike lanes and bike paths. Similarly, mechanical factors might be addressed by product modification. In addition, all of these factors may be addressed by the use of safety equipment which prevents or mitigates the severity of injury when accidents occur.

Although the bicycle study could not quantify the causal relationship between the behavioral, environmental, and mechanical factors and the injury risk, the study's results indicate that the behavioral factors constitute an important component. A large proportion of bicycle injuries result from behaviors which are risky or reflect poor riding judgment (e.g., stunting or riding too fast given the riding conditions). In addition, the cognitive and physical immaturities of children are likely contributing factors in many of their injuries. The bicycle study also found that environmental factors, such as riding terrain and riding conditions, play an important role in the injury risk. On the other hand, while poor bicycle maintenance was a hazard factor, the structure of the bicycle itself appeared to play little role in the injury risk.

The remainder of this section discusses these general conclusions, and their implications for injury reduction.

Mechanical Factors

One purpose of the bicycle project was to determine whether there are significant mechanical failure patterns that warrant amendments or revisions to the existing mandatory standard for bicycles. Although there was no reason at the outset of the project to believe that revisions were necessary, possible mechanical hazard patterns have not been evaluated on a systematic basis since the standard went into effect almost 20 years ago. In addition, changes in the bicycle market (such as the availability of mountain bikes) may have resulted in new mechanical hazard patterns not envisioned in the original standard.

The bicycle study, however, provides no evidence that any bicycle type (e.g., lightweight racing, BMX, mountain, etc.) is inherently more hazardous than any other. Hazard patterns involving bicycle types were found to be related primarily to the age and riding patterns of users.

In addition, the ES review of the injury data found no evidence of systematic mechanical hazards that would warrant amendments or revisions to the existing mandatory standard for bicycles. Although mechanical failure was identified as a possible contributing factor in as many as 13 percent of the injury reports, ES concluded that a large proportion of these injuries involved poor bicycle maintenance and/or bicycle modifications, as well as external riding conditions such as wet, slippery riding surfaces. Because of the findings concerning bicycle maintenance and modification, ES recommends that both adults and children be made aware of the importance of maintaining a bicycle in good working condition and of the risks of modifying a bicycle.

Environmental Factors

The risk analysis revealed a substantial risk differential between paved roadways (which are shared with motor vehicles) and bike paths (which are generally shared with other bicycles, joggers, walkers, and skaters). When holding other factors statistically constant, the risk of injury on neighborhood streets was about seven to eight times the risk on bike paths, and the risk on major thoroughfares was even greater than on neighborhood streets. Moreover, about 90 percent of bicyclist deaths involve crashes with motor vehicles on public roadways.

These findings suggest that the riding environment should be an important focus of efforts to reduce bicycle injuries and deaths. Such efforts might focus on improvements in roadway design aimed at reducing many of the serious injuries involving collisions with automobiles every year. The development of bike paths (i.e., paths that separate bicycles from parallel motor vehicle traffic) and bike lanes (i.e., designated lanes on roadways which are off-limits to motor vehicles) should also be considered.

Efforts to improve the bicycle riding environment are already underway at all levels of government. As mentioned above, the DOT's 1991 Appropriations Act instructed DOT to develop a plan to promote bicycling and walking, and to enhance the safety of these transportation modes. The goals of the plan are to double the percentage of trips made by bicycling and walking by the year 2000, and to simultaneously reduce by 10 percent the number of bicyclists and pedestrians killed or injured in traffic crashes (Federal Highway Administration, 1994). DOT hopes to do this by, among other things, promoting the use of federal funds for the development of a bicycle-friendly infrastructure (i.e., riding surfaces, lighting at night, and facilities), and for education and training. The Intermodal Surface Transportation Efficiency Act (ISTEA) also promotes improvements in the riding environment. ISTEA requires that all state and local governments incorporate programs and facilities for bicyclists in transportation plans. ISTEA also requires states to establish and fund bicycle and pedestrian coordinator positions for promoting and facilitating the increased use of non-motorized modes of transportation.

The higher injury risk on roadways also suggests that motorists and bicyclists need to be educated in bicycle safety. Motorists need to be aware of the many road hazards that confront bicyclists, to help them avoid collisions when approaching bicyclists on the road. Being aware of road hazards confronting bicyclists can also help them better assess high risk areas, such as intersections, and be more attentive in areas where bicyclists may not be clearly in view. Safety programs geared toward adult bicyclists who ride in traffic, such as the League of American Bicyclist's hands-on training program "Effective Cycling," should also be encouraged.

Behavioral Factors

The bicycle study found that many of the bicycle-related injuries and deaths every year are related to what the rider does and how the rider interacts with environmental factors. Riding practices that are risky, that reflect poor riding judgment, or that fail to account for environmental conditions, play a major role in injury and fatality scenarios. This finding suggests that information and education (I&E) might play a role in injury reduction.

Many groups and organizations, including the CPSC, actively promote bicycle safety through informational efforts. The promotion of bicycle safety through public service announcements, brochures, poster campaigns, and other means must continue. These messages reach new audiences and reinforce safety behavior. However, I&E efforts, particularly those which are short term or do not present new information to consumers, may have limited additional impact on rider behavior. Moreover, information by itself is unlikely to change the behavior of children.

One of the most striking findings of the study is the higher risk of injury for children. About 71 percent of the emergency room treated injuries, and 37 percent of the deaths involved children under age 15. In addition, when other factors are held statistically constant, the expected injury risk for a child under age 15 is over 5 times the risk for an older rider.

A clear implication is that there is a potentially big injury reduction payoff that may be gained by focusing on the behavior of the highest risk population, children. One remedy is to train children in safe riding practices. Child training programs need to be developed judiciously. From a review of the available bicycle training literature, HF finds a consensus among child development experts that many safety concepts cannot be learned by children before a certain maturational level, regardless of the amount of training. In large part, this is because of children's physical and cognitive limitations in dealing with a complex and constantly changing riding environment. Determining the time appropriate to begin bicycle safety education is therefore essential in designing effective programs.

Existing behavioral studies find that the optimal time for intensive bicycle safety education for children is between the third and sixth grades (i.e., riders 9 to 12 years of age). (See references in Part IV.) This does not mean that younger children should not have any type of training, but that a comprehensive program is most effective beginning in the third or fourth grades, with refresher courses for older children and adults. By the sixth grade, most children have the ability to understand and perform the taught behaviors.

The analysis of risk and hazard patterns reveals several areas that should be stressed in training programs for children. Helmet use should be encouraged to reduce the incidence of head injury, which was especially high for children. Roadway skills should be emphasized, as indicated by the substantially higher risks on streets. The higher risks during non-daylight hours indicate that night riding by children should be discouraged. Training courses should also include some basic information on how to maintain bicycles in good working order.

It would also be useful to convey child safety information to parents who, if they were aware of risks, might encourage safer riding habits, such as the use of helmets. Given children's risk patterns and available human factors information on the cognitive and physical development of children, parents might want to discourage or prohibit children under the age of about 10 from riding on roadways (without direct parental supervision) or from riding at all during non-daylight hours.

Other Implications: Safety Equipment

The importance of the behavioral and environmental factors in hazard patterns also has implications for the use of protective safety equipment, which can prevent or mitigate injuries when accidents occur. Encouraging children to use safety equipment, such as helmets, is especially important because of the difficulty in teaching young children certain safety skills.

Head injuries represent the most serious and potentially life threatening injuries that can be sustained by bicyclists. According to the injury survey results, almost one-third of hospital emergency room treated injuries involve the head, and children under age 10 are significantly more likely than older riders to suffer head injuries. In addition, Sacks et al. (1991) estimate that about 62 percent of all U.S. bicycle-related deaths involve injuries to the head. Based on these estimates, the societal costs associated with the bicycle-related injuries and deaths involving head injury amounted to more than $3 billion in 1991.

Available evidence indicates that helmets reduce both the likelihood and severity of head injury (Dorsch et al, 1987; Thompson et al., 1989). Results from the exposure survey, however, indicate that only about 17.6 percent of bicyclists currently wear helmets. This is higher than the 5 to 10 percent usage rate estimated in studies conducted only a few years ago (see references at Part II), and suggests that attitudes towards helmet use are improving. Nevertheless, helmet usage rates remain low. Increasing helmet use may therefore be the single most important factor in reducing the incidence of serious bicycle injuries.

The high incidence of fatal accidents after dark also suggests night riding is an area for future safety efforts. People who ride at night should be aware of the need to see and be seen. This suggests that the use of bicycle headlights and reflective clothing should be encouraged. Night riders should also make sure that their bicycles are equipped with reflectors, as required by the CPSC bicycle standard.

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Part II.
Bicycle and Bicycle Helmet Use Patterns in the United States: A Description and Analysis of National Survey Data

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Introduction

Bicycle riding is an important means of transportation, as well as one of the most popular recreational activities in the United States (National Sporting Goods Association, 1992). This popularity is accompanied by a large number of injuries and deaths every year. Based on data from the U.S. Consumer Product Safety Commission's (CPSC) National Electronic Injury Surveillance System (NEISS), a stratified random sample of U.S. hospital emergency rooms (CPSC, 1988), there are more than an estimated 500,000 nonfatal bicycle-related injuries treated in the nation's hospital emergency rooms annually. When other medically-attended injuries are counted, such as injuries treated in physicians' offices, there may be on the order of about one million medically-attended injuries involving bicycles every year (J. Robb Associates, 1976). In addition, based on information from the National Safety Council (1992), there are almost 1,000 bicycle-related deaths annually.

The societal costs of bicycle-related injuries and deaths are large. Based on the CPSC's Injury Cost Model (Technology & Economics, 1980), the costs of the medically-attended injuries amount to about $6 billion annually. In addition, based on an imputed cost of $2 million per life lost, fatalities add $2 billion annually. The total estimated societal costs of bicycle-related injuries and deaths may therefore be about $8 billion annually.

In spite of the large number of injuries and deaths, there has never been a comprehensive national survey designed to gather information on the characteristics and use patterns of the general population of bicyclists.[1] The published literature on bicycle hazards consists primarily of injury analyses, most of which have been carried out at the level of the

[1] Rodale Press recently conducted a major survey of adult bicycle riders in the United States (Rodale Press, 1991). However, the Rodale Press survey was limited to bicycle riders age 18 and older who had acquired new bicycles, and accounts for only about 60 percent of all U.S. bicycle riders.

individual hospital or in limited geographical areas. Several recent studies have also attempted to measure the effectiveness of helmets in reducing head injuries.

Injury studies provide valuable information about injury characteristics and scenarios. However, in the absence of control (or "exposure") data describing the characteristics and use patterns of the rider population, injury studies are not enough to allow us to quantify the injury and fatality risks associated with bicycle use (Dewer, 1978; HDR Engineering, 1991).[2]

This report presents the results of a comprehensive, nationwide 1991 survey of U.S. bicycle riders (the "exposure survey") conducted by the U.S. Consumer Product Safety Commission. It provides information on: the number of riders and bicycles in use; the demographic characteristics of rider households; rider characteristics and use patterns; helmet use patterns; and the types of bicycles in use.

The report also presents an analysis of the factors associated with helmet use. These factors are determined and quantified with a probit regression model, a qualitative response model that can be used to estimate helmet use probabilities for individual bicyclists and for various population subgroups.

Survey Methodology

Abt Associates, Inc. ("Abt"), a survey firm located in Cambridge, Massachusetts, designed for the CPSC a telephone survey to provide a national probability sample of households with bicycle riders in the 48 contiguous states and the District of Columbia. The survey used the Mitofsky-Waksberg method of random-digit-dialing (Waksberg, 1978), a two-stage sampling procedure intended to give all telephone numbers in the continental U.S. an equal probability of selection. The survey's initial goal was to complete about 1,150 interviews with bicycle riders from around the nation. A detailed description of the sampling procedure is provided in the appendix.

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[2] Consider an example. About 70 percent of nonfatal injuries treated in hospital emergency rooms involve children under the age of 15 (Tinsworth, 1987). However, there are no nationwide data describing the riding patterns and behaviors of these children, or the amount of riding they engage in. This makes it difficult to determine whether the large proportion of injuries suffered by children results from high levels of exposure (i.e., aggregate riding times), risky riding patterns, or limitations in motor or cognitive skills. Exposure information, as well as injury information, is needed to evaluate these risks, to determine the relative importance of the various hazard patterns, and, ultimately, to develop effective intervention strategies to reduce injuries.

The survey questionnaire was designed by CPSC staff, in consultation with Abt and interested user and industry groups.[3] Although no major problems were found in a pretest of the questionnaire, responses in the pretest resulted in revisions and refinements to several of the questions.

The survey was conducted during June and July 1991 (Abt, 1991). When households were reached, respondents were asked the number of bicycle riders (i.e, those who rode a bicycle at least once during the year prior to the survey) in the household. If there was more than one rider in the household, one was selected at random to be interviewed. If the selected rider was a young child, an adult in the household was asked to respond on the child's behalf.

In total, 6,076 residential numbers were called. The disposition of telephone calls to residential numbers is described in Table 1. (Tables begin on page 41.) A maximum of six attempts were made to obtain an answered call for each sampled telephone number. The 1,009 telephone numbers which were busy or for which there were no answers were presumed to be residential numbers, although some are likely to have been nonresidential.

Of the residential numbers called, 4,346 households were successfully screened to determine whether or not a household member qualified as a respondent. The screening resulted in 1,254 completed interviews with bicycle riders (or designated respondents for young children). The remainder was comprised of 2,613 households that owned no bicycles, and 479 screenings with households that owned bicycles that had not been ridden during the previous year.

The response rate can be measured in several ways. Since 4,346 screenings were completed (the sum of rows 1 to 3 of Table 1), the response rate was 92 percent of the 4,705 cases (rows 1 to 5) in which contact was made with the appropriate respondent and 86 percent of the 5,067 cases (rows 1 to 6) in which contact was made with a household member but not necessarily the respondent. Finally, when the 1,009 cases (row 7) in which the telephone rang busy or there was no answer on all attempts are included, the minimum response rate was 71 percent. The 1,254 interviews exceeded the 1,150 target number because the minimum response rate was higher than expected.

After the survey data were collected, the sample was weighted to make population projections of bicycle use in the continental U.S. In order to make the projections reflect the estimated 94 million U.S. households in 1991, each of the successfully screened sample households received a weight of 21,629.1 (i.e., 94 million/4,346). That is, each of the successfully screened households was assumed to represent 21,629.1 U.S. households. In addition, since only one rider per household was interviewed, the household weight for each of

[3] The groups included the Bicycle Federation of America, the Bicycle Helmet Safety Institute, the Bicycle Manufacturers of America, the National Highway Traffic Safety Administration, and the National Safe Kids Campaign.

the 1,254 sample households containing one or more bicycle riders was multiplied by the number of bicycle riders in the household. This yields a "rider" population weight reflecting the total number of bicycle riders in the U.S. (Kish, 1965).

Information on the age and gender of all bicycle riders in the 1,254 sample households was also gathered in the survey. This enabled further refinement of the weighting process to account for the apparent over or under-representation of some of the age-gender categories interviewed. For example, while male riders under age 10 accounted for about 9.3 percent of those interviewed, they accounted for about 11.9 percent of the total number of household riders. The "rider" population weight for these riders was therefore adjusted by the ratio of 1.28 (i.e, 0.119/0.093) to account for the apparent under-representation of riders in this category. The ratio adjustment factors for eight age categories and two gender categories, ranged from 0.79 (25-34 year-old females) to 1.40 (10-14 year-old females).

The survey results are subject to some nonsampling errors (Abt, 1991). First, the survey excluded households that do not own telephones, about six percent of all use households. In addition, Alaska and Hawaii were excluded from the survey. However, these states only account for about 0.6 percent of total households in the U.S.

Rider Characteristics and Use Patterns

Population Estimates and Household Demographics

Based on the survey results, there were an estimated 66.9 million bicycle riders residing in about 27.1 million households in 1991. Thus, there were riders in an estimated 28.8 percent (27.1 million/94 million) of all U.S. households. These riders used an estimated 65.9 million bicycles during the year.[4] This indicates that the vast majority of bicyclists ride a specific bicycle not shared with other household members.

The survey also gathered information on the number of bicycles owned by households, and whether or not the bicycles had been ridden during the previous year. In total, there were an estimated 96.0 million bicycles in about 37.4 million bicycle-owning households. Thus, about 40 percent of the 94 million U.S. households have one or more bikes, but about 31 percent of the 96 million bicycles in these households had not been used during the past year.

Table 2 summarizes data on riders and bicycle ownership, per household, and calls attention to the large proportion of households with multiple riders and bicycles. Over 70 percent of households with riders have more than one rider, and about 23 percent have four or

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[4] This estimate is considerably less than the National Safety Council's estimate of 105 million bicycles in use in 1991 (National Safety Council, 1992, p. 65). The National Safety Council's estimate was based on a ten-year total of domestic production plus imports less exports.

more riders; similarly, about 23 percent of bicycle-owning households had four or more bicycles. On average, there are about 2.5 riders per household with riders, and about 3.4 bicycles per bicycle-owning household.[5]

Table 3 compares rider households with census data on all U.S. households. There are no major regional differences in the location of rider and U.S. households. On the other hand, though the population density figures from the survey and the 1990 census are not directly comparable, it appears that greater proportions of rider households are located in low density areas. About 57 percent of rider households live in a "small city or town" or "open country or farm," compared with 32 percent of all households which are in non-Metropolitan Statistical Areas (MSA) and MSAs with a population of less than 0.25 million. Only about 20 percent of rider households are from a "large city or suburbs," compared with 31 percent of households in MSAs with a population of 2.5 million or more.

Rider households are larger than the U.S. norm, reflecting the large number of children who ride bicycles. Two-thirds of all rider households have four or more members, compared with only about 26 percent for all U.S. households. In contrast, single-person households account for 24.5 percent of U.S. households, but only 3.1 percent of rider households.

Rider households also have higher education levels and incomes than the U.S. norm. Almost 50 percent of rider households have at least one college graduate, compared to 23 percent of all U.S. households. In addition, while the median U.S. income was $30,000 in 1990, the median income was about $40,000 or more in rider households. The higher income for rider households reflects the larger average household size and the higher education levels.

Characteristics of Riders

Characteristics of the rider population are shown in Table 4. Rider ages varied widely, from 2 to 77 years, but 25.2 percent were under age 11 and about half (49.9 percent) were under age 21. Only about 6 percent were over age 50. In addition, just over half of all riders (52.3 percent) were male.

About 81 percent of bicyclists learned to ride at least four years prior to the survey, and just over half (52.4 percent) learned to ride more than 10 years prior to the survey. As in other recreational activities, the number of years since a bicyclist learned to ride is a measure of riding "experience," and hence riding skills (see, e.g., Rodgers, 1990). However, this variable is also highly correlated with rider age ($r = 0.76$, $p < 0.01$) and suggests (not surprisingly) that most individuals learn to ride bicycles as children. Consequently, this particular measure of

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[5] For households which own bicycles but have no riders there are an average of 1.9 bicycles per household.

"experience" may be a weak predictor of bicycle riding skills, especially for adults, since there may have been long intervals in which bicycles were not used.

Bicycle Use Patterns

Since the injury risk is affected by the ways in which bicycles are used (Dewer, 1978), substantial amounts of information were gathered on rider use patterns. The amount of time spent riding a bicycle, a measure of rider exposure to risk, was estimated from a series of questions intended to determine (1) the number of months bicycles were used in the previous year, and (2) the number of hours individuals spend riding in an average month.[6]

According to the results shown in Table 5, the estimated mean and median annual riding times for bicyclists are 236 and 105 hours per year. These estimates imply an aggregate of about 15 billion hours of bicycle riding annually in the continental U.S. However, riding times vary substantially from individual to individual. Over 20 percent ride less than 25 hours per year, and about 12 percent ride more than 400 hours per year.

Table 5 also provides information on riding times by age category. Annual riding times are highest for the youngest riders, and generally decrease with age. Children under age 11 ride for an average of about 318 hours per year (about 35 percent more than the average of 236 for all riders) and are followed by 11-to-14 year-olds with an average of about 262 hours per year (about 11 percent more than average). Because of these higher averages, younger bicyclists account for a disproportionate amount of riding time. Riders under age 11 account for about 33.9 percent of all riding time, and riders under age 15 account for about 49.8 percent.

Table 6 provides information on the relative amount of riding time spent in various environments or on various riding surfaces. Such information is important in analyzing risk patterns since different environments are likely to have varying impacts on the injury risk. Relative frequencies were quantified by means of the following discrete categories:[7]

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[6] The Rodale Press survey estimated bicycle use in terms of distance (i.e., miles in an average warm weather month). However, following discussions with industry and user groups, it was concluded, since bicycle riding is primarily a recreational activity, that hours of rider use is a better measure of exposure, especially for children. It was also believed that bicyclists are able to estimate hours of use more accurately than miles ridden.

[7] Since frequency responses were requested for multiple surface types, responses from some riders were not internally consistent. Some riders, for example, indicated that they rode "more than half of the time" on more than one surface type, a logical impossibility. The responses are nevertheless quite instructive of basic riding patterns since they provide an approximate ranking of surface types.

- (1) always or almost always;
- (2) more than half of the time;
- (3) less than half of the time;
- (4) never or almost never.

Table 6 presents two measures of the "frequency" associated with the various use patterns. The top line for each category provides the percentage of riders at each frequency response; the second line (numbers in parentheses) adjusts rider responses for estimated annual riding times. For example, the 18.4 percent of riders who "always or almost always" ride on sidewalks or playgrounds account for 19.3 percent of total riding time.

The predominant riding surface is neighborhood streets. Over 60 percent of bicyclists ride primarily (i.e., spend all or most of their riding time) on neighborhood streets with low traffic volume.[8] Almost 30 percent (mostly children) ride primarily on sidewalks and playgrounds.

Only about 6.8 percent ride primarily on major thoroughfares and highways with high traffic volume and 16.9 percent ride primarily on bike paths.[9] Finally, about 17.6 percent ride primarily on unpaved roads and about 10.5 percent ride primarily on other types of unpaved surfaces or trails. Adjustments for riding time do not substantially alter these estimates, but they do suggest that riders who spend all or most of their time on major thoroughfares, highways, or unpaved surfaces tend to ride more than the average.

Table 6 also indicates the relative time spent in several other activities or practices. About 17.6 percent of bicyclists wear helmets all or most of the time and account for about 20.6 percent of aggregate riding times. Another 6.0 percent said they wear helmets some (i.e., less than half) of the time. Helmet use is discussed more in the next section of this report.

About 8.7 percent of riders (representing a projected 5.8 million bicyclists) spend all or most of their riding time commuting to work or school and account for about 12.6 percent of total annual riding times. Another 10.1 percent use their bicycles for commuting less than half of the time.

A relatively small proportion of bicycle riding takes place after dark. About 12.4 percent of bicyclists indicated that they ride at least occasionally after dark, but only 3.1 percent of the bicyclists ride primarily after dark. Despite the relatively small amount of

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[8] This response was so pervasive that it may include some bicyclists who frequently ride on neighborhood streets to get to other surfaces such as bike paths.

[9] However, the respective proportions were higher for 21-30 year-olds; 12.8 percent of these bicyclists report that they ride primarily on major thoroughfares and highways and 24.1 percent ride on bike paths.

nighttime riding, available studies suggest that nighttime accidents account for a large share of bicycle-related injuries and deaths (Cross, 1977; Ferguson and Blampied, 1991; NHTSA, 1993; Tinsworth, 1987).[10] Lights are considered important safety equipment when riding after dark. However, of those who ride at least occasionally after dark, less than one-third use headlights or tail lights.

About 2.8 of riders wear earphones all or most of the time; another 4.5 percent do so at least occasionally. Finally, about 2.3 percent of respondents said that when riding they carry infants all or most of the time. Another 1.7 percent indicated they do so at least occasionally. However, these are generally infrequent riders and account for only about 1.5 percent of total riding time. In addition, about 56 percent of those who carry young children reported that the child always wears a helmet, and another 5 percent reported that the child wears a helmet most of the time.

Characteristics of Bicycles In Use

Table 7 presents information about the bicycles used most frequently by the respondents. (See Figure 1 for pictorial representations of the various bicycle types.) Lightweight racing or touring bicycles are the most common, with about 34.5 percent of the total. Only 14.1 percent of riders use BMX or high rise bicycles, but, because BMX and high rise bicycles are used largely by children who ride more than an average amount of time, these riders account for 24.5 percent of total bicycle use.

Mountain, city, or all-terrain bicycles, which were first marketed on a large scale in the mid-1980s, have become increasingly popular with recreational riders in recent years. Although they account for only about 17 percent of all bicycles in use, they account for about 25 percent of the newer bicycles purchased within a year of the survey. On the other hand, lightweight racing and touring bicycles are becoming correspondingly less popular: while they account for 34.5 percent of all bicycles in use, they account for only 26.6 percent of those acquired in the year prior to the survey.[11]

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[10] According to NHTSA (1993), about 23.5 percent of the bicyclist fatalities involving motor vehicles in 1991 occurred between the hours of 9:00 PM and 5:59 AM.

[11] Market share estimates of the bicycle types purchased during the year preceding the survey (shown in Table 7) are generally consistent with 1990 domestic sales estimates provided by the Bicycle Manufacturers Association (BMA, 1991). BMA sales estimates indicate that about 20 percent of 1990 domestic sales were children's sidewalk models, 26 percent were BMX and high rise models, 14 percent were lightweight racing and touring models, and about 40 percent were in the mountain, all-terrain, and city bicycle or middleweight/cruiser categories.

Table 7 also describes the types of bicycles used by various age groups. Not surprisingly, most children under age 11 use children's sidewalk bicycles (38.2 percent), or BMX or high rise bicycles (31.1 percent). Lightweight racing or touring bicycles are the most commonly used bicycle for riders over age 10, accounting for over 40 percent of the total. Mountain, city, or all-terrain bicycles appear to be most popular with 21-to-30 year-old riders, with about 27.6 percent of the total, but they are also used by 19.1 percent of 11-to-20 year-old riders. Middleweight and cruisers are most popular with older riders. Although not shown in the table, 34.2 percent of riders over the age of 50 reported that they used a middleweight or cruiser.

The bicycles in use tend to be relatively new. About 28.5 percent were acquired during the year preceding the survey, and another 54.2 percent were acquired from one to five years before the survey was conducted. The mean and median length of time since the bicycles were acquired were 3.6 and 2.0 years. In addition, about 19 percent were acquired used, indicating a substantial aftermarket for bicycles.

Few (less than 3 percent) of the bicycles had been substantially modified since acquisition. Reported modifications included changes to the handlebars (1.0 percent), wheels (0.6 percent), and seats (1.1 percent). Tail lights and headlights which, according to Ferguson and Blampied (1991), can substantially reduce the nighttime accident risk, were the most widely reported bicycle safety accessories. Tail lights and headlights were respectively reported on 20.6 percent and 14.5 percent of bicycles.

Helmet Use Patterns

Sacks et al. (1991) estimate that 62 percent of all U.S. bicycle-related deaths and 32 percent of bicycle-related injuries treated in hospital emergency rooms involve head injuries.[12] Recent studies reveal substantial safety benefits from helmet use: Dorsch et al. (1987) showed that helmets substantially reduce the severity of head injury when head injuries occur; Thompson et al. (1989) found that helmets can reduce the likelihood of head injury by 75 to 85 percent. Helmet usage rates have nevertheless been found to be generally low. Although no firm nationwide data were available prior to this survey, estimates generally put helmet use at under 10 percent for all riders (Wasserman et al., 1988; Weiss, 1990). Moreover, studies of specific localities found that less than 5 percent of school age children wore helmets (DiGuiseppi, 1989; Howland, 1989; Weiss, 1986 and 1992). This section discusses the bicycle survey findings regarding helmet use patterns and presents the results of an analysis to determine the factors that go into the decision to use a bicycle helmet.

[12] These estimates are based on data from the Center for Health Statistics and the CPSC's National Electronic Injury Surveillance System.

Description of Survey Results

As shown in Table 8, about 27.3 percent of riders (representing a projected 18.3 million bicyclists) own or have the use of a helmet. About 77.9 percent of the helmets are "hard" shell (i.e., a polystyrene shell covered with a hard plastic covering), 14.1 percent are soft shell (i.e., a lightweight polystyrene shell with no plastic covering), and 5.1 percent are "thin" shell (i.e., polystyrene with a light or thin plastic covering).[13] However, the lighter weight soft and thin shell helmets are becoming increasingly popular. Over 30 percent of helmets purchased or received during the year prior to the survey were the soft or thin shell types, compared to about 14 percent of those purchased or received three or more years ago.

Of the riders who have the use of helmets (27.3 percent of all riders), 64.2 percent wear them all or most of the time and 21.8 percent wear them less than half of the time; 13.5 percent of riders who have helmets never use them. These figures indicate that about 17.6 percent of all riders (11.8 million bicyclists) wear helmets all or most of the time, 6.0 percent (4.0 million) wear helmets less than half of the time, and about 76.0 percent (50.9 million) never (or almost never) wear helmets.

Helmet use is highest for the 41-to-50 year-old age group, with a reported 24.6 percent usage rate (i.e., percent reporting that they wear helmets all or most of the time), and lowest for the 11-to-14 year-old age group with a 11.4 percent usage rate. The usage rate for children under the age of 11, which was usually reported by parents who were responding for their young children, was 17.0 percent.

These estimates, in comparison to estimates of helmet use in earlier studies, suggest that helmet use for all riders has increased from under 10 percent to almost 18 percent in the last few years. The survey finding that about 52.7 percent of helmet wearers began wearing helmets in the last two years supports the conclusion that the change is real and recent.

Information was also gathered on the reasons why individuals use or do not use helmets, as shown in Table 9. For the approximately 17.7 percent of riders who purchased helmets for their own use, as opposed to receiving one as a gift, comfort and safety considerations were very important in the purchase decision. Two additional comfort factors, the weight of the helmet and ventilation, were also described as "very important" by over 40 percent of purchasers. Cost and appearance were apparently secondary considerations for those who did buy helmets, but were still reported to be at least "somewhat important" by over 55 percent of purchasers.

Of the 13.4 percent of riders who always wear helmets, (see Table 8), nearly all (97.8 percent) described "safety" as an important reason for doing so. The "insistence of family

[13] The type of helmet was unknown by about 2.9 percent of respondents.

members," was reported to be important by about 56 percent. In addition, local legal requirements were mentioned by about 13.5 percent of these riders.

When riders who sometimes, but not always, wear helmets (i.e., the 10.2 percent of riders who wear helmets "more than half of the time," or "less than half of the time") were asked to describe the circumstances under which they "usually" wear a helmet, 40.0 percent indicated "when riding in traffic" and 25.2 percent indicated "when on long rides." About 17.9 percent usually wear helmets when reminded to do so.

These riders were also asked when they do not wear a helmet. The most frequent responses were when riding a short distance (31.6 percent), when not riding in traffic (23.8 percent), and when they forget (22.9 percent).

Finally, the estimated 76.0 percent of riders (see, Table 6) who said they never or almost never wear helmets were asked why. About 21.6 percent said that they had never thought about it. While 15.6 percent said they had not gotten around to wearing a helmet (and thereby implied a positive attitude toward helmet use), a large proportion also indicated a lack of need for helmet use: 21.0 percent said that helmets were unnecessary and 18.8 percent said they did not wear helmets because they seldom ride in traffic. Smaller percentages said that helmets were not comfortable (8.9 percent), not attractive (4.9 percent), and too expensive (7.3 percent).

Statistical Analysis of Helmet Use

<u>The Model.</u> This section develops a probit regression model to determine and quantify the factors associated with helmet use. Probit analysis, like multiple regression analysis, is a statistical procedure in which variation in the dependent variable is explained by variation in the explanatory variables. The probit specification of the regression model is used to examine the relationship between a series of explanatory variables and a dependent variable that represents two (or more) distinct alternatives (Pindyck and Rubinfeld, 1991).

In this analysis the dependent variable represents whether or not riders use helmets. Survey respondents were assumed to be helmet users if they reported that they wore a helmet all or most of the time. There could be some upward bias in the reported helmet use rates, as has been described in some automobile seat belt use studies (Knapper et al., 1976; Hakkert et al., 1981). However, since the extent of bias, if any, is unknown, it will be assumed that reported usage rates provide a reasonable approximation to actual helmet use patterns.

The explanatory variables comprise various rider characteristics, use patterns, and household demographic factors that may influence the bicyclist's decision to wear a helmet. About 22 percent of the observations were lost because of missing information on the independent variables. A sensitivity analysis, conducted by replacing missing values with the mean value of the variable in question (Pindyck and Rubinfeld, 1991), indicated that the models were not substantially affected by the missing data. Table 10 defines the explanatory variables used in the analysis.

Statistical Results. Table 11 shows the results of three specifications of the regression model. These specifications differ by the way in which the age and riding time variables are entered into the models. Rider age is included as a series of "dummy" variables (i.e., *AGE(1-10)* to *AGE(41-50)*) in Models 1 and 2. These variables are intended to pick up the relationship between the various discrete age categories and the likelihood of helmet use, relative to riders over the age of 50. Model 3, in contrast, includes age as a continuous variable (*AGE*). In addition, Model 1 expresses riding time (i.e., hours of exposure to risk) as the natural logarithm of the estimated annual hours of use (*LN(HOURS)*).[14] Models 2 and 3, on the other hand, include riding time as part of an interaction term defined as the product of the natural log of riding time and rider age (*AGE·LN(HOURS)*).

All of the equations are statistically significant. In addition, inclusion of the interaction term improved somewhat the fit of Models 2 and 3, relative to Model 1, as is indicated by the higher model chi-square and score statistics.

The regression results show several strong relationships between helmet use and the surface types over which bicyclists ride. These relationships are measured with a series of dummy variables representing various riding surface types, relative to unpaved and other surfaces. Helmet use is higher for riders who spend all or most of their riding time on bike paths (*BIKEPATH*) and on major thoroughfares, highways, or streets with high traffic volume (*HIGHWAY*). In contrast, helmet use is lower for riders who spend all or most of their riding time on neighborhood streets with low traffic volume (*STREET*). Helmet use on playgrounds or sidewalks (*SIDEWALK*) is not significantly different from use on unpaved and other surfaces, but it is significantly lower than use on bike paths and major thoroughfares.

There is also a strong positive relationship between riding time and helmet use -- helmet use increases with riding time. This relationship is evidenced clearly in Model 1, where riding time is entered as a natural logarithm (*LN(HOURS)*). It is also indicated in Models 2 and 3, where riding time is entered as part of the interaction term with age (*AGE·LN(HOURS)*). However, in contrast to the specification of the riding time variable in Model 1, the coefficients for the interaction terms in Models 2 and 3 suggest that helmet use increases with riding time at an increasing rate for older riders. That is, the change in the rate of helmet use is more sensitive to changes in riding time for older riders.

These relationships provide some evidence that riders are more likely to wear helmets if, by virtue of riding a lot or by riding frequently on major thoroughfares with high traffic

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[14] Transforming the riding time variable to a natural logarithm (as opposed to using it as a continuous linear variable) increased its explanatory power by reducing the distorting effect of outliers on the results.

volume, they face potentially higher accident rates.[15] The relationships are also consistent with some recent analyses of behavioral response in inherently risky activities, such as in automobile driving. These studies indicate that consumers increase safety efforts (i.e., by wearing seat belts) in response to greater perceived risk (Blomquist, 1988 and 1991; McCarthy, 1986).

Helmet use is only slightly related to specific rider characteristics. Rider experience (*LN(EXPER)*)and gender (*GENDER*), for example, have no independent statistical impact on helmet use.[16] Nor do the results of Model 1 indicate any measurable relationship between age and helmet use. However, when age is allowed to interact with riding time, as in Models 2 and 3, the results suggest that helmet use is systematically related to age, though in a somewhat complex way.

For riders over the age of 10, the Model 3 coefficients for the *AGE* and *AGE·LN(HOURS)* variables indicate that helmet use increases with age for bicyclists who ride more than about 20 hours per year (about three-quarters of bicyclists), and decreases with age for those who ride less than 20 hours per year. More generally, the results suggest that bicyclists who ride a lot of the time are more inclined to wear helmets as rider age increases; on the other hand, infrequent bicyclists are less likely to wear helmets as age increases.

Notice also that Model 3 includes as a shape parameter a dummy age variable set equal to one for riders 1-to-10 years of age (*AGE(1-10)*). The significant positive coefficient for this variable indicates a higher likelihood of helmet use for these riders than can otherwise be explained by the overall relationship between age and helmet use (as expressed by the coefficients for the *AGE* and *AGE·LN(HOURS)* variables). The obvious implication, assuming accurate responses to the helmet use questions, is that, on balance, young children tend to wear helmets because their parents require it.[17] This may suggest that the substantial recent publicity in favor of helmet use has influenced the behavior of parents.

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[15] There was also some evidence that helmet use increases if the riders experienced an accident requiring medical attention during the three years prior to the survey. However, this relationship was not significant at the usual 5 percent significance level (p = 0.06, two-tailed test).

[16] A small proportion of bicyclists (about 2 percent), reported a greater number of years of riding experience than their age. However, a sensitivity analysis, conducted by eliminating the inconsistent observations from the analysis and by imposing a plausible replacement scheme for the inconsistent observations, indicated that these inconsistencies did not affect the results.

[17] This does not mean that a majority of parents require their children to wear helmets, but rather that enough do so that the helmet use patterns of children can be distinguished from those of older bicyclists.

The regression results also show that helmet use is influenced by household demographic factors, such as education and geographical location. Households headed by members who attended college use helmets more frequently than households headed by members with less education, as indicated by the positive and increasing coefficients for *SCH2* and *SCH3*.[18]

There also appears to be some regional variation in helmet use. The regional variables are included as a series of dummy variables and indicate regional differences in helmet use relative to use in the Pacific Coast States. Helmets are used more frequently in the Pacific Coast and Northeast States than in the Midwest, Southern, and Mountain States.

Predicted Helmet Usage Rates

Table 12 shows the estimated probability of helmet use for various combinations of rider and bicycle characteristics, based on the econometric results from Model 3. Each of the estimates is obtained by evaluating the probability of helmet use for a bicyclist who has five years of riding experience and who resides in a large or medium sized city in a northeastern state. Values for the other characteristics are specified in the table.

Part A shows the effect of age on the likelihood of helmet use, by selected hours of annual riding time and riding terrain, for a male bicyclist. The first column shows helmet use estimates for a male bicyclist who rides 10 hours per year on quiet residential streets, and whose household members have no more than a high school education. The expected likelihood of helmet use declines slightly with age from 3.9 percent for a 20 year-old rider to 3.4 percent for a 50 year-old rider. This illustrates the finding that helmet use declines with age for relatively infrequent riders. The second column, in contrast, shows that if riding time is 300 hours per year, helmet use increases with age for riders over the age of 10 -- the expected probability of helmet use increases from 6.8 percent for a 20 year-old rider to 13.0 percent for a 50 year-old rider. The third column shows that the expected probability of helmet use increases substantially for the bicyclist (of any age) if he rides 300 hours per year on a bike path rather than on quiet residential streets. Finally, in all the columns of part A, the expected probability of helmet use is higher for a 10 year-old rider than it is for a 20 year-old rider, reflecting in part the impact of the dummy age variable (*AGE(1-10)*) on the risk estimates.

Part B shows the effect of hours of annual riding time on the likelihood of helmet use, by selected combinations of education and riding terrain, for a 30 year-old female bicyclist. The first column provides helmet use estimates for the bicyclist if she rides primarily on quiet residential streets and if no household member has more than a high school education. If, for example, she rides 200 hours per year the probability of helmet use is 7.5 percent. If, however,

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[18] Although income is not included in the model, helmet use also increases with household income. Income was excluded from the model because it was highly correlated with the schooling variables, and because data on household income were frequently missing from the database.

she comes from a household with a college graduate, the probability of helmet use increases to 21.8 percent. Finally, if she rides primarily on highways or major thoroughfares with high traffic volume, the probability of helmet use further increases to 45.6 percent.

Table 13 provides another view of the sensitivity of helmet use to discrete changes in the independent variables by reporting the average predicted probability of helmet use for various population subgroups. These estimates, which are also based on the econometric results of Model 3, do not statistically hold other variables constant, but they do provide consistent group estimates of the proportion of individuals who will choose to wear a helmet (Train, 1986).

Predicted helmet usage rates are lowest for the 11-to-20 year-old age group, and, except for the over 50 year-old age bracket, generally increase with age.[19] Predicted helmet usage rates are also higher for male bicyclists, who generally have greater annual riding times than females.

Helmet use is higher for more frequent riders. Bicyclists who ride 100 hours per year or more are twice as likely to wear helmets as bicyclists who ride less than 25 hours per year. Helmet use also increases with household education and income. While helmet use appears to increase gradually with income, households with college graduates are about three times as likely to wear helmets as households with members having no higher than a high school education.

Individuals from large or medium size cities are more likely to wear helmets, as are individuals who ride all or most of the time on highways and major thoroughfares with high traffic volume, or bike paths. In fact, bicyclists who ride primarily on highways and bike paths are roughly twice as likely to wear helmets as other bicyclists. In contrast, helmet use is lower for bicyclists who ride primarily on quiet residential streets, and somewhat lower for bicyclists who ride primarily on sidewalks or playgrounds.

Finally, there are notable differences in the predicted helmet use in the various regions of the country. Helmet use is highest in the Pacific Coast States (26.7 percent) and lowest in the Mountain States (12.7 percent).

Summary and Discussion

This report described and evaluated the results of the 1991 CPSC bicycle exposure survey. The survey was based on a "random-digit-dialing" sampling methodology. Its primary goal was to collect statistically sound information on the characteristics of the general

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[19] Average usage rates are lower for bicyclists over the age of 50 primarily because their annual riding times are substantially lower than they are for other age groups.

population of riders, their use patterns, and the types of bicycles they use, data which are necessary to quantify risk and hazard patterns.

Survey results confirm the popularity of bicycle riding in the U.S. There are an estimated 66.9 million bicyclists who reportedly spend about 15 billion hours riding bicycles in a year. Although most bicycle riding is for recreational purposes, bicycles are also widely used as a form of transportation. About 8.7 percent of riders, who account for almost 13 percent of total riding times, use their bicycles primarily for commuting to school or work.

Bicycles are used by riders of all ages, but young riders tend to predominate. About one-fourth of bicyclists are under age 11, and about half are under age 21. Moreover, young bicyclists ride more than the average for all bicyclists; when riding times are taken into account, bicyclists under age 11 account for about one-third of all riding time, and those under age 21 account for about 61 percent of all riding time.

Riding patterns and behaviors are closely tied to accident risk and must therefore be considered when evaluating risk patterns. Most bicyclists said that they ride on quiet neighborhood streets with low traffic volume, but sizable proportions also ride on sidewalks and playgrounds, bike paths, and unpaved surfaces. On the other hand, a relatively small proportion rides primarily on busy streets or major thoroughfares with high traffic volume, a surface type which is associated with a higher likelihood of collisions with automobiles. Similarly, relatively small proportions of bicyclists engage in potentially unsafe practices, such as riding after dark, carrying infants, and wearing earphones.

While there are about 96.0 million bicycles available for use, about 65.9 million had been used in the year prior to the survey. Lightweight racing or touring bicycles are the most commonly used models by all riders over the age of 10. However, these models, which were highly popular through the early-1980s, have been losing their relative sales share to the mountain, city, or all-terrain models which have become increasingly popular in recent years.

Not surprisingly, age appears to be an important factor in the choice of bicycle types. Children tend to ride sidewalk, BMX, or high rise bicycles, and the mountain/city/all-terrain bicycles appear to be most popular with young adults in the 21-to-30 year-old age group. Middleweight and cruisers are most popular with older riders.

The survey also obtained a substantial amount of information on helmet use patterns, some of which was used to model the helmet use decision. The results of the probit regression analysis indicate that helmet use is systematically related to riding patterns, household demographic characteristics, and some personal rider characteristics. Riding time is a major determinant of helmet use; riders who spend more time riding are more likely to wear helmets. Other major determinants include the primary riding surface and demographic factors. Helmet use tends to be higher for those who ride primarily on highways and bike paths, and lower for those who ride primarily on neighborhood streets with low traffic volume and on sidewalks and playgrounds. Helmet use also increases with household education levels.

The relationship between age and helmet use is complex, suggesting that helmet use increases with age for frequent riders and declines with age for infrequent riders. There is also evidence that children under age 11 are more likely to wear helmets, relative to older riders, than can be explained by the general relationship between age and risk.   This suggests, assuming responses to the helmet use questions were accurate and unbiased, that parents are requiring their young children to wear helmets more frequently than they had in the past.

The survey finding that about 17.6 percent of bicyclists wear helmets all or most of the time (two- to three-times the usage rate found in studies conducted only a few years ago) suggests that attitudes towards helmet use have been improving. The reasons for the change in helmet use patterns are probably related to the increasing publicity given to the benefits of helmet usage in the popular and scientific press in recent years. Improvements in helmet construction (i.e., the development of soft- and thin-shelled helmets), that reduce the discomfort of helmet usage by increasing helmet ventilation and by making helmets lighter and more attractive, may also have played a role in increasing helmet use.[20]

In addition, the growing trend toward local helmet use laws, which have also been widely publicized in the media, may also play a role (see, e.g., Beyers, 1992). According to the National Safe Kids Campaign (1992), five states and seven local jurisdictions have enacted some form of helmet requirements. All but one of the state requirements apply to child passengers, and the local requirements apply generally to children who are operators or passengers.[21] For the most part, these requirements do not appear to be rigidly enforced, and may therefore be viewed as strong informational warnings with minor penalties under some circumstances. Nevertheless, a recent study of the effects of one locality's helmet requirements for child operators suggests that they may have significantly increased helmet usage rates (Cote et al., 1992).[22]

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[20] The long run increasing wealth of society (or segments of society) may also be an underlying factor, since increased wealth is likely to increase the private demand for safety (Viscusi, 1983).

[21] The New Jersey state law applies to operators and passengers under the age of 14; requirements in Chico, California and Rockland, New York, apply to all operators.

[22] Cote et al. (1992) report, in an observational study, that child helmet usage rates increased from about 4 percent to 47 percent in Howard County, Maryland, following the institution of helmet requirements of children under the age of 16 in July 1990. This compared with an increase from 8 to 19 percent over the same time period in Montgomery County, Maryland, a county which had sponsored a community education program at about the same time. Montgomery Country later enacted helmet requirements similar to those in

In spite of improvements in the overall helmet use rate, it remains low. Less than one-fifth of all bicycle riders regularly wear helmets. The reported effectiveness of helmets in reducing head injuries (see, e.g., Thompson et al., 1989 and Dorsch et al., 1987) suggests that innovative informational and educational efforts designed to increase helmet use by riders of all ages should be encouraged. Moreover, the survey results provide some reason to believe that such efforts may be at least somewhat effective. Almost 40 percent of survey respondents who do not own or wear helmets reported that they had never thought about doing so or that they had simply not gotten around to buying a helmet. Many of these riders may respond to information and education efforts that explain honestly the advantages of helmet use.

Appendix: Sampling Methodology

The Mitofsky-Waksberg method of random-digit-dialing (Waksberg, 1978) is a two-stage sampling procedure intended to give all telephone numbers in the continental U.S. an equal probability of selection. In the first stage, all of the nation's active area code/central office telephone code combinations (called <u>prefix codes</u>) are stratified by the nine Census Divisions. Prefix codes are randomly selected from each Census Division, and four-digit random numbers are appended to the selections to generate complete telephone numbers. The complete numbers are then dialed to determine which are residential, as opposed to commercial.

The first stage residential numbers are used to generate a second-stage sample. The first eight digits of these residential numbers are referred to as <u>prefix areas</u> in the sampling literature, and each prefix area defines a cluster of 100 contiguous telephone numbers.[23] At the second stage, complete (10 digit) telephone numbers are randomly sampled from each prefix area until a fixed number of residential numbers, referred to as the <u>cluster size</u>, have been sampled from all sample prefix areas.

In the bicycle survey, 10 telephone numbers were initially sampled from each prefix area. Nonresidential numbers were replaced until a total of 10 residential numbers were found from the prefix area. This one-to-one replacement yields a self-weighting sample of residential telephone numbers since the same number of residences are sampled from each prefix area.

Given the expected incidence of bicycle ownership, 682 residential telephone numbers were generated in the first stage of the Mitofsky-Waksberg random-digit-dialing procedure to provide the prefix areas. These prefix areas were randomly divided into 11 replicates, or

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Howard County.

[23] For example, the first-stage prefix area given by the number 301-504-09XX defines a cluster of 100 telephone numbers ranging from 301-504-09<u>00</u> to 301-504-09<u>99</u>.

subsamples, of 62 prefix areas residential numbers each. Each replicate can be viewed as providing a miniature national sample of residential numbers. The second stage was administered on a replicate-by-replicate basis to come as close as possible to completing the desired 1,150 interviews.

Given the actual incidence of bicycle use found in the survey, only 10 replicates were activated to generate the desired number of interviews. Thus, the first stage sample contained 620 prefix areas (i.e. 62 prefix areas per replicate times 10 replicates). In addition, since the cluster size was set at 10 residences per prefix area, the second stage sample consisted of about 6,200 residential telephone numbers (i.e. 620 prefix areas times 10 residential numbers per prefix area).

As described above, a total of 6,076 residential numbers were called. This is less than the expected number of 6,200 because in a small number of prefix areas less than 10 residential numbers were found when all 100 residential numbers were called. In addition, this total excludes 4,343 calls to nonworking numbers and non-residential working numbers, which were replaced as part of the sampling procedure.

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Table 1. Disposition of Telephone Calls

	Disposition of Call	Number	%
(1)	Completed interview with rider	1,254	20.6
(2)	Screened out: household owns no bicycles	2,613	43.0
(3)	Screened out: household owns a bicycle, but no household member rode in past year	479	7.9
(4)	Refused to answer any question	323	5.3
(5)	Broke off interview before completion	36	0.6
(6)	Contact with household made, but interview could not be conducted*	362	6.0
(7)	Busy or no answer on all attempts	1,009	16.6
	Total number of attempted calls	6,076	100.0

* Interview could not be conducted because of language barrier or because the designated respondent was not available during interviewing period.

Source: Abt Associates

Table 2. Riders and Bicycles Per Household

Riders Per Household*			Bicycles Per Household**		
Riders	Percent	Households (millions)	Bicycles	Percent	Households
(millions)					
1	28.0	7.6	1	27.7	10.4
2	30.5	8.3	2	29.8	11.1
3	18.0	4.9	3	19.3	7.2
4	13.9	3.8	4	11.5	4.3
5	6.5	1.7	5	6.1	2.3
≥ 6	2.7	.7	≥ 6	5.0	1.9
unknown	.4	.1	unknown	.6	.2
Total	100.0	27.1	Total	100.0	37.4

* For households with riders.
** For households with bicycles.

Table 3. Household Demographics

	Survey Results (%)	1990 Census (%)
Geographic Region		
New England	5.5	5.4
Middle Atlantic	12.6	15.1
East North Central	19.7	17.0
West North Central	9.8	7.3
South Atlantic	15.8	17.9
East South Central	5.1	6.2
West South Central	11.8	10.5
Mountain	6.2	5.5
Pacific	13.5	15.1
Population Density		
Large City or Suburbs	20.5	NA
Medium City or Suburbs	22.5	NA
Small City or Town	35.1	NA
Open Country or Farm	21.9	NA
MSA, ≥ 2.5 million pop.	NA	31.3
MSA, 1.0-2.5 million pop.	NA	18.0
MSA, .25-1.0 million pop.	NA	19.0
MSA, < .25 million pop.	NA	9.2
non-MSA	NA	22.5
(MSA=Metropolitan Statistical Area)		
Household Size		
One Person	3.1	24.5
Two Persons	13.3	32.3
Three Persons	16.0	17.3
Four Persons	31.1	15.5
Five Persons	23.5	6.7
Six or More Persons	13.0	3.7
Highest Education Attainment		
High School or Less	25.5	58.4
Trade or Vocational Sch.	3.3	NA
Some College	22.0	18.4
College Graduate	33.8	12.8
Attended Graduate School	15.4	10.4
Total Household Income		
Less than $15,000	8.5	24.4
$15,000-$29,999	22.5	25.7
$30,000-$44,999	30.2	20.3
$45,000-$59,999	20.7	12.7
$60,000 or more	18.1	16.9

Note: The unknown values from the survey (population density, 0.4 percent; income, 14.6 percent; household size, 0.5 percent;

and, education, 0.7 percent) were distributed evenly among the other categories.

Table 4. Profile of Riders

Characteristics	Riders (%)	Projected Riders (Millions)
Age (years)		
10 or less	25.2	16.9
11-14	14.3	9.5
15-20	10.4	7.0
21-30	15.6	10.4
31-40	18.3	12.2
41-50	8.6	5.8
51 or more	6.1	4.1
Unknown	1.5	1.0
Total	100.0	66.9
Gender		
Female	47.0	31.4
Male	52.3	35.0
Unknown	0.7	0.5
Total	100.0	66.9
Years Since Learned to Ride		
3 or less	18.9	12.6
4-6	15.9	10.6
6-9	12.2	8.2
10 or more	52.4	35.1
Unknown	0.6	0.4
Total	100.0	66.9

Table 5. Bicycle Use, Hours Per Year

Annual Riding Time (hours/year)	% of Riders
1-24	20.2
25-49	8.7
50-99	11.8
100-199	15.2
200-399	15.2
400-599	3.9
600 or more	8.1
Unknown	16.9
Total	100.0
Mean Riding Time	236.2 hours/year
Median Riding Time	105.0 hours/year

Age Group	Mean Annual Riding Time (hours/year)	Estimated Riding Time (%)
≤ 10 years	317.6	33.9
11-14 years	262.4	15.9
15-20 years	250.4	11.0
21-30 years	216.3	14.3
31-40 years	164.4	12.7
41-50 years	177.0	6.4
> 50 years	103.4	2.7
Age Unknown	195.5	3.1
Total	236.2	100.0

Table 6. Rider Practices and Use Patterns

Practice	Proportion of Time: Always %	More than Half %	Less than Half %	Never %	Unknown %
Time Spent Riding on:					
Sidewalk/Playground	18.4 (19.3)	10.8 (13.0)	17.7 (17.9)	53.1 (49.8)	0 (0)
Streets with Low Traffic Volume	42.5 (38.8)	21.6 (19.7)	13.6 (14.5)	22.2 (26.9)	0.1 (0.1)
Major Thoroughfares or Highways	2.9 (3.8)	3.9 (4.5)	12.9 (14.0)	80.1 (77.3)	0.2 (0.4)
Bike Paths	7.1 (6.1)	9.8 (11.6)	18.2 (19.4)	64.7 (62.8)	0.2 (0.1)
Unpaved Roads	9.9 (12.3)	7.7 (11.0)	17.6 (17.6)	64.6 (58.8)	0.2 (0.3)
Other Unpaved Surfaces or Trails	5.7 (8.2)	4.8 (7.7)	14.9 (21.4)	74.3 (62.6)	0.3 (0.1)
Time spent:					
Commuting	5.0 (8.0)	3.7 (4.6)	10.1 (10.5)	80.8 (75.9)	0.4 (1.0)
Riding After Dark	1.0 (1.6)	2.1 (3.0)	9.3 (11.2)	87.1 (84.0)	0.5 (0.2)
Wearing Helmet	13.4 (12.7)	4.2 (7.9)	6.0 (4.9)	76.0 (74.2)	0.4 (0.3)
Carrying Infant in Carrier or Trailer	1.5 (.4)	0.8 (.1)	1.7 (1.0)	96.0 (98.5)	0 (0)
Wearing Earphones	1.0 (.7)	1.8 (1.5)	4.5 (6.7)	92.5 (90.8)	0.2 (0.3)

* Percentages without parenthesis represent percentages of bicyclists. Percentages in parenthesis are adjusted to account for estimated annual riding times.

Table 7. Profile of Bicycles in Use

Bicycle Type Used Most Frequently By Respondent

Bicycle Type Used Most Frequently By Respondent	%	Estimated Riding Time %
Children's Sidewalk	13.5	14.3
BMX/High Rise	14.1	24.5
Middleweight/Cruiser	14.1	9.0
Mountain/City/All-Terrain	17.3	16.6
Lightweight Racing/Touring	34.5	26.2
Unknown	6.5	9.4
Total	100.0	100.0

Bicycle Type Used, by Length of Time Since Acquired

	Years Since Acquired			
Type	≤ 1	1 to <3	≥ 3	Total
	%	%	%	%
Children's Sidewalk	18.7	15.2	6.1	13.5
BMX/High Rise	16.5	18.0	5.7	14.1
Middleweight/Cruiser	8.0	10.2	25.8	14.1
Mountain/City/All-Terrain	24.9	19.5	6.8	17.3
Lightweight Racing/Touring	26.6	30.1	48.7	34.5
Unknown	5.3	7.0	6.9	6.5
Total	100.0	100.0	100.0	100.0

Bicycle Type Used, by Age of Rider

	Rider Age, in years				
Type	≤ 10	11-20	21-30	≥ 30	All
	%	%	%	%	%
Children's Sidewalk	38.2	5.8	5.1	4.8	13.5
BMX/High Rise	31.1	16.1	4.8	4.0	14.1
Middleweight/Cruiser	5.0	9.9	12.8	24.4	14.1
Mountain/City/All-Terrain	6.5	19.1	27.6	19.3	17.3
Lightweight Racing/Touring	11.3	40.7	44.9	42.5	34.5

Unknown	7.9	8.4	4.8	5.0	6.5
Total	100.0	100.0	100.0	100.0	100.0

Table 7 (continued)

Length of Time Since Acquired	%
One year or less	28.5
2-3	42.1
4-5	12.1
6-7	6.2
8 or more	10.9
Unknown	0.2
Total	100.0
Mean Number of Years Since Acquired	3.6
Median Number of Years Since Acquired	2.0

How Acquired	%
New	80.6
Used	19.2
Unknown	0.2
Total	100.0

General Condition of Bicycle	%
Like New	38.8
Better Than Average	30.5
About Average	26.3
Poor (i.e., abused, scarred, rusted, etc.)	3.9
Unknown	0.5
Total	100.0

Modifications Made to Bicycle	%
None	97.0
Modification	2.9
Handlebars	(1.0)
Wheels	(0.6)
Seat	(1.1)
Others	(0.2)
Unknown	0.1
Total	100.0

Bicycle Accessories	Yes (%)	No (%)	Unknown (%)
Headlight	14.5	85.2	0.3
Tail Lamp	20.6	78.7	0.7
Bell or Horn	12.5	87.4	0.1
Child Carrier	4.5	95.5	0
Front Basket	8.5	91.4	0.1
Rear Basket or Carrier	8.8	90.9	0.3

Table 8. Helmet Use Information

	Riders (%)	Projected Riders (millions)
Rider Owns or Has Use of Helmet		
Yes	27.3	18.3
No	72.4	48.4
Unknown	0.3	0.2
Total	100.0	66.9
Length of Time Owned or Had Use of Helmet*		
Less than 1 year	30.1	5.5
1 to < 2 years	22.6	4.1
2 or more years	45.8	8.4
Unknown	1.5	0.3
Total	100.0	18.3

Type of Helmet, by Length of Time Owned (or Had Use of)*

Type	Years < 1	Years 1 to <2	Years ≥ 3	Total	
	%	%	%	%	
Hard Shell	64.9	80.9	85.0	77.9	14.3
Soft Shell	21.5	15.9	8.4	14.1	2.6
Thin Shell	8.6	0	5.4	5.1	0.9
Unknown	5.0	3.2	1.2	2.9	0.5
Total	100.0	100.0	100.0	100.0	18.3

	Riders (%)	Projected Riders (millions)
Proportion of Time Spent Wearing Helmet (for All Riders)		
Always/Almost Always	13.4	9.0
More Than Half of Time	4.2	2.8
Less Than Half of Time	6.0	4.0
Never or Almost Never	76.0	50.9
Unknown	0.4	0.2
Total	100.0	66.9
Proportion of Riders Who Wear Helmets All or Most of the Time (for All Riders)		
≤ 10 years	17.0	2.9
11-14 years	11.4	1.1
15-20 years	13.7	1.0
21-30 years	18.5	1.9
31-40 years	19.7	2.4
41-50 years	24.6	1.4
> 50 Years	23.1	0.9
Age Unknown	15.4	0.2
Total	17.6	11.8

* For the 27.3% of riders (projected at 18.3 million) who own or have the use of helmets.

Table 9. Helmet Use Patterns

<u>For the 17.7 percent of Riders (projected at 11.8 million) Who Purchased a Helmet (as opposed to receiving as a gift)</u>

Importance of Factors in Purchase Decision:	Very (%)	Some What (%)	Not (%)	Unknown (%)
Cost	13.5	47.3	38.8	0.4
Appearance	10.6	45.0	42.6	1.8
Comfort	74.0	21.3	4.4	0.3
Weight of Helmet	46.7	31.7	19.8	1.8
Ventilation	41.9	35.0	22.2	0.9
Safety Certification	77.2	13.6	7.6	1.6

<u>For the 13.4 percent of Riders (projected at 9.0 million) Who Always Wear Helmets</u>

Reasons for Wearing Helmet:	Yes (%)	No (%)	Unknown (%)
Safety Reasons	97.8	2.2	0
Family Members (i.e., parent, spouse) insist	55.8	44.2	0
Local Legal Requirement	13.5	78.0	8.5

<u>For the 10.2 percent of Riders (projected at 6.8 million) Who Sometimes Wear a Helmet</u>

Circumstances Under Which Usually Wear Helmet:	%
When Riding in Traffic	40.0
When on Long Rides	25.2
When Remember To	12.4
When Riding with Family Members	11.6
When Reminded	17.9

Reasons Why Riders Do Not Always Wear A Helmet:	%
Rider Forgets	22.9
Helmet Uncomfortable	14.4
When Riding A Short Distance	31.6
When Not Riding in Traffic	23.8
When Riding at Low Speeds	6.6
When on Bike Paths	6.9

<u>For the 76.0 percent of Riders (projected at 50.9 million) Who Do Not Own or Do Not Use a Helmet</u>

Reasons Why Not Use Helmet	%
Do Not Ride Often	8.6
Never Thought About	21.6
Haven't Gotten Around To It	15.6
Seldom Ride in Traffic	18.8
Helmet Not Comfortable	8.9
Helmet Not Attractive	4.9
Helmets Are Too Expensive	7.3

Helmets are Unnecessary	21.0
Did Not Buy One for Child	17.2

Table 10. Independent Variable Definitions

Rider Characteristics	
-LN(EXPER)	The natural logarithm of years since learned to ride a bicycle,
-LN(HOURS)	The natural logarithm of the estimated number of riding hours per year,
-GENDER	1 if the rider is male, 0 if the rider is female,
-AGE	Rider age,
-AGE(X-Y)	1 if aged X to Y, 0 otherwise
Riding Surfaces	
-SIDEWALK	1 if sidewalks or playgrounds are ridden on all or most of the time, 0 otherwise,
-STREETS	1 if neighborhood streets with low traffic volume are ridden on all or most of the time, 0 otherwise,
-HIGHWAY	1 if major thoroughfares, highways, or streets with high traffic volume are ridden on all or most of the time, 0 otherwise,
-BIKEPATH	1 if bike paths that are separate from roadways are ridden on all or most of the time, 0 otherwise,
Demographic and other factors	
-SCH1	1 if no household member has more than a high school education, 0 otherwise,
-SCH2	1 if at least one household member attended college but no household member graduated, 0 otherwise,
-SCH3	1 if any household member was a college graduate, 0 otherwise,
-CITY	1 if the household resides in a large or medium size city (or suburbs of), 0 otherwise,
-NORTHEAST	1 if the rider household is in the New England or Middle Atlantic States, 0 otherwise,
-MIDWEST	1 if the rider household is from the East North Central or West North Central States, 0 otherwise,
-SOUTH	1 if the rider household is from the South Atlantic, East South Central, or West South Central States, 0 otherwise,
-MOUNTAIN	1 if the rider household if from the Mountain States, 0 otherwise,

-PACIFIC	1 if the rider household is from the Pacific Coast States, 0 otherwise.

Table 11. Regression Results -- Factors Associated with Helmet Use

VARIABLE	MODEL 1 COEFF.	MODEL 1 SE	MODEL 2 COEFF.	MODEL 2 SE	MODEL 3 COEFF.	MODEL 3 SE
INTERCEPT	-1.745	0.415	-2.308	0.476	-1.680	0.272
LN(EXPER)	0.072	0.080	0.065	0.079	0.091	0.081
LN(HOURS)	0.136**	0.033	--	--	--	--
GENDER	0.030	0.099	0.028	0.099	-0.020	0.099
AGE(1-10)	-0.113	0.284	0.981**	0.378	0.412**	0.158
AGE(11-20)	-0.452	0.250	0.467	0.326	--	--
AGE(21-30)	-0.269	0.243	0.397	0.293	--	--
AGE(31-40)	-0.190	0.234	0.278	0.265	--	--
AGE(41-50)	-0.206	0.251	0.068	0.265	--	--
AGE	--	--	--	--	-0.015*	0.007
AGE·LN(HOURS)	--	--	0.005**	0.001	0.005**	0.001
SIDEWALK	-0.172	0.118	-0.156	0.117	-0.160	0.117
STREET	-0.214*	0.108	-0.232*	0.108	-0.229*	0.107
HIGHWAY	0.481**	0.173	0.473**	0.173	0.460**	0.173
BIKEPATH	0.629**	0.124	0.630**	0.124	0.626**	0.124
CITY	0.066	0.103	0.062	0.103	0.061	0.103
SCH2	0.540**	0.152	0.557**	0.153	0.546**	0.152
SCH3	0.776**	0.141	0.779**	0.141	0.774**	0.140
NORTHEAST	-0.253	0.168	-0.259	0.168	-0.259	0.167
MIDWEST	-0.390**	0.152	-0.399**	0.152	-0.400**	0.152
SOUTH	-0.337*	0.151	-0.336*	0.151	-0.334*	0.151
MOUNTAIN	-0.583*	0.244	-0.605*	0.244	-0.600*	0.243

** significant at $p \leq 0.01$, two-tailed test
* significant at $p \leq 0.05$, two-tailed test

	MODEL 1	MODEL 2	MODEL 3
N (helm=1)	177	177	177
N (helm=0)	795	795	795
DF	19	19	16
Model Chi-Sq	116.591	119.862	121.404
Score	115.269	119.867	121.349

Table 12. Expected Probability of Helmet Use, for Selected Rider-Bicycle Characteristics

Part A

Age	Male, High School, 10 hours/year, Street	Male, High School, 300 hours/year, Street	Male, High School, 300 hours/year, Bike path
	(%)	(%)	(%)
10	7.7	9.9	30.2
20	3.9	6.8	22.2
30	3.8	8.4	26.6
40	3.6	10.5	31.5
50	3.4	13.0	36.9

Part B

Hours Per Year	Female, High School, Street, 30 years	Female, College, Street, 30 years	Female, College, Highway, 30 years
	(%)	(%)	(%)
25	4.6	14.1	33.1
50	5.4	16.4	37.1
100	6.3	18.9	41.3
200	7.5	21.8	45.6
400	8.8	24.9	49.9
600	9.6	26.9	52.5

Table 13. Average Predicted Probability of Helmet Use, for Selected Population Subgroups

Variable	Group	Average Probability (%)	N
Age	≤ 10	16.5	219
	11-20	14.5	246
	21-30	19.3	179
	31-40	18.8	170
	41-50	27.6	78
	> 50	24.4	80
Hours/Year	< 25	12.2	253
	25-99	18.0	250
	100-400	21.0	339
	> 400	21.4	130
Gender	Male	19.6	546
	Female	16.6	426
School	H. Sch. or less	7.8	259
	Some College	18.4	241
	College Grad.	23.7	472
Income (in $1000)	< $15	15.2	72
	$15-$29.9	15.3	202
	$30-$44.9	17.7	256
	$45-$59.9	20.1	166
	$60 or more	22.4	139
Region	Northeast	19.6	168
	Midwest	15.7	285
	South	17.2	327
	Mountain	12.7	52
	Pacific	26.7	140
Live in City	No	16.3	537
	Yes	20.7	435
Ride on:			
Sidewalk	No	19.0	686
	Yes	16.4	286
Street	No	21.5	335
	Yes	16.3	637
Highway	No	16.7	884
	Yes	37.3	88

Bike Path	No	15.1	797
	Yes	34.8	175

Part III.
Bicycle-Related Injuries: Injury, Hazard, and Risk Patterns

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Introduction

The Directorate for Epidemiology estimates that about one-half million bicycle-related injuries are treated annually in U.S. hospital emergency rooms. An additional 1,000 fatalities occur each year, according to the National Safety Council (1). About two-thirds of the injuries and about one-third of the deaths involve children under the age of 15 years. Head trauma has been reported to be associated with the majority of these deaths and a substantial portion of the injuries (2, 3, 4, 5).

The U.S. Consumer Product Safety Commission's (CPSC) early commitment to reducing this annual toll was evidenced by the promulgation of a mandatory safety standard for bicycles in 1976 (6). This standard included requirements for mechanical and performance aspects of bicycles, as well as requirements for instructions on bicycle assembly, operation, and maintenance. In more recent years, CPSC has been involved in the development and revision of voluntary safety standards [American Society for Testing and Materials (ASTM), American National Standards Institute (ANSI)] for bicycle helmets (7, 8). A recently established Memorandum of Understanding between CPSC and the National Highway Traffic Safety Administration (NHTSA) promotes cooperative efforts between these agencies in the area of bicycle safety (9).

This report provides the results of a 1991 Directorate for Epidemiology special study of the circumstances contributing to bicycle-related injuries treated in U.S. hospital emergency rooms. It incorporates information from a 1991 Directorate for Economics exposure survey of the current U.S. population of bicycle users and their patterns of bicycle and helmet use (10). A brief overview of data on bicycle-related deaths is also included. Together, these data were used to quantify and evaluate risk factors associated with bicycle use.

This information was developed in support of Commission efforts to address bicycle-related hazards, and may be used as a resource by other organizations and individuals who have an interest in bicycle safety.

Data and Methodology

The first stage of this analysis involved the descriptive presentation of data collected about the circumstances involved in bicycle-related injuries treated in U.S. hospital emergency rooms.

The second stage involved the development of statistical models to identify and evaluate risk factors associated with bicycle use. These models were developed to assess factors associated with the general risk of injury to children and to adults. They utilized parallel sets of data collected from injured as well as non-injured U.S. bicyclists so that risk comparisons could be made.

While the primary purpose of the study was to evaluate risk factors associated with bicycle-related injuries, national mortality data was presented to highlight some of the circumstances involved in the most serious incidents involving bicycles. The following sections describe the data sources and methodologies used for this study.

Injury Data

The bicycle-related incidents used for this study were identified through the National Electronic Injury Surveillance System (NEISS). This system consists of a nationally representative sample of over 90 U.S. hospital emergency rooms that report consumer product-related injuries to CPSC on a daily basis. Information routinely collected through NEISS includes the type of product associated with the injury; the victim's age, sex, diagnosis, disposition, and body part injured; and a short narrative description of how the injury occurred. When further information is needed, selected incidents may be followed by a more detailed investigation.

From January through December 1991, injuries reported to have involved bicycles were sampled for telephone investigation to obtain additional information about the circumstances involved in the incident and the victim's general patterns of bicycle use. Incidents in which a mechanical failure of the bicycle was reported were reassigned for on-site investigation for further examination of the bicycle.

CPSC investigators were instructed to discuss the incident circumstances and usage patterns with the injured victim whenever possible. However, for cases in which the victim was under the age of 15 years, the investigators were asked to contact the parent, guardian, or other adult familiar with the incident.

In the telephone investigations, open-ended questions were used to obtain a narrative description of the incident scenario and the nature and extent of the injury received. Other questions were primarily closed-ended and were used to collect such information as: where the victim was riding at the time of the incident; time of day; daylight conditions; use of lights and reflectors; type, ownership, and condition of the bicycle; use of and damage to a helmet; and other factors that may have contributed to the incident.

Data intended specifically for use in developing models to assess factors contributing to the risk of bicycle-related injuries in general were collected primarily through closed-ended questions. These questions were usually identical to those asked of the non-injured respondents in the "exposure" survey described in the following section. They related to the frequency, location, and time of bicycle use; the frequency and circumstances of bicycle helmet use; and victim demographics such as area of residence, income, and education.

In all, 597 cases were selected (every 23rd bicycle case reported). Of these, 123 could not be verified as being within the scope of the study because the victim could not be contacted or was unwilling or unable to provide information about the incident. Of the remaining 474 cases, 11 (about 2 percent) were determined to be out-of-scope (e.g., involved a tricycle, motorcycle, etc.). This analysis contains information from the 463 injury reports verified to have involved bicycles. However, the majority of this analysis is based on the 420 cases that involved injury to the bicycle operator, rather than to passengers, bystanders, and others.

Thus, information from the injury cases identified through NEISS was used 1) to provide a general description of the circumstances involved in bicycle-related incidents, 2) to develop statistical models that identified risk factors associated with bicycle use in general, when combined with comparable information from the "exposure" survey.

Exposure Data

The "exposure" data noted earlier was obtained from a national probability survey of about 1,250 households with bicyclists. It was conducted by Abt Associates during June and July 1991, for CPSC's Directorate for Economics. One rider was randomly selected in multiple rider households; an adult was asked to respond for any randomly selected child. The sample was weighted to reflect the number of riders in each household, and further weighted to represent the 94 million U.S. households in 1991.

Preliminary highlights from this survey indicated that there were about 67 million bicycle riders in U.S. households in 1991, about one-half under 21 years of age. More than one-half of nearly 12 million helmet wearers began wearing helmets in the last two years, and about 18 percent wear helmets all or more than half of the time (10).

Risk Comparisons

The national probability sample of verified in-scope bicyclist injury cases identified through NEISS was combined with non-injury cases from the exposure survey. Respondents were asked to provide information about the characteristics of persons, bicycles, and environments involved in either bicycle-related injuries or bicycle use. From the information received, the factors associated with injuries to children under 15 years of age, and with injuries to adults age 15 and older, were examined.

Logistic regression techniques were used to develop statistical models (logit models) to answer each question. Logit models are used to examine the relationship between a set of factors, such as characteristics of persons, bicycles, or environments, and a dichotomous outcome, such as injury or non-injury. This type of analysis is typically used to examine the contribution of each factor while holding other factors constant (11).

Death Data

Information on bicycle-related fatalities was obtained primarily from two sources, the National Center for Health Statistics (NCHS), and the National Highway Traffic Safety Administration (NHTSA).

NCHS collects information on all deaths that occur in the United States each year. Data on deaths involving bicycles were obtained from NCHS mortality data tapes for 1989, the latest year available. Using international classifications published by the World Health Organization, bicycle-related deaths were selected from External Cause of Death Codes E800 through E807, with fourth digit .3; E810 through E819, with fourth digit .6; E826.1; and E826.9 (12).

NHTSA maintains the Fatal Accident Reporting System (FARS), which includes information on fatal traffic crashes in the United States, including bicyclist fatalities involving motor vehicles. Published FARS data from 1991 were used for this report (13, 14).

Analysis of Operator Injury Data

The 1991 estimate of bicycle-related injuries treated in U.S. hospital emergency rooms was 588,000.[1] From the special study, about 90 percent (about 531,000) of those injured were the bicycle operators, about 4 percent were passengers, and about 3 percent were bystanders. An additional three percent were injured in such other ways as when repairing or tripping over a bicycle, etc.

Those injured as non-operators (i.e., passengers, bystanders, etc.) were significantly younger ($p < .01$) than those injured while operating the bicycle. About 66 percent of the non-operators were under the age of 10 years whereas 37 percent of the operators were under age 10 (See Appendix Table A1.) Of note was that none of the passengers treated in hospital emergency rooms was reported to have been in a child carrier or wearing a helmet.

The remainder of this section includes information from 420 incidents in the sample in which the bicycle operator was injured. Described are the riders' age, sex, rate of injury, body part injured, diagnosis and disposition; hazard patterns; location of incident; time of day and daylight conditions; helmet use; and bicycle type.

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[1]This estimate was adjusted using the proportion of special study cases verified to have involved a bicycle.

Victim Age, Sex, Rate of Injury

As shown in Table 1, about 37 percent of those injured were under the age of 10 years, and about 71 percent were under the age of 15. About 62 percent of the victims were male.

Data from the CPSC Directorate for Economics' exposure survey indicated that there were approximately 66.9 million bicycle riders in the United States in 1991. (The survey defined a rider as a U.S. resident who rode a bicycle during the year prior to the survey.) Using this information in conjunction with data from the injury study, age-specific injury rates were calculated. Bicyclists were injured at an overall rate of 8.8 per thousand riders. Those in the 5-14 age group exhibited the highest rate, about 17 emergency room-treated injuries per thousand individuals in that age group who rode bicycles. Those age 45-64 had the lowest rate, about 2.9 injuries per thousand riders in that group.

Age-specific injury rates were also calculated using annual riding times obtained from the exposure survey. The estimated average riding time for U.S. bicyclists was about 237 hours per year. Annual riding times were highest for younger riders, and generally decreased with age. Overall, bicyclists were estimated to have been injured at a rate of 37.2 injuries per million hours of use. Those age 65 and older demonstrated the highest rate of injury, about 61 injuries per million hours of use.[2] Bicyclists in the 5-14 age range also exhibited a high rate of injury, over 55 injuries per million hours of use. Bicyclists in the 25-44 age group were estimated to have had the lowest rate of injury, about 18 injuries per million hours of use.

Thus, bicyclists in the 5-14 age range demonstrated higher rates of injury than most of the other age groups, whether evaluated in terms of numbers of riders or in terms of annual riding time. Riders age 25-64 demonstrated the lowest rates of injury. While the

[2]Injury rates for bicyclists age 65 and older should be interpreted with caution due to small sample size for this age group (n = 6).

Table 1

Bicycle Injuries: Age of Victim by Percent of Total Injuries, Injuries per Thousand Riders, nd Injuries per Million Hours of Use

Victim Age	Percent of Total Injuries	Annual Injuries per Thousand Riders	Annual Injuries per Million Hours of Use
Total	100.0*	8.8	37.2
≤ 4	3.1	7.3	25.3
5-9	33.6	16.9	57.0
10-14	34.7	16.7	55.4
15-24	10.9	5.9	29.4
25-44	13.4	3.6	18.1
45-64	3.1	2.9	22.0
≥ 65	1.1	7.2	61.0

* Column detail may not add to total due to rounding.

Source: National Electronic Injury Surveillance System (NEISS): Special Study, January-December 1991; National Survey of Bicycle and Helmet Use Patterns in the United States, 1991 U.S. Consumer Product Safety Commission sample size of injured bicyclists age 65 and older was small, the data suggested that bicyclists of this age had a relatively low rate of injury per thousand riders in that age group. However, they had the highest rate of injury per million hours of riding time.

Body Part, Diagnosis, Disposition

As shown in Table 2, the arm/hand and head/face areas each accounted for about one-third of the injuries, followed by the leg/foot area, accounting for about one-fifth of the injuries.

Younger victims exhibited a significantly higher proportion of head injuries than older victims ($p < .01$).[3] About one-half of the injuries to those under the age of 10 years were to the head/face area, as compared to about one-fifth of the injuries to victims over the age of 10.

Table 2
Bicycle Injuries: Body Part by Age of Victim

Body Part	Total	Age of Victim: <10 Years	Age of Victim: ≥10 Years
Total	100%	100%	100%
Arm/Hand	32%	19%	39%
Head/Face	30%	50%	19%
Leg/Foot	22%	21%	23%
Other	16%	10%	19%

Source: National Electronic Injury Surveillance System (NEISS): Special Study, January-December 1991 U.S. Consumer Product Safety Commission

Table 3 indicates that about 69 percent of the head/face injuries were lacerations, contusions, and abrasions, relatively minor diagnoses. However, about 27 percent were reported to be potentially serious injuries such as fractures, internal injuries, and concussions. Injuries to the arm/hand area tended to be lacerations, contusions or abrasions (42 percent), and fractures (40 percent). Injuries to the leg/foot area were primarily lacerations, contusions, and abrasions (72 percent). Fractures were reported for about 13 percent of the leg/foot injuries. Less than three percent of the victims were admitted for further hospitalization, similar to all consumer product-related injuries reported through NEISS in 1991 (about four percent).

[3] In this section, all tests of significance were chi-square tests of independence. The p-value, or the Type I error rate, indicates the probability of rejecting a true null hypothesis. For this study, the maximum probability for a Type I error was set at 0.05.

Table 3

Bicycle Injuries: Diagnosis by Body Part

Diagnosis	Total	Head/Face	Arm/Hand	Leg/Foot	Other
		Body Part			
Total	100%*	100%	100%	100%	100%
Lac./Contus./Abras.	61%	69%	42%	72%	65%
Fractures	20%	6%	40%	13%	17%
Strains/Sprains	8%	1%	15%	9%	7%
Internal Inj.	5%	14%	-	-	3%
Concussions	2%	6%	-	-	-
Other	5%	3%	4%	6%	8%

* Column detail may not add to total due to rounding.

Source: National Electronic Injury Surveillance System (NEISS):
Special Study, January-December, 1991
U.S. Consumer Product Safety Commission

Hazard Patterns

Investigators recorded up to three factors that may have contributed to the incident, using information collected through structured questions. Information collected through open-ended questions was used to verify these factors and to provide additional details about the circumstances involved. Table 4 provides the proportion of cases associated with each of the factors reported. Appendix Tables A2 and A3 provide, for each contributing factor, the distribution of victim ages and where the incident occurred.

Table 4
Bicycle Injuries: Hazard Patterns

Hazard Pattern	%
Uneven Surface	27%
Going Too Fast	22%
Slippery Surface	15%
Collis./Moving Object	15%
Mechanical Failure	13%
Collis./Non-Mov. Obj.	13%
Performing Stunts	11%
Obj. Caught in Spokes	6%
Other	29%

Note: Column sums to more than 100% due to multiple causal factors contributing to some incidents.

Source: National Electronic Injury Surveillance System: Special Study, January-December, 1991 U.S. Consumer Product Safety Commission

Following is a brief summary of information on the incidents involving each hazard pattern.

<u>Uneven Surfaces</u>. About 27 percent of the incidents were reported to have involved uneven riding surfaces such as bumps, ruts, curbs, grates, holes, etc.

<u>Riding Too Fast</u>. About 22 percent of the incidents were reported to have involved the victim "riding too fast." This was frequently reported in conjunction with other contributing factors such as uneven or slippery surfaces, or performing stunts. "Lack of experience" was also often mentioned in conjunction with this factor.

Slippery Surfaces. Slippery riding surfaces, such as those having loose stones/gravel, sand, dirt, mud, grass, leaves, puddles, oil, ice, or snow were said to have contributed to about 15 percent of the incidents. About two-thirds of these incidents occurred on non-street locations such as unpaved surfaces, trails, sidewalks, playgrounds, and bike paths.

Collisions with Moving Objects. Collisions with moving objects such as operating motor vehicles, animals, pedestrians, and other bicyclists were reported for about 15 percent of the incidents. Incidents associated with this hazard pattern most frequently occurred on neighborhood streets (54 percent) or major thoroughfares (24 percent).

Mechanical Failure. Victims attributed about 13 percent of the incidents to a mechanical or performance problem with the bicycle. CPSC's Directorate for Engineering Sciences evaluated these cases and determined that the most frequently reported problems were bicycle chains breaking or falling off, brakes failing, and various components such as handlebars or brakes coming loose (15). While the causes of these reported failures could not be absolutely determined, it appeared that poor bicycle maintenance and bicycle modification were likely contributors to some of these incidents. In addition, it appeared possible that factors such as a slick riding surface or unfamiliarity with the bicycle (e.g., brakes) could have contributed to the operators' perception that a failure occurred.

Hit Non-Moving Object. About 13 percent of the incidents involved collisions with non-moving objects, such as parked vehicles, traffic signs, posts, walls, fences, bushes, large rocks, chains, and toys. More than two-thirds of these incidents occurred on non-street locations such as sidewalks, playgrounds, trails, and bike paths.

Performing Stunts. About 11 percent of the incidents involved victims performing such stunts as jumping over mounds of dirt, ramps, speed bumps, etc., and performing "wheelies." Most of these victims (88 percent) were under the age of 15 years. Three out of four of these incidents occurred on non-street locations such as sidewalks, playgrounds, trails, and unpaved surfaces.

Items caught in spokes. About six percent of all incidents involved items caught in the bicycle spokes, such as a foot/shoe, book bag, purse, pant leg, book, board, etc.

Other. Other factors reported as contributing to incidents were victims' inexperience, inattention, and unfamiliarity with braking systems (either hand or foot brakes). Victims were also reported to have been riding at night without a light; to have been riding a bicycle either too big or too small for them; and to have fallen while avoiding motor vehicles, other bicyclists, pedestrians, and animals.

Incidents involving motor vehicles involved collisions with both operating and parked vehicles, and cases in which the victim swerved to avoid collision with a moving vehicle.

Those that involved collision or near-collision with an operating motor vehicle (not parked) accounted for only about 10 percent of all incidents.

In the development of the study plan, there was interest expressed, from both within and outside CPSC, in the contribution of radios or other devices with earphones to bicycle incidents. However, there was little indication that these devices played a major role in the incidents reported. Very few of the victims were said to have been wearing earphones at the time of the incident.

Location of Incident

Overall, streets with relatively low traffic volume (e.g., neighborhood streets) were associated with 41 percent of the injuries, more than any other location (Table 5). This was followed by sidewalks or playgrounds, where about 12 percent of the injuries were reported to have occurred. Major thoroughfares were associated with about 7 percent of the injuries; unpaved roads and trails, each with about 5 percent; and bike paths, with less than 1 percent. "Other" locations included driveways, yards, parking lots, alleys, etc.

When injuries were grouped to compare bicyclists age 25 and older to those of younger age, and major thoroughfares to other locations, riders age 25 and older were injured on major thoroughfares more frequently than younger riders
($p < .01$). About 25 percent of those 25 and older were injured on major thoroughfares, as compared to about 3 percent for younger victims.

Table 5
Bicycle Injuries: Location of Incident
by Age of Victim

Location	Total	Victim Age <10	10-14	15-24	≥25
Total	100%*	100%	100%	100%	100%
Neighborhood street	41%	33%	50%	50%	38%
Sidewalk/playground	12%	19%	10%	9%	8%
Major thoroughfare	7%	-	6%	7%	25%
Unpaved road	5%	6%	6%	2%	1%
Trail	5%	4%	6%	7%	-
Bike path	<1%	-	1%	-	3%
Other	28%	38%	20%	25%	25%

* Column detail may not add to total due to rounding.

Source: National Electronic Injury Surveillance System (NEISS): Special Study, January-December,1991

U.S. Consumer Product Safety Commission

Time of Day, Daylight Conditions

Overall, about two-thirds of the incidents occurred between 6:00 am and 6:00 pm, primarily in the afternoon. About one-third occurred between 6:00 pm and midnight, and less than one in one hundred occurred between midnight and 6:00 am.

To accommodate seasonal variations in the length of day, a question was also asked about the daylight conditions at the time of the incident (Table 6). This revealed that about 79 percent of the incidents occurred during daylight, about 16 percent during dawn or dusk, and about 5 percent at night.

Incidents were combined to compare daylight with non-daylight conditions and major thoroughfares to other locations. Non-daylight incidents (i.e., occurring at dawn, dusk or night) were significantly more common on major thoroughfares than in non-thoroughfare locations ($p < .01$). About 35 percent of the incidents that occurred on major thoroughfares occurred during non-daylight conditions, as compared to about 19 percent of the incidents in other locations.

While the small number of cases precluded drawing specific conclusions about the use of bicycle lights during incidents that occurred in non-daylight conditions, less than eight percent of all bicycles involved in incidents were reported to have been equipped with lights. Of those with lights, victims were not always using the lights during incidents that occurred at dawn or dusk. About nine out of ten victims were reported to have had reflectors on their bicycles. Reflectors are currently required by the CPSC mandatory standard for bicycles.

Table 6
Bicycle Injuries: Location of Incident by Daylight Category

		Daylight Category			
Location	Total	Dawn	Daylight	Dusk	Night
Total	100%	<1%	79%	15%	5%
Sidewalk/playground	100%	-	75%	21%	5%
Neighborhood street	100%	<1%	81%	15%	4%
Major thoroughfare	100%	5%	65%	26%	4%
Bike path	100%	20%	80%	-	-
Unpaved road	100%	-	87%	-	13%
Trail	100%	-	98%	2%	-
Other	100%	<1%	78%	16%	6%

Source: National Electronic Injury Surveillance System (NEISS): Special Study, January-December 1991
U.S. Consumer Product Safety Commission

Helmets

About 12 percent of the victims were wearing a helmet. However, victims under 15 years of age were significantly less likely than older victims to have been wearing a helmet ($p < .01$). See Table 7. About five percent of the victims under age 15 were reported to have been wearing a helmet, as compared to about 30 percent of the victims age 15 and older.

Table 7
Bicycle Injuries: Age of Victim
by Helmet Use at Time of Incident

		Helmet Worn	
Age Group	Total	No	Yes
All Ages	100%	88%	12%
Total <15	100%	95%	5%
<10	100%	93%	7%
10-14	100%	98%	2%
Total ≥15	100%	70%	30%
15-24	100%	84%	16%
≥25	100%	61%	39%

Source: National Electronic Injury Surveillance System (NEISS): Special Study, January-December, 1991, U.S. Consumer Product Safety Commission

About one-half of the helmets were reported to have been hard shell types, about one-third were soft-shell, and the remainder were primarily thin-shell.

In about one-third of the cases in which the victim was wearing a helmet, it was reported that the helmet was damaged in some way during the incident. Damage included scrapes, scratches, dents, and cracks.

Of the 16 helmets in the sample that were damaged, 11 (69 percent) were worn by victims who did not sustain head injuries. However, in all of the cases in which damage was observed, the victim expressed the opinion that the helmet prevented a head injury or made the head injury less severe. For helmet-wearers in general (regardless of helmet damage), about two-thirds expressed the opinion that the helmet prevented a head injury or made the head injury less severe.

Bicycles

BMX, freestyle, sidewalk, and high-rise bicycles were reported to have been involved in about 43 percent of the incidents. Mountain, city, or all-terrain bicycles were said to have been involved in about 25 percent of the incidents; lightweight racing or touring bicycles in about 19 percent; and middleweight or cruisers in about 6 percent (Table 8).

An estimated 56 percent of the victims under 15 years of age were injured while using types of bicycles typically intended for use by children, such as BMX/freestyle, sidewalk, or high-rise bicycles. Only about 10 percent of those 15 and older were injured using these types of bicycles. Instead, these victims were most frequently injured while using mountain, city, or all-terrain bicycles, and lightweight racing or touring bicycles.

About 86 percent of the bicycles involved were owned by the victim's household, rather than borrowed or rented. Of the bicycles owned by the victim, about 80 percent were purchased new, rather than used. About three-fourths of the bicycles owned by the victim were described as being like new, or in better than average condition at the time of the incident. For bicycles purchased new, about one-half had been purchased less than one year prior to the incident, and almost all (97 percent) had been purchased five years or less prior to the incident.

The data suggested that borrowed or rented bicycles may not have been in as good condition as those owned by the victim's household. About one-half of the borrowed or rented bicycles were reported to have been in average or poor condition rather than like new or in better than average condition.

About 94 percent of the respondents indicated that the structure or design of the bicycle had not been changed or modified (other than minor repairs) prior to the incident. Where modifications were made, they were primarily to the wheels, seat, and handlebars.

Other

About 80 percent of the injuries occurred during the six month period from April through September. The months of June and July were associated with the greatest proportion of injuries, each accounting for about 15 percent of the total injuries reported for the year. January had the fewest injuries reported, accounting for about one percent of the total injuries for the year.

Less than three percent of the incidents were reported to have occurred during conditions of rain or snow, suggesting that precipitation was not a major contributor to bicycle-related injuries treated in U.S. hospital emergency rooms.

Table 8
Bicycle Injuries: Type of Bicycle by Age of Victim

Bicycle Type	Total	Age of Victim <15 Years	Age of Victim ≥15 Years
Total	100%*	100%	100%
BMX/Freestyle, Sidewalk, High-rise	43%	56%	10%
Mountain, City, All-Terrain	25%	21%	33%
Lightweight Racing/Touring	19%	14%	34%
Middleweight, Cruiser	6%	4%	13%
Other	7%	6%	10%

* Column detail may not add to total due to rounding.

Source: National Electronic Injury Surveillance System (NEISS): Special Study, January-December 1991
U. S. Consumer Product Safety Commission

Risk Assessment

Logit models were used to examine factors that may contribute to the risk of injury for 1) children and 2) adults. Variables that were included in the models were age, gender, number of hours ridden per month[4], location where the bicycle was most frequently ridden, size of metropolitan area in which the bicyclist resided, and whether a person rode predominantly during the day or when there was less light. Some variables were not retained in the models because they were not significantly related to the risk of injury and there was not a strong theoretical basis for their inclusion. Other variables were excluded because of small sample sizes.

[4]Missing values for hours of use per month reduced the sample size of the models. No variable in the data set seemed to predict the average hours of use per month for an observation, so the mean value was imputed for the missing values in the injury and exposure samples. The highest correlation between any variable and log hours of use was 0.12, indicating that other parameters would change little when missing values were imputed. Imputation increased the sample size by nine percent for the children's model and by 15 percent for the adults' model. This also decreased the standard errors for the variables in the models, allowing several variables which had been borderline to emerge as significant.

The relative risk between levels of these variables was evaluated by estimating odds ratios. These were calculated from the coefficients obtained from the logistic analysis. Odds ratios indicate the change in risk between two categories of a variable being compared.

The variables were coded so that meaningful comparisons could be made. For example, the variable that identified the location upon which a person predominantly rode was coded so that the effect of riding on each location (i.e., riding on major thoroughfares, sidewalks, bike paths, or unpaved surfaces) could be directly compared to riding on streets. The variable that identified the size of the metropolitan area in which a person resided was coded so that the effects of living in a suburb, a smaller city, and a rural environment were compared to living in a large city. Age of bicyclist was coded in continuous form to measure the effect of maturing one year. Average hours of use per month was coded in logarithmic form to reduce the effect of extreme responses. For easier interpretation, the effect of more riding time was estimated by doubling the number of hours of riding per month. Gender and daylight were coded to compare the effect of being male to female and the effect of riding in daylight to a category that included riding in dawn, dusk, or night.

Separate models were developed for children and adults in order to provide a clear assessment of the risk factors associated with each age group. Of note was that while victim age was not significantly related to the risk of injury in either the children's or adults' models, children were found to be at significantly greater risk than adults when data from both age groups were combined.[5] The definitions of the independent variables and results of the regression analysis are presented in Appendix Tables A4 through A6.

Model I: Factors Associated with Children's Bicycle-Related Injuries

Table 9 presents the variables that were included in the model for children, along with the comparison groups and the changes in relative risk between comparison groups.

Increased risk of injury was associated with certain riding locations, time of day, and place of residence. Children who rode in non-daylight hours, on streets,[6] and who lived in large cities were more likely to be injured.

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[5]In a combined model (Appendix Table A5), victims' ages were grouped for easier comparison. Those under 10 years of age were 6.28 times as likely to be injured in a bicycle-related incident as those age 45 and older. Those age 10 through 14 years were about 6.83 times as likely to be injured as those age 45 and older. In addition, as a group, those riders under age 15 were almost six (5.66) times as likely to be injured as those 15 years of age and older.

[6]Data for major thoroughfares and streets were combined in the children's model because of the relatively small number of cases reported for major thoroughfares.

Table 9

Bicycle Injuries: Relative Risks for Characteristics of Children

Characteristics of Bicycle Riding and Bicyclist	Comparison Group	Risk Relative to Comparison Group; Odds Ratio
Rider aging one year	Rider age	Non-significant
Males	Females	Non-significant
Double hrs. of use/mo.	Hours of use per month	Non-significant
Living in suburbs	Living in large cities	Non-significant
Living in small towns	Living in large cities	0.56 (1.79)*
Living in rural areas	Living in large cities	0.47 (2.12)
Riding on sidewalks	Riding on streets	0.60 (1.65)
Riding on bike paths	Riding on streets	0.12 (8.02)
Riding on unpaved surfaces	Riding on streets	0.29 (3.44)
Riding in daylight	Riding at dawn, dusk, or night	0.27 (3.64)

* Numbers in parentheses are inverted odds ratios, and may be used for easier interpretation when the direction of the risk comparison is reversed; e.g., living in large cities was 1.79 times riskier than in small towns (1 ÷ 0.56 ≈ 1.79).

Source: National Electronic Injury Surveillance System (NEISS): Special Study, January-December 1991; National Survey of Bicycle and Helmet Use Patterns in the United States, 1991

For each measured effect on relative risk, all other effects that were modeled were held constant. A child in a large city would be 1.79 times more likely to incur a bicycle-related injury than a child in a small town, if they have the same riding habits.[7] Similarly, a child in a large city would be 2.12 times more likely to sustain an injury than a child in a rural environment. Riding predominantly on streets was estimated to be 1.65 times more risky than riding on sidewalks, 8.02 times more risky than riding on bike paths,[8] and 3.44 times more risky than riding on unpaved surfaces. The risk of riding predominantly at night was estimated to be 3.64 times greater than riding in daylight.

The variables age, gender, hours of use per month, and living in suburbs were not found to be significant predictors of bicycle injury to children.

Model II: Factors Associated with Adults' Bicycle-Related Injuries

Table 10 presents the variables that were included in the model for adults, along with the comparison groups and the changes in relative risk between comparison groups. Bicyclists age 15 and older differed from younger riders in 1) the effects which were significant for the comparison groups and 2) the magnitude of change in relative risk for the significant effects.

Adults who rode more frequently, who rode on streets and major thoroughfares, and who lived in large cities, were more likely to be injured.

An evaluation of relative risk revealed that for bicyclists age 15 and older, doubling the number of riding hours per month increased the relative risk of bicycle injury by an estimated 1.40 times. Living in large cities was about 2.08 times as risky as living in small towns. As with children, riding on streets was more risky than riding on bike paths and unpaved surfaces. Riding on streets was estimated to be 6.93 times more risky than

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[7]Within the discussion of these models, some of the differences in relative risk were expressed using inverted odds ratios. This reversed the risk comparison for greater ease of interpretation. For example, it was more meaningful to say that a child living in a large city was about 1.79 times more likely to be injured than a child in a small town, rather than to say that a child living in a small town would be about 0.56 times as likely to be injured as a child in a large city (i.e., $1 \div 0.56 \approx 1.79$). Calculated values may differ from those in the text due to rounded odds ratios presented in Tables 9 and 10.

[8]The number of children who rode predominantly on bike paths in the exposure sample was 26 (7.3 percent). In the injury group, there were only three observations (2 percent). This may be due to bike paths being safer places for children to ride a bicycle or it may be due to sample variation yielding an injury estimate that was very small.

Table 10

Bicycle Injuries: Relative Risks for Characteristics of Adults

Characteristics of Bicycle Riding and Bicyclist	Comparison Group	Risk Relative to Comparison Group; Odds Ratio
Rider aging one year	Rider age	Non-significant
Males	Females	Non-significant
Double hrs. of use/mo.	Hours of use per month	1.40
Living in suburbs	Living in large cities	Non-significant
Living in small towns	Living in large cities	0.48 (2.08)*
Living in rural areas	Living in large cities	Non-significant
Riding on sidewalks	Riding on streets	Non-significant
Riding on major thoroughfares	Riding on streets	2.45
Riding on bike paths	Riding on streets	0.14 (6.93)
Riding on unpaved surfaces	Riding on streets	0.11 (8.84)
Riding in daylight	Riding at dawn, dusk or night	Non-significant

*Numbers in parentheses are inverted odds ratios, and may be used for easier interpretation when the direction of the risk comparison is reversed; e.g., living in large cities was 2.08 times riskier than in small towns (1 ÷ 0.48 ≈ 2.08).

Source: National Electronic Injury Surveillance System (NEISS): Special Study, January-December 1991; National Survey of

riding on bike paths and 8.84 times more risky than riding on unpaved surfaces. Riding on major thoroughfares was found to be 2.45 times more dangerous than riding on streets.[9]

The variables age, gender, living in suburbs, living in rural areas, and riding predominantly on sidewalks were not found to be significant predictors of bicycle injury to adults.

Other

Currently, there is widespread interest in the effectiveness of helmets in preventing head injuries. Therefore, logit models were developed to identify factors associated with head injuries, using data from the injury cases identified through NEISS. These models, however, were affected by small sample size and significant conclusions could not be drawn about the effects of helmets.

Bicycle-Related Deaths

The focus of this study was to evaluate bicycle-related injuries treated in U.S. hospital emergency rooms. Almost all were non-fatal, as were the great majority of casualties associated with bicycles. The majority did not involve motor vehicles. However, some information about bicycle-related fatalities, which are primarily traffic-related, has been included. This section provides a brief overview of these deaths, and highlights some of the differences in the patterns of injury associated with fatal versus non-fatal incidents. Hazard patterns specifically associated with fatal bicycle incidents involving motor vehicles also are described.

According to the National Safety Council, an average of about 1,000 bicycle-related deaths occur annually in the United States (1). Additional information about these fatalities was obtained from the National Center for Health Statistics (NCHS).[10] In 1989, the latest year for which data were available, there were about 890 deaths reported in which a person was fatally injured while riding a road transport vehicle operated solely by pedals, such as a bicycle.

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[9]As with the children's sample, the sample sizes for some categories of injuries occurring to adults was small. This may be because the risk of bicycle-related injury for adults was less than that for children. Only 79 injury observations had the information required for the analysis of adult risk factors. There were small sample sizes in the injury sample for living in rural areas, and for being injured on sidewalks, bike paths and unpaved surfaces. There were only three injury observations for bike paths (4 percent of the injury sample) and only two injury observations for unpaved surfaces (3 percent of the injury sample). However, the small sample sizes for injuries in these locations would make the estimated odds ratios sensitive to small changes.

[10]In recent years, CPSC has not collected death certificate data for bicycle-related incidents involving motor vehicles.

About 90 percent of these deaths involved motor vehicles, in contrast to about 10 percent of the injuries treated in U.S. hospital emergency rooms.

As shown in Table 11, those who died from bicycle-related incidents tended to be older than those treated in hospital emergency rooms for primarily non-fatal injuries. About 63 percent of those who died were age 15 or older, and about 17 percent were 45 or older. This compares to about 29 percent and 4 percent, respectively, of the victims reported through NEISS.

In addition, fatal incidents appeared more likely to have involved males. About 85 percent of the fatalities were male, in contrast to about 62 percent of those treated in hospital emergency rooms.

Table 11
Bicycle Injuries: Age and Gender of Victims
by Percent of Deaths and Injuries

Victim Age and Gender	Deaths (NCHS)	Injuries (NEISS)
Total	100.0 %	100.0 %
≤ 4	2.0	3.1
5-14	35.0	68.4
15-24	21.3	10.9
25-44	25.2	13.4
45-64	9.5	3.1
≥ 65	7.0	1.1
Male	85.3	62.3
Female	14.7	37.7

Source: National Center for Health Statistics (NCHS), 1989; National Electronic Injury Surveillance System (NEISS): Special Study, January-December 1991, U.S. Consumer Product Safety Commission

Fatal incidents involved a greater proportion of head injuries than those resulting in non-fatal injuries treated in hospital emergency rooms. A recent study (2) indicated that about 62 percent of all bicycle-related deaths involved head injury, as compared to about 30 percent of the non-fatal injuries reported through NEISS. The majority (about 87 percent) of the bicycle-related head injury deaths involved motor vehicles.

The National Highway Traffic Safety Administration's (NHTSA) Fatal Incident Reporting System (FARS) contains additional information on pedalcyclist fatalities involving motor vehicles (13, 14). In 1991, 841 pedalcyclists died from motor vehicle traffic crashes, about two percent of all motor vehicle traffic crash fatalities for that year.

For about two-thirds of the pedalcyclist incidents included in FARS, police reported at least one factor that may have contributed to the crash. Failure to yield right-of-way was the most frequently reported factor, contributing to about 22 percent of the fatal incidents. Improper crossing of roadway or intersection was the second most frequently reported factor, contributing to about 13 percent of the incidents. Other factors included failure to obey traffic signs, signals, or officer (9 percent); inattention (8 percent); operating vehicle in erratic, reckless, careless, or negligent manner (6 percent); failure to keep in proper lane or running off road (5 percent); and operating without required equipment (5 percent). About three-fourths of these deaths occurred at non-intersection locations.

Almost one-half (46 percent) of the fatal incidents involving motor vehicles occurred between 6:00 pm and 5:59 am, suggesting that night riding may be a contributing factor in a portion of bicycle-related deaths.

For more than one-third of the motor vehicle crashes that resulted in a cyclist fatality, alcohol involvement was reported for either the motor vehicle driver or the cyclist. For pedalcyclists specifically, about one-fourth had blood alcohol concentration levels of 0.01 grams per deciliter (g/dl) or greater, and one-sixth were intoxicated (blood alcohol concentration levels 0.10 g/dl or greater).

Discussion

Issues included for additional discussion were those related to head injuries and helmet use, the need for modifications to the mandatory standard for bicycles, and risks associated with night riding.

Head Injuries/Helmet Use

In recent years, there has been a growing public awareness of head injuries and helmet safety. Data collected for this study corroborated this concern.

Almost one-third of all bicycle-related injuries treated in U.S. hospital emergency rooms in 1991 involved the head/face area. About one-fourth of these injuries involved potentially serious injuries such as fractures, internal injuries, and concussions. A recent study indicated that almost two-thirds of all bicycle-related deaths involved head injury (2).

Children appeared to be at particular risk of head injury. About one-half of the injuries to children under the age of ten involved the head and face, as compared to about one-fifth of the injuries to older children. Children were also less likely to have been wearing a helmet at the time of a bicycle-related incident than adults.

Examination of the 16 cases in the sample for which helmet damage was reported revealed that in 11 cases (69 percent), the helmets were worn by victims who did not sustain head injury. Using the assumption that the helmet damage resulted from head impact, a "best guess" estimate of the effectiveness of helmets in preventing head injury would therefore be about 69 percent. It is clear, however, that this estimate was based on a very limited number of cases.

Statistical modeling techniques used to evaluate factors that contributed to the risk of bicycle-related head injury were not conclusive about the effects of helmet use.

Neither the examination of damaged helmets nor the statistical modeling techniques should be viewed as definitive methods of measuring helmet effectiveness. Neither included cases in which bicyclists were involved in helmet impact incidents and did not seek emergency room treatment (because injuries were prevented or were minor). While these cases were beyond the scope of this study, the inclusion of such cases probably would have increased the potential for accurately estimating the benefits of helmet use. It is also possible that if sufficient data had been available to discriminate adequately between levels of head injury severity, benefits could have been estimated.

Nevertheless, other research has shown that helmets substantially reduce the risk of head injuries to bicyclists (16). This is also consistent with the opinion expressed by about two-thirds of those injured while wearing helmets, which was that the helmet either prevented a head injury or made the head injury less severe.

From all available information, it is clear that helmet use should be encouraged.

Modifications to the Mandatory Bicycle Standard

The mandatory safety standard for bicycles includes requirements for mechanical and performance aspects of bicycles, as well as requirements for instructions on bicycle assembly, operation, and maintenance.

For about 13 percent of the estimated injuries, the victim attributed the injury to a mechanical or performance failure of the bicycle. Reported problems included chains breaking or falling off, brakes failing, and various components such as handlebars or brakes coming loose.

CPSC's Directorate for Engineering Sciences evaluated these cases and determined that while the causes of these reported failures could not be absolutely determined from the investigations, poor bicycle maintenance and bicycle modification were likely contributors to a number of incidents. In addition, it appeared possible that environmental factors or unfamiliarity with the bicycle (e.g., brakes) could have contributed to the perception that a failure occurred. Based on information from this study, modifications to the standard were not recommended. However, it would be appropriate to emphasize the importance of periodic bicycle maintenance in future information and education activities.

Night Riding

Riding during non-daylight conditions (i.e., dawn, dusk, and night) was a significant factor in the risk of injury for children. Non-daylight incidents were more common on major thoroughfares than in other locations. NHTSA data on pedalcyclist deaths involving motor vehicles suggest that night riding also may be a contributing factor in fatal incidents (14).

While it seems intuitively apparent that riding during dawn, dusk, or night would be riskier than at other times, it is possible that some people perceive reflectors as adequate protection at times when they may not be sufficient. It was reported that most bicycles were equipped with reflectors. However, it was beyond the scope of this study to determine the adequacy of the mandatory standard's reflector requirements.

While specific conclusions could not be drawn about the use of bicycle lights during non-daylight incidents, less than eight percent of all bicycles involved in injuries were reported to have been equipped with lights (regardless of daylight conditions). Of those with lights, a few were involved in incidents that occurred at dawn or dusk while the light was not being used.

Night riding may be an area deserving future information and education efforts (e.g. the need for bicycle lights, reflective clothing, etc.).

Other

As might be expected, there was a higher risk of injury on streets and major thoroughfares than in such areas as bike paths. Adults were at particular risk on major thoroughfares. National data on bicycle-related deaths indicated that the great majority of fatal incidents involved motor vehicles, and that adults were most often involved. From a safety standpoint, it is reasonable to encourage bicycle use in low-risk locations appropriate for the age of the rider.

Conclusions

These findings suggested the need for wider use of safety helmets, particularly by children. In addition, riding in non-daylight conditions significantly increased the risk of injury for children. Night riding may be an area for future information and education efforts. While some mechanical problems associated with bicycle assembly, operation, and maintenance were observed, no modifications to the existing mandatory safety standard for bicycles are recommended based on this study.

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Appendix: Tables

Table A1

Bicycle Injuries: Age of Victim
by Mode of Involvement

Age of Victim	Mode of Involvement				
	Total	Operators	Passengers	Bystanders	Other
Total	587,970 (100%)	531,450 (100%)	22,240 (100%)	16,830 (100%)	17,450 (100%)
0-4	8%	3%	55%	66%	25%
5-9	32%	34%	19%	13%	17%
10-14	33%	35%	23%	18%	19%
15-24	11%	11%	2%	-	24%
25-64	15%	17%	-	3%	15%
≥ 65	1%	1%	-	-	-

Source: National Electronic Injury Surveillance System (NEISS); Special Study, January-December 1991 U.S. Consumer Product Safety Commission

Table A2

Bicycle Injuries: Hazard Pattern by Age of Victim

Hazard Pattern	Total	< 10	10-14	15-24	≥25
Total	100%*	37%	35%	11%	18%
Uneven Surface	100%	38%	42%	7%	14%
Going Too Fast	100%	47%	26%	10%	16%
Slippery Surface	100%	35%	46%	8%	11%
Collis./Mov. Object	100%	18%	44%	12%	27%
Mechanical Failure	100%	19%	35%	27%	19%
Collis./Non-Mov. Obj.	100%	42%	39%	14%	6%
Performing Stunts	100%	49%	39%	11%	2%
Obj. Caught in Spokes	100%	29%	43%	10%	19%
Other	100%	42%	29%	9%	20%

(Age Group: < 10, 10-14, 15-24, ≥25)

* Row detail may not add to total due to rounding.

Source: National Electronic Injury Surveillance System (NEISS): Special Study, January-December, 1991
U.S. Consumer Product Safety Commission

Table A3

Bicycle Injuries: Hazard Pattern by Location of Incident

Hazard Pattern	Total	Neighbr. Street	Sidwk/. Plgrnd.	Major Thor.	Unpav. Road	Trail	Bike Path	Other
		Location						
Total	100%*	41%	12%	7%	5%	5%	< 1%	28%
Uneven Surface	100%	37%	7%	6%	8%	14%	< 1%	27%
Going Too Fast	100%	30%	17%	3%	7%	3%	< 1%	40%
Slippery Surface	100%	34%	4%	--	13%	10%	1%	38%
Collis./Moving Obj.	100%	54%	8%	24%	3%	--	1%	9%
Mechanical Failure	100%	50%	22%	6%	--	--	1%	21%
Collis./Non-Mov. Obj.	100%	25%	30%	6%	--	9%	2%	29%
Performing Stunts	100%	17%	14%	2%	13%	14%	--	40%
Caught in Spokes	100%	71%	4%	10%	--	--	--	15%
Other	100%	41%	17%	4%	3%	5%	1%	29%

* Row detail may not add to total due rounding.

Source: National Electronic Injury Surveillance System (NEISS): Special Study, January-December 1991
U.S. Consumer Product Safety Commission

Table A4

Definitions of Independent Variables in Risk Models

Age	=	Bicyclist's age
Age < 10	=	1 if bicyclist was under age 10; 0 otherwise
Age 10-14	=	1 if bicyclist was age 10-14; 0 otherwise
Age 15-24	=	1 if bicyclist was age 15-24; 0 otherwise
Age 25-44	=	1 if bicyclist was age 25-44; 0 otherwise
Gender	=	1 if male; 0 if female
Ln(hrs/mnth)	=	Natural log of hours ridden per month
Sidewalk	=	1 if bicyclist was injured on a sidewalk (injury sample), or if bicyclist rode over 50 percent of the time on sidewalks (exposure sample); 0 otherwise
Bike path	=	1 if bicyclist was injured on a bike path (injury sample), or if bicyclist rode over 50 percent of the time on bike paths (exposure sample); 0 otherwise
Highway	=	1 if bicyclist was injured on a major thoroughfare (injury sample), or if bicyclist rode over 50 percent of the time on major thoroughfares (exposure sample); 0 otherwise
Unpaved	=	1 if bicyclist was injured on an unpaved surface (injury sample), or if bicyclist rode over 50 percent of the time on unpaved surfaces (exposure sample); 0 otherwise
Suburb	=	1 if bicyclist lived in a suburb; 0 otherwise
Small town	=	1 if bicyclist lived in a small town; 0 otherwise
Rural	=	1 if bicyclist lived in a rural area; 0 otherwise
Daylight	=	1 if bicyclist was injured in daylight (injury sample), or if bicyclist rode over 50 percent of the time in daylight (exposure sample); 0 otherwise

Source: Bicycle Special Study, January-December 1991
U.S. Consumer Product Safety Commission

Table A5

Bicycle Injuries: Risk Factors, All Victims
(Results of Regression Analysis)

Variable	Coeff.	Std. Error	Stdzd. Coeff.
Intercept	-1.9912	0.4118	.
Age < 10	1.8375*	0.3559	0.3977
Age 10-14	1.9218*	0.3448	0.4248
Age 15-24	0.3780	0.3800	0.0790
Age 25-44	0.0667	0.3589	0.0171
Gender	0.1576	0.1587	0.0431
Ln(hrs/mnth)	0.2463*	0.0645	0.1743
Sidewalk	-0.3283	0.2203	-0.0599
Bike path	-2.1715*	0.4764	-0.3936
Highway	0.6616*	0.2889	0.0884
Unpaved	-1.3914*	0.2626	-0.2998
Suburb	-0.2510	0.2131	-0.0594
Small town	-0.6279*	0.2028	-0.1650
Rural	-0.7786*	0.2679	-0.1650
Daylight	-0.6304*	0.2136	-0.1216
N (injury)	259		
N (no injury)	1129		
* Significant at p < .05			

Source: National Electronic Injury Surveillance System (NEISS): Special Study, January-December 1991; National Survey of Bicycle and Helmet Use Patterns in the United States, 1991
U.S. Consumer Product Safety Commission

Table A6

Bicycle Injuries: Risk Factors Associated with Children and Adults
(Results of Regression Analysis)

Variable	MODEL I. CHILDREN Coeff.	Std. Error	Stdzd. Coeff.	MODEL II. ADULTS Coeff.	Std. Error	Stdzd. Coeff.
Intercept	0.7024	0.5604	.	-2.2771	0.5698	.
Age	0.0085	0.0330	0.0149	-0.0139	0.0101	-0.1072
Gender	0.2462	0.2011	0.0665	0.1768	0.2625	0.0486
Ln(hrs/mnth)	0.1146	0.0799	0.0775	0.4851*	0.1098	0.3222
Sidewalk	-0.5036*	0.2549	-0.1169	0.4278	0.4322	0.0551
Bike path	-2.0823*	0.6423	-0.2581	-1.9352*	0.6121	-0.3997
Highway	--	--	--	0.8959*	0.3245	0.1403
Unpaved	-1.2361*	0.2941	-0.2803	-2.1790*	0.7425	-0.4513
Suburb	-0.0201	0.2814	-0.0047	-0.5582	0.3336	-0.1340
Small town	-0.5820*	0.2639	-0.1549	-0.7328*	0.3196	-0.1908
Rural	-0.7522*	0.3362	-0.1650	-0.8958	0.4646	-0.1850
Daylight	-1.2917*	0.3155	-0.2131	-0.1547	0.3158	-0.0324
N (injury)	186			N (injury) 77		
N (no injury)	358			N (no injury) 771		

* Significant at p < .05

Source: National Electronic Injury Surveillance System (NEISS): Special Study, January-December 1991; National Survey of Bicycle and Helmet Use Patterns in the United States, 1991
U.S. Consumer Product Safety Commission

Part IV.
Human Factors Assessment of Bicycle Incidents and Training

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The Division of Human Factors reviewed bicycle injury data from the Division of Hazard Analysis and exposure survey data from the Directorate for Economic Analysis. Human Factors also evaluated literature on bicycle safety education and training. The literature focused on incident data and implications for training, with emphasis on the capabilities of children.

This paper focuses on incidents involving children under 15 years of age. The physical and cognitive development of children in this age group is discussed. Training recommendations are considered and issues related to helmet usage for all ages are addressed.

Physical and Cognitive Development of Children

The Consumer Product Safety Commission (CPSC) estimates that each year there are approximately a half million bicycle-related, emergency room-treated injuries, based on the CPSC's National Electronic Injury Surveillance System (NEISS). A 1991 special Hazard Analysis survey of bicycle incidents indicates that approximately 71 percent of the incidents involved children under 15 years of age, with almost two-thirds (62 percent) of them boys (Tinsworth et al., 1993). The physical and cognitive development of children may help to explain why these incidents are occurring.

Children between 5 and 14 years of age experience many physical and cognitive changes. It is during this age period that children are fond of testing their skills, such as riding their bikes without holding the handlebars (Schickedanz et al., 1982). They try to see just how far they can push their bodies physically, and may get their answers through injuries. Boys are more daring and reckless; girls are more cautious (Gesell et al., 1977). This may explain why 80 percent of the injuries reportedly resulting from stunts involved males.

Also, children tend to display egocentric behavior (i.e., inability to perceive other people's positions or viewpoints). Child development experts indicate that it is not until around the age of 10 years that a child is able to consider his or her point of view and another person's point of view simultaneously (Schickedanz et al., 1982). Before this time, children assume that everyone sees the world as they do and, therefore, everyone knows what they are thinking and planning. For example, children do not consider their behavior unexpected when they suddenly turn in front of a car or dart out of a driveway, because that appears to them as the only way to go.

Children generally learn to ride on flat, straight surfaces, so when they start to ride on a variety of surfaces, they need to readjust how they ride their bikes. Riding on uneven surfaces, which was reportedly involved in 27 percent of all incidents, requires children to concentrate on several factors at the same time. Children need to know where they are going, what is directly in front of them that could interfere with the motion of the bike, how to avoid obstacles, how to avoid hitting other riders when riding with a group, and how to maintain their balance. Maintaining balance while riding on uneven surfaces requires more control and, in some cases, more physical strength than riding on a straight, flat surface.

Riders need to be constantly on the alert to avoid hazardous situations and need to be physically able to avoid them. For example, children need to be able to pull up on the handlebars to avoid ruts and roots on the surface if there is no other way to go around them. Children also need to be aware of the likelihood that the tires may suddenly slide or turn because of loose gravel or other hazards on the path. According to the incident data, slippery riding surfaces, such as loose stones, gravel, sand, dirt, mud, grass, leaves, puddles, oil, ice or snow were reported to have contributed to about 15 percent of the incidents.

Another factor frequently associated with child-rider injuries is speed. Riding too fast was reported in 22 percent of the incidents. Children reportedly go too fast and lose control. Typically, they simply think about how fast they can go. They do not think about the riding surface, or the possibilities of something getting in the way, or even the chances of losing control because of the high speed. Just as with uneven surfaces, riding fast requires children to mentally process a lot of information at one time and then consider the alternatives. Unfortunately, this cognitive ability is not something that can be taught to children at an early age, but rather is a process learned over time as children reach higher maturational levels. Since young children do not have the ability to mentally process all factors associated with a behavior, they cannot adequately assess the consequences.

This cognitive immaturity may also explain why the number of bicycle injuries for this age group has typically stayed the same over the years. Simple basic training on bicycle skills may be necessary. However, training dealing with cognitive skills that are beyond young children's mental capacity is not effective.

Training

Education programs should not simply tell cyclists what to do, but should teach why. Bicyclists need to understand their role in safe bike riding and the consequences for failing to follow safe practices. Frequently incidents occur because cyclists only consider the risk factor for themselves and fail to consider others. Education programs should address the issue of risk to other cyclists and motorists when cyclists choose to disobey traffic rules.

Several research studies report that urban bicycle and motor-vehicle incidents occur most frequently at an intersection (Cross, 1978; Mathieson, 1986; Dewar, 1978). Typically, bicyclists fail to obey traffic regulations by disregarding signals or signs, failing to yield the right-of-way, and entering intersections from the wrong side of the street. This failure to obey the regulations was seldom the result of the bicyclist's misunderstanding of the law - even for the younger-aged cyclists. Rather, it was the cyclist's misjudgment of the risk associated with the action (Cross, 1978). Some studies have indicated that a majority of serious, non-fatal bicycle injuries are caused by cyclist error. When child cyclists are involved, they are legally at fault close to 90 percent of the time (Mathieson, 1986; Dewar, 1978).

The City of Santa Barbara in California conducted a study to determine if a minimum age for bicyclists should be required (City of Santa Barbara, 1975). In the study, the researchers examined and compared stages of cognitive development of children with bicycle and traffic safety requirements. The results show that children are unable to perform like adults because they lack not only the knowledge and learning, but also the cognitive capacity to perform functions as adults perform them (City of Santa Barbara, 1975). Too much information is bidding for the children's attention, and they do not have the ability to filter it all, much less filter it correctly. The study recommended that children between 7 and 13 years of age only be allowed to ride bicycles on the street when accompanied by an adult. By 13 years, most children have reached a maturity level that allows them to understand and comply with traffic rules. While the recommendation seems reasonable developmentally, it is unrealistic. Children between 7 and 13 years often ride their bikes to school and on neighborhood streets. Requiring adult supervision would essentially ban bike riding for this age group. Since this is not practical, other means of protecting children are necessary.

Child development experts also agree that certain concepts cannot be learned before a certain maturational level, regardless of the amount of training. Therefore, determining the time appropriate to begin bicycle education is essential. Generally, research findings suggest that the optimal time for intensive bicycle-safety education campaigns is between the third and sixth grades (9 to 12 years old) (Cross, 1978; City of Santa Barbara, 1975). This is not to say that younger children should not have any type of training, but that a comprehensive program would be most effective beginning in the third or fourth grades with refresher courses for older children and adults. Most children by the sixth grade have the ability to understand and perform the taught behaviors.

Another area of consideration is the use of protective equipment. In addition to teaching simple basic bicycle skills and rules, teaching children and adults to wear protective equipment such as bike helmets may help reduce the severity of their injuries.

Bicycle Helmets

While more and more information is becoming available to the public about the benefits of bicycle helmets for all riders, the percentage of bicycle riders who use helmets all or most of the time is still relatively low (Rodgers, 1992).

About 12 percent of all victims injured on bicycles were wearing helmets, and only about two percent of those in the 10-14 age group were doing so (Tinsworth, 1992). Part of this may be attributed to peer pressure and parental influence. While peer influence and parental influence are not mutually exclusive, peer influence tends to have more value in such matters as tastes in music and entertainment, and fashions in clothing. Parental influence has more weight in moral and social values and understanding the adult world (Conger, 1973). Therefore, the use of a bicycle helmet by children in this age group may be influenced more by their friends than their parents, but reinforced when parents have the same attitude.

In two separate studies, children in grades 4 through 6 completed self-administered questionnaires regarding their beliefs about helmet use. According to one study, the students least motivated to wear helmets believe the social group to which they belong disapproves of using a helmet (Otis et al., 1992). In a study conducted by the Eau Claire, Wisconsin Police Department (1992), 33 percent of the respondents said they would wear a helmet if their friends did and 46 percent said they might wear one if their friends did, compared to the 17 percent who said they would not wear one even if their friends did.

Other reasons students stated for not wearing helmets had to do with parental opinion and misconception of the benefits of a helmet. Of the students who do not own a helmet, 18 percent stated their parents did not think helmets were necessary (Eau Claire, 1992). Of all the students, 27 percent (14 percent of helmet owners; 30 percent of non-helmet owners) said they do not need a bicycle helmet for the kind of bicycle riding they do. Specifically, helmets are viewed as not necessary when children are only riding occasionally, or near their house (Eau Claire, 1992).

Both the CPSC exposure survey and the special study asked respondents of all ages the circumstances in which they wear and do not wear helmets. The most frequently stated reasons for not wearing helmets were: riding only a short distance and not riding in traffic. Coincidentally, riding a long distance and riding in traffic were the positive reasons stated for wearing helmets by individuals who do wear them.

Based on these answers it appears that consumers are aware of the benefits of wearing helmets when riding in traffic, but appear to be less likely to wear them when they believe they are in less dangerous situations. This appears to be the same conclusion bicyclists give for disobeying traffic rules.

Conclusions

Nearly three-quarters of bicycle-related injuries treated in hospital emergency rooms involve children under 15 years of age. Almost twice as many boys as girls are treated. The reasons for these incidents vary, but the main contributing factor may be children's cognitive immaturity. Children under 15 years of age go through stages of cognitive development which cannot be taught, but are learned over time. A major implication is that children are unable to fully process in their minds situations and consequences, thus, they have accidents. While training in basic bicycle riding skills and laws is important, trying to teach children concepts that are cognitively too advanced is ineffective. Because children cannot be taught certain skills that could help them avoid accidents, using protective equipment to help reduce the severity of injury is an alternative.

Studies show that consumers recognize the benefits of wearing bicycle helmets when riding in traffic and on long trips. However, they assess the risk level as low when they ride only occasionally or for just short trips in their neighborhood. They are less likely to wear a helmet in these situations. Peer influence also appears to be a factor in determining if a child wears a helmet. Education programs and media campaigns should demonstrate that head injuries occur on neighborhood streets and on short trips just as they do on long trips. Education programs should not simply tell cyclists what to do, but should teach why. The bicyclist needs to understand his/her role in safe bike riding and the consequences for failing to follow safe practices.

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Part V.
Role of Mechanical Design and Performance in Selected Bicycling Incidents

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Introduction

The Directorate for Epidemiology performed a special study of bicycling incidents reported in calendar year 1991, through the National Electronic Injury Surveillance System (NEISS). Using systematic random selection from nearly 14,000 reported bicycle-related injuries, 463 investigations were completed, of which 420 involved injuries to the operator. Epidemiology identified alleged mechanical failure as a possible contributing factor in approximately one in ten (41/420) of the operator-injury cases. The Directorate for Engineering Sciences analyzed these 41 incidents to confirm the alleged mechanical problem and to identify any significant patterns of bicycle mechanical failure that could be addressed by some means to reduce the frequency of accidents caused by mechanical failure.

The following discussion examines these bicycling incidents, grouped by the particular component that reportedly failed and induced or contributed to the incident in some manner. The forty-one incidents were divided into the following component groups: chains (13 cases), brakes (15 cases), handlebars (6 cases), gear cables (1 case), seats (1 case), tires (2 cases), spokes (1 case), handgrips (1 case), and pedals (1 case). A definitive cause for component failure in these cases could not be established from the data. However, for each component group the report discusses factors that may have contributed to the component failure. These factors include bicycle maintenance and bicycle modification. External conditions are also discussed as possible contributors in reported component malfunctions. In addition, the analysis will present other identified factors which may have contributed to incidents in a manner typically unrelated to the alleged component failure. These factors include operator behavior and bicycle unfamiliarity. Table 1 gives an overview of the components involved and any contributing factors associated with each incident.

Bicycle Component Groups and Injuries

Chains

Thirteen of the forty-one incidents involved bicycle chains. Six of the thirteen cases reported the chain fell off the sprocket while the victim was riding. Two of the thirteen cases reported chain breaks. The rider in these incidents typically lost control of the bicycle when the chain released, causing the victim to fall. In three cases in which the chain either fell off or broke, the victim was thrown from the bike when the released chain jammed the rear wheel.

Three of the thirteen chain incidents involved the rider attempting to make hand adjustments to a loose or misadjusted bicycle chain while they were riding the bike. These incidents resulted in serious finger injuries when fingers became pinched between the drive sprocket and chain.

In two of the thirteen chain incidents, the victims reported losing control of the bikes after experiencing performance-related problems. In one incident, the chain reportedly jerked while shifting gears. In the second incident, the victim reported that the chain was skipping.

Contributing Factors. Maintenance was identified as a significant contributor in three of the six chain incidents in which the chain fell off the sprocket. For example, in one of these incidents, a sixteen-year-old boy lost control of the bike when the chain popped off. The investigation stated that the sprocket was loose and the condition of the bicycle was poor.

Maintenance was also a likely contributor to the incident in which the victim lost control and fell because the chain was "skipping". The bicycle in this case was described as very old and in poor condition.

Operator behavior was a contributor to the injuries in the three incidents in which the rider's fingers were pinched between the sprocket and chain. It is ill-advised for a rider to make hand adjustments to a bicycle chain while riding the bike.

In one of the three finger pinching cases, a bicycle modification was a possible contributor to the injury, although it had no active role in the initial chain malfunction. The chain guard had been removed from the bike, which may have facilitated finger access to the chain/sprocket area, leading to the pinching injury.

A bicycle chain modification may have been a direct contributor in one incident in which the victim purposely shortened his chain. This modification may have induced a chain to slip off the gears and into the rear wheel, stopping the bike suddenly and throwing the rider.

Other modifications were identified as a possible contributor in two additional chain-related incidents. In the first case, the handbrakes had been removed from a bicycle. Handbrakes may have prevented this accident in which the rider lost control of her bike and drove into a roadside ditch when the chain came off the sprocket. In the second case, the chain fell off the sprocket of a bike in which the chain guard had been removed. If a chain guard had been present, it may have prevented the released chain from becoming caught in the rear wheel, causing the bike to suddenly stop and throw the rider.

Five of the thirteen chain investigations reported chain malfunctions without identifying the cause or other factors contributing to the incident.

Brakes

A total of fifteen incidents involved alleged brake problems. Twelve of these fifteen reported that the brakes failed to adequately stop the bike. Nine of these twelve alleged brake failures were reported to involve bicycles equipped with handbrakes. Two of twelve incidents involved coaster brakes and one incident did not report whether it was a hand or coaster type brake.

Loose brake components were reported in the three remaining brake cases. In these three cases, front brake components (e.g. brake pad, caliper) came loose and jammed the front wheel, causing the bikes to stop suddenly. The victims of these incidents were subsequently thrown over the handlebars.

Contributing Factors. Inadequate maintenance was a possible contributor to one of the coaster brake and one of the handbrake incidents. Further, poor maintenance was likely a significant contributor to two other handbrake cases and one other coaster brake case. Examples include two cases in which the victims had previous knowledge that the brakes were not working properly. In one case the victim claimed that the handbrakes "went out", leading him to ride into a cement post. The victim stated that he was having problems with his brakes prior to the accident. In the second case, the victim fell off the bike after she realized she had no brakes and she was about to collide with a stopped car. The victim stated that her brakes had broken the previous day.

Rider behavior may have been a factor in one of the handbrake cases and two of the coaster brake cases. An example of this is a case in which the victim had been drinking at the time of the accident and described the cause of the accident as a combination of alcohol, inexperience, and poor brakes.

A possible reason for reports of brake failure in several cases was the rider's unfamiliarity with the bicycle and braking system. In three of the nine handbrake cases, it was reported that the rider was not familiar with the bike or the bike's features and that this could have contributed to the accident. For example, in one incident a forty-two-year-old woman claimed that the handbrakes stuck and failed to bring the bike to a complete stop. However, the investigation further reported that the victim was riding a borrowed bike and was not used to handbrakes.

It is also possible that a slick riding surface contributed to two coaster brake incidents and one handbrake incident. An example of this is a coaster brake incident that involved an eight-year-old boy who was riding downhill on a wet, slippery surface. The boy could not stop the bike, causing him to run into a piece of playground equipment. Although he claimed that he was not able to stop the bike because the "chain guard or something" got stuck in the brakes, the wet, slippery surface may have been a contributing factor.

Six of the fifteen brake related cases did not identify a cause for mechanical failure or other factors contributing to the incident. This included all three of the incidents involving front brake components coming loose and jamming the front wheel.

Handlebars

There were six cases in which loose handlebars were reported to be the cause of accidents. Typically, riders were injured by falling from the bike after handlebars slipped within the gooseneck clamp or at the gooseneck/fork tube connection. This occurred either while riding or while attempting to mount the bicycle.

<u>Contributing Factors</u>. Poor maintenance was a possible contributing factor in four of the six handlebar incidents. Two of the four incidents were attributed to loose bolts that fasten the handlebars to the bike. In one of the four incidents, maintenance was viewed as a secondary contributor. This case involved a worn handgrip that exposed sharp edges of the metal handlebar. The victim was injured after the handlebars slipped and he lost control of the bike. The exposed metal edge from the handlebar lacerated his leg.

Modification may have played a role in one of the handlebar incidents in which the bike was constructed from various parts of a number of bikes. Combining parts of many bikes could have led to an improper fit between the bicycle frame and handlebars.

Significant impact loading appears to have contributed to one handlebar incident. In this case a twenty-year-old male was jumping over railroad ties. This subjected the bicycle to abuse which may have led to the handlebars slipping within their "brace" and causing the rider to lose control.

Gear Cable

In another loose component case, a gear cable and retention clip came loose and tangled with a bicycle pedal. This stopped the bike suddenly, causing the victim to be thrown over the handlebars. No other contributing factors were identified in this case.

Seat

One incident involved a five-year-old boy who was injured when he lost control of the bike when the seat moved. Maintenance was likely a significant factor in this case since the seat was described as loose prior to the incident and the bike was described as very old and in poor condition.

Tires

Two incidents involved bicycle tires. In one case, it was reported that a rear tire, low on air, may have been a contributing factor in an incident in which the rider fell off the bike while turning. The second incident involved a rider who was thrown from the bike when it stopped suddenly. The bike stopped when an inner tube caught on the front spokes after a tire blow out. The tire was described to be in such poor condition that threads were visible on the tire sides. Maintenance was viewed as a contributor in both of these incidents.

Operator behavior may have contributed to the above incident in which the rear tire was low on air. The investigation reported that the victim was not feeling well which may have affected her balance when she made a sharp turn and lost control.

Spokes

One incident reported that a front wheel spoke broke and wound around the fork. This caused the victim to be thrown when the bike stopped suddenly. No other contributing factors were apparent in this incident.

Handgrips

This incident involved another worn handgrip that allowed sharp metal edges on the handlebars to be exposed. Operator behavior and bicycle maintenance were determined to be factors in this incident in which the rider had stopped the bike and leaned down to pick up something off the ground while he was straddling the bike. The victim lost control and fell. The exposed metal edges on the handlebar landed on and fractured his finger.

Pedals

One incident that did not involve an active component failure was one in which a rider fell after her foot slipped off a pedal. Wet conditions appear to have been a possible contributor to the foot slippage. Also, maintenance may have played a secondary role since the victim stated that the gear shifter was "wearing out". This demanded more concentration to shift gears which the victim claims contributed to her foot slipping.

Borrowed Bikes

Unfamiliarity with a bicycle may not be limited to alleged brake failures as discussed earlier. It was observed that eleven of the forty-one incidents involved riders who were using borrowed bikes but did not report unfamiliarity with the bike as a contributing factor. A person using a borrowed bike may be less aware of or less likely to inspect for mechanical problems prior to riding the bike. In addition, a person riding a borrowed bike is much more likely to be unfamiliar with its controls and features. These factors could contribute to bicycling accidents.

Conclusions

A special study of bicycling accidents reported in calendar year 1991 through the NEISS system identified a total of 41 bicycling accidents in which a mechanical problem with the bicycle may have contributed to the incident. The most frequently reported problems were bicycle chains breaking or falling off, brakes failing, and various components such as handlebars and brake components coming loose.

While the cause of these alleged mechanical failures could not be absolutely determined from the investigations, this analysis found that poor bicycle maintenance and/or bicycle modification were contributors in a minimum of nine cases and possible contributors in an additional eleven cases. External conditions, such as a slick road surface, were possible contributors in four incidents. In addition, factors such as operator behavior and unfamiliarity with a bicycle were possible contributors in twelve incidents, although typically not directly related to component malfunctions.

Fifteen of the forty-one mechanically-related cases reported component malfunctions without identifying the cause of the malfunction or any other factors contributing to the incident. Investigative information was insufficient to determine if these incidents resulted from inherent mechanical failure, that is, not attributable to poor maintenance, ill-advised modifications, or other factors.

The results of this analysis do not show any significant mechanical failure patterns that warrant an amendment to the existing mandatory bicycle standard. However, it is certainly desirable to include some of the findings of this report in any future information and education efforts relating to bicycle safety. Both adults and children should be made aware of: the importance of maintaining a bike in good condition, the possible risks of modifying a bicycle, and the possible risks presented by external conditions such as a wet, slippery riding surface.

The results of this analysis also suggest that operator behavior and unfamiliarity with a bicycle may be contributors to many bicycle incidents. It would be beneficial to further explore these factors as they relate to all bicycling incidents, since they do not apply solely to those that report a mechanical malfunction.

Part VI.
Bicyclist Deaths and Fatality Risk Patterns

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May 1993

In addition to nonfatal bicycle-related injuries evaluated in the CPSC injury survey, there are large numbers of deaths involving bicyclists every year. Data from the National Safety Council (1992) indicate that there have been an average of about 1,000 bicycle-related deaths annually since 1975. The purpose of this report is to provide some information on bicycle-related fatalities and on fatality risk patterns.

Data and Methods

The CPSC does not gather information on all bicycle-related deaths.[1] However, data are available from the National Highway Traffic Safety Administration's (NHTSA) Fatal Accident Reporting System (FARS). Although the FARS data are limited to bicyclist deaths resulting from crashes with motor vehicles on public roadways, FARS captures the great majority of bicycle deaths. Based on information provided in Sachs et al. (1991) and NHTSA (1993), the FARS system probably captures about 90 percent of all bicycle deaths.[2]

According to FARS (NHTSA, 1993), there were 841 bicycle-related deaths involving crashes with motor vehicles in 1991. Table 1 presents the death data, by age and gender of the victim. Just over one-third of the deaths (36.9 percent) involve children age 15 and under; 21.3 percent of the victims are over age 44, and 6.6 percent of the victims are age 65 and older. In addition, almost 86 percent of victims are male.[3]

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[1] The CPSC's main source of information on deaths is from death certificates, which are purchased by E-code from the states. However, only a subset of the E-codes pertaining to bicyclist deaths is collected.

[2] The National Center for Health Statistics (NCHS) also provides information on bicycle-related deaths, including non-traffic deaths. However, the most recently available NCHS data are from 1989. Based on the 1989 data about 10 percent of the bicycle-related deaths did not involve collisions with motor vehicles (NCHS, 1992).

[3] The age and gender distribution of the 1989 NCHS data on bicycle-related deaths were quite similar to those of the FARS data. However, the victims of non-traffic related deaths (about 10 percent of the total) appeared to be somewhat older than the victims of traffic-

The FARS data do not provide sufficient information for a detailed risk analysis of bicycle deaths. However, it is possible to estimate relative risk factors for the various gender and age categories. Table 2 shows the results of applying Bayes' Rule to the distribution of the 1991 FARS deaths and estimates of riding exposure from the 1991 CPSC exposure survey.[4]

Results

Column 1 of Table 2 shows the percentage distribution of the deaths, by gender and age. For example, 85.6 percent of the victims were males and 14.2 percent were under age 10. Column 2 shows the percentage distribution of riding exposure by gender and age; it is calculated by determining the aggregate annual riding times for riders in each category, and dividing this figure by the estimated aggregate riding time for all riders. For example, males accounted for about 55.0 percent of all bicycle riding, and riders under age 10 accounted for about 27.1 percent of riding time.

The risk for each of the age and gender categories, relative to the average risk for all bicyclists, can then be calculated by dividing the percentage of deaths by the percentage of riding exposure. Consider an example. As shown in the table, 85.6 percent of the fatal accidents involved males, but males accounted for only 55.0 percent of aggregate riding times. The risk of having a fatal accident, given that a rider is male, can therefore be estimated to be about 1.56 (0.856/0.550) times the average risk. (This figure may be referred to as an index of risk for males, because it describes their risk relative to the average risk.) Using the same approach, the risk of a fatal accident for female bicyclists is about 0.32 (0.144/0.450) times the average risk.

This method also yields comparative risk factors for the various age and gender categories, relative to one another. Dividing the risk index for males by the risk index for females, for example, indicates that males are about 4.88 (1.56/0.32) times as likely to be involved in fatal accidents as females. That is, the "relative risk" for males is about five times that of females.

The results from Table 2 also reveal some interesting findings with respect to the relationship between age and the fatality risk. Although just over one-third of the deaths involve children age 15 and under, this group of riders has a lower than average fatality risk

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related deaths. For example, while 43.4 percent of the traffic-related deaths involved children age 15 and under, only 18.1 percent of the non-traffic deaths did. Similarly, while 14.2 percent of the traffic-related deaths involved riders over age 44, 37.4 percent of the non-traffic related deaths did.

[4] For further discussion of the application of Bayes' Rule, see Newman (1987) or Rodgers (1989).

because they account for a large proportion of total riding times. In contrast, the exposure-adjusted fatality risk for the 16-to-24 year-old age group is higher than average. When these two groups are compared, the risk for 16-to-24 year-old riders is about 2.06 (1.38/0.67) times higher than the risk for riders age 15 and under. Moreover, risk appears to be even higher for older adult bicyclists, particularly those age 65 and older. When adjusted for riding exposure, riders age 65 and older are about 3.19 (4.40/1.38) times more likely to be involved in fatal accidents than 16-to-24 year-old riders, and about 6.57 (4.40/0.67) times more likely to be involved in fatal accidents than riders age 15 and under.[5]

Additional Descriptive Information

NHTSA (1992, 1993) also provides some additional description of the bicycle-related fatalities. In about 65 percent of the cases in 1991, police reported one or more errors in bicyclists' behavior. The factor most often noted was "failure to yield right-of-way" (21.8 percent), followed by "improper crossing of the roadway or intersection" (12.6 percent), and "failure to obey traffic signs and traffic control devices" (8.6 percent). In addition, one-fourth of the cyclists killed had blood alcohol concentration (BAC) levels of 0.01 grams per deciliter (g/dl) or greater, and one-sixth were intoxicated (i.e., BAC levels of 0.10 g/dl or greater).

Less than half of motor vehicle drivers involved in bicycle deaths were cited by police for driving errors or other factors related to driver behavior. The factors most often noted were "driving too fast for conditions or exceeding the speed limit" (21 percent), "drivers were inattentive" (16 percent), and "vision obscured" (14 percent).

Almost three-quarters (73.0 percent) of the bicycle-related deaths occurred at non-intersection locations of roadways. Only 26.9 percent occurred at intersections. In addition, 23.5 percent of the deaths occurred between the hours of 9:00 PM and 5:59 AM. Although daylight conditions vary somewhat during the year and by geographical location, most of these probably occurred after dark.[6] In comparison, 12.4 percent of riders from the exposure survey reported that they ride at least occasionally after dark.[7] Since most of these nighttime riders (i.e., those from the exposure survey) ride only a small proportion of the time after dark, nighttime riding appears to be an important contributing factor to bicycle deaths.

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[5] This analysis was also conducted using the NCHS data for 1989. The results were essentially the same, and led to the same conclusions in all cases.

[6] Another 22.8 percent of the deaths occurred between 6:00 and 8:59 PM, some of which probably occurred after dark.

[7] About 3.1 percent reported that they ride more than half of the time after dark and 9.3 percent said they ride less than half of the time after dark (Rodgers, 1992).

Summary and Discussion

The findings of this report suggest that age and gender are risk factors in bicycle-related fatalities. When adjusted for riding exposure, risk appears to be higher than average for 16-to-24 year-old riders and for riders over age 44. Risk is highest for riders age 65 and older, possibly because of a deterioration in their reaction time, an important characteristic in avoiding accidents involving motor vehicles. Older persons involved in accidents may also tend to suffer adverse outcomes because of medical complications and other factors associated with post-injury homeostasis. Maring and van Schagen (1990), in a study of bicycle accidents in the Netherlands, also found an increased accident risk for bicyclists over the age of 60. They suggested that the higher risk might be related to changing cognitive and perceptual processes that tend to reduce the flexibility of older riders in responding to unforeseen situations.

The exposure adjusted risk for male riders is almost 5 times the risk for females, even when risk is adjusted for riding exposure. This is consistent with automobile and other fatal accident rates (see, e.g., National Safety Council, 1992; Rodgers, 1990), and suggests that males are more likely to take risks than are females.

In addition, nighttime riding appears to be a contributing factor. While only a small proportion of bicycle riding takes place after dark, approximately one-fourth of all fatal accidents occur at night.

Information from police reports that were reported to NHTSA also suggests that many fatal accidents are related to bicyclist roadway errors or other factors related to the riding behavior. One or more bicyclist errors were reported by police in almost two-thirds of the bicyclist deaths in 1991. Failure to yield right of way was reported for one out of every five bicyclists killed. In addition, about one-sixth of the bicyclists were intoxicated at the time of accident.

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Table 1. 1991 Bicyclist Deaths, by Age and Gender

Age	Deaths: Males	Deaths: Females	Deaths: Total	
(years)	cases	cases	cases	(percent)*
< 10	94	24	118	(14.2%)
10-15	153	36	189	(22.7%)
16-24	102	18	120	(14.4%)
25-34	117	15	132	(15.8%)
35-44	82	15	97	(11.6%)
45-54	69	4	73	(8.8%)
55-64	45	4	49	(5.9%)
≥ 65	50	5	55	(6.6%)
Unknown	8	0	8	---
Total	720	121	841	(100.0%)

Source: National Highway Traffic Safety Administration

a The percent column applies to the 833 cases in which the age of the victim is known.

Table 2. Risk Characteristics

Characteristics	(1) Deaths (%)		(2) Exposure (%)		(3) Risk Index (1)/(2)	
Gender	100.0		100.0		1.00	
Male	85.6		55.0		1.56	
Female	14.4		45.0		.32	
Age	100.0		100.0		1.00	
< 10	14.2	} 36.9	27.1	} 54.7	.52	} .67
10-15	22.7		27.6		.82	
16-24	14.4		10.4		1.38	
25-34	15.8		15.5		1.02	
35-44	11.6		12.6		.92	
45-54	8.8		3.9		2.26	
55-64	5.9		1.5		3.93	
≥ 65	6.6		1.5		4.40	

Source: National Highway Traffic Safety Administration and the 1991 CPSC Exposure Survey

Part VII.
Characteristics of Adult Bicyclists in the United States: Selected Results from a National Survey

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April 1993

In 1990, Rodale Press, the publisher of *Bicycling* magazine, sponsored a major survey of adult bicycle owners. The survey gathered comprehensive information about the U.S. adult bicycling population, their use patterns, and the bicycle equipment market. The CPSC purchased this survey data to complement the CPSC bicycle injury and exposure surveys conducted in 1991. Although the Rodale Press survey did not collect information on children, a major focus of the CPSC exposure survey, it provided substantial marketing information unavailable from the CPSC survey.

This paper summarizes the Rodale Press survey methodology and highlights information of particular interest to CPSC[1].

Methodology

Commissioned by Rodale Press, National Family Opinion, Inc. (NFO) conducted the survey using its consumer mail panel. While not a probability sample, the panel is balanced to match U.S. statistics on five demographic variables: geographic region, population density, household income, household size, and age of panel member.

The survey, conducted in 1990, obtained information on the bicycle riding habits and purchasing behavior of adult bicycle owners who purchased their bicycles new. To accomplish this, NFO screened 150,000 panel households for bicycle ownership. Of the 103,774 households responding to the screening questionnaire, 40,381 were selected for further analysis. These households had at least one adult, aged 18 or older, who owned a bicycle for personal use. From this sample of 40,381 households (which included 61,587 adult bicyclists), NFO further screened out those who did not purchase their last bicycle new and those who did not answer three screening questions on rider characteristics: the number of visits to a bicycle shop in the past year; the number of miles ridden in an average warm weather month; and, the

[1] Rodale Press, *The Cycling Consumer of the 90's, A Comprehensive Report on the U.S. Adult Cycling Market*, Emmaus, PA: Author; 1991.

price paid for the last bicycle purchased. Of the 61,587 adult bicyclists mentioned above, 37,863 (61 percent) qualified for the survey.

NFO then applied a clustering technique, based on answers to the three screening questions, to separate bicyclists into groups ranging from those who hardly ever ride to those who could be considered enthusiasts. From this analysis, four distinct groups emerged. These groups were categorized by their level of participation and were described as "enthusiast", "moving-up, "casual", and "infrequent" riders. Enthusiasts and moving-ups are the more avid of the four clusters. As shown in Table 1, these two groups ride more, buy more expensive bicycles, and visit shops more often than casual and infrequent riders (Rodale Press, 1991). (Tables start on page 116.)

From each of the four identified clusters, NFO selected at least 1,000 households to receive an indepth questionnaire. Of 4,209 households selected, 3,248 responded, including 624 enthusiast, 895 moving-up, 875 casual, and 854 infrequent riders. NFO assigned weights to the responses to make them representative of the U.S. population of adult bicycle riders who purchased their last bicycle new. (Rodale Press, 1991).

Overview of Survey Results

The results of the survey are representative (for 1990) of bicycle riders 18 years of age and older, who bought their most recent bicycle new. NFO estimates that there are approximately 32.8 million bicyclists who fit this description. By level of participation, NFO projects that there are 0.9 million enthusiasts representing 2.7 percent of the total; 2.4 million moving-up riders representing 7.3 percent of the total; 6.8 million casual riders representing 20.8 percent of the total; and 22.7 million infrequent riders representing 69.2 percent of the total. Figure A graphically presents the breakdown by cluster of the total population reflected by the survey. (Figures start on page 132.) The discussion and attached tables present information on demographic characteristics of riders and their households, bicycle use patterns, helmet use and safety behavior, bicycles and equipment owned, future purchase plans, and equipment problems.

Rider and Household Demographics

The survey obtained detailed demographic information about the respondents and their households. Respondents provided information on age, gender, marital status, education, employment, and income. These data are shown in Tables 2 through 9.

The mean age of adult riders is 37.1 years and there is little variation between cluster groups. Greater disparity is found in a breakdown of cluster groups by gender. Although about half (49.4 percent) of riders are female, three-fourths of the enthusiasts and two-thirds of the moving-up riders are male.

The survey indicates that adult bicyclists tend to be more educated than the overall population, a finding that is consistent with the results of the CPSC exposure survey. About 40 percent of all adult bicyclists are college graduates, compared with about 23 percent of the population as a whole. Enthusiast and moving-up riders have even higher education levels, with over 50 percent holding college degrees.

The largest proportion of employed riders, 39 percent, work in managerial and professional fields. The second largest category, with 27 percent, includes riders in the technical, sales, and administrative support fields. Personal employment income is higher among the enthusiast and moving-up categories, as would be expected, given their higher education levels. Of those who said they were not employed, retired individuals and homemakers predominate in the infrequent and casual categories, while students and homemakers predominate in the enthusiast and moving-up categories.

Tables 10 through 15 summarize the demographic characteristics of rider households. Some of the information is comparable to information gathered by the 1990 U.S. Census. There are no major regional differences in the location of rider and U.S. households. However, there appears to be a higher concentration of enthusiast and moving-up riders in the Mountain and Pacific regions and a higher concentration of casual and infrequent riders in the North Central and South Atlantic regions. Adult bicyclists also live in larger households than the U.S. population overall. Nearly 80 percent live in houses and 75 percent own or are buying their homes. More than half (56 percent) live in metropolitan areas with populations greater than 500,000.

Use Patterns

A substantial amount of information from the survey provided details on use patterns and riding habits. May through September are the peak riding months. At least 74 percent of bicyclists ride their bicycles during these months. See Figure B. However, the more avid the bicyclist, the higher the year round level of participation. During warm weather months, almost 50 percent of bicyclists ride at least once a week. The median number of miles ridden during a warm weather month is 10. Average monthly mileage in warm weather is 34. By participation level, the average monthly warm weather mileage ranges from 205 for enthusiasts to 24 for the infrequent riders. See Tables 16 and 17.

An overwhelming majority (80 percent) of bicyclists ride on neighborhood streets at least some of the time. They also indicate that they sometimes ride on quiet streets or quiet highways (37 percent), bike paths/rail trails (29 percent), rural roads (26 percent), busy streets or busy highways (21 percent), bike routes (18 percent), off-road trails (9 percent), and other places (11 percent). The higher the level of participation, the greater the number of places ridden. However, the relative ranking of places ridden does not vary much between clusters. See Table 18.

The largest percentage of bicyclists (62 percent) ride most often on neighborhood streets. Other places most often ridden are rural roads (10 percent), bike paths/rail trails (8 percent), quiet streets and quiet highways (7 percent), busy streets or busy highways (3 percent), bike routes (3 percent), off-road trails (1 percent), and other places (2 percent). Among clusters, the enthusiast and moving-up groups spend a relatively smaller proportion of their riding times on neighborhood streets and more of their time on other streets or highways, rural roads, and bike paths. See Table 19.

When questioned about the reasons for riding their bicycles, most riders (77 percent) indicate that they ride for fitness and exercise and almost 50 percent ride as a family activity. Commuting is listed as a purpose by 10 percent of all riders. However, over 20 percent of enthusiasts and moving-up riders indicate that commuting is a reason for riding their bicycles. See Table 20.

Bicyclists say they would ride more if there were 'someone to ride with' (46 percent), 'safer places to ride' (35 percent), 'more comfortable seats' (34 percent), and 'more scenic places to ride' (29 percent). Even so, 57 percent have access to community bike paths and 28 percent have access to extra wide roads or bike lanes within their communities. Others would ride more if they were in 'better physical condition' (27 percent), could 'ride to work' (14 percent), had 'gears easier to shift' (11 percent), had 'access to organized riding events' (4 percent) or took 'a training course in bicycle riding' (1 percent). See Tables 21 through 23.

Helmet Use and Safety Behavior

Overall, 16 percent of bicyclists said they owned helmets. By cluster, helmet ownership is highest among enthusiasts (69 percent) and lowest among the infrequent riders (9 percent). However, not all helmet owners wear their helmets. Of those who own helmets, 60 percent always wear them, 22 percent sometimes wear them, 8 percent rarely wear them, and 8 percent never wear them. See Tables 24 and 25.

Overall, 10 percent of adult bicyclists wear helmets all of the time, 5 percent wear them some of the time, and the remainder wear them rarely or never. There were no substantial differences in helmet usage rates by age group. However, there were some differences by gender. Although 13 percent of males always wear helmets, only 7 percent of females do. A large disparity also exists between the cluster groups. See Figure C. Slightly more than 50 percent of enthusiasts indicate that they always wear helmets, as compared with 6 percent of infrequent riders, 13 percent of casual riders, and 31 percent of moving-up riders. Helmet use also varies by region. The Pacific region has the highest rate of helmet use with 23.5 percent using helmets some or all of the time. The South Atlantic region has the lowest helmet usage rate of 10 percent some or all of the time. See Tables 26 through 29.

Table 30 shows helmet use by places ridden most often. Helmet use is lowest on neighborhood streets, where 7 percent always wear helmets. Helmet use rises to about 19-24 percent on other streets and highways, and is highest on off-road trails, where 39 percent of riders always wear helmets.

Besides helmet use, certain other behaviors (such as regard for state traffic laws and headphone use while cycling) may reflect attitudes towards bicycling safety. Approximately 9 percent of adult cyclists (about three million cyclists) wear headphones at least occasionally while riding their bicycles[2]. This rate is highest (15 percent) among the moving-up category of cyclists. See Table 31. In addition, about one-third or over 10 million cyclists report that they do not always adhere to traffic laws[3]. See Table 32.

About 9 percent of riders report that they had crashed or fallen off of their bicycles within 12 months of the survey. Those who ride the most experience more falls and crashes. Enthusiasts experience more than four times the incidence of falls and crashes than the infrequent riders do[4]. See Table 33. However, those who wear headphones or do not always obey traffic laws are not significantly more likely to have crashed or fallen off of their bicycles.[5]

Table 34 contains information concerning bicycle safety equipment used within a year of the survey. Reflectors have the highest rate of usage; over 50 percent of bicyclists have them. However, this is probably an underestimate since the CPSC mandatory standard for bicycles requires reflectors on all bicycles sold in the U.S. Headlights are used by 14.5 percent of bicyclists and taillights are used by 6.6 percent. Reflective clothing is worn by 11 percent of cyclists; the highest usage rate is among the enthusiasts (34 percent). Seven percent of bicyclists use whistles, bells, or horns.

Bicycles, Equipment in Use, and Future Purchase Plans

The survey gathered detailed marketing information about bicycles and bicycle equipment owned by respondents and their households, as well as their future purchase plans. Results are shown in Tables 35 through 48.

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[2]Headphone use is defined as a "yes" answer to the question, "Do you ever go bicycling with headphones on both ears?"

[3]This is probably an underestimate. Previous studies indicate a much higher non-compliance with traffic laws. See, Tinkaus, J., Stop Light Compliance by Cyclists: An Information Look, *Perceptual and Motor Skills* (61), 814; 1985.

[4]A chi-square test for independence concludes that membership in cluster groups and accident experience are not independent of one another (χ^2=30.4, $p<.01$).

[5]A chi-square test found that the incidence of falling or crashing was independent of headphone use (χ^2=3.39, $p>.05$) and adherence to traffic laws (χ^2=6.07, $p>.05$).

Adult bicyclists own an estimated 36.5 million bicycles for personal use which were purchased new and used. Most bicyclists (76 percent) own one bike. However, almost half of the enthusiasts own more than one bicycle for personal use. About 67 percent of riders report that they used general purpose bicycles. Touring bikes and mountain bikes reportedly are owned by 15.5 and 14 percent of riders, respectively. Racing bikes are owned by 7 percent. Less than 1 percent of bicyclists own tandem, custom or folding bicycles. Categorized by speeds, 10 speed bicycles are owned most commonly (54.6 percent) with the next most popular being 3-speed (16.3 percent) and 1-speed (12.2 percent). Other speeds owned are 15 (4.0 percent), 12 (12.2 percent), 5 (4.8 percent), and other (8.6 percent).[6]

Slightly more than half (55 percent) of the most recently purchased bicycles were bought within five years of the survey. In contrast, 83 percent of the bicycles in the CPSC exposure survey were less than five years old. This difference, close to 30 percent, may be because the CPSC survey included bicycles for children, which may be purchased more frequently due to children's growth.

Of the 18.5 percent of riders who expect to purchase a new bicycle within two years, the mean expected outlay is $334. This represents a 82 percent nominal increase over the mean price paid by consumers who purchased a bicycle within a year of the survey ($183). By cluster, enthusiasts expect to pay the most for their next bicycle, $913. The moving-up bicyclists expect to pay $647. Casual and infrequent bicyclists plan to pay $363 and $224, respectively. See Figure D. The primary reason cited for purchasing a bicycle was 'replacement' (51.4 percent). Other reasons cited included: 'additional bicycle for self' (28.9 percent) and 'additional bicycle for someone else' (13.7 percent).

One trend that may be deduced from the survey is that mountain bikes are becoming increasingly popular across all levels of participation. Approximately 44 percent of bicyclists planning to purchase a new bicycle within two years plan to purchase a mountain bike, an increase from 14 percent of those bicycles purchased most recently. In contrast, 28 percent of bicyclists said they plan to buy general purpose bicycles, a decrease from 60 percent of bicycles purchased most recently. Another 14 percent plan to purchase touring bikes. Most riders (75 percent) who plan to purchase a new bicycle within two years expect to purchase a bicycle with 10 or more speeds. This is not a substantial change from previous purchases.

Table 49 lists accessories owned and plans for accessory purchases. While 16.4 percent of riders own helmets, another 13.8 percent of riders plan to purchase a helmet within two years. Of those who plan to purchase a new helmet, 4.7 percent already own helmets. Therefore, if the plans materialize, an additional 9.1 percent will possibly have acquired helmets by 1992. This would bring the total helmet ownership to over 25 percent. Also noteworthy, 14.5 percent of adult bicyclists own child seat carriers.

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[6]Multiple responses were accepted for owners of more than one bicycle.

Problems with Equipment

When asked about current mechanical problems with their bicycles, close to 60 percent of bicyclists indicate that they do not have problems. However, of those who do, 12 percent have problems with shifters, 9 percent with rubbing or dragging brakes, and 8 percent with stopping. Bicycles that squeak or need lubrication cause problems for 8 percent of bicyclists. Chains falling off and jamming cause problems for 3 percent of bicyclists. Wobbly wheels are a problem for 3 percent of cyclists. See Table 50.

Summary and Conclusions

This report summarizes findings of a major survey of adult bicyclists sponsored by Rodale Press and conducted by NFO. The 1990 survey provides a substantial amount of information on the demographic characteristics, equipment preferences, and riding patterns of these bicyclists. Based on the survey results, there are an estimated 32.8 million adults bicyclists who bought their last bicycle new. These bicyclists have higher household incomes and education levels than the U.S. population as a whole. They ride predominantly in the warmer months, and average about 34 miles per warm weather month.

These adult riders own approximately 36.5 million bicycles for personal use. In addition, an estimated 18.5 percent intend to purchase another bicycle within two years. Mountain bikes are becoming increasingly popular: 44 percent who say they plan to purchase a new bicycle within two years expect to purchase a mountain bike.

The survey also provides information about helmet use and other safety related behavior. Most notable only about 16 percent of bicyclists own helmets, and a smaller proportion, approximately 10 to 15 percent, wear them all or some of the time. However, 9 percent of riders who don't already own a helmet expect to purchase one within two years.

Tables

Table 1. Clustering Characteristics: Median Values of Responses to the Initial Screening of Adult Bicyclists, by Cluster Group

	Enthusiast	Moving Up	Casual	Infrequent
No. of Shop Visits/Yr	3	2	1	0
Miles/Warm Month	128	37	15	10
Price Paid for Last Bicycle	$642	$369	$213	$122

Rider Demographics

Table 2. Rider Age, by Cluster Group

Years	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
18-30	38.8	38.9	38.6	32.7	34.6
31-40	36.1	36.3	35.1	33.8	34.3
41-50	16.5	15.8	15.3	17.4	16.9
51-60	6.0	5.9	6.9	8.5	7.9
61+	2.6	3.1	4.1	7.5	6.4
Mean	35.1	35.1	35.3	37.9	37.1

Table 3. Gender, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
Male	76.8	67.4	54.5	44.9	50.6
Female	23.2	32.6	45.5	55.1	49.4

Table 4. Marital Status, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infreq. (%)	Total (%)
Married	48.5	50.3	61.1	66.0	63.4
Single	40.8	39.2	30.0	23.8	26.7
Widowed	0.6	0.9	1.1	1.7	1.5
Sep/Divorced	9.5	9.0	7.8	8.2	8.2
Unknown	0.6	0.6	0.0	0.4	0.3

Table 5. Educational Level, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infreq. (%)	Total (%)	1990 Census (%)
High school or less	13.2	10.5	15.2	26.6	22.6	58.4
Some college	33.0	37.0	36.3	38.4	37.6	18.4
College deg.	53.8	52.5	48.5	34.9	39.3	23.2
Unknown	0.3	0.5	0.1	0.7	0.5	--

Table 6. Employment Status, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infreq. (%)	Total (%)
Employed	88.9	88.6	83.3	76.2	78.8
Not employed	11.1	13.4	16.7	23.8	21.2

Table 7: Occupation of Employed, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
Managerial/ Professional	46.3	46.6	42.5	37.2	39.4
Technical/ Sales/ Admin Support	22.7	21.5	27.1	27.2	26.6
Service	9.2	8.3	8.2	11.7	10.6
Farming/ Forestry/ Fishing	0.4	0.8	0.8	1.0	0.9
Craft/Repair	6.6	7.0	6.8	6.1	6.3
Operator/ Laborer	3.9	4.5	5.5	7.3	6.6
Other	6.8	5.7	4.1	3.6	4.0
Unknown	4.1	5.6	5.0	5.9	5.7

Table 8. Personal Employment Income (in $1,000s), by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
< 15	13.7	13.8	12.8	21.2	18.6
15-29	26.4	27.8	31.4	31.3	31.0
30-44	27.3	26.1	29.1	24.7	25.9
45-59	15.1	14.2	11.5	10.2	10.9
60 +	14.1	12.2	10.6	7.5	8.8
Unknown	4.9	3.7	5.9	4.5	5.0

Table 9. Status of those Not Employed, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
Retired	23.8	22.6	21.3	29.4	27.7
Disabled	9.4	4.3	3.2	4.7	4.5
Unemployed	18.0	20.4	9.3	14.2	13.7
Homemaker	24.2	28.8	45.7	45.9	44.7
Student	33.7	31.1	25.5	14.4	17.3

Unknown	--	0.5	3.5	1.8	2.0

Household Demographics

Table 10. Geographic Region, by Cluster Group

	Enthusiast	Moving Up	Casual	Infreq.	Total	1990 Census
	(%)	(%)	(%)	(%)	(%)	(%)
New England	7.3	8.5	7.4	4.4	5.4	5.4
Mid Atlantic	13.4	12.0	15.4	14.8	14.7	15.1
East North Central	14.2	16.7	22.1	23.9	22.7	17.0
West North Central	5.8	6.2	8.6	8.5	8.3	7.3
South Atlantic	10.4	10.2	12.9	16.2	14.9	17.9
East South Central	1.6	2.5	2.3	3.8	3.3	6.2
West South Central	7.3	5.7	6.0	10.1	8.9	10.5
Mountain	12.1	10.1	6.6	5.6	6.3	5.5
Pacific	27.9	28.2	18.6	12.7	15.5	15.1

Table 11. Household Income (in $1,000s), by Cluster Group

	Enthusiast	Moving Up	Casual	Infreq.	All Riders	1990 Census
	(%)	(%)	(%)	(%)	(%)	(%)
< 15	6.1	7.3	7.3	9.7	9.0	24.4
15-29	18.6	16.9	17.8	20.8	19.8	25.7
30-44	26.2	27.0	22.1	30.5	28.3	20.3
45-59	17.2	19.6	19.9	22.4	21.5	12.7
≥ 60	32.1	29.0	32.9	16.6	21.3	16.9

Table 12. Regional Population Density, All Riders

	Percent
<50,000	22.1
50,000-499,000	21.4
500,000-1,999,999	16.4
2,000,000 +	40.0

Table 13. Number of Persons in Household

	All Riders (%)	1990 Census (%)
One	12.3	24.5
Two	28.7	32.3
Three	21.9	17.3
Four	22.9	15.5
Five or more	14.2	10.4

Table 14. Type of Residence, All Riders

	Percent
House	78.6
Apartment	10.9
Mobile Home	3.1
Condominium	2.8
Twinplex	2.5
Other	1.4
Unknown	0.6

Table 15. Home Ownership, All Riders

	Percent
Own or buying	74.7
Rent	18.7
Live w/relative	2.7
Other	1.2
Unknown	2.7

Bicycle Riding Habits

Table 16. Frequency of Warm Weather Riding, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
<once/month	4.8	9.2	16.6	20.8	8.6
once/month	3.4	6.1	8.6	8.5	8.2
2-3 times/month	12.1	19.7	23.7	23.7	23.1
once/week	11.4	15.5	16.4	14.0	14.6
2-3 times/week	37.4	31.2	27.6	24.2	25.8
daily	29.4	16.6	5.9	7.0	8.0
Unknown	1.3	1.5	1.1	1.8	1.6

Table 17. Average Miles Ridden in Warm Month, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
<20	20.8	41.7	66.4	73.5	68.2
21-40	10.4	16.0	14.8	11.0	12.1
41-60	6.7	10.4	9.1	7.7	8.2
61-80	3.2	4.0	2.1	1.4	1.8
≥ 81	59.0	27.9	7.5	6.4	9.7
Mean	205.4	80.9	29.8	24.1	34.4
Median	98.9	28.9	14.2	9.3	9.8

Table 18. Places Ridden in Past 12 Months, by Cluster Group (Multiple response)

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
Neighborhood streets	83.2	84.9	82.3	79.2	80.4
Quiet streets or quiet highways	68.1	57.5	43.7	32.2	37.4
Busy streets or busy highways	53.0	41.4	24.9	16.6	21.2
Bike path/ rail trail	58.9	53.4	36.8	23.1	29.1
Bike route	50.5	40.7	23.3	13.5	18.5
Rural roads	56.7	40.5	26.4	23.5	26.3
Off-road trails	30.1	25.6	10.8	5.5	8.7

Other places	20.4	14.9	11.0	10.4	11.1
Unknown	1.8	2.2	4.7	6.9	5.9

Table 19. Place Ridden Most Often, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
Neighborhood streets	28.2	42.7	65.7	62.5	62.3
Quiet streets or quiet highways	18.3	13.6	4.6	9.7	6.7
Busy streets or busy highways	9.7	6.8	2.7	2.8	3.2
Bike path/ rail trail	10.7	13.8	6.3	9.2	7.6
Bike route	4.1	4.9	2.2	2.9	2.6
Rural roads	18.4	10.7	11.4	7.5	10.7
Off-road trails	5.4	3.8	0.6	1.1	1.1
Other places	2.4	1.7	2.5	1.8	2.3
Unknown	2.6	2.1	4.0	2.5	3.5

Table 20. Purposes for Using Bicycle, by Cluster Group
(Multiple response)

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
Family activity	30.4	37.2	47.2	50.1	48.1
Visiting friends/ relatives	22.6	23.3	20.1	20.6	20.7
Fitness/exercise	88.5	86.3	81.1	75.0	77.4
Commuting	25.0	22.2	11.1	7.9	10.1
Fast rec. riding	40.9	23.3	11.5	5.5	9.0
Road racing	12.0	3.5	0.5	0.5	1.0
Mountain bike racing	5.8	2.7	1.1	0.2	0.7
Mountain bike rec. riding	27.4	23.3	8.2	1.6	5.2
Triatholon/ biathlon event	9.3	3.5	0.9	0.7	1.1
Century rides	18.2	6.1	0.4	0.0	1.0
Day-long tours	23.0	14.6	3.7	1.3	3.4
Weekend tours	11.9	7.1	3.0	0.7	1.9
Week-long tours	7.2	2.4	0.8	0.1	0.6
Commercial bicycle tours	3.6	2.1	0.6	0.1	0.4
Unknown	1.4	1.6	1.5	4.0	3.2

Table 21. Reasons to Ride More, All Riders (Multiple Response)

	Percent
More comfortable seat	34.0
Training course	1.5
Gears easier to shift	10.9
Person to ride with	46.4
Safer places to ride	34.7
More scenic places to ride	28.6
Access to organized riding events	4.1
Ability to ride to work	14.0
Better physical condition	26.8
Unknown	9.1

Table 22. Existence of Community Bicycle Paths in Parks and Other Recreational Areas, All Riders

	Percent
Yes	57.1
No	41.2
Unknown	1.7

Table 23. Availability of Extra Wide Lanes or Bike Lanes on Roads, All Riders

	Percent
Yes	28.5
No	69.2
Unknown	2.2

Table 24. Helmet Ownership, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
Yes	69.1	46.5	22.4	9.3	16.4
No	29.9	52.6	2.8	87.6	80.8
Unknown	1.0	0.9	74.8	3.1	2.8

Table 25. Helmet Use
(for the 16.4% of bicyclists who own helmets)

	Percent
Always	60.4
Sometimes	22.4
Rarely	8.3
Never	8.0
Unknown	1.0

Table 26. Helmet Use for All Riders, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
Always	50.1	31.4	12.7	5.7	10.2
Sometimes	14.4	11.7	7.0	3.0	4.8
Rarely	7.4	6.8	5.4	3.6	4.3
Never	27.3	48.9	73.5	86.2	79.3
Unknown	0.8	1.2	1.3	1.6	1.4

Table 27. Helmet Use, by Age

	18-30 (%)	31-40 (%)	41-50 (%)	51-60 (%)	>60 (%)	Total (%)
Always	10.6	9.6	10.4	10.1	11.0	10.2
Sometimes	4.9	4.9	4.6	6.0	2.3	4.8
Rarely	3.9	5.5	3.8	4.8	0.6	4.3
Never	79.2	78.9	79.7	79.1	81.1	79.3
Unknown	1.3	1.2	1.5	--	5.0	1.4

Table 28. Helmet Use, by Gender

	Males (%)	Females (%)	Total (%)
Always	13.2	7.3	10.2
Sometimes	5.2	4.3	4.8
Rarely	4.1	4.4	4.3
Never	76.0	82.6	79.3
Unknown	1.4	1.3	1.4

Table 29. Helmet Use, by Geographic Region

	Always (%)	Sometimes (%)	Rarely (%)	Never (%)	Unknown (%)
New England	16.9	2.9	4.1	74.5	1.6
Mid Atlantic	12.8	6.2	4.4	73.1	3.5
East North Central	7.8	3.6	4.3	83.2	1.1
West North Central	6.2	5.2	2.2	84.2	2.2
South Atlantic	8.1	1.9	4.5	84.7	0.8
East South Central	12.8	6.1	2.9	78.2	---
West South Central	6.7	4.2	2.3	86.0	0.9
Mountain	9.1	4.7	9.0	76.6	0.6
Pacific	15.2	8.3	4.7	70.7	1.1

Table 30. Helmet Use, by Places Ridden Most Often

	Always (%)	Sometimes (%)	Rarely (%)	Never (%)	Unknown (%)
Neighborhood Streets	7.4	3.6	4.3	83.4	1.2
Quiet Sts/Quiet Hwys	24.3	8.0	2.1	63.3	2.2
Busy Sts/Busy Hwys	19.1	3.3	3.5	72.2	2.0
Bike Paths/Rail Trails	10.6	12.6	7.0	67.8	2.1
Bike Routes	13.9	3.6	5.6	76.9	---
Rural Roads	12.0	4.0	3.2	80.2	0.7
Off-Road Trails	39.1	12.9	5.1	42.9	---
Other	7.4	8.5	4.8	79.1	0.2

Table 31. Headphone Use While Riding Bicycle, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
Yes	11.0	15.1	12.6	7.6	9.2
No	88.3	84.0	85.9	90.8	89.3

Unknown	0.7	0.9	1.5	1.6	1.5

Table 32. Adherence to State Traffic Laws, by Cluster Group

	Enthusiast	Moving Up	Casual	Infrequent	Total
	(%)	(%)	(%)	(%)	(%)
Always	62.8	59.3	61.5	66.4	64.8
Sometimes	34.6	35.0	33.8	28.6	30.3
Rarely	1.1	3.6	1.7	2.1	2.1
Never	0.6	0.7	1.0	0.7	0.8
Unknown	1.0	1.3	2.0	2.2	2.0

Table 33. Incidence of Falls or Crashes Within Past 12 Months, by Cluster Group

	Enthusiast	Moving Up	Casual	Infrequent	Total
	(%)	(%)	(%)	(%)	(%)
Yes	31.6	21.9	7.6	6.9	8.8
No	67.2	77.5	91.7	92.2	90.4
Unknown	1.1	0.6	0.6	0.9	0.8

Table 34. Bicycle Safety Equipment Used, by Cluster Group (Multiple Response)

	Enthusiast	Moving Up	Casual	Infrequent	Total
	(%)	(%)	(%)	(%)	(%)
Rear reflector	59.1	64.9	63.9	55.6	58.1
Pedal reflector	56.5	66.8	63.4	53.0	56.3
Wheel reflector	43.6	56.9	58.7	47.1	50.1
Reflective clothing	34.0	21.1	15.9	8.2	11.4
Whistle, horn or bell	7.8	8.4	7.4	7.1	7.3
Head light	23.0	16.1	17.1	13.1	14.5
Tail light	10.7	7.2	6.6	6.3	6.6
Unknown	8.6	12.2	20.4	30.4	26.4

Respondent Bicycle Ownership

Table 35. Bicycles Owned for Personal Use, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
None	0.5	0.4	1.3	1.0	1.0
One	53.5	65.7	77.2	77.3	75.8
Two	32.0	27.5	17.2	18.5	19.2
Three or more	13.9	4.7	3.1	2.3	2.9
Unknown	--	1.8	1.3	0.9	1.0

Table 36. Number of Bicycles Currently Owned Purchased New for Personal Use, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
None	4.0	2.6	4.8	6.5	5.8
One	51.2	64.6	72.3	70.9	70.2
Two	29.9	26.8	17.1	18.9	19.4
Three or more	14.0	4.6	4.8	3.2	3.9
Unknown	1.0	1.3	1.0	0.5	0.7

Table 37. Types of Bicycles Owned for Personal Use, by Cluster Group (Multiple Response)

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
General Purpose	17.7	21.7	49.0	79.8	67.5
Mountain	43.2	43.4	21.5	7.5	14.0
Touring	33.3	33.2	25.1	10.1	15.5
Racing/Triatholon	38.5	20.3	8.3	4.5	7.3
Tandem	2.7	0.8	0.1	0.4	0.4
Custom Made	9.4	1.1	0.9	0.2	0.7
Folding	0.7	0.8	1.3	0.4	0.7
Other	4.5	2.7	2.6	1.2	1.7
Unknown	0.1	1.1	0.4	0.4	0.4

Table 38. Speeds of Bicycles Owned, All Riders (Multiple Response) (Multiple Response)

	Percent
One	12.2
Three	16.3
Five	4.8
Ten	54.6

Twelve	11.8
Fifteen	4.0
Other	8.6
Unknown	0.3

Information about Last Bicycle Purchased

Table 39. Time of Acquisition, by Cluster Group

	Enthusiast	Moving Up	Casual	Infrequent	Total
	(%)	(%)	(%)	(%)	(%)
< 12 months	20.6	16.2	10.0	8.3	9.6
1-2 years ago	35.2	33.0	21.0	21.7	22.7
3-4 years ago	24.9	25.5	25.5	21.5	22.7
5 or more years ago	18.4	24.6	42.6	48.3	44.6
Unknown	0.8	0.6	0.9	0.2	0.4

Table 40. Price Paid, by Cluster Group

	Enthusiast	Moving Up	Casual	Infrequent	Total
	(%)	(%)	(%)	(%)	(%)
0-$99	1.5	0.5	2.2	30.9	21.9
			$100-$199	5.9	6.3
26.8 40.3	41.0				
$200-$299	7.1	13.4	38.6	6.8	13.9
$300-$399	9.8	33.4	16.8	2.3	7.9
$400 or more	69.9	40.3	5.1	0.4	6.1
Unknown	5.8	6.2	10.4	9.3	9.2
Mean Price Paid	$666	$381	$242	$124	$183
Median Price Paid	$597	$356	$220	$100	$130

Table 41. Type of Bicycle, by Cluster Group

	Enthusiast	Moving Up	Casual	Infrequent	Total
	(%)	(%)	(%)	(%)	(%)
General Purpose	8.2	13.7	43.9	71.7	60.0
Mountain	35.2	40.0	21.7	7.9	13.8
Touring	18.9	25.0	20.9	10.1	13.7
Racing/triatholon	28.5	16.2	6.9	3.5	5.8
Tandem	0.8	0.5	--	0.2	0.2
Custom	4.6	0.5	0.8	0.2	0.5
Folding	0.2	1.4	1.1	0.3	1.5
Other	1.1	0.4	1.8	0.8	1.0
Unknown	0.9	0.4	0.9	1.0	1.0

Table 42. Number of Bicycle Speeds, All Riders

	Percent
One	9.4
Three	13.5
Five	4.2
Ten	49.6
Twelve	11.4
Fifteen	3.5

Other	7.9
Unknown	0.6

Future Purchase Plans

Table 43. Plan to Purchase Bicycle within Two Years, All Riders

	Percent
Within 6 months	2.3
Within 1 year	6.2
Within 2 years	10.0
No plans	81.2
Unknown	0.4

For Those Who Plan to Purchase a Bicycle within Two Years
(18.5% of respondents)

Table 44. Plan to Purchase New vs. Used Bicycle, All Riders

	Percent
New	84.2
Used	1.3
Don't know	11.4
Unknown	3.1

Table 45. Expected Price, by Cluster Group

	Enthusiast	Moving Up	Casual	Infrequent	Total
Mean	$913	$547	$354	$224	$334
Median	$677	$406	$277.5	$188	$245

Table 46. Type of Bicycle Expected to Purchase, by Cluster Group

	Enthusiast (%)	Moving Up (%)	Casual (%)	Infrequent (%)	Total (%)
General purpose	7.1	10.2	18.8	35.4	27.4
Mountain	41.2	52.6	53.2	42.0	44.4
Touring	19.8	14.9	18.9	11.3	13.4
Racing	19.8	13.7	5.7	5.9	7.1

Tandem	2.9	2.8	--	0.6	0.8
Custom	3.8	1.5	0.5	--	0.4
Folding	--	--	0.5	0.5	0.4
Stationary	0.5	0.4	0.9	2.4	1.8
Other	1.9	2.9	0.9	--	0.6
Unknown	2.9	0.8	0.5	1.9	3.7

Table 47. Number of Speeds on Bicycle Expected to Purchase, All Riders

	Percent
One	4.6
Three	8.9
Five	6.5
Ten	35.8
Twelve	13.2
Fifteen	13.9
Other	12.0
Unknown	5.1

Table 48. Reason for Future Purchase, All Riders

	Percent
First purchase	3.2
Replacement	51.4
Additional bicycle for self	28.9
Additional bicycle for someone else	13.7
Unknown	2.8

Bicycle Equipment

Table 49. Accessories, All Riders (Multiple Response)

	Owned (%)	Purchase Plans (%)
Indexed derailleur system	5.9	1.2
Helmet	6.4	13.8
Lights	17.1	5.6
Toe clips	12.5	2.6
Mirror (eyeglass/helmet)	4.6	3.0
Mirror (handlebar)	9.2	2.0
Child seat carrier	14.5	3.8
Handlebar tape	13.6	3.1
Bicycle trailer	0.6	0.6
Unknown	2.8	29.8

Table 50. Problems With Bicycle, All Riders (Multiple Response)

	Percent
No problems	60.2
Flat tire	15.1
Wheels wobble	2.7
Brakes rub or drag	8.8
Brakes do not stop bike quickly	7.8
Shifters need adjustment	11.8
Chain falls off or jams	3.2
Squeaks/needs lubrication	7.9
Unknown	3.1

Part VIII.
The Risk and Helmet Use Patterns of Adult Bicyclists: An Analysis of the 1990 Rodale Press Survey

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Introduction

The CPSC purchased the results of a 1990 national survey of adult bicyclists conducted by the Rodale Press, the publishers of *Bicycling* magazine, to enhance the staff analysis of bicycle use and risk patterns. The Rodale Press survey did not gather information on bicycle use by children, a major focus of the CPSC bicycle project. However, it did gather information on a wide range of topics relevant to an analysis of the risk and safety behavior of adult bicyclists.

This report uses the Rodale Press survey results to model the accident risk and safety-related behavior of adult bicyclists in the United States. Safety behavior on the part of individuals is measured by the use of bicycle helmets, which has been shown to reduce both the likelihood and severity of head injury. The analysis shows that the risk and helmet use patterns of adult bicyclists are predictable: they are related to personal rider characteristics, bicycle use patterns, and demographic factors. The analysis also finds that risk and helmet use patterns are related: factors associated with higher bicycle accident risks tend to be associated with higher expected rates of helmet use.

The Model

The risk and safety-related behavior of adult bicyclists may be represented by the following two equation model.

$$(1)\quad RISK = f(SAF\text{-}EFF, RIDER, USE, TYPE)$$
$$(2)\quad SAF\text{-}EFF = g(RIDER, USE, TYPE, DEMO)$$

where,

RISK	=	the risk of injury accident,
SAF-EFF	=	individual safety efforts,
RIDER	=	the personal characteristics of bicyclists,
USE	=	patterns of bicycle use,
TYPE	=	bicycle type,

DEMO = demographic characteristics.

The first equation attempts to explain the bicycle-related injury risk (*RISK*) in terms of several *general* explanatory variables. Individual safety efforts, represented by the variable *SAF-EFF*, are assumed to affect the injury risk directly, by affecting the likelihood of accident or the severity of injury given that an accident has occurred.

Rider use patterns (*USE*) and the personal characteristics of bicyclists (*RIDER*) are also assumed to affect the injury risk. Risk is likely to increase with riding distances and to be higher on certain riding surfaces, such as highways or various unsafe terrains. Risk may also be affected by rider characteristics such as age and gender. Teenagers, as a group, tend to exhibit risk-taking propensities (Hodgdon, Bragg, and Finn, 1981; Noe, McDonald, and Hammit, 1983), and males may be more likely than females to take risks, as evidenced by automobile and other accident rates (Hodgdon et al., 1981; Holinger, 1979; National Safety Council, 1992; Rodgers, 1990).

The type of bicycle used (*TYPE*) may also affect the injury risk. There is no evidence that certain bicycle model types are inherently more or less safe than others. However, Mortimer et al. (1976) conducted performance tests designed to measure the relationship between bicycle maneuverability and handlebar configuration. They found, in several tests, that the maneuverability of bicycles with "high rise" and "standard" handlebars was better than that of bicycles with the "dropped" (i.e., C Bend) handlebar configuration found on lightweight racing style bicycles.

Individual safety efforts (*SAF-EFF*), an explanatory variable in equation (1), is itself determined endogenously in equation (2). That is, safety efforts are assumed to be determined within the model as a function of a set of explanatory variables. Although there are many types of safety efforts that might be exhibited by bicyclists, helmet use will be taken as the measure of safety effort in this analysis.[1] As shown by Thompson et al. (1989) and Dorsch et al. (1987), helmet use can substantially reduce both the injury risk and severity of head injury, given that an accident has occurred.

Just as use patterns and rider characteristics affect the injury risk, they may influence the helmet use decision. For example, riders who use their bicycles on off-road trails may wear helmets to protect their heads from tree limbs, brush, or falls. Those who ride on highways or other major thoroughfares may be more likely to wear helmets because of higher accident risks, or because of the likely greater severity of injury in accidents involving collisions with motor vehicles.

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[1] Other types might include, for example, being careful to stop at stop-signs or being cognizant of surrounding automobile traffic. However, information on these types of safety efforts are difficult to obtain from telephone or mail surveys.

Demographic characteristics are also likely to affect individual safety efforts, such as helmet use. Under the assumption that safety is a normal economic good, helmet use should increase with household income. Riders in households with higher education levels may also wear helmets more frequently since they may be more aware of, or more capable of evaluating, the benefits of helmet use.

Data

Data for the analysis are from a 1990 survey of adult bicyclists conducted by National Family Opinion, Inc. (NFO) from its national consumer mail panel. The NFO consumer panel is not a probability sample, but is balanced to match U.S. statistics on five demographic variables: geographic region, population density, household income, household size, and age of panel member.[2]

The survey, which was sponsored by Rodale Press, the publishers of *Bicycling* magazine, elicited information on a wide range of topics relevant to bicycle riding. Topics included, among others, riding patterns and habits (e.g. riding distances and where bicycles are ridden), the physical characteristics of riders (e.g. age and gender), the types of bicycles used, future purchase plans, bicycling safety (e.g. information on accidents and helmet use), and rider and household demographic characteristics.[3]

Screening questionnaires were initially sent to a sample of 150,000 panel households from around the nation. About 104,000 households (69 percent) responded and about 40,300 indicated that they had at least one adult bicycle owner. In total, there were about 61,600 individual adult bicycle owners in these households.

To qualify for the survey, respondents had to be age 18 or older, they had to own a bicycle intended for an adult, and they had to have purchased their last bicycle new. Since a major goal of the survey was to gather information of interest to the bicycle industry, qualifying respondents also had to answer three questions on the screener. The questions included: 1) the number of miles they ride in an average warm month; 2) the number of times they visited a bike shop in the last year; and, 3) the price they paid for the last bicycle purchased. About 37,900 respondents, out of the 61,600 individual bicycle owners (61 percent), qualified. The respondents who did not qualify were, for the most part, those who

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[2] The NFO panel has also been used by the CPSC in the analysis of hazards associated with ATVs.

[3] For a detailed description of the survey methodology and results, see Donaldson (1993), in Part VII of this report.

had purchased their last bicycle used or did not answer one or more of the questions on miles ridden, bike shop visits, or price paid (Rodale Press, 1990).[4]

NFO separated qualifying respondents into four groups by means of a cluster analysis applied to the screening questions. The cluster analysis was intended to identify groups of bicyclists who ranged from those who hardly ever ride to those who might be considered biking "enthusiasts." In-depth questionnaires were subsequently mailed to about 4,200 households, including at least 1,000 households from each of the four clusters. Each cluster sample was selected by NFO to be representative of the households in the cluster. Questionnaires were returned from 3,248 respondents, for a response rate of about 77 percent.

The purpose of sampling the various clusters was to provide representative samples of bicyclists in several "marketing" categories. However, NFO also provided weights for the observations from each of the clusters so that the entire sample could be used to make projections representative of all U.S. adult bicyclists.

Statistical Analysis

Analytic Techniques

The risk and helmet use functions are estimated in reduced form with probit regression models.[5] Probit analysis, like multiple regression analysis, is a statistical procedure in which variation in the dependent variable is explained by variation in the explanatory variables. The multiple regression approach allows us to determine and quantify the factors associated with changes in the dependent variable and to sort out the potentially complex interrelationships between the dependent and independent variables.

The probit specification of the regression model is used to examine the relationship between the independent variables and a dependent variable that represents two distinct alternatives (Pindyck and Rubinfeld, 1991). The dependent variable in the risk model (equation 1) represents whether or not the respondents had "crashed or fallen off [their] bicycle" in the 12 month time span prior to the survey. It is set equal to one if there had been a

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[4] Out of the 61,600 adult bicyclists, about 20 percent purchased their last bicycle used, and about 18 percent did not answer all of the questions.

[5] Estimating equation (1) directly, with the endogenous explanatory variable on the right hand side of the equation, produces inconsistent estimates of the parameters (Pindyck and Rubinfeld, 1991). However, it can be estimated consistently in reduced form, an approach which is sufficient for our purposes because we are primarily interested in the net effects of the exogenous explanatory variables on the accident risk and the likelihood of helmet use.

crash, zero otherwise. It should also be noted that it represents the accident risk, rather than the injury risk, since some crashes or falls may not result in physical injury. The dependent variable in the safety efforts model (equation 2) is a dichotomous variable based on the frequency of helmet use.[6] The helmet use variable is set equal to one for bicyclists who always wear helmets, and is set equal to zero for bicyclists who wear helmets only sometimes, rarely, or never.[7]

The specific independent variables to be used in the analysis are defined in Table 1. (The tables begin on page 149.)

Results

Tables 2 and 3 present, respectively, the accident risk and the helmet use regression models. In the first model of each table rider age is entered as a series of dummy variables. In the second, age is entered as a continuous variable. Since the equations were estimated in reduced form, the explanatory variables in both the risk and helmet use models are the same.

All of the equations in Tables 2 and 3 are statistically significant. About 15 percent of the observations were lost because of missing information on the variables. A sensitivity analysis, conducted by replacing missing values with the mean value of the variable in question (Pindyck and Rubinfeld, 1991), indicated that the models were not substantially affected by the missing data.

<u>Accident Risk</u>. First consider the risk models of Table 2. The results show several strong relationships between the accident risk and rider use patterns. As expected, risk increases with miles ridden per month. This is indicated by the positive and significant coefficient for the variable *MILES*.

The relationship between risk and riding surface is measured with a series of dummy variables representing the various riding surface types, relative to neighborhood streets. The accident risk increases for bicyclists on off-road trails (*TRAILS)*, and decreases for riders on bike paths (*BIKEPATH)*.

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[6] Helmets are intended to reduce the likelihood or severity of injury, given an accident, rather than the accident risk itself. Nevertheless, the structural equation for the accident risk should include safety efforts as an explanatory variable (as in equation 1) since helmet use is but one type of safety effort: other types are likely to affect the risk of accident.

[7] Alternatively, the helmet use variable could have been set equal to one for bicyclists who always or sometimes wear a helmet. The results of the analysis were, however, virtually identical when "sometime" wearers (about 4 percent) were included in the category of helmet users.

Somewhat surprisingly, riding on highways (*HIGHWAY*) has no independent impact on the accident risk. However, this may be because responses to the survey question on riding location combined highways with streets (i.e., busy highways/busy streets and quiet highways/quiet streets), and may therefore have diluted distinctions based on traffic volume. The relationship may also have been confounded by the significant correlation between the highway and distance variables (r=0.21, p<0.0001).[8] Riding on rural roads (*RURAL*) has no independent impact on the accident risk.

The accident risk is also affected by bicycle type. Risk is higher for riders of both all-terrain (*ATB*) and racing style (*RACING*) bicycles, relative to the more general purpose models. This result does not necessarily imply that these types of bicycles are more dangerous than general purpose models, and probably reflects in part the relationship between risk and riding patterns not picked up by the other use pattern variables.[9]

While there is no independent statistical relationship between gender (*GENDER*) and risk, the accident risk is related to age. Age is entered into Model 2 as a quadratic variable (*AGE* and *AGESQ*), and captures the apparently nonlinear relationship between age and risk; that is, risk initially declines with age, but then rises for older riders.[10] Based on the results from Model 1, the risk for riders over age 64 is significantly higher than for riders 25-64 years of age.

While the higher risk for the younger adults was anticipated and may be related to risk-taking propensities, the reason for the increased risk of older bicyclists is unclear. It might be explained by a deterioration in reaction time, a characteristic that is important in avoiding accidents. Maring and van Schagen (1990), who also found an increased accident risk for bicyclists over the age of 60 in the Netherlands, suggested that the higher risk might be related to changing cognitive and perceptual processes that tend to reduce the flexibility of older riders in responding to unforeseen situations. Older persons involved in accidents may also tend to suffer adverse outcomes because of medical complications and other factors associated with postinjury homeostasis.

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[8] It is also possible that some individuals ride more carefully on highways than on neighborhood streets because of the potentially greater injury severity that might be expected in highway accidents.

[9] RACING was significantly correlated with riding on highways, and ATB was significantly correlated with riding on trails. In addition, both the RACING and ATB variables were significantly correlated with MILES.

[10] A similar relationship was found between age and the fatality risk for drivers of all-terrain vehicles (Rodgers, 1990).

There is no evidence that the accident risk is directly correlated with rider demographic characteristics such as household income (*INCOME*) and education level (*EDUC*). However, there are apparently some regional variations in the accident risk, with lower risks in the Northeast and Mid-Atlantic States (represented by the variable *EAST*) and higher risks in the Pacific Coast States.

Helmet Use. The likelihood of helmet use is affected by a number of factors that also affect the accident risk. Helmet use increases with greater monthly riding distances, and is higher for bicyclists who ride most often on off-road trails. The coefficient for the bike path variable (*BIKEPATH*) is negative (as in the accident risk models), but not significant at the usual 5 percent significance level (p=0.11). The impact of riding on rural roads on helmet use patterns is also nonsignificant.

In contrast to the nonsignificant relationship between risk and the *HIGHWAY* variable in Table 2, helmet use is significantly higher for bicyclists who ride on highways. This may suggest that bicyclists who ride primarily on highways are more likely to wear helmets because of the potentially greater injury severity that might be expected in highway accidents involving motor vehicles (rather than simply because of a higher accident risk), a factor that would not necessarily be picked up in the risk equation.

Helmet use, like the accident risk, is also affected by bicycle type. Riders are more likely to wear helmets if they ride racing or all-terrain bikes. On the other hand, the coefficients for the age and gender variables are both nonsignificant, suggesting that age and gender have no independent effect on the likelihood of helmet use.

In contrast to the accident risk models, rider demographic characteristics have a substantial impact upon helmet use patterns. As expected, helmet use increases with household income and with rider education. There are also some regional variations in helmet use: bicyclists in the Central, Southern, and Mountain States were less likely to wear helmets than bicyclists in the Pacific Coast States.

Risk and Helmet Use Estimates

This section examines the sensitivity of changes in the accident risk and the likelihood of helmet use to changes in the independent variables. One way to do this is to estimate and compare differences in the average accident and helmet use probabilities for various population subgroups, such as female bicyclists or bicyclists between the ages of 18 and 24. Although such estimates *do not* statistically hold other variables constant, they provide consistent group estimates of the proportion of individuals who are likely to have accidents and wear helmets (Train, 1986).

The expected accident and helmet use probabilities for selected population subgroups are presented in Table 4. The expected accident probabilities are based on Model 2 of Table 2;

the helmet use probabilities are based on Model 2 of Table 3. A major pattern that emerges is that differences in the average accident risk from one population subgroup to another tend to be matched by similar changes in the average likelihood of helmet use.[11]

A number of the results follow directly from the discussion of regression results. Both the average accident risk and the expected rate of helmet use are higher for bicyclists who ride greater distances, for bicyclists who ride most often on trails, and for bicyclists who use racing and ATB style bicycles. On the other hand, the expected risk and helmet use rates are lower for bicyclists who ride most often on neighborhood streets.

Notwithstanding the nonsignificant regression findings for the gender variable, the expected risk and helmet use rates are significantly higher for male riders. In addition, the accident risk (as well as the expected rate of helmet use) is higher for bicyclists who ride most often on highways. This is because males and those who ride on highways ride longer average distances than females and others who do not often ride on highways, and distance is positively related to risk and helmet use. Males ride about twice the distance of females (47 versus 24 miles in an average warm weather month). Similarly, bicyclists who ride most often on highways ride about 2.5 times the distances of other bicyclists (76 versus 31 miles per month).

Finally, as indicated by the regression results, helmet use varies systematically with income and education. The expected rate of helmet use increases monotonically from about 7.1 percent of those bicyclists with household incomes of less than $15,000 per year to almost 18 percent for those with household incomes of $100,000 or more per year. Similarly, expected helmet use rates increase from 4.4 percent of bicyclists with a high school education or less to almost 17 percent for college graduates.

Discussion

This study examined the risk- and safety-related behavior of adult bicyclists, based on the results of a national cross-section survey conducted by Rodale Press in 1990. The results show that the accident risk and helmet use patterns of adult bicyclists are predictable and depend upon the characteristics and riding patterns of bicyclists.

The expected accident risk for adult bicyclists increases with greater riding distances. Risk also varies by riding surface. Relative to riding on neighborhood streets, riding primarily on off-road trails increases risk. In contrast, riding primarily on bike paths lowers risk. There was no evidence that riding on highways independently increases the accident risk, relative to

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[11] For example, when comparing bicyclists who ride less than 11 miles per month with those who ride more than 50 miles per month, the average expected accident risk rises from 4.5 to 22.5 percent, and the expected rate of helmet use rises from 3.7 to 30.4 percent. Similarly, the average expected accident risk and helmet use rates rise from 7.1 and 7.3 percent, respectively, for females, to 12.0 and 13.8 percent, respectively, for males.

riding on neighborhood streets, but this finding may have been due to combining the highway variable with other "streets." Risk is also related to rider characteristics. Risk declines with age, but then increases for riders over the age of 64. Although rider gender has no independent effect on risk when other factors are held constant, the average risk is higher for males because, on average, they ride greater distances than females.

In addition, factors associated with higher bicycle accident risks tend to be associated with higher expected rates of helmet use, and factors associated with lower bicycle accident risks tend to be associated with lower expected rates of helmet use. For example, the expected rate of helmet use increases with riding distances, tends to be higher for those who ride most often on trails or highways, and tends to be lower for those who ride most often on neighborhood streets and bike paths. Neither rider age nor rider gender has an independent effect on the likelihood of helmet use. However, the average rate of helmet use is higher for males, who on average ride greater distances than females. In addition, as anticipated, helmet usage rates are affected by demographic characteristics -- helmet use increases with rider education levels and household income.

These results are generally consistent with a theory of compensatory behavior in risky activities, which has been discussed by Peltzman (1975) and others.[12] This theory hypothesizes that in familiar risky activities, such as driving, individuals tend to compensate for changes in the risk environment. Individuals are expected to increase safety efforts in response to exogenous increases in risk, and to reduce safety efforts in response to reductions in risk.[13]

The finding, for adults, that higher (lower) rates of helmet use tend to be associated with higher (lower) accident risks does not imply that helmet usage rates are high enough. Individuals may systematically underestimate the value of helmet use and therefore use them less than they should. The 1991 CPSC bicycle exposure survey found, for example, that almost half of the bicyclists who never wear helmets said they never thought about doing so (Rodgers, 1992b). Nevertheless, the results suggest that adult bicyclists tend to increase helmet use when they perceive that they are at greater risk.[14] Providing the public with

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[12] See, e.g., O'Neill, 1977; Blomquist, 1986, 1988; Evans, 1985; Orr, 1982; and, Viscusi, 1984. For a non-technical discussion of the hypothesis, see Rodgers (1992a). For examples of recent empirical analysis involving the behavior of automobile drivers and motorcyclists, see Blomquist 1991; Crandall and Graham, 1984; Graham, 1984; McCarthy, 1986; Evans and Graham, 1991; Winston, 1987; and Graham and Lee, 1986.

[13] As an example, drivers might be expected to increase seat belt use when driving in rainstorms or on congested highways.

[14] In fact, the Rodale Press survey results also indicate that helmet usage rates have increased substantially in the last couple of years; more than half of current helmet users reported that they began wearing helmets in the last two years. This may suggest that the

information describing the bicycle-related accident risks and advantages of helmet use in reducing head injuries may therefore be an effective strategy in efforts to reduce injuries to adult bicyclists.

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demand for helmets has increased as consumers have become more aware of the safety benefits, which have been widely publicized in the safety literature and in the media, (see, e.g., Beyers, 1992).

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Table 1: Variable Definitions

Rider Characteristics (*RIDER*)	
-AGE	rider age;
-AGESQ	the square of rider age;
-AGE(X_1-X_2)	1 if rider is of the age described in the brackets (i.e., age X_1 to age X_2), 0 otherwise;
-GENDER	1 if the rider is male, 0 if the rider is female.
Use patterns (*USE*)	
-MILES	The natural logarithm of the number of miles traveled in an average warm month;
-NEIGH	1 if the bicyclist rides most often in neighborhood streets, 0 otherwise;
-HIGHWAY	1 if the bicyclist rides most often on quiet highways/quiet streets or busy highways/busy streets, 0 otherwise;
-BIKEPATH	1 if the bicyclist rides most often on bike paths or bike routes, 0 otherwise;
-RURAL	1 if the bicyclist rides most often on rural roads, 0 otherwise;
-TRAIL	1 if the bicyclist rides most often on off-road trails, 0 otherwise;
-OTHER SURF.	1 if the bicyclist rides most often in "other places," 0 otherwise.
Bike Types (*TYPE*)	
-ATB	1 if all-terrain or mountain bicycle, 0 otherwise;
-RACING	1 if racing/triathlon bicycle, 0 otherwise;
Demographic Characteristics (*DEMO*)	
-INCOME	Household income, in thousands of dollars;
-EDUC1	1 if the rider has a high school education or less, 0 otherwise;
-EDUC2	1 if the rider attended college but did not graduate, 0 otherwise;
-ECUC3	1 if the rider is a college graduate, 0 otherwise;
-EAST	1 if the rider resides in a Northeastern or Mid-Atlantic State, 0 otherwise;
-MIDWEST	1 if the rider resides in a East Central or West Central State, 0 otherwise;
-SOUTH	1 if the rider resides in a Southern State, 0 otherwise;

-MOUNTAIN	1 if the rider resides in a Mountain State, 0 otherwise;
-PACIFIC	1 if the rider resides in a Pacific Coast State, 0 otherwise.

Table 2: Regression Results: Risk of Accident

Variable	Model 1: Coefficient	SE	Model 2: Coefficient	SE
INTERCEPT	-1.7092	.1993	-.4323	.3095
MILES	.2804**	.0288	.2763**	.0287
GENDER	.0651	.0741	.0765	.0737
AGE	--	--	-.0795**	.0145
AGESQ	--	--	.0008**	.0002
RACING	.3266**	.1239	.3389**	.1239
ATB	.2950**	.0935	.2914**	.0933
HIGHWAY	-.0671	.1095	-.0668	.1092
BIKEPATH	-.3065*	.1243	-.3261**	.1240
RURAL RD.	-.0101	.1127	-.0211	.1122
TRAIL	1.1348**	.2404	1.1387**	.2403
OTHER SURF.	.1147	.2385	.1591	.2358
INCOME	-.0005	.0013	-.0003	.0013
EDUC2	-.1482	.0985	-.1259	.0981
EDUC3	.1472	.0977	.1757	.0973
EAST	-.3113**	.1156	-.2981**	.1151
MIDWEST	-.1927	.1045	-.1923	.1043
SOUTH	-.2669*	.1098	-.2543*	.1096
MOUNTAIN	-.3341*	.1607	-.3221*	.1601
AGE (18-24)	.0637	.1711	--	--
AGE (25-34)	-.3551*	.1605	--	--
AGE (35-44)	-.4436**	.1647	--	--
AGE (45-54)	-.4791*	.1894	--	--
Age (55-64)	-.8456**	.2495	--	--

* significant at p < 0.05, two-tailed test.
** significant at p < 0.01, two-tailed test.

	Model 1	Model 2
N (Accident)	452	452
N (non-Accident)	2,499.5	2,499
c	.760	.764
Score	315.5	313.6
Model Chi-square	270.1	264.1

Table 3: Regression Results: Likelihood of Helmet Use

Variable	Model 1: Coefficient	SE	Model 2: Coefficient	SE
INTERCEPT	-2.6424	.2209	-2.6739	.3441
MILES	.3752**	.0298	.3746**	.0298
GENDER	-.0186	.0753	-.0233	.0751
AGE	--	--	-.0173	.0158
AGESQ	--	--	.00024	.00018
RACING	.6876**	.1180	.6764**	.1177
ATB	.3203**	.0941	.3157**	.0941
HIGHWAY	.2560*	.1036	.2554*	.1036
BIKEPATH	-.1794	.1173	-.1780	.1169
RURAL RD.	.1239	.1160	.1161	.1152
TRAIL	.9476**	.2499	.9135**	.2485
OTHER	-.4237	.3497	-.4278	.3480
INCOME	.0026*	.0012	.0024*	.0012
EDUC2	.2039	.1173	.2155	.1178
EDUC3	.6866**	.1142	.7189**	.1144
EAST	-.0015	.1113	-.0061	.1111
MIDWEST	-.2780*	.1091	-.2746*	.1089
SOUTH	-.2067	.1120	-.2041	.1119
MOUNTAIN	-.3569*	.1677	-.3570*	.1676
AGE (18-24)	-.4064*	.1956	--	--
AGE (25-34)	-.2785	.1731	--	--
AGE (35-44)	-.3619*	.1763	--	--
AGE (45-54)	-.2606	.1953	--	--
AGE (55-64)	-.2596	.2212	--	--

* significant at $p < 0.05$, two-tailed test.
** significant at $p < 0.01$, two-tailed test.

	Model 1		Model 2	
N (Helmet User)	724		724	
N (non-Helmet User)	2,227		2,227	
c		.827		.827
Score	489.3		483.8	
Model Chi-square	448.5		445.9	

Table 4. Average Accident Risk and Helmet Use Probabilities, for Selected Population Subgroups

Variable	Group	Accident Risk %	Helmet Use %	% of observations (weighted)
$\bar{X}$	All	9.5	10.6	100.0
Miles per month	≤ 10	4.5	3.7	50.6
	11-25	9.3	9.2	19.3
	26-50	13.8	15.2	15.1
	> 50	22.5	30.4	15.0
Age	18-24	17.9	11.4	12.4
	25-34	9.9	10.0	36.9
	35-44	6.8	10.7	29.9
	45-54	6.9	11.6	10.4
	55-64	6.5	9.1	6.0
	≥ 65	12.6	11.2	4.2
Gender	Female	7.1	7.3	50.0
	Male	12.0	13.8	50.0
Surface Type Ride On Most Often:				
Neigh. Streets	No	12.0	15.4	35.6
	Yes	8.2	7.9	64.4
Highway	No	9.0	9.1	89.6
	Yes	14.4	22.9	10.4
Bikepath	No	9.8	10.5	89.3
	Yes	7.5	11.3	10.7
Rural Rd.	No	9.5	10.4	88.6
	Yes	9.9	11.5	11.4
Trail	No	9.0	10.2	98.9
	Yes	53.8	43.4	1.1
Bike Type:				
Racing	No	8.9	9.2	93.6
	Yes	18.7	30.2	6.4
ATB	No	8.2	9.2	85.7

Yes	17.4	18.8	14.3

Table 4 (continued)

Variable	Group	Accident Risk %	Helmet Use %	% of observations (weighted)
Income (in $1000s)	< $15	9.7	7.1	7.7
	$15-$29.9	10.0	8.5	19.5
	$30-$44.9	9.2	9.9	29.1
	$45-$59.9	8.9	10.2	21.7
	$60-$74.9	9.9	12.9	9.8
	$75-$99.9	10.0	16.4	6.2
	≥ $100	10.3	17.8	4.9
School	H. Sch. or less	8.7	4.4	22.6
	Some College	8.2	7.7	37.7
	College Grad.	11.2	16.8	39.6
Region	East	8.9	14.2	20.4
	Midwest	8.9	7.7	31.4
	South	7.8	8.7	26.4
	Mountain	9.7	9.3	6.4
	Pacific	14.4	15.4	15.4