AN ABSTRACT OF THE THESIS OF

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Title: Evaluation of the Oregon Bicycle Helmet Use Law on Bicycle Helmet Usage and Bicycle-Related Head Injuries

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The objectives of this study were to 1) assess the effectiveness of the law in increasing helmet use and compare methods of measuring helmet use, and 2) determine the impact of the law on bicycle-related head injury and fatalities.

To measure changes in helmet use by children under 16 years of age, we conducted three statewide pre- and post-law surveys: direct observations, telephone surveys of parents, and classroom surveys of students. We identified bicycle-related head injury cases during July 1989 - June 1995 through the Oregon Trauma Registry and Vital Statistical Department. Time series analysis was employed to determine if the secular trend and intervention were actual effects rather than random noise.

Observed helmet use increased from 24.5% pre-law to 49.3% post-law ($P<0.01$). Classroom survey self-reported "always" use of helmets increased from 14.7% to 39.4% afterwards ($P_{(2)}<0.01$). Younger girls were more likely to comply the law. Helmet ownership increased from 51.5% pre-law to 75.5% afterwards on the student surveys ($P_{(2)}<0.01$) and from 67.4% to 83.9% on the parent surveys ($P_{(2)}<0.01$). The increase in helmet ownership was greater among children with low household-income. The results obtained from classroom surveys and direct observations were correlated (r=0.76,

P<0.01). The majority of students (87.8%) and parents (95.4%) knew about the Oregon bicycle helmet law, but only half of the students thought the law was a "good idea."

One year after the law was effective, the incidence rate of statewide bicycle-related head injury decreased from 3.9 per 100,000 person-years pre-law to 2.9 per 100,000 person-years ($P_{(2)}<0.001$). The decrease was most profound in children under 16 years of age. For children under 16 years of age, the decreasing trend of bicycle-related head injuries appeared to mirror the increasing trend of helmet usage.

We conclude that 1) the law increased helmet use; 2) the law helped reduce the bicycle-related severe head injuries; and 3) although use estimates differ, all helmet surveys showed similar degrees of pre- and post-law change. Our results suggest that the laws may be an effective approach to increase helmet use and reduce head injury in other states.

Evaluation of the Oregon Bicycle Helmet Use Law on Bicycle Helmet Usage and Bicycle-Related Head Injuries

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1. INTRODUCTION

Bicycle-related head injuries (BHIs) are a cause of morbidity and mortality in the United States. Each year, more than 900 people die from injuries caused by bicycle crashes; 20,000 are admitted to hospitals; and 580,000 persons are treated in emergency departments for bicycle-related injuries.[1] Head injuries are responsible for two-thirds of bicycle-related deaths, one-third of bicycle-related emergency department visits, and two-thirds of bicycle-related hospital admissions.[2,3] About 65% of bicycle-related head injuries occurred among children under 16 years of age.

Despite the apparent benefits of helmet use in prevention of head injury on a bicycle crash, the national prevalence of helmet use among child bicyclists under 16 years of age is only about 15%, which is much lower than the Year 2000 National Health Objective of 50% helmet use.[4,5] These low estimated helmet usage rates, combined with research findings showing protective effect of helmets in reducing head injures, have spurred a number of states and local communities to design programs to increase helmet use rates, particularly among children.

Education and subsidizing the cost of helmets have been used as main strategies to promote helmet use. Yet, they have not been shown to be as effective as expected.[6,7,8] Confronted with the above problems, nine states, including Oregon, are implementing laws mandating child bicyclists to wear helmets.[3] The Oregon helmet use law, which became effective in July 1994, requires children under 16 years of age to wear helmets while bicycling or while riding as a passenger on a bicycle. Although the laws have been considered the best strategy to promote helmet use, the effectiveness of these statewide laws has not been evaluated. To achieve the Year 2000 Health People objective, data are needed concerning the effectiveness of legislation in increasing bicycle helmet use and reducing BHIs.

The objectives of this study were to 1) assess the effectiveness of the law in increasing helmet use by children and compare different methods of measuring helmet use, and 2) determine the impact of the law on bicycle-relate severe head injury and fatalities.

The resulting information from this evaluation will help the state of Oregon improve and expand the existing injury prevention programs. It also will help other states develop effective intervention strategies to reduce BHIs.

2. BACKGROUND

2.1 Bicycle-related head injuries: a major public health problem among children

Bicycle riding is one of the most popular recreational activities in the United States. Bicycles are owned by nearly 30% of the U.S. population and over 80% of children.[9,10] According to a report by National Sporting Goods Association, bicycle riding is the third leading recreational activity in the country, after exercise walking and swimming.[11] Cycling also offers people an inexpensive, convenient, independent, and environmentally sound form of transport. More than an estimated 12 million riders in this country use their bicycles for commuting to work or school, or for other nonrecreational purposes.[12]

Unfortunately, bicycle riding also involves risks to health through accident and injury in bicycle crashes. In 1991, Sack et al reported that during 1984 through 1988, bicycling accounted for 4,812 injury deaths and 2,789,678 nonfatal injuries.[2] Head injury is the most common cause of death and serious disability in bicycle-related crashes. Approximately 62% of these fatal injuries and 32% of the nonfatal injuries involved head trauma, a condition that may cause profound, disabling, and long lasting sequelae. Forty-one percent of head injury deaths and 76% of head injuries occurred among children under 15 years of age.

The problem of bicycle safety also exists in the Oregon population. From 1991 through 1993, 467 bicycle-related injuries were entered into the Oregon trauma system and 65% of them were head injuries. Almost half of the injuries (208) occurred among children less than 16 years of age and 14 of them died in a bicycle crash. Among the injured children, two-thirds (134 of 208) involved head trauma. Half of the head injuries in Oregon resulted from collisions with motor vehicles. Other causes included falls, striking fixed objects, and collisions with other bicyclists. The incidence of bicycle-related injuries obtained from the Oregon Trauma Registry is likely to be an underestimation of the actual level of bicycle-related injuries in Oregon, because only the most severe injuries were reported to the registry.

Head injury and resultant injury to the brain is not amenable to treatment as are broken arms and legs. The subsequent outcomes of head and brain injuries such as hypoxia, hypercarbia, hypotension, intracranial hypertension, or infection, often lead to a poor outcome and increased mortality.[13] There is little satisfaction in operative reduction of complex fractures or closure of disfiguring lacerations during the early hours after the injury if the person suffers undetected intracranial hypertension with cerebral herniation while under the effects of anesthesia. Although serious head injury in older adolescents or adults affects the years of greatest productivity, infants and children face the need for continuing education with often diminished capacity for learning. Therefore, parents and schools confront significant emotional and educational challenges for children with severe head injuries. Even after minor head injuries, persons may experience "postcontusional syndrome" with persistent neurologic symptoms such as headache, dizziness, reduced memory, increased irritability, fatigue, inability to concentrate, and emotional instability.[14] In addition, the cost of bicycle-related head injuries cannot be ignored. The annual societal cost of bicycle-related injuries and deaths is nearly $8 billion, which is an average expected cost of injury of $120 per rider per year in the

United States.[4] According to a report by Ted Miller et al., the life-time cost of every nonfatal bicycle-related head injury in Oregon is $16,796.[15] Moreover, the emotional cost of patients and their families can never be measured.

2.2 The role of bicycle helmets in head injury prevention

The severity of a bicycle-related head injury depends not only on the velocity of the collision that produced it, but also on the shapes of the colliding objects and their rigidity. Severity can be reduced by energy-absorbing structures and padding materials by allowing simultaneous deformation of the body and of the surface collided with.

The importance of head injuries among causalities from two-wheeler crashes was noted more than 50 years ago by Cairns in army motorcyclists.[16] He advocated protective helmets, which became compulsory in the British Army in 1941 and in the Air Force in 1942.[17] In 1943, Cairns and Holbourn showed that wearing helmets reduced the incidence of skull fracture.[18] The use of helmets spread to non-military motorcyclists, and helmets themselves were much improved. Later, helmet use became more common in many countries.

The use of helmets by bicyclists is much more recent. In 1980, bicycle helmets were suggested as a way to reduce head injuries.[19-22] It was reasonably assumed that the benefits of helmet wearing would readily transfer from motorcyclists to riders of other two-wheeled vehicles. Like motorcycle helmets, bicycle helmets can prevent skull fracture and brain contusion by redistributing crash forces from localized points. Support for this assumption is given by McDermott and Klug, and by Waters who show that head injuries were proportionately more frequent in injured bicyclists (few of whom wore helmets) than in motorcyclists (most of whom wore helmets) despite the more severe body injuries and presumed more severe impact sustained by motorcyclists.[23-25] More recently, Williams studied the performance of helmets in bicycle accidents in Melbourne in 1989.[21] Of 143 bicyclists wearing a helmet at the time of an accident, 64 sustained an impact to the helmet. When the helmet stayed on the head and was not defective, no serious head injuries occurred despite some severe impacts. Serious head injuries and skull fractures occurred when the helmet came off the head or if it was defective.

The effectiveness of helmets in reducing injury has been shown in a number of studies that compared the frequencies of helmeted and unhelmeted riders who sustained head injury in bicycle crashes. In 1987, Dorsch et al., by means of a questionnaire to cycle club members who were asked to recall accidents and helmet use, found a reduction of 46% in the risk of brain injury by wearing a hard helmet of any quality.[22] In 1990, Wasserman and Buccini made use of a magazine-based questionnaires and found a 29% reduction in contusions and 82% in skull fractures.[26] These two studies have the limitations, as the authors acknowledged, of bias in both response and recall.

A case-control study by Thompson et al. in Seattle in 1989 compared 235 emergency room-attended patients with bicycle-related head injuries with a control group consisting of 433 persons who received emergency care at the same hospitals for bicycle injuries not involving the head.[27] The authors found that riders with helmets had an 85% reduction in their risk of head injury and an 88% reduction in their risk of brain injury. Since the study well controlled for cycling experience and the severity of the accidents in addition to sex and age, it provided compelling evidence of the effectiveness of bicycle helmets. The study finding was supported by a more recent case-control study conducted by Thomas S. et al. in 1994, who found that wearing a helmet reduced the risk of head injury by 63%.[28]

In 1993, McDermott et al. assessed the efficacy of helmet use by comparing crashes and injuries in 366 helmeted and 1344 unhelmeted causalities treated at Melbourne and Geelong hospitals or dying before hospitalization. They found that for wearers of approved helmets, the overall risk of head injuries was significantly reduced by at least 39% and face injury by 28%. When causalities with dislodged helmets were excluded, head injury was reduced 45% by approved helmets. Although their findings supported the study in Seattle, the magnitude of the injury reduction was less impressive.[29]

In summary, the protective effect of helmets in bicycle crashes have been shown accumulatively in previous studies. The magnitude of the head injury reduction varied from 40% to 88% in the different studies.

2.3 Biomechanical characteristics of bicycle helmets

A good helmet protects head by giving skull and brain a little time to match speeds with suddenly encountered objects. The outer palstic shell of a helmet adds load-spreading capacity and prevents objects from penetrating the helmet and causing injury to the head. The main body of the helmet has ventilation holes and is made of dense, crushable material that distriutes and absorbs the energy of an impact. During an impact, one's head actually crushed the helmet and the brain thereby gains a little extra time and distance to slow down. As the helmet is crushed, it applies siufficient force to slow one's head to a relatively gentle stop rather than the potentially lethal levels of force the head would sustain without a helmet. The chin strap is also very important. It must be strong, comfortable to wear and well-fitting. It should be buckled securely and snugly at all time so that in the event of a crash, helmet could keep on and protect the head.

The effectiveness of different helmet designs have been assessed by field tests and laboratory studies. The testing of bicycle helmets approved by either the American National Standards Institute or the Snell Memorial Foundation indicated that using any helmet will protect the brain and neck during a crash more effectively than not using any helmet at all.[30] However, these tests recognized several problems with helmet design. First, there is a tendency for all helmets to slip out of proper position with the unequal application of force. Second, hard-shell helmets tend to slide on concrete and thus potentially increase the risk for facial injury in a crash. Finally, it is possible for soft or no-shell helmets to catch or drag on concrete surfaces, which may cause the head to decelerate at a faster rate than the rest of the body and therefore potentially increase the risk of neck injuries.

The efficacy of different bicycle helmets varied notably depending on type and brand.[31,32] Subsequent tests indicated that helmets covered with a hard shell or microshell were less likely to cause injury to the head and neck region.[33] The amount of impact protection of helmets are generally tested by dropping the upper torso and helmeted head of a crash-test dummy onto a metal anvil and measuring the amount of force on the headform.[3] Testing for strap-system strength is done by dropping a weight on the fastened strap. There are three bicycle helmet standards: the Snell Memorial Foundation, the American Society for Testing and Materials, and the American National Standards Institute (ANSI) standards. Helmets that meet Snell standards provide better protection against bicycle-related head injury than do helmets that meet the less rigorous ANSI standard. Current testing standards do not take into account the fact that children <6 years of age cannot tolerate the same head impact as can older children and adults. Furthermore, helmets generally are not designed to fit the heads of children under 6 years of age.

In an effort to determine whether or not helmet wearing could result in more severe head injuries, Grimard et al. recently studied the characteristics of head injuries in 34 helmeted child bicyclists and 155 non-helmeted bicyclists aged 5-14 years of age. Their results showed that most of the head injuries sustained by the helmeted children were of mild severity, even though children in the helmeted group were in a greater proportion of bike-car collisions than the no helmet group. Therefore their findings did not provide evidence supporting the possibility that the helmet contributed to injury.[34] Unfortunately, the study was unable to obtain information on the type, damage to, and goodness of fit of the helmet.

2.4 Helmet use and its barriers

Although bicycle helmets have been shown to be effective in reducing the risk of bicycle-related head injuries, only approximately 18% of bicyclists in the United States wear helmets all or most of time.[4] The lowest prevalence (15%) of helmet use was found among school-age children who are at highest risk of bicycle-related injury.

In the spring of 1993, the Oregon Health Division conducted the Youth Risk Behavior Survey on 2,620 students in 25 middle and high schools.[35] The survey showed that 7% of students who rode bicycles reported wearing a helmet either all or most of the time; only 3.6% students reported always wearing their helmets. Further, information from the Oregon Trauma Registry indicated that only 18 of 134 children sustaining head injuries were wearing helmets at the time of injury.[36] Base on these statistics, the prevalence of helmet use by Oregon children was substantially lower than the year 2000 objective - a helmet use prevalence $\geq$ 50%.[5]

Confronted with low prevalence of helmet use by children, several studies have been conducted to understand the barriers to helmets wearing among child bicyclists. Using the focus group method with the fourth, fifth, and sixth graders, Howland et al. indicated that derision from their peers was one of the leading barriers to helmet use by children.[37] When students were asked whether they thought there should be a law requiring helmet use while riding bicycles, most students' responses suggested compliance: "I would wear one." "Nobody would laugh at you because you could laugh at them." "I wouldn't care because then everybody would have to wear one." "There should be a law. Nobody would be laughed at then."

Two studies by Diguiseppi et al. in Seattle revealed that helmet use was associated with the wearability of helmet, derision from peers, and a lack of knowledge regarding helmet effectiveness.[38,39] In addition, their study suggested that only 56% of children who owned helmets always wore them. Helmet ownership was found to be associated with parental education and cost. These findings were supported by Hu et al. recently who conducted a random digit dialing telephone survey to examine bicycle helmet ownership, helmet use, and related factors among 707 students in metropolitan Toronto.[40] Hu's study also indicated a positive role of parents in their children's helmet wearing.

Joshi et al. examined the association between helmet use and knowledge of helmet use benefits by conducting a survey among 655 cyclists aged 14-18 years in four large secondary schools in Oxford. They found that helmet wearers and non-wearers equally believed in efficacy of helmets. Two-thirds of teens thought that helmets looked ridiculous, and four-fifths of teens found them hot and uncomfortable. Both groups said that helmets spoiled the sense of freedom when you get on a bike. However, multiple regression suggested three attitudinal factors distinguished between helmet wearers and non-wearers. The first factor can be described as the amount of active consideration given to the helmet use. More non-wearers said that they had ‘so many issues to think about these days that helmets are pretty low’ on their agendas. The second factor was anticipated regret, which is characterized by their response to the statement 'I would never forgive myself if I had an injury that could have been prevented by wearing a helmet.' Helmet wearers were significantly more likely than non-wearers to agree with this statement. The third factor explaining helmet wearing was called conformity. Helmet wearers were more likely to wear a helmet if their friends also wore them. When asked about legislation to enforce helmet use, 55% of the entire sample felt that helmet wearing 'should be made law.' The results of this study suggested that beliefs in the effectiveness of helmets was not predictive of helmet wearing. Knowledge of the effectiveness of helmets may be a necessary, but not sufficient determinant of behavior.[41]

In summary, the prevalence of helmet use remains low, particularly among child bicyclists. Factors associated with helmet ownership include the level of parental education, annual family income, and the cost of helmets. Barriers of helmet wearing include derision from peers, poor design of helmets, lack of parental role in helmet using, and perhaps lack of knowledge about the efficacy of helmets by children and their parents.

2.5 Methods used to promote helmet use

Numerous efforts are under way across the country to increase helmet use. Of these efforts, education, subsidization of the costs of helmets, and legislation are three main approaches used by communities to promote helmet use. The methodology of each approach is discussed as follows.

2.5.1 *Education and subsidizing the cost of helmets*

People tend to attribute injuries to "human error" and hope that the injuries can best be prevented through voluntary behavior change. Therefore, education and subsidizing the cost of helmets have been widely used as main strategies to persuade individuals to change their behavior and thereby reduce the risk of injury. Educational programs have generally been conducted in schools by means of videos, literature, distribution of workbooks emphasizing methods for teaching bicycle safety, distribution of coupons for discounts on helmets to low income children, distribution of posters and handbooks on bicycle safety, incorporation of a bicycle safety curriculum into physical education courses, and promotion of bicycle safety as part of local news media coverage. During 1986, the Children's Bicycle Helmet Coalition in Seattle implemented an intensive educational program to reduce bicycle-related head injuries among children by promoting the use of helmets.[6] Components of the Seattle children's bicycle helmet campaign included public and physician education, school safety programs, an outreach campaign for low-income populations, extensive media coverage, and informational brochures on monthly insurance and utility bills. To assess the effect of the program, DiGuiseppi et al. observed 9827 children bicyclists before, during, and 16 months after the start of the campaign.[38] The results showed that helmet use increased from 5.5% before the campaign to 15.7% afterwards; 84.3% of children were still unhelmeted. However, this evaluation study suggested that educational efforts alone could not persuade the majority of child bicyclists to wear helmets.

The findings from Seattle were supported by Morris and Trimble in Canada.[42] They compared the strategies of helmet promotion in three schools that were randomly allocated to receive either no intervention, education only program, or education plus providing reduced-price helmets. Their results showed no impact of the educational program, while the proportion of helmet wearers at the school that obtained the subsidy plus education significantly increased from 0% to 22%. This study implies that an educational program in conjunction with a subsidy may effectively increase helmet use among children.

In 1993, Parkin et al. evaluated the effectiveness of a school-based bicycle helmet promotion program in Toronto, Canada.[7] The program activities included developing resources package, producing posters that promoted helmet use, heightening parents' awareness about bicycle-related head injuries and the effectiveness of the helmets, and providing reduced price helmets to children from low-income families. The results of the

Another problem with education-based approaches is that, despite the large body of research on human behavior, individual traits that are easily modifiable for injury control have thus far not been identified. Although age and sex were identified as factors associated with helmet use, they are not modifiable.

2.5.2 *Laws mandating bicycle helmet use*

The findings from the above studies served as the foundation for the states to mandate bicycle helmet use in children under 16 years of age, as an alternative best way to encourage children to wear helmets. Although lack of knowledge about the importance of helmet use was being addressed in numerous educational campaigns, education alone has not been sufficient to increase helmet use substantially. Peer pressure changes as behavioral norms change. When most children wear helmets, peer pressure may bring nonwearers into conformity. Therefore, the advantage of implementing a helmet use law may lie in its ability to eliminate peer derision to helmet ownership and use.

The effectiveness of laws and regulation in changing individual behaviors also is suggested in studies evaluating the impact of seat belt use laws and motorcycle helmet use laws.[45-47] For example, in the absence of laws requiring the use of protective helmets, only about 50% of motorcyclists voluntarily wore them, but helmet use laws resulted in almost 100 percent use.[45]

Howard County in Maryland was the first community in the U.S. to mandate the wearing of bicycle helmets for children under 16 years of age, after the bicycling deaths in 1989 of two children in the county.[48] The law, which became effective in October 1990, provides for fines ranging from $25 to $200 that may be waived if a helmet is purchased. The police send warning letters to parents of unhelmeted children and issue a citation after the third offense. The effects of legislation were evaluated by comparing the observed helmet use of Howard county to use in two adjacent counties: Montgomery (education only) and Baltimore (laissez faire). The results demonstrated that observed helmet use in Howard county increased from 4% pre-law to 47% post-law, whereas the helmet use only increased by 11% in Montgomery county and even decreased by 15% in Baltimore county.

The effect of the law in Howard county was confirmed by a self-report survey among fourth-, seventh-, and ninth-grade students attending a stratified sample of public schools in Howard County and in two adjacent counties (Montgomery and Baltimore) without helmet laws. Self-reported helmet use in Howard County rose from 11% to 37% after the law and an accompanying educational campaign were implemented. Like the results from direct observations, helmet use changed only from 8% to 13% in Montgomery County and from 7% to 11% in Baltimore County.[49] Although this study validated the observational study, it suffered from the problem of having a low response rate (48%). Since participation in the survey was voluntary and anonymous, it was unknown whether the nonrespondents differed significantly from the respondents.

Limitations of the two evaluation studies in Howard County notwithstanding, the experience in Howard county provide strong evidence in support of the helmet use law. Yet, it is questionable whether a generalized conclusion can be drawn, because Howard county is an affluent and homogeneous community, whose action was precipitated by the well publicized tragic deaths of two children from bicycle crashes.

The findings from Victoria, Australia also support the effectiveness of legislation on helmet use and bicycle-related injuries.[50] On July 1990, a statewide law requiring the wearing of an approved safety helmet by all bicyclists became effective in Victoria. Implementation of the law was followed by a sustained and comprehensive campaign to promote helmet use, including educational programs, mass media publicity, financial incentives, and efforts by professional, community, and bicycle groups. The overall helmet wearing proportions in Victoria were estimated by combining the results of observation surveys in the city of Melbourne and elsewhere in proportion to the population distribution. Observational surveys of helmet use indicated an increase from 31% during 1980 to 75% during 1991. Substantial increases occurred among all age groups, although the proportions of use were lowest among teenagers. Concurrent with the increase in helmet use, the number of cyclists killed or hospitalized with head injuries decreased by 51%, and the number with similarly severe injuries other than to the head decreased by 24%; for public hospital admissions, these numbers decreased 37% and 21%, respectively.

The substantial increase in helmet use accompanied by a reduction in head injury notwithstanding, the changes in helmet use and the injuries in Victoria may be attributable to several other factors, including the decline in bicycle use by children, the possibility that, by wearing helmets, bicyclists are more likely to be noticed by motorists; the effect of educational efforts and publicity in improving the safety practices of bicyclists, and risk behavior changes of motorists such as avoiding drinking and high speeding driving. Further efforts are needed to identify the most important components of the combined legislative and educational approach and to measure the effectiveness of the program in reducing head injuries.

The effectiveness of the laws was evaluated from a cost-effectiveness point of view. Hatziandreu et al. compared a legislative program with a community-wide program and a school-based program, regarding the cost of the program and its effect on helmet use.[51] The legislative program had the lowest cost ($36,643) per head injury avoided, compared with the community and school programs ($37,732 and $144,498, respectively). Additionally, the legislative program resulted in an immediate increase in helmet use. Therefore the authors concluded that the legislative program appeared to be the most cost-effective.

However, the value of the laws has been challenged despite the overwhelming evidence of the injury-reducing benefits of many mandated laws. First, the laws tend to be least effective in changing individual behavior among the groups that are at higher risk of injury. For example, in several countries with seatbelt use laws, seatbelt use was observed to be substantially lower among teenagers and persons with high blood alcohol concentrations - two groups with high risk of involvement in serious motor-vehicle crashes.[52] As a result, seatbelt use laws typically do not reduce fatalities as much as would be expected on the basis of the known effectiveness of belts when used.[53] Additionally, some people have argued that the effectiveness of mandatory approaches could be partially or wholly offset by changes in behavior by persons who take greater risks to compensate for their increased safety.[54] A number of variations on this notion of human behavior has been developed, and they have been referred to as the "risk-compensation" hypothesis.[55] This view of human behavior has been the subject of considerable theoretical debate, as well as prolonged dispute on the extent to which the benefits of federal motor-vehicle safety standards might have been reduced because of such compensation.[56,57,58]

The debate continues, but the evidence is compelling that the legislation mandating the use of safety devices have substantially reduced fatalities.[59] Moreover, a study of cyclists in Australia suggested that there was no increase in risk taking behavior after helmet legislation.[60] Recently, their finding was supported by Joshi et al..[41] In their study, most of the bicyclists surveyed rejected the notion that helmets would or do cause them to increase their risk taking behavior.

At this time, nine states and four localities have enacted laws requiring bicycle helmet use.[3] These states and communities include California, Connecticut, Georgia, Massachusetts, New Jersey, New York, Oregon, Pennsylvania, Tennessee, Howard county, Montgomery county, and Allegheny in Maryland, and the city of Beechwood in Ohio. Before expanding enactment of other bicycle helmet laws, it is critical to determine whether the legislative approach in more diverse, larger geopolitical levels is as effective as been shown in smaller geographic areas.

2.6 The Oregon bicycle helmet use law

In 1993, the Oregon legislative passed Senate Bill 1088 that requires children under 16 years of age to wear helmets while bicycling or while riding as a passenger on a bicycle. The law, which became effective in July 1994, provides for a maximum fine of

$25 for children not wearing helmets while bicycling on public roadways. The legal guardian will be issued the citation if the child is 11 years or younger. If the child is 12-15 years of age, either the child or the guardian may be issued the citation. The fine will be waived for the first offense, if the person proves that he or she has obtained the necessary helmet.

2.7 Methods used to evaluate the helmet use laws

The effectiveness of the Oregon helmet use law can be determined by its impact on helmet use and occurrence of bicycle-related head injury, and by its economic impact on society. The current study focuses on the effect of the law on helmet use and bicycle-related head injury. Because the law targets promotion of helmet use, the latter is reasonable only if the law increased helmet use.

2.7.1 *Measurement of changes in helmet use*

To evaluate the effectiveness of the laws in increasing helmet use, three main approaches generally have been used to measure helmet use in evaluation of bicycle helmet promotion programs: classroom surveys of students, telephone surveys of parents, and direct observational surveys.[38,49,61]

In classroom surveys, teachers read questions concerning students' bike riding, helmet owning, and helmet use, etc.[38] Students were asked to raise their hands if their responses are "yes" to each question. Teachers question girls and boys separately and tally the answers on the questionnaire. The classroom surveys are inexpensive, are easy to be administered, and thus are commonly used to obtain information on helmet use and owning.

Nevertheless, classroom surveys have several limitations. First, these surveys provide only aggregated data instead of individual data on bike riding and helmet use frequencies. Thus, influential factors identified at the classroom level may be questionable. For example, an association between helmet use and attitudes about the helmet law may be established if classes with a high proportion of children who support the law tend to have higher proportion of helmet wearing. Yet, this association may not be true, if children who support the law actually do not wear helmets. Secondly, because of peer pressure, a child might tend to respond to each question as did his/her peers, which would result in a homogenous response within a classroom and a heterogenous response between the classrooms. Finally, the surveys rely on self-reported data that are subject to low reliability and validity.

Telephone surveys of parents are another commonly used approach in evaluation studies.[61] Parents of bike-riding children are asked about their child's bike riding habits, helmet ownership, and helmet wearing. Information regarding parents' education level and family income also can be obtained. Since the attitude of parents regarding helmet use affects their children's helmet wearing behavior, surveys of parents can provide information on barriers of helmet ownership and helmet use. Like classroom surveys, this type of survey is subject to problems of possible low reliability and validity. Parents of bike-riding children may overestimate their children's helmet use because they are not aware of children's behaviors outside of home neighborhood.

An alternative evaluation approach is to directly observe bicycle riders to determine whether they wear helmets.[38] Because observational surveys offer far greater confidence in the validity of measures than do self-reported surveys, they are considered a gold standard method of helmet measurement.

Observational studies, however, can require considerably more resources than do surveys. Sampling for observational studies is more problematic than for surveys. In many cases observational studies are designed without adequate consideration for the extent to which the locations selected for study provide observations that represent bike riding behavior of the target population. Optimal observation locations of the study vary depending upon the purpose of a study. In many traffic safety studies, locations generally are chosen strictly on the basis of a high volume of traffic flow. Interpretation of observational study data as a reflection of the "true" helmet use pattern of the bike riding population in the community is difficult from such samples. In studies in which children are the subjects, school yards and/or playgrounds often are selected. However, it may not be possible to determine whether school yard or playground bike riding represent the total bike riding population or if trips to the playground are representative of typical biking trips. In many schools, the number of children who ride bikes to school is small, especially in communities in which schools are located on major roads with no sidewalks or bike paths.

Consequently, researchers should keep in mind that each method has limitations. Application of these approaches should be based on actual circumstance, surrounding environment, and specific study purpose.

2.7.2 *Measurement of changes in head injury*

The majority of studies utilized data collected at emergency departments to identify changes in head injury.[50,62,63,64] The advantage of using this data source lies in its convenience and availability. The disadvantage of using emergency-room data is that these data include only the most severely injured cases, but miss those mild injury cases who only visit the outpatient clinic. It is possible that mildly injured cases are more likely to wear a helmet at the time of bicycle crashes. If there are more (or less) mild injury cases at post-law, results based on these data could be biased. Another disadvantage of using hospital data is that these data do not include fatal injury cases who die at the scene and thus are not sent to hospitals. If fatal injury cases are less likely to wear helmets and there are more (or less) fatal injury cases after the legislation, the evaluation results based hospital data could be misleading.

Another approach to measure changes in head injury is to link trauma data to death certificate records to identify cases of riders who die at the scene of accident. The problem with death certificates is that medical examiners usually do not report the use of helmets at the time of bicycle crashes.[64]

Self-report surveys can be used to collect data on mild injury cases which are not included in trauma and death data. Because the incidence of the injury is low, population-based surveys can be expensive, and therefore surveys have not been used as a main approach for evaluation.

In summary, competitive and recreational bicycling carries a health risk, especially among children. Although a growing body of evidence supports the protective effect of bicycle helmets on head injuries, the prevalence of helmet use among Oregon children has remained low. Numerous efforts have been made across the country to promote helmet use, including education, subsidizing the cost of helmets, and legislation. Previous studies in several communities suggested that legislation, along with an educational effort, might be an effective approach to persuade children to wear helmets. Yet only one fifth of states are implementing such helmet laws. Additionally, few studies have provided evidence from a statewide experience about the effectiveness of a helmet law. Implementing the Oregon helmet law provides an opportunity to examine whether or not such legislation can effectively promote bicycle helmet use in a diverse population of children, and if so, to clarify the efficacy of helmet use in reducing bicycle-related injuries.

3. DO LAWS INCREASE BICYCLE HELMET USE? - THE OREGON EXPERIENCE

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3.1 Abstract

Objectives. To evaluate an Oregon law requiring bicyclists <16 years of age to wear a helmet and compare methods of measuring helmet use.

Design. Four pre- and post-law statewide helmet use surveys: 1) statewide observations; 2) observations at schools; 3) classroom self-report surveys; and 4) telephone surveys of adults.

Setting. Oregon.

Subjects. Statewide observations: 3,313 child bicyclists at 13 sites; school observations: 995 child bicyclists at 33 randomly selected middle schools; classroom surveys: 4th, 6th, and 8th graders (8,955 students) in 448 classrooms (pre-law) and 456 classrooms (9,811 students) post-law in 66 randomly selected schools; and telephone survey: 1,219 randomly-dialed parents of 1,437 children <16 years of age.

Main Outcome Measures. Pre- and post-law helmet use and ownership; knowledge and opinion about the law.

Main Results. Observed helmet use among youth was 24.5% pre-law and 49.3% post-law. School-observed use went from 20.4% to 56.1%. Classroom survey self-reported "always" use of helmets went from 14.7% to 39.4%; reported use on the day of the survey went from 25.8% to 76.0%. Telephone survey-reported "always" helmet use went from 36.8% to 65.7%. Younger and female children were more likely to use helmets. Most students (87.8%) and parents (95.4%) knew about the law; however, only 42.6% of children thought the law was a good idea.

Conclusions. We conclude that 1) the law increased helmet use; 2) although use estimates differ, all helmet surveys showed similar degrees of pre- and post-law change; 3) half of child bicyclists are still unhelmeted, indicating a need for additional helmet promotion. Laws appear an effective way to increase helmet use.

3.2 Introduction

Head injury is the most common cause of death, disability, and serious injury in child bicyclists who crash.[1-3] Despite growing and convincing evidence showing that helmets are effective in reducing the risk of bicycle-related head injuries,[4-6] only 15% of bicyclists under 16 years of age in this country wear helmets all or most of the time.[7]

To address this problem, Oregon passed a law that, as of July 1994, requires children under 16 years of age to wear a helmet while riding a bicycle on public property or be subject to a $25 fine. The effectiveness of such statewide legislation in increasing helmet use has not been well documented. Moreover, it remains unclear which method (e.g., observation[8], self reports of children,[9] proxy reports by adults[10]) should be used to evaluate helmet use. Clarification of the effectiveness of the law and the best method to measure helmet use could help others determine optimal methods for promotion of helmet use and evaluation of the effort.

We report here the results of a study begun in 1993 by the Oregon Health Division and the National Center for Injury Prevention and Control. The study objectives were to determine the effectiveness of the statewide law, compare different methods of measuring helmet use, and measure public knowledge and opinion about the law.

3.3 Methods

We conducted four types of pre- and post-law helmet use surveys: 1) statewide observational surveys; 2) observational surveys at schools; 3) classroom surveys of self-reported helmet use; and 4) statewide telephone surveys of adults, i.e., the Behavioral Risk Factor Survey (BRFS).[11]

Since using a helmet is conditional on having access to one, helmet ownership becomes one of the main factors influencing helmet use. On the other hand, owning a helmet is not necessarily followed by wearing it. Therefore, we assessed the effect of the law on both helmet use and helmet ownership. Whereas all surveys assessed helmet use, classroom surveys of children and telephone surveys of parents also measured helmet ownership, determined the law's effects in subpopulations, and examined knowledge and opinion about the law. Methods for each survey type follow:

3.3.1 *Statewide observational survey*

The Oregon Department of Transportation has been conducting statewide observational surveys of bicycle helmet use biennially since 1986. The July through September 1993 survey was used for the pre-law data. At the request of the Oregon Health Division, the State Department of Transportation repeated the survey during the same months in 1994 for the post-law data.

Observations were taken at 13 sites throughout Oregon, on arterial streets with fairly high traffic volumes where most bicyclists travel for utilitarian purposes. Four of the sites were in the Portland metropolitan area, four in large towns, and five in smaller towns or rural areas. The surveys were conducted primarily during weekdays with occasional checks during weekends. Each location was observed for two 7.5-hour shifts. Trained observers either sat in an automobile or stood nearby and marked their observations on a tally sheet. On the basis of physical appearance, observers estimated riders' ages as more than 17 years or less than 18 years.

3.3.2 *Middle school observational survey*

Observations were made during May and June 1994 (pre-law) and the same months of 1995 (post-law). Because few elementary school students rode bicycles to school, observations were made at 33 middle schools randomly selected throughout the state. Middle schools in Oregon typically include 6th, 7th, and 8th graders, although a few of them also include 5th graders (our sample contains no middle schools with 5th graders). Because few middle school students in Oregon are older than 16 years of age, all children observed were considered as under 16 years of age. Each site was observed for one hour either during the morning or afternoon period. Morning observations began 45 minutes before the start of the school day and continued for 15 minutes after the start of school. Afternoon observations began 15 minutes before the end of the school day and continued for 45 minutes after school ended. During the post-law observations, one middle school closed; thus, the post-law survey was conducted at 32 schools. Data collected included sex of the rider, helmet usage, and improper use or not. Improper use of helmets refers to bicyclists who had a helmet in possession but were not using it or wore an unfastened helmet.

3.3.3 *Classroom survey*

In collaboration with the Oregon Department of Education, we surveyed students at the 33 middle schools where the observations were made. In addition, we surveyed students at 33 elementary schools randomly selected throughout the state. At each school, all 4th, 6th, and 8th graders were surveyed during May and June 1994 as a baseline (pre-law). The survey was repeated among new 4th, 6th, and 8th graders during September and October 1994 (post-law). During the post-law survey, one elementary and one middle school had closed; thus, the post-law survey was completed in 64 schools.

Homeroom teachers administered the survey by asking the children to raise their hands for "yes" responses to each question. Teachers questioned girls and boys separately and recorded tallies for each question. The survey covered bicycle riding, helmet ownership, helmet use during the past month (never, rarely, half the time, most of the time, and always), and helmet use while riding a bicycle to school on the day of the survey. Students were asked whether they knew if there was a law in Oregon that requires people less than 16 years of age to wear a helmet at all times while riding a bicycle, whether they thought that the law was a good idea, and whether or not they would wear a helmet if they had to pay a $25 fine for not doing so.

Since data were collected at the class level, results obtained from students may not be independent of each other. To test for statistical significance and to determine confidence intervals, the variances of proportions of helmet use were calculated using the number of classrooms surveyed as the number of independent events (n).[8] This gave smaller values for the effective sample sizes and larger values for the variances, and thus resulted in more conservative significance tests.

3.3.4 *Behavioral risk factor telephone survey (BRFS)*

Beginning in September 1993, Oregon added questions to the BRFS to assess bicycle helmet use by children. About 231 Oregon households are randomly selected each month with the Waksberg random digit three-stage sampling technique.[12] Parents of bike-riding children under 18 years of age were asked about their children's bicycle riding habits, helmet ownership, frequency of helmet use during the past month (never, less than half the time, about half the time, more than half the time, and always), and the respondent's knowledge about the existence of the law. Demographic information collected included age, education of respondents, and annual income of the household. Our analysis is based on data collected from September 1993 through November 1994. Bicycle-riding children 16 to 18 years of age were excluded from this analysis since the law did not mandate helmet use for them.

To make projections from the sample to the general population, BRFS data are weighted by a national standard procedure .[13] When data on helmet use by Oregon children were analyzed, we modified the standard weighting procedure by: 1) removing the number of adults in a household and 2) by using 1994 state population figures for children under 16 years of age instead of the adult population figures. Consequently, we adjusted for the following: 1) the number of telephone numbers per household; 2) the number of interviews completed per cluster; and 3) the demographic distribution of the child sample. When data on parental knowledge of the existence of the law were analyzed, the standard weighting procedure was used. We present weighted prevalence for the BRFS data throughout the text. Because of the large sample sizes, a z test was used to test for pre- and post-law differences.

3.4 Results

Pre-law and post-law samples for each of the four types of surveys appeared comparable with respect to rider sex, place, grade or age, household income, and parents' education (Table 3.1).

3.4.1 *Helmet use*

All survey types showed significant increases in helmet wearing from the pre-law to post-law period (Table 3.2). The largest pre- and post-law difference in helmet use (50.2%) was recorded by the classroom survey question about helmet use while bicycling to school that day. The least amount of difference was noted in the statewide observations (24.8%) and the classroom survey of "always" use during the past month of riding (24.7%). In terms of actual estimated use, the statewide and school-site observational surveys were quite comparable. The telephone survey gave the highest estimates of actual use. The classroom survey employing "always" use gave the lowest use estimates and the day of survey riding gave the highest post-law estimate (76.0%).

Based on the self-reported "always" helmet use, the pre- and post-law increase was similar for 4th and 6th graders, but less for 8th graders (Table 3.2). Among children who reported bicycling to school on the day of the survey, the increase in use diminished with increasing grade (Table 3.2).

Table 3.1 Characteristics of child bicyclists, by types of studies, Oregon, 1994

Characteristic	Pre-law No. of Riders (%)	Post-law No. of Riders (%)
Statewide observation[a]	1610 (100.0)	1703 (100.0)
Portland metro	418 (26.0)	500 (29.4)
Large city	708 (44.0)	705 (41.4)
Small town	484 (30.1)	498 (29.2)
School observation	558 (100.0)	437 (100.0)
Sex Male	456 (82.0)	348 (80.0)
Female	102 (18.0)	89 (20.0)
Place Urban	133 (23.8)	91 (20.8)
Non-urban	425 (76.2)	346 (79.2)
Classroom survey		
Past month riders	7088 (100.0)	7417 (100.0)
Sex Male	3880 (54.7)	4089 (55.1)
Female	3208 (45.3)	3328 (44.9)
Grade 4th	1284 (18.1)	1320 (17.8)
6th	2720 (38.4)	2994 (40.4)
8th	3084 (43.5)	3103 (41.8)
Day of survey riders	481 (100.0)	430 (100.0)
Sex Male	380 (79.0)	340 (79.1)
Female	101 (21.0)	90 (20.9)
Grade 4th	83 (17.3)	55 (12.8)
6th	171 (35.6)	171 (39.7)
8th	227 (47.2)	205 (47.6)

Table 3.1 Continued

Characteristic	Pre-law No. of Riders (%)	Post-law No. of Riders (%)
Telephone survey	961 (100.0)	476 (100.0)
Age(years)		
<5	86 (8.9)	40 (8.4)
5-10	515 (53.6)	251 (52.7)
11-15	360 (37.5)	185 (38.9)
Education of respondents		
< 12 years	86 (8.9)	43 (9.0)
12 or GED	326 (33.9)	151 (31.7)
13-15	301 (31.3)	165 (34.7)
16+	248 (25.8)	117 (24.6)
Household income ($)[b]		
<15000	163 (17.9)	48 (11.4)
15000-	179 (19.6)	78 (18.5)
25000-	174 (19.1)	78 (18.5)
35000-	230 (25.2)	138 (32.8)
≥50000	166 (18.2)	79 (18.8)

[a]Average of 124 riders observed per site pre-law and 131 post-law.
[b]Income level was not obtained from 49 subjects pre-law and 55 subjects post-law.

Female students showed the biggest increases in use in both the classroom surveys and the school site observations (Table 3.2). The school site survey also found improper use of helmets among 6.6% of riders with helmets pre-law and 8.6% post-law.

Table 3.2 Pre- and post-law helmet use by bicycle-riding children, Oregon, 1994

Characteristic		% helmeted Pre-law	% helmeted Post-law	Prevalence difference[a]	Effectiveness[b]
Statewide observation		24.5	49.3	24.8	32.8
Portland metro		27.3	49.4	22.1	30.4
Large city		25.8	49.6	23.8	32.1
Small town		20.0	48.8	28.8	36.0
School observation		20.4	56.1	35.7	44.8
Sex	Male	19.5	53.7	34.2	42.5
	Female	24.5	65.2	40.7	53.9
Classroom survey					
Always use past month		14.7	39.4	24.7	30.0
Sex	Male	12.8	34.0	21.2	24.3
	Female	17.0	45.9	28.9	34.8
Grade	4th	30.0	58.0	28.0	40.0
	6th	18.0	47.0	29.0	35.4
	8th	5.6	24.0	18.4	19.5
Days of survey riders		25.8	76.0	50.2	32.9
Sex	Male	26.3	72.6	46.4	63.0
	Female	23.8	88.9	65.1	85.4
Grade	4th	39.8	96.4	56.6	94.0
	6th	28.7	80.7	52.0	72.9
	8th	18.8	66.3	47.5	58.5

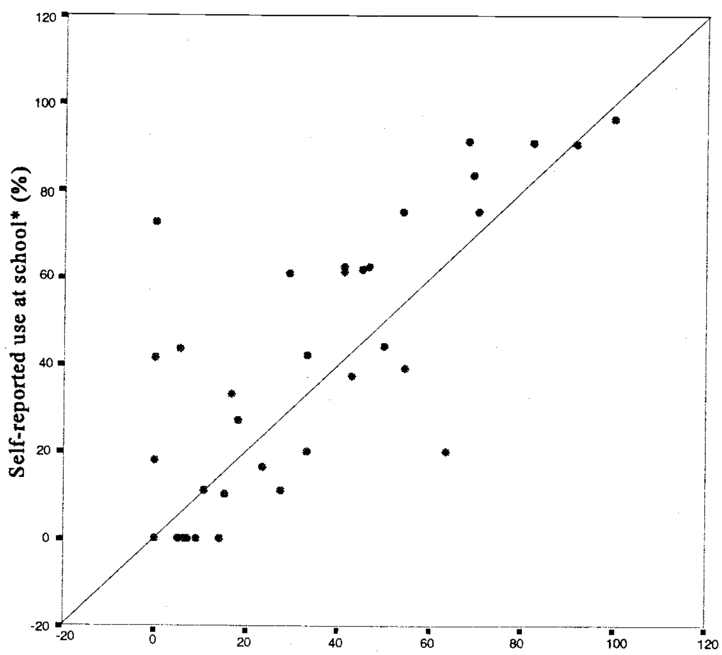
Table 3.2 Continued

Characteristic	% helmeted		Prevalence difference[a]	Effectiveness[b]
	Pre-law	Post-law		
Telephone survey[c]	36.8	65.7	28.9	45.7
Education of respondents (years)				
<12	15.3	54.8	39.5	46.6
12 or GED	34.6	66.8	32.2	49.2
13-15	42	69.9	27.9	48.1
16+	49.7	77.8	28.1	55.9
Household income ($)[d]				
< 15000	28.2	60.4	32.2	44.8
15000-	32.2	64.1	31.9	47.1
25000-	37.6	77.6	40.0	64.1
35000-	45.4	72.5	27.1	49.6
≥50000	49.4	68.3	18.9	37.4

[a]All pre- and post-law differences are statistically significant ($P<0.01$).
[b]Effectiveness = (pre-law unhelmeted% - post-law unhelmeted%)/pre-law unhelmeted%.
[c]Weighted percentages are presented.
[d]Income level was not obtained from 19 helmeted subjects pre-law and 38 helmeted subjects post-law.

Because both surveys reflect helmet use among children who rode bicycles to school, we compared the school observations to the reported use on the day of survey from the classroom survey. To obtain reliable estimates, we only included schools that had five or more bike riders seen on the school-site observational surveys and reported by the students on the day of the classroom survey (20 such schools pre-law and 14 post-law). The observed use for the entire school was found to be highly correlated with self-reported use at the school were highly correlated (r=0.76, $P< 0.01$) (Figure 3.1). In general, estimated helmet use by the classroom survey was greater than what was observed at that school.

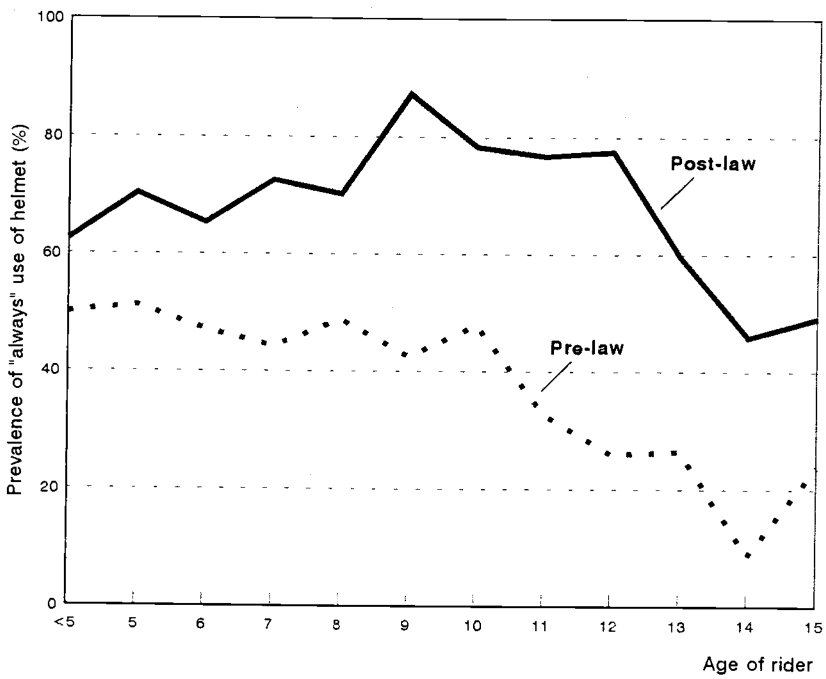
Figure 3.1 Scatter plot of schoolwide helmet estimates: school observation vs classroom self-report survey, Oregon, 1994



*Helmet use on the day of the classroom survey

From the telephone survey, we noted that helmet use increased across all age groups, though the change was more pronounced among older children aged 9 through 12 (Figure 3.2). The increasing trend was also found across all parental education and household income levels (Table 3.2). Helmet use was correlated with household income (trend test: $P<0.001$) pre-law, but not post-law.

Figure 3.2 "Always" use of helmet, by age and law status, behavioral risk factor survey, Oregon, 1993-1994



3.4.2 *Helmet ownership*

According to the classroom survey, helmet ownership increased from 51.5% of bicyclists pre-law to 75.5% post-law (Table 3.3); the increase was more striking among students in higher grades. The effect of the law on helmet ownership was unassociated with sex and place (urban vs. non-urban).

According to the telephone survey, helmet ownership increased to a lesser degree than reported in the classroom survey (Table 3.3). The law appeared to have a greater effect on ownership among children whose parents or guardians were not highly educated

Table 3.3 Pre- and post-law helmet ownership, Oregon, 1994

Characteristic		Pre-law No. studied	Pre-law Owning helmet%	Post-law No. studied	Post-law Owning helmet%	Prevalence difference[a]
Classroom survey		8277	51.5	9303	75.5	24.0
Sex	Male	4319	51.1	4754	76.5	25.4
	Female	3958	51.9	4549	74.4	22.5
Place	Urban	2542	55.0	3501	76.5	21.5
	Non-urban	5735	50.0	5802	74.4	24.4
Grade	4th	1348	68.7	1534	83.4	14.7
	6th	3094	60.5	3506	81.7	21.2
	8th	3835	38.2	4263	67.6	29.4
Telephone survey[b]		961	67.4	476	83.9	16.5
Education of respondents (years)						
	< 12	86	46.3	43	60.8	14.5
	12 or GED	326	59.0	151	84.0	25.0
	13-15	301	71.6	165	87.7	16.1
	16+	248	81.4	117	86.9	5.5
Household income ($)[c]						
< 15000		163	49.1	48	70.8	21.7
15000		179	63.7	78	82.1	18.4
25000		174	66.7	78	92.3	25.6
35000		230	73.0	138	87.0	14.0
≥50000		166	80.7	79	84.8	4.1

Table 3.3 Continued

Characteristic	Pre-law		Post-law		
	No. studied	Owning helmet%	No. studied	Owning helmet%	Prevalence difference[a]
Age (years)					
<5	86	71.4	40	85.0	13.6
5-10	515	75.7	251	88.1	12.4
11-15	360	54.3	185	77.8	23.5

[a]All pre- and post-law differences are statistically significant; for the classroom survey, the number studied. refers to the number of bicycle owners; for the telephone survey, it refers to the number of bicycle riders.
[b]Weighted percentages are presented with unweighted cell counts.
[c]Income level was not obtained from 49 subjects pre-law and 55 subjects post-law.

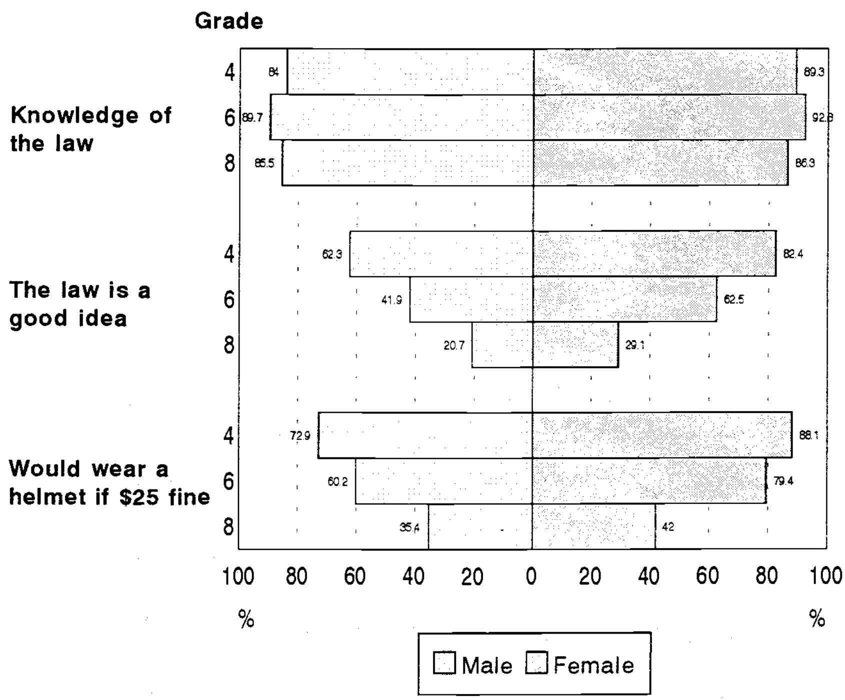
and among low income children. As with helmet use, the association between helmet ownership and household income was significant pre-law but not post-law. Reported "always" use among helmet owners increased from 57.7% pre-law to 83.0% post-law (P<0.001).

3.4.3 *Knowledge and opinion about the law*

The majority (87.8%) of students knew about the helmet law after it went into effect (Figure 3.3). Male and female students were equally well informed, as were all grades. Overall, only about half (42.6%) of the students thought the law was a good idea. Boys in all grades were less likely than girls to think it a good idea and also less willing to wear a helmet even if there was a $25 fine for not doing so ($P<0.01$ for boys/girls comparisons of all grades). Similarly, older children appeared less likely to think the law a good idea (trend test: $P<0.01$) and less likely to be influenced by the threat of a fine (trend test: $P<0.01$).

Like students, 95.4% of parents were aware of the law after it went into effect. Knowledge of the law was unassociated with respondents' sex, income or education.

Figure 3.3 Post-law knowledge and opinion about the helmet use law, by sex and grade, classroom survey, Oregon, 1994



3.5 Comments

Oregon's mandatory helmet use law was accompanied by roughly a doubling in helmet use; one-third of unhelmeted child bicyclists started to wear helmets. Thus, Oregon's children have already achieved the Year 2000 National Health Objective of 50% helmet use.[14] Positive effects from helmet laws have also been found in studies in Howard county, Maryland[9,15] and Victoria, Australia.[16] In Howard County, observed helmet use went from 4% pre-law to 47% post-law. This increase occurred in an affluent, homogeneous community, whose law was precipitated by the well-publicized tragic deaths of two children from bicycle crashes.[17] In Victoria, the passage of the all ages use law was preceded by a decade of sustained and comprehensive helmet promotion and education. Pre-law use was 31% and post-law use was 75%.

Only one similar evaluation of a statewide law targeted at children less than 16 years of age without prior intense promotion has been reported.[10] Using adult BRFS telephone respondents giving proxy reports about their children's behavior, the study found that helmet use in Georgia went from 33% pre-law to 52% post-law and that helmet use was associated with household income and inversely associated with rider age. In that study, 29.5% of post-law households were unaware of the law.

Our study found that, although helmet use increased with household income, low income children had greater increases in helmet use and ownership. These increases in ownership may be partly attributed to community helmet giveaway programs. Parkin et al. found that a helmet subsidy program in a low-income area increased helmet ownership but not use, suggesting that removal of economic barriers did not ensure a change in children's behavior.[18] The Oregon experience demonstrates that legislation is an effective strategy in increasing helmet use in low-income children as well as higher income children, perhaps by obviating the fear of peer derision, one of the main barriers to helmet use by children.[19,20] Our finding that older children were less likely to use helmets is consistent with previous studies.[9] Because younger children appear more likely to comply the law, helmet use by Oregon children may continue to increase as younger children grow up with the law. Prior studies have suggested equal compliance by gender,[9,10] a finding not replicated here.

Direct observation of helmet use is considered by many the "gold standard" method for measuring helmet use. Unfortunately, observational surveys are logistically complex and expensive to conduct. In particular, it is problematic to define a sampling frame and to estimate correctly the age of passing bicyclists. For observations at schools, relatively few child bicyclists ride to school on a given day, i.e., 6.9% pre-law and 5.8% post-law. On the other hand, self-report surveys can gather detailed data that observational surveys cannot, e.g., helmet ownership, knowledge of and attitudes towards the law, and demographic characteristics such as income or correct age. In addition, they are simpler to administer, have a known sampling frame, and are less costly than observational surveys. Self-report surveys have been questioned, however, because of the tendency to overreport "healthy" behaviors relative to the way respondents actually behave.[21] The extent of this overreporting problem for estimating child helmet use via proxy reports from adults is unknown, but our data would suggest it is substantial.

Our study suggests that classroom and telephone surveys are useful in assessing pre- and post-changes, although the actual estimates of helmet use appear inflated relative to what was observed. The extremely high reported use in the post-law classroom survey about riding to school that day may be attributable to the children's desire to display acceptable behaviors or to seasonal variation. Compared to self-reports by children, parents reported higher values for helmet ownership and use. The choice of which survey type to use will probably depend on the question to be answered. Based on the similar estimates of effectiveness of the law (Table 2), any of the survey types seem adequate to detect the changes due to the legislation.

There are a number of limitations to our studies. First, the selected sites for the statewide observations were arterial routes with high traffic flow. Cyclists near traffic may be more likely to wear helmets and are, therefore, nonrepresentative; alternatively, these observations may be heavily weighted towards older child bicyclists (e.g., 16 to 17 years of age) who are less likely to wear helmets than younger children, yet are counted as child cyclists. Similarly, the children observed riding to school may not be representative of helmet use in all children affected by the law; for example, middle school children use may be less than that of elementary school children. This inaccuracy is suggested by the difference in what was reported in the classroom survey and what was observed. The Oregon studies were conducted after the law had been passed in July 1993, although it was not in effect until one year later (July 1994). Some law awareness and related promotional activities had already occurred before our studies, probably inflating "baseline" use and decreasing our estimate of the law's effectiveness. We did not have a control group to account for secular trends and intervening events unrelated to the Oregon law. However, earlier observational studies from Oregon Department of Transportation suggest that use among youth had been relatively stable prior to passage of the law.

Moreover, all four types of study had relatively short pre- and post- intervals and most showed a similar change in helmet use.

Our study suggests that helmet laws may be an effective way to increase helmet use in other states. However, since half of Oregon child bicyclists are still unhelmeted, a comprehensive helmet promotion and educational program coupled with enhanced enforcement of the law will be necessary to achieve higher usage.[22-24] Attention should be given to the 6% to 8% rate of improper use of helmets. Because the goal of such laws is to prevent bicycle-related head injuries, further study is needed to evaluate the effect of the law on reducing bicycle-related head injuries.[25]

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4. THE IMPACT OF THE OREGON BICYCLE HELMET LAW ON BICYCLE-RELATED HEAD INJURIES AND FATALITIES

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4.1 Abstract

Objective. To determine the impact of the Oregon bicycle helmet law on bicycle-related severe head injuries and fatalities.

Design. Review of the statewide Trauma Registry data and death certificate records to identify all bicycle-related severe head injury and deaths from July 1989 through June 1995.

Subjects. 563 (247 under 16 years of age) bicycle-related head injury patients who attended an emergency trauma center and 37 (2 under 16 years of age) cases who died at the scene from July 1989 through June 1995.

Main outcome measures. Pre- and post-law occurrence and characteristics of bicycle-related head injuries and deaths.

Results. The incidence of bicycle-related severe head injury incidence significantly decreased from 3.9 injury cases per 100,000 population pre-law to 2.9 per 100,000 population post-law (P<0.001). The decease was most profound in children: 47% decrease in the number of injury to children under 10 years of age; and 37% decrease in the injury to children aged 10 to 15 years old. The decreasing trends were apparent in both boys and girls, and in metro and non-metro areas. Pre- and post-law changes were not found in severity of head injury. Helmet use among patients attended an emergency room increased from 9.0% pre-law to 44.1% post-law among children <16 years of age (P<0.001) and from 14.3% to 20.0% in people over 15 years of age (P=0.69). The time series analysis revealed an abrupt decline in bicycle-related head injuries among the whole population, during the twelve months after the law was enacted. For children

under 16 years of age, the decreasing trend of bicycle-related head injuries appeared to mirror the increasing trend of statewide observed helmet use.

Conclusion. The Oregon bicycle helmet law helped reduce the bicycle-related severe head injuries. Legislation appears to be an effective approach to prevent head injuries by increasing helmet use.

4.2 Introduction

Efficacy of bicycle helmet use in reducing bicycle-related head injuries has been well documented.[1-5] Confronted with the major threat of head injury in children,[6-7] nine out of fifty states in the U.S. have implemented laws that require children to wear a helmet while riding a bicycle on public property.[8] Although studies in several communities suggested that such laws increase bicycle helmet use,[9-12] few data provide direct evidence that such laws result in reduced bicycle-related head injuries and deaths. It could be argued that because of "selective recruitment" only the safer bicyclists comply with the law;[13] the net result being that the occurrence of bicycle-related head injury remains unaffected because the highest risk group is not wearing.

In July 1993, the state of Oregon passed a law mandating that children under 16 years of age wear helmets while bicycling or while riding as a passenger on a bicycle on public roadways. The law, which became effective in July 1994, provides for a maximum fine of $25 for children not wearing a helmet. A statewide evaluation study conducted during 1993-1994 indicated that helmet use by Oregon children increased from 25% pre-law to 49% post-law.[14] The objective of this study was to determine the effect of this change in helmet use on the occurrence of bicycle-related head injuries and deaths.

4.3 Methods

4.3.1 *Data sources*

We identified bicycle-related head injury patients through the Oregon Trauma Registry maintained by the Emergency Services and Systems Section of the Oregon Health Division. The Trauma Registry has been in place since 1986 and collects data from 46 designated trauma hospitals statewide, which covers 96% eligible trauma hospitals in Oregon. A trauma system patient is identified using triage criteria that included physiological findings, anatomic injury, mechanism of injury, comorbid factors, and paramedics' discretion.[15] The patients identified by the triage criteria are considered having severe life-threatening injuries and thus are transported to designated trauma centers where resources and personnel are committed to immediately treatment of injured patients. Data are submitted to the trauma registry from three sources: emergency medical technicians who are first responders at trauma scenes; emergency departments at hospitals; and referral hospitals who treat trauma patients are transferred for care.

Each year, approximately 50% of the cases come from the urban Portland area, and 50% from other parts of the state. Information collected on each patient includes demographics; place and date of injury events; type of crash (contact with motor-vehicle or not); body site of injury; circumstances of bicycle crashes; Abbreviated Injury Scale (AIS) score for the head injury; use of protective devices; and the patient's outcomes (alive or dead).[15]

Bicycle-related head injury deaths were identified through the death certificate records maintained by the Vital Statistics section of the Oregon Health Division. Death certificate data were linked to trauma registry data to identify cases that died at the scene and thus were not entered into the trauma registry system.

Helmet use by Oregon children was based on the statewide direct observational surveys conducted biennially by the Oregon Department of Transportation since 1985. Observations were taken at 11-13 sites throughout the state on arterial streets with fairly high traffic volumes where most bicyclists are traveling for utilitarian purposes. Age of a bicyclist was estimated as more than 15 years or less than 16 years on the basis of physical appearance. For the current analysis, we selected only children under 16 years of age who were covered by the law. Detailed methodology of the direct observational survey previously has been described elsewhere.[14]

4.3.2 *Case definitions*

We defined a head injury as a bicycle-related injury that had any of the following head injury diagnoses as an associated condition: skull fracture (ICD-9 800.0 through 801.9 and 803.0 through 804.9); intracranial injury (ICD-9 850.0 through 854.9); and late effects of either skull fracture (ICD-9 905.0) or intracranial injury without skull fracture (ICD-9 907.0). Brain injury was defined as fracture of the vault or base of the skull, intracranial injury (including concussion, contusion, laceration, and hemorrhage), or other multiple fractures of the skull. Severity of the injury was assessed by AIS score (1-3 or 4-5).[15-16]

We defined a bicycle-related death as any Oregon resident coded as dying as the result of a bicycle crash in Oregon (E800 through E807, with fourth digit 0.3; E810 through E825, with fourth digit 0.6; E826.1 or E826.9; or E827 through E829, with fourth digit 0.1).

4.3.3 *Statistical analysis*

Using Chi-square tests, changes in helmet use, type, and severity of bicycle-related injuries were compared between three years: pre-law (July 1992 - June 1993), transition period (July 1993 - June 1994), and post-law (July 1994 - June 1995). During the transition period, the law was passed but not enacted yet. Data prior to 1992 were not used in this analysis because information on helmet use was not completed before 1992. All *P*-values quoted were two-tailed.

The effect of the Oregon helmet law on overall bicycle-related head injuries and deaths was examined using the intervention analysis in time series methodology, a modified ARIMA (AutoRegressive, Integrated, and Moving average) model, which quantifies the decomposition of legal intervention and secular trend effects.[17] The secular trend takes into account combined effects of changes in possible factors such as demographic composition, riding behaviors, road conditions, and education programs. The method permits the testing of statistical significance to determine if the secular trend and intervention are actual rather than random effects.

Because of the seasonal changes in bicycle-related head injuries, time series analysis was based on monthly injury data from July 1989 through June 1995, a total of 72 months. The months from July 1989 through June 1994 were used to determine a "before" baseline level. The months from July 1994 through June 1995 were used to quantify the abrupt impact of the law. The evaluation model considered that data collected at 12 month intervals are autocorrelated, that is, correlated with previous data points. Thus, the dependent variable Z_t was computed as the twelfth order difference between the monthly observations, Y_t and Y_{t-12}. Trend effect was simply modeled as the constant in the equation. Intervention effect was modeled using a dummy variable with a value of 0 prior to July 1994 and 1 thereafter for the twelve months through June 1995.

Computations were performed using the SPSSPC for Trend Analysis software package. The coefficients of the model were estimated by the maximum likelihood method. The goodness-of-fit of the model was examined by the residual plot (Auto-Correlation Function plot) and Box-Ljung statistic.

4.4 Results

From July 1989 through June 1995, a total of 899 patients sought treatment in a hospital emergency department for bicycle-related injuries and two thirds of them involved head trauma. Approximately 45% of the head injuries occurred among children under 16 years of age. During the same period, 37 people died at the scene from bicycle crashes before they were taken to an emergency department; two of them were under 16 years of age. Table 4.1 presents the number of bicycle-related head injuries and deaths on an annual basis beginning from July 1989.

Table 4.1 Number of bicycle-related injuries and head injuries by time period, Oregon, July 1989 - June 1995

Time period	Total injuries	Head injury	% head injury	Fatal HI[1]
July 89-June 90	142	83	58.5	15 (10)
July 90-June 91	130	86	66.2	14 (7)
July 91-June 92	166	105	63.3	3 (0)
July 92-June 93	175	115	65.7	9 (5)
July 93-June 94	161	112	69.6	12 (5)
July 94-June 95	125	89	71.2	9 (5)
Total	899	590	65.6	62 (32)

[1]Refers to prehospital deaths due to head injury

The changes of BHIs during the past three years were presented in Table 4.2. The decreasing trends in BHIs were most profound among children under 16 years of age. One year after implementation of the law, the incidence of BHIs decreased by 47% in children aged 9 or younger and by 37% in children aged 10 through 15 years. The decreasing trends were apparent in both boys and girls, and in both metro and non-metro areas.

Table 4.3 shows that almost half of the bicycle-related injuries occurred by contact with motor vehicles. Pre- and post-law proportions of head injuries due to collision with motor vehicles were not statistically significant. Among the patients who attended an emergency department, helmet use at the time of crashes significantly increased from 1.9% pre-law to 48.4% post-law in children under 16 years of age (for trend: $P<0.001$).

Although a slightly higher prevalence of helmet use was noticed in people over 16 years of age, the difference was not statistically significant.

Table 4.2 Demographic characteristics of bicycle-related head injury by year, Oregon, July 1992 - June 1995

Characteristic	Pre-law (1992 July-1993 June) CI[a] (n)	Inter- (1993 July - 1994 June) CI (n)	Post-law (1994 July - 1995 June) CI (n)
Total	3.9 (115)	3.7 (112)	2.9 (89)
Age (years)			
≤ 9	5.1 (21)	3.2 (14)	2.7 (12)
10-15	13.1 (31)	11.9 (31)	8.3 (22)
16-24	6.2 (21)	4.9 (18)	4.2 (16)
25-44	2.8 (26)	2.7 (26)	3.3 (31)
45-64	2.4 (13)	2.7 (16)	1.1 (7)
65+	0.5 (2)	1.7 (7)	0.2 (1)
Gender			
Male	6.4 (90)	6.3 (94)	4.9 (74)
Female	1.7 (25)	1.2 (18)	1.0 (15)
Place of occurrence			
Metro	4.3 (84)	4.1 (81)	3.5 (71)
Other	3.5 (31)	3.4 (31)	2.0 (18)

[a]Cumulative incidence (per 100,000 population)
[a]Metropolitan areas include Multnomah, Clackamas, Washington, Marion, Lane, Polk, Jackson, and Yamhill counties (Center for Population Research and Census, Portland State University).

Table 4.3 Characteristics of bicycle crash by age group, Oregon, July 1992 - June 1995

Characteristic	Pre-law (1992 July-1993 June) No. (%[1])	Inter- (1993 July - 1994 June) No. (%)	Post-law (1994 July - 1995 June) No. (%)	*P* value
Contact with motor vehicle				
<16 years old	27 (51.9)	30 (66.7)	16 (47.1)	0.36
≥16 years old	25 (39.7)	30 (44.8)	30 (54.5)	0.35
Helmet use (Yes)[2]				
<16 years old	1 (1.9)	7 (15.6)	15(44.1)	<0.01
≥16 years old	9 (14.3)	15 (22.4)	11(20.0)	0.69

[1]Proportion of cases over total number of head injury cases in the age- and year-specific group.
[2]Restricted to cases identified through the Oregon Trauma Registry system.

The proportion of BHIs which occurred in children under 16 years of age decreased from 47.3% pre-law, 40.2% when the law was passed, to 36.9% post-law (for trend, $P<0.001$) (Table 4.4). A similar trend was noted also for the brain injuries, whereas the proportion of brain injuries in all head injury did not change over the time. Proportion of people having severe head injuries based on the AIS scores was consistent over the time.

Figure 4.1 presents the trend, seasonal, and autocorrelated nature of the monthly data on bicycle-related head injuries occurred among all ages. The number of bicycle-related head injuries increased from 1989 to 1993, started to level off in 1993 after the law was passed, and declined after the law was enacted.

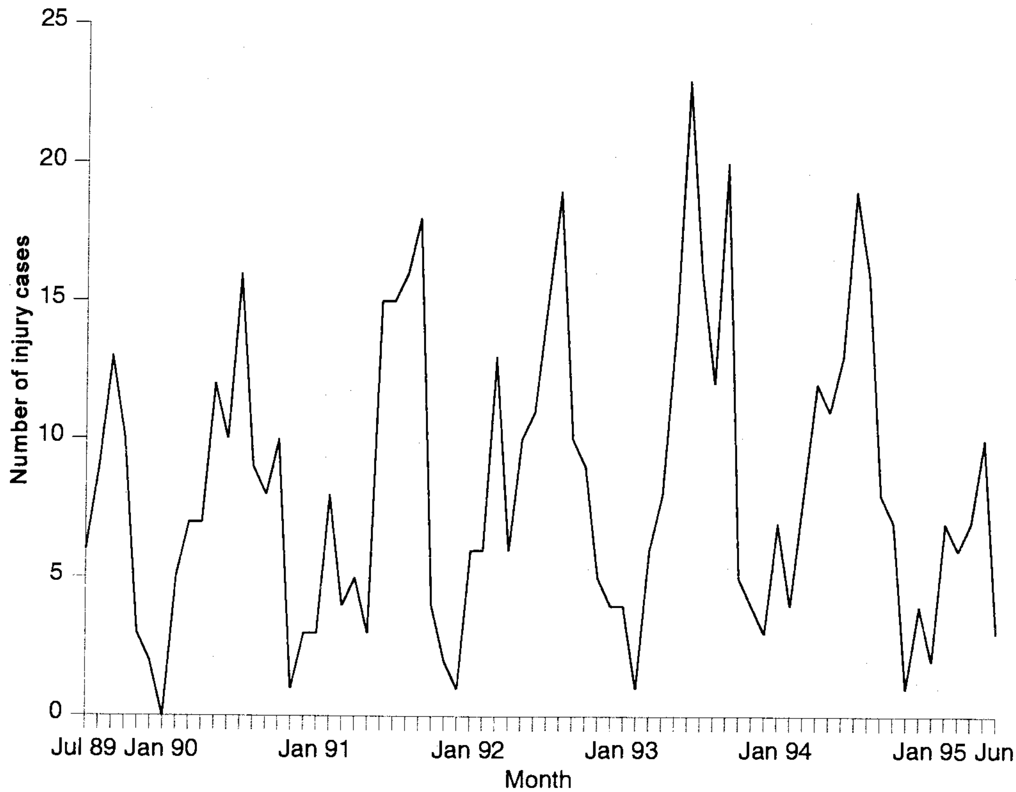
Table 4.4 Severity of bicycle-related head injury, Oregon, July 1992 - June 1995

Characteristic	Pre-law (1992 July-1993 June) No. (%)	Inter- (1993 July - 1994 June) No. (%)	Post-law (1994 July - 1995 June) No. (%)	P value
Head injury	115 (100.0)	112 (100.0)	89 (100.0)	
<16 years old	52 (45.2)	45 (40.2)	34 (38.2)	<0.01
≥16 years old	63 (54.8)	67 (59.8)	55 (61.8)	
Brain injury	114 (100.0)	110 (100.0)	88 (100.0)	
<16 years old	52 (45.6)	42 (40.0)	34 (38.6)	<0.01
≥16 years old	62 (54.4)	63 (60.0)	54 (61.4)	
AIS score[1]				
<16 years old				0.68
1-3	40 (76.9)	36 (83.7)	24 (77.4)	
4-5	12 (23.1)	7 (16.3)	7 (22.6)	
≥16 years old				
1-3	44 (75.9)	50 (78.1)	41 (77.4)	0.50
4-5	14 (24.1)	14 (21.9)	12 (22.6)	

[1]Restricted to cases identified through Trauma Registry system

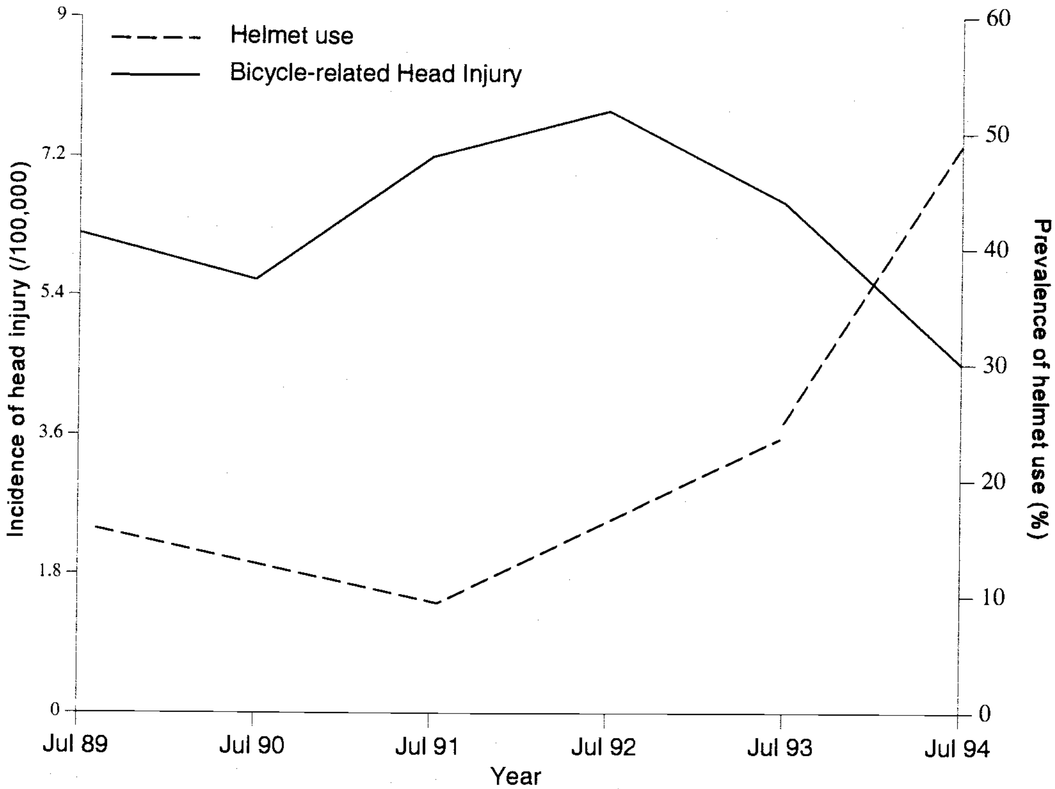
The final time series model includes four parameters: trend (constant), intervention, autoregressive effect of order 12, and moving average effect of order 12. The value of the trend parameter reveals a significant increase in BHIs prior to July 1994 (coefficient = 0.749, t=2.5, *P*=0.01). The value of the intervention parameter indicates a significant drop in BHIs at post-law (coefficient=-3.288, t=-2.2, *P*=0.03). According to the model, a total of 120 bicycle-related head injuries was expected at post-law, based on the increasing trend in BHIs at pre-law. The residual plot of the fitted model revealed a pattern of white noise (random fluctuation). Moreover, the Box-Ljung statistic showed no significant autocorrelation of the residuals, indicating a good model fit.

Figure 4.1 Bicycle-related severe head injury, Oregon, July 1989 - June 1995



For children under 16 years of age, the trend in BHI incidence was negatively correlated with the trend in helmet use, that is, the incidence of bicycle-related head injury increased from 1989-1993 and decreased afterwards, whereas the prevalence of helmet use among youth remained low from 1989 to 1991 and started to increase in 1993 (Figure 4.2).

Figure 4.2 Bicycle-related head injury and helmet use among youth, Oregon, July 1989 - June 1995



4.5 Comments

This statewide study demonstrates that bicycle-related severe head injuries decreased, especially among children under 16 years of age, one year after implementation of the Oregon bicycle helmet law. This decrease coincided with an increase in helmet use by children from 25% pre-law to 49% post-law.[14] The findings of these two studies provide strong evidence that these laws were effective in reducing the head injuries through promotion of helmet use.

Miller Ted et al estimated that the lifetime medical cost for a bicycle-related head was $16,796 in Oregon.[18] According to this estimate and the 31 (=120-89) head injuries avoided at post-law, the legislation helped save a total of $520,676. Although we did not have enough information to estimate the cost of legislation, a study by Hatziandreu et al indicated that the legislative program was a most cost-effective approach, compared with school-based and community-based educational programs, to promoting the bicycle helmet use.[19]

The effect of the law in reducing bicycle-related head injuries may be partly attributable to some other factors that changed following the implementation of the law. In 1993, after passage of the legislation, the Oregon Bicycle Helmet Coalition was convened to collaborate on a public campaign to notify Oregon residents about the new law and to facilitate compliance with the law. The coalition also developed specific programs such as "Trauma Nurse's Talk," "Think first," and "Smart cycling" to provide injury prevention knowledge and improve children's biking skills. These programs may bring positive changes in awareness of potential injury risk when riding a bicycle, safety education, biking skill among child bicyclists, and attention paid by drivers to bicyclists. All these changes may contribute to the slightly decline trend in bicycle-related head injuries after the law was passed and an additional decline after the law was enacted.

The effect of statewide legislation on reducing BHIs previously was suggested by only one study conducted in Victoria, Australia.[18] This study reported a 37% decrease in hospitalization for bicycle-related head injuries after implementation of the helmet law.

However, the study did not consider the secular trend in the head injuries, that is, the possibility of fluctuation over time due to other influential factors such as weather, road condition, and characteristics of the injuries. Additionally, the author did not consider persons who immediately died in the field and thus were not sent to hospitals. If more bicyclists died at the scene, estimates based on hospitalized injury cases could underestimate the incidence of BHIs.

Although the Oregon helmet use law targets on children under 16 years of age, our study revealed a decline trend at post-law in bicycle-related head injuries for whole population. This "halo" effect on adults may be explained by the increased level of helmet use post-law among adults, even though the increase was not as apparent as seen among children. Further, it may be attributable to changes in social norms regarding the injury prevention. For example, more attention might be paid by motor vehicle drivers to bicyclists after people were aware of the law. In addition, adults might ride more carefully post-law even without wearing helmets.

The increasing trend of bicycle-related head injuries pre-law partly may be attributable to the improvement of the trauma transferral system. If it is true, the expected number of the head injuries based on the time series model would be overestimated. Using the hospital discharge dataset, Mullins et al evaluated proficiency of a large regional trauma system in Oregon. According to their results, the proportion of severe injured patients hospitalized at the trauma centers increased between 1984 and 1991, whereas this proportion decreased at the non-trauma centers during the same period.[21] When data from trauma center and non-trauma center were combined, however, an increasing trend was noticed in overall severe injuries, despite of a decreasing trend in the total number of injuries. Additionally, we failed to identify an increasing trend in the proportion of patients who admitted to the trauma system because of the bicycle-related severe head injuries between 1989 and 1995.

Several potential limitations in this study warrant discussions. The first limitation lies on our studying only bicycle-related severe head injuries. Patients who have other injuries, but who escape head trauma because of helmet use, often do not require emergency trauma care and therefore are not included in our data. As a result, we may underestimate the impact of the law on the head injuries. Secondly, the incidence rate estimates were calculated based on the total Oregon population or specific-group population figures rather than on the population of Oregon bicyclists. We assumed a steady status of bicycle ridership from 1989 through 1995. However, the law may have reduced the number of high-risk riders who did not own or would not obtain a helmet, and thus chose to forgo bicycling. If this effect occurred, the decreasing head injury incidence could be attributed to the decreasing number of high-risk bicyclists. According to the data from the Oregon Department of Transportation, overall population figures of bicyclists were stable, but a slight decrease in number of bicyclists was noticed among people under 18 years of age. However, those numbers were from the observations at only four sites of the states (two Portland sites and two small town sites), and the representability of the data is unclear.

Additionally, we assumed that the riding habits such as riding miles by Oregon bicyclists were consistent over time. If bicyclists tended to ride less or on shorter distances after the law was passed and were thus less likely to be exposed to the risk of injury, our estimates could be overestimated. On the other hand, if bicyclists tended to ride more or on longer distances after wearing a helmet, our estimates could be underestimated. Unfortunately, information on miles ridden by Oregon bicyclists were not available. Nevertheless, parents questioned by the Oregon behavioral risk factor survey reported a stable status of bicycle riding frequency by children between 1993 through 1994.

Finally, social and environmental changes over time may have accounted for a portion of the reduction in the fatalities and injuries, although we failed to identify any significant changes in overall weather conditions and bicycle design features.

In conclusion, our findings suggest that the legislation requiring helmet use for children appear to be an effective approach to reduce bicycle-related head injuries in children through the promotion of helmet use. It also is important for us to address that implementation of the laws does not exclude the necessity of improving other influential factors associated with BHIs, such as road conditions, helmet design, and behavior changes of motor vehicle drivers. Yet, because children often ride bicycles around neighborhood or on short distances, helmet wearing plays an important role in prevention of head injury when they fall on the ground.

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5. SUMMARY AND CONCLUSION

We evaluated the effectiveness of the Oregon bicycle helmet use law from two aspects. First, we evaluated whether or not the law increased bicycle helmet use by children. Second, we evaluated whether or not the law had an impact on reducing bicycle-related head injury and fatalities.

To assess the effect of the law on helmet use, we conducted three pre- and post-law surveys: statewide direct observational surveys at both community and school sites, telephone surveys of parents, and classroom surveys of students in elementary and middle schools. Observational surveys observed 3,313 child bicyclists at 13 community sites and 995 child bicyclists at 33 selected middle schools. Classroom surveys were conducted among all 4th, 6th, and 8th graders (8,955 students) in 66 randomly selected schools throughout the state. Telephone surveys obtained information on bike riding and helmet use from 1,219 random-dialed parents of 1,437 children <16 years of age.

Although helmet use estimates differ, all surveys showed significantly increase in helmet use after the law became effective. Observed helmet use dramatically doubled from 24.5% to 49.3% on the community-site observations and from 20.4% to 56% on the school-site observation. In the classroom surveys, child bicyclists answering "always" wearing helmets increased from 15% to 39%; in the telephone survey of parents the number increased from 36.8% to 65.7%. The increase was most noticeable in younger and female children. Among children who owned a helmet, helmet use increased from 57.9% to 82.9%. Helmet ownership was considerably increased from 51.5% pre-law to 75.7% afterwards on the classroom surveys and from 67.4% to 83.9% on the telephone surveys. The increase was greater in children with low household income. In general, estimated helmet use by the classroom survey was greater than what was observed at that school. However, the estimates were highly correlated ($r=0.76$, $P<0.01$). The majority of students and parents knew about the law. However, only half of the students thought the law was a good idea. Younger girls are more likely to support and comply with the law.

To assess the impact of the law on bicycle-related head injury and fatalities, we analyzed data gathered at the Oregon Trauma Registry and Vital Statistical Department. From July 1989 through June 1995, 563 bicycle-related severe head injury patients attended emergency rooms and 37 cases died at the scene. One year after implementation of the helmet use law, statewide bicycle-related severe head injury incidence significantly decreased from 3.9 to 2.9 per 100,000 population ($P<0.001$). Based on the time series analysis, a total of 50 head injury cases were avoided during the first year after the law enacted. The decrease was most profound in children under 16 years of age: 47% decrease in the number of injury to children under 10 years of age and 37% decrease to children aged 10-15 years old. During the same period, helmet use among patients attended an emergency room increased from 9.0% pre-law to 44.1% post-law among children <16 years of age ($P<0.001$). The decreasing trend of bicycle-related head injuries appeared to mirror the increasing trend of helmet use.

We conclude that 1) the law increased helmet use; 2) the law helped reduce the bicycle-related severe head injuries; 3) although use estimates differ, all helmet surveys showed similar degrees of pre- and post-law change; 4) the law helped reduce the bicycle-related severe head injuries, and 5) half of Oregon child bicyclists are still unhelmeted, indicating a need for additional helmet promotion. Our results suggest that the laws may be an effective approach to increase helmet use and reduce head injury in other states.

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