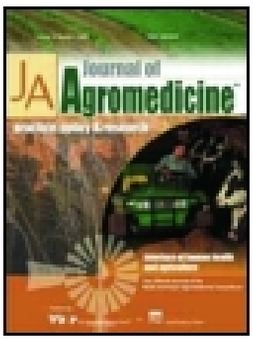

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Cost Effectiveness of Wearing Head Protection on All-Terrain Vehicles

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ABSTRACT. The use of all-terrain vehicles (ATVs) has increased in the United States and elsewhere over the last three decades, along with an increased frequency of incidents resulting in serious injuries, among which have been head injuries. ATVs are designed for motorized off-highway work and recreation, can weigh up to 600 lbs (272 kg), and may reach speeds as high as 75 mph (120 km/h). ATV crashes, including collisions and overturns, were responsible for 8104 fatalities from 1982 to 2006. One third of those killed were youth under 16 years of age. Helmets may reduce risk of death by 42% and nonfatal injury by 64%. In this study, a decision analysis was applied to determine the potential reduction in the rate of fatal and nonfatal head injuries associated with crashes, based upon the universal wearing of head protection while riding on ATVs. In addition, based upon this reduction in injury rate, a cost-effectiveness analysis was conducted to determine the savings per injury averted among ATV riders with head protection. The authors found that 238 head injuries, including 2 fatalities per 100,000 ATV drivers with an average of 145 hours of annual operation, could be averted by the universal wearing of head protection while riding on ATVs. Taking into account the social direct and indirect costs of fatal and nonfatal head injuries at a 5% discount rate, US$364,306 could be saved per injury averted over a 50-year period if there were universal wearing of head protection by ATV drivers. If the exposure is adjusted to 2000 hours per year for an equivalent work year, 3276 head injuries could be averted including 23 fatalities per 100,000 at a social cost savings of US$509,172.

KEYWORDS. Abbreviated injury scale, all-terrain vehicles, ATVs, cost-effectiveness, injuries, safety

INTRODUCTION

All-terrain vehicles (ATVs) were introduced into the United States in 1971 and their prevalence has grown to 7 million in use by 2004. They weigh up to 600 lbs (272 kg) and have speeds that reach 75 mph (120 km/h), and children as young as 5 years of age have increased in frequency of ATV-related injuries.[1] A total of 2.5 million ATVs were in use in 1990,[2] growing to 3.91 million by 1997,[3] and to 5.8 million in 2001.[4] As shown in Figure 1, an

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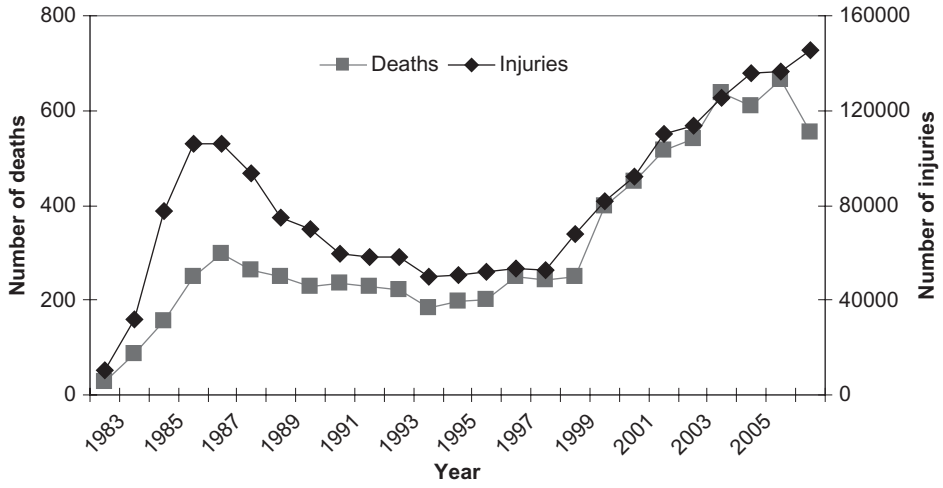
FIGURE 1. Number of fatal (*n* = 7942) and nonfatal injuries (*n* = 2,015,200) associated with ATV crashes in the United States, 1985–2004. Data for fatalities were still being reported for the years, 2003–2006.



Source: Streeter RA. 2006 Annual Report of ATV Deaths and Injuries. Bethesda, MD: U.S. Consumer Product Safety Commission; February 2008.

epidemic of ATV-related injuries emerged in 1985. In that year, the Consumer Product Safety Commission (CPSC) initiated an investigation to determine what regulations should be promulgated to address this epidemic. As a result of this investigation, CPSC entered into a 10-year consent decree in 1988 with ATV manufacturers and distributors that banned the manufacture of three-wheeled ATVs, implemented a national training program, and aimed to develop voluntary safety standards. The industry implemented age recommendations for their ATVs, a large public awareness program, and a warnings campaign to former and current customers. Nevertheless, ATV crashes including collisions and overturns were responsible for 8104 fatalities from 1982 to 2006, and 29% of the decedents were 16 years of age or younger.[5]

A dramatic drop in injuries occurred during the period of the consent decree. However, since the decree expired in 1998, ATV-related injuries have increased dramatically from 398 to 555 fatalities and from 82,000 to 146,600 emergency department (ED) treatments, respectively, from 1999 to 2006. The fatalities are admittedly under counted, relying upon death certificates and any other information source that names ATV as a factor in the death. The ED data, also undercounted, are based upon a sample of emergency room admissions, excluding other sources of treatment such as at physician offices and excluding occupational injuries.[4]

About one fifth of hospital admissions regarding ATVs involve injuries to the head.[6] ATV-related head injuries have a greater proportion than injuries associated with motorcycle crashes,[7] and head injuries have a high potential for lethality.[8] Furthermore, in the United States, ATV patients have been found to have a higher incidence of head injuries than motorcycle patients.[9]

In a 2003 study of admissions to a trauma center in Puerto Rico regarding ATV crashes, investigators found that 48.6% involved head injuries, yet only 10.5% of the patients were known to have worn helmets. In contrast, the percentage of persons experiencing motorcycle-related head injuries was 29.6% in the study, 68.0% of whom were known to have worn helmets. The higher percentage of head injuries related

to ATV crashes was attributed to the lack of helmet usage.[9] In another study at a trauma center in Ohio, a 3-fold increase in helmet use by children on ATVs was associated with a lower head injury rate when compared to bicycle-related head injury patients, although the helmet usage on the ATVs remained low at 23%.[10] In a 1990 study, the CPSC determined that helmets were effective at reducing deaths by 42% and nonfatal injuries by 64% in ATV crashes.[11] Similarly, motorcycle helmets have been found to be 37% effective in preventing death and 65% effective in preventing brain injuries in a crash.[12]

The purpose of this study was to determine the cost-effectiveness of wearing a helmet to protect against head injury while operating an ATV, and the results are presented as the cost (or savings) per head injury averted by helmet use on ATVs. The analysis was based upon a narrative used for changing the attitudes of young ATV drivers,[13] and is similar to previous analyses based upon other narratives.[14] The narrative that preceded this analysis, *Brad's Last Ride,* is based upon actual incidents and involves a youth who suffered a serious head injury as a result of an ATV collision with a fence post.

In this exercise, students participated in a story about the injury incident, which is based on actual events, then work in teams through a case study of the costs and interventions related to the story using a spreadsheet in a computer lab. This second step identified cost factors related to the injury and an effective intervention and its cost. The third step was to conduct a population-based decision analysis that compared health outcomes between using and not using the intervention with a rate of injuries averted as a result of the intervention. A decision tree, which we will introduce later, is the analytical tool used. The fourth step was a cost-effectiveness analysis that combined cost savings from the injuries averted and the cost of the intervention to determine the cost (or savings) per injury averted. In this analysis, time factors are taken into account, such as correcting for inflation and discounting future costs to a present value by applying a discount rate that recognizes the time value of money, e.g., a dollar today is worth more to us than a dollar a year from now. An analytical horizon is chosen in order to take into account future costs and savings, typically years into the future. The social perspective is used in which all costs to those within society are included regardless of who pays the costs. Through these curricula, students are taught both public health and economic principles.

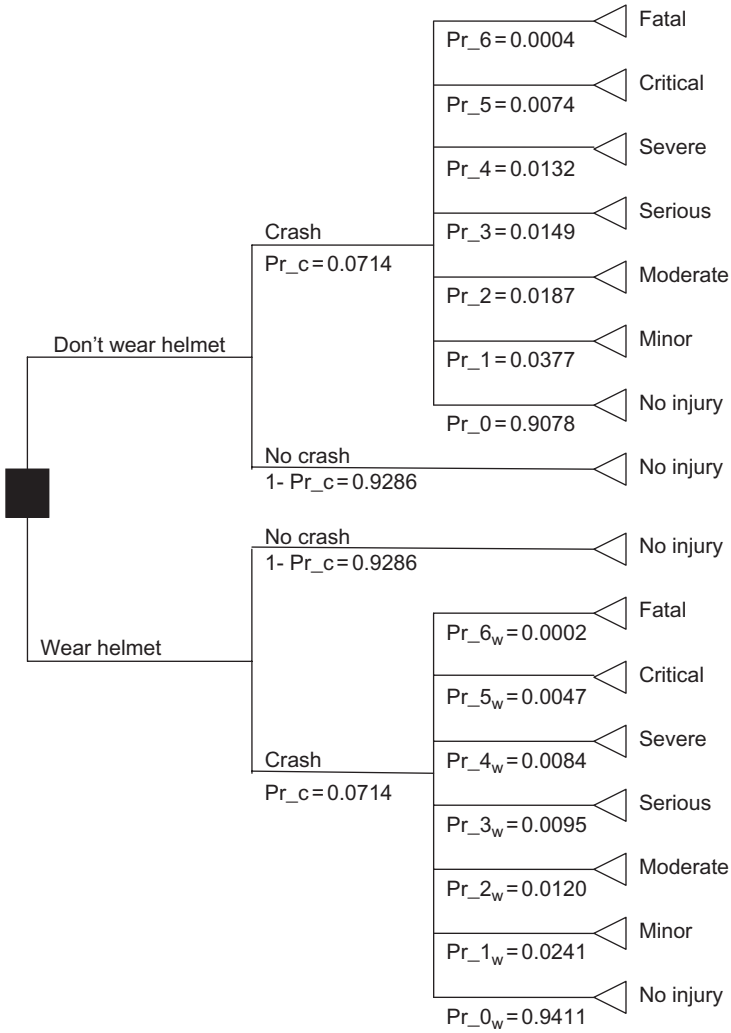
METHOD

Decision Analysis

The decision analysis involves deriving probabilities of events that affect the health outcome of an ATV crash.[15] As shown in Figure 2, these probabilities include the annual likelihood of an ATV crash (*Pr_c*) and the probabilities of different levels of injury severity associated with the crash based upon the maximum abbreviated injury score (MAIS) measures shown in Table 1.[16,17] In multiple injuries, MAIS is applied to the worst abbreviated injury score (AIS), which is based upon body part injured and a 6-point injury severity score, with 6 representing a fatal injury and 1 representing a minor injury; 5 for a critical injury, e.g., brain stem contusion; 4, a serious injury, e.g., artery occlusion; 3, a serious injury, e.g., traumatic aneurysm; 2, a moderate injury, e.g., skull fracture; and 1 representing a minor injury, e.g., cerebral concussion. Coding of head injuries head injuries are gauged by the duration of unconsciousness, respectively for 5 through 1: 6 to >24 hours, <25 hours, <6 hours, <1 hour, and none.[16] An AIS 0 is assigned if an incident results in no injury.

In addition, the effectiveness of the helmet at reducing the risk of injury differentiates the two options: "don't wear helmet" and "wear helmet." CPSC data based upon ATV drivers were used in deriving the probability of a crash since the driver and the ATV represent a unit, whereas ATV riders (drivers plus passengers) were referred to in deriving the outcome probabilities because they represent the injured victims.

FIGURE 2. Decision tree comparing the probabilities and potential health consequences of an ATV crash (145 average hr operation/yr) when wearing a helmet and not wearing a helmet.



Probability of an ATV Crash Per Year (Pr_c)

The rate of ATV crashes per year, *Pr_c*, is the quotient of the total number of ATV crashes divided by the total number of ATVs in operation per year, including both crashes that result in an injury and crashes that result in no injury. CPSC data allow us to calculate the annual frequency of fatal and nonfatal injuries,[4] but data for the noninjury crashes are sparse. Indeed, no study save one in Australia provides noninjury data.[16] That study reported 2.03 crashes that resulted in no injuries for each hospital treatment. Using this ratio as a multiplier, we were able to calculate crashes with "close calls" indexed against the CPSC data for ED treatment. However, this datum has a number of limitations: it is self-reported, it involves only youth in rural areas, it combines two-wheel motorcycles with ATVs, and it may not be generalizable to the total population, particularly regarding urban recreational ATV use. Also, this number does not include those who were injured who might have also experienced a close call or those who might have experienced more than

TABLE 1. Injury Costs for Different Levels of Severity Based Upon the Abbreviated Injury Scale (AIS) for Automobile Incidents

MAIS* level	Severity scale	Head outcome		Comprehensive cost‡	
		Unconscious**	Example	2000 US$†	2008 US$
0	No injury		Normal	$0	$0
1	Minor	None	Cerebral concussion	$15,017	$19,182
2	Moderate	<1 hour	Skull fracture	$157,958	$201,772
3	Serious	<6 hours	Traumatic aneurysm	$314,204	$401,356
4	Severe	<24 hours	Artery occlusion	$731,530	$934,438
5	Critical	6 to >24 hours	Brain stem contusion	$2,402,997	$3,069,529
6	Untreatable	Death	Massive skull destruction	$3,366,388	$4,300,140

*Maximum Abbreviated Injury Scale = AIS severity score for the worst injury.

**Brooks CA, Lindstrom J, McCray J, Whiteneck GG. Cost of medical care for a population-based sample of persons surviving traumatic brain injury. *J Head Trauma Rehabil*. 1995;10:1–13.

†Blincoe L, Seay A, Zaloshnja E, Miller T, Romano E, Luchter S, Spicer R. The economic impact of motor vehicle crashes, 2000. Report No. DOT HS 809 446. Washington, DC: National Highway Traffic Safety Administration, U.S. Department of Transportation; 2002.

‡Inflation for the year 2000 cost figures was adjusted using the Consumer Price Index that was available at the U.S. Bureau of Labor Statistics Web site, www.bls.gov (accessed August 15, 2008).

one injury. Nonetheless, 59% of vehicle use was recreational and helmet use was at 49%, similar to helmet use in the United States at 51.8%.[3] Because of the uncertainty in the use of the Australian multiplier and its dominance in the value of *Pr_c*, we conducted a sensitivity analysis by doubling this probability in our decision analysis.

We calculated the annual number of crashes as a sum of CPSC reports of fatalities and ED cases averaged for the years 2002–2006 at 601 deaths and 131,560 nonfatal injuries.[3] The number of crashes with no injuries was calculated as 267,657 incidents. This latter product resulted from the multiplication of 2.034 times the number of ED cases based upon the proportion of "close calls" with no injury as reported from the Australian survey.[18] The sum of these three numbers was 399,818 ATV crashes per year. CPSC estimated that 5.6 million ATVs were in use in the United States in 2001, averaging 145 hours of annual driving time for each ATV.[4] From the estimated number of 399,818 ATV crashes per year divided by the reported 5.6 million ATVs in operation that year (145 hours/ATV), the probability of an ATV crash annually (*Pr_c*) was computed as 0.0714, i.e., 7.0%. This probability is likely conservative because one study observed that there was a 90% increase in ATV-related hospitalizations in the United States for the years 2000–2004, whereas ATVs in use over this period increased nationwide by 64%.[4]

*Probability of No Injury Associated With an ATV Crash (*Pr_0*) When a Helmet Is Not Worn*

As calculated above relative to the CPSC data, the number of crashes with no injuries regardless of whether they were head injuries or not was 267,657 incidents. However, three adjustments, tracked as shown from columns A to D in Table 2, were made that affect this number. As shown in column B of Table 2, the number of total injuries must be delimited to head injuries, and a national study[6] found that head injuries accounted for 20% of ATV-injured hospital patients. The assumption in our study was that the same percentage also relates to fatalities, which may be conservative because head-injured victims have a high mortality rate, and many head injury victims die before reaching the hospital or are dead on arrival.[19] Thus, the number of head injuries represented in the CPSC data was calculated as 120 fatalities and 26,312 ED cases. This calculation resulted in a rise in noninjury frequency

TABLE 2. Derivation of Head Injury Outcome Annual Probabilities Associated With ATV Crashes

MAIS	A	B	C	D	E	F	G	H	I	Probabilities	
0 No injury*	267,657	373,386	367,621	362,944					362,944	*Pr_0*	0.9078
1 Minor								0.409	15,081	*Pr_1*	0.0377
2 Moderate					0.612		0.611	0.202	7,466	*Pr_2*	0.0187
3 Serious	131,560	26,312	32,036	36,714	0.162	0.120	0.161	0.161	5,943	*Pr_3*	0.0149
4 Severe					0.144	0.269	0.143	0.143	5,257	*Pr_4*	0.0132
5 Critical					0.083	0.611	0.080	0.080	2,941	*Pr_5*	0.0074
6 Fatal	601.2	120	160	160	0.003		0.005	0.005	160	*Pr_6*	0.0004
Crashes	399,818	399,818	399,818	399,818					399,818		1.0000

*No injury in column A refers to all ATV-related injuries, but the remaining columns reflect only head injury outcomes.

A: Averaged CPSC case reports, 2002–2006 for use as the base data: *Source:* Streeter RA. 2006 Annual report of ATV deaths and injuries. Bethesda, MD: U.S. Consumer Product Safety Commission; February, 2008. "No injury" cases were calculated based upon the proportion of close calls to hospital visits of 2.03: *Source:* Lower T, et al. Reducing all-terrain vehicle injuries: a randomized control study of the effect of driver training. A report for the Rural Industries Research and Development Corporation. 2005. Australian Government, RIRDC Publication No. 04/174.

B: Reduced CPSC data by 80% for cases presumed to be head injuries. *Source:* Helmkamp JC, et al. All-terrain vehicle-related hospitalizations in the United States, 2000–2004. *Am J Prev Med.* 2008;34:39–45.

C: The number of cases was increased to simulate a population that does not wear helmets. Helmet use was measured as 58.1%. *Source:* Rodgers GB. The characteristics and use patterns of all-terrain vehicle drivers in the United States. *Accid Anal Prev.* 1999;31:409–419. Helmets were determined to be 64% effective for nonfatal injures and 42% effective for fatal injuries. *Source:* Rodgers GB. The effectiveness of helmets in reducing all-terrain vehicle injuries and deaths. *Accid Anal Prev.* 1990;22:47–58.

D: ED cases were increased to reflect 14.7% of head injuries that were not seen in the ED. *Source:* Walker R, et al. Kentucky Traumatic Brain Injury Prevalence Study. Lexington: University of Kentucky Center on Drug and Alcohol Research Technical Report No. 2004–01; 2004.

E: Used coding at a trauma center to determine the proportion of scores between AIS 1 and 5. *Source:* Demetriades D, et al. Mortality prediction of head abbreviated injury score and Glasgow Coma Scale: analysis of 7,764 head injuries. *J Am Coll Surg.* 2004;199:216–222.

F: Determined proportion of deaths that occurred after initial scoring for AIS 3–5. *Source:* ibid.

G: From column F, adjusted scores for proportion of deaths to ED visits based upon CPSC data.

H: Determined AIS 1 based upon 55.5% of cases with no coma less 14.7% (see D above) of cases not seen in ED. *Source:* Walker R, et al. Kentucky Traumatic Brain Injury Prevalence Study. Lexington: University of Kentucky Center on Drug and Alcohol Research Technical Report No. 2004-01; 2004.

I: Calculated adjustments to the CPSC base data and added AIS = 0 from which probabilities were calculated.

to 373,386 incidents, because other types of injuries were not counted.

The CPSC data do not differentiate between riders who wore helmets and those who did not. Thus, we made an adjustment for additional injuries that would be incurred as if no rider wore a helmet, adjusting for helmet use and its effectiveness in reducing the risk of injury. A 2002–2003 household prevalence study reported 51.8% helmet use by ATV riders,[20] and the CPSC concluded that the effectiveness of helmets for reducing the risk of fatalities and nonfatal injuries was 42% and 64%,[11] respectively. We used these factors to adjust the ATV crash data for helmet use, increasing the CPSC-based numbers to 160 fatalities and 32,036 ED cases and decreasing the number of noninjury incidents to 367,621.

The CPSC ED cases excluded injured persons who do not seek ED treatment, the nonfatal injury frequencies were adjusted for additional victims not seeking this treatment. In a household prevalence study, 14.60% of head injured ATV-riders reported not seeking ED treatment.[20] Thus, the frequency of ED cases was increased to 36,714 nonfatal injuries, which resulted in a decrease in the noninjury total to 362,944 incidents. This total is used to establish the probability of no injury associated with an ATV crash (*Pr_0* = 0.9078) when a helmet is not worn, the calculation of which depends upon the collateral derivation of the probabilities of injury outcomes that are addressed next. Probabilities of a crash in this calculation total 1.0000.

Probabilities of Injury Associated With an ATV Crash When a Helmet Is Not Worn

Whereas AIS = 0 depends upon sparse data, and AIS = 6 cases can be identified through the CPSC count, deciphering the proportion of intervening AIS scores presents a challenge. In an analysis of head injuries at a California trauma registry,[19] 6813 involved blunt trauma—excluding penetrating trauma and neck injuries. This study provided relative percentages of AIS scores, whereas the CPSC fatality data were used directly to determine AIS = 6.

Columns E though H in Table 2 show our analytical progression used to determine the proportions of cases between AIS 1 through 5 (column E) and their application to our base data. In the California study, an AIS measure was assigned to each case. Of these cases, 61% had an AIS of 1 or 2, 16% AIS = 3, 14% AIS = 4, 8% AIS = 5, and 0.03% AIS = 6. However, mortality increased to 9%, when adjusted for dead-on-arrival victims and patients who died after coding AIS < 6.[19] We adjusted for patient deaths that were coded as AIS 3, 4, and 5 by removing these deaths from these classifications (columns F and G).

The remaining challenge in deciphering these data across the AIS spectrum was to separate the AIS 1–2 data as combined in the California study into its two parts. The key to this separation resided in the scoring of traumatic brain injury with no loss of consciousness as AIS = 1, whereas an AIS = 2 is based on a loss of consciousness for up to an hour.[21] In a 2004 Kentucky prevalence survey of 3267 households, participants reported that in 737 cases involving their family members, 55.5% of the injured parties did not lose consciousness, which represents AIS = 1.[20] However, 14.6% were not seen in EDs; thus the proportion of ED cases would be Pr_1 = 0.409 (55.5% – 14.6%), and thus, Pr_2 = 0.202 within the context of the California study. These proportions were transferred to our adjusted CPSC data, modifying the frequencies across all AIS categories so all outcome probabilities could be calculated. As shown in Table 2 and Figure 2, the probabilities for no, minor, moderate, serious, severe, critical and fatal injuries were, respectively, Pr_0 = 0.9078, Pr_1 = 0.0377, Pr_2 = 0.0187, Pr_3 = 0.0149, Pr_4 = 0.0132, Pr_5 = 0.0074, and Pr_6 = 0.0004.

Effectiveness of Helmet Use to Reduce the Risk of Injury

When a helmet was worn, shown as the second option in the decision tree in Figure 2, the probability of a crash was the same as without a helmet. A helmet was effective at reducing fatalities by 42% and nonfatal injuries by 64%;[11] thus the probability of injuries is decreased by the effectiveness of helmets to prevent fatal and nonfatal injury. By multiplying the series of probabilities along branches of the decision tree, the annual rate of injuries was calculated: Pr_1_w = 0.0241, Pr_2_w = 0.0120, Pr_3_w = 0.0095, Pr_4_w = 0.0084, Pr_5_w = 0.0047, and Pr_6_w = 0.0002. Pr_0_w = 0.9411 when calculated for all probabilities to total 1.000. Subtracting the injury rate of the intervention option (wear helmet) from the no intervention option for each companion branch, e.g., minor injury, resulted in the rate of injuries averted for each injury category.

Economic Analysis

Each of the differences that produced the number of injuries averted for each AIS score were multiplied by the cost of each respective category, which then were summed to determine the total cost of the injuries and subtracted from the intervention cost. The sum was the value of wearing a helmet in the event of a crash divided by the total injuries averted to determine the cost-effectiveness of the intervention. The intervention cost was US$6773 in *Brad's Last Ride*, which included the US$53 price of the helmet and the cost of 4 years of supervision to assure the donning of the helmet 100% of the time during ATV operation. To simplify our analysis, we assumed the intervention of 100% helmet use to occur within the first year. A sensitivity analysis was conducted to evaluate considering only the price of the helmet in the cost-effectiveness calculation. As to *Brad's Last Ride*, the cost beyond that of the helmet can also be assumed, alternatively, as the cost of a helmet promotion campaign.

A social perspective was used in which all costs and benefits were considered no matter who incurred them.[15] The analytic time horizon was assumed to be 50 years because many victims were children with many years of potential life remaining.[4] The costs were discounted to arrive at a present value based upon a 5% social discount rate, a common rate used across numerous public health studies,[22] and inflation for past cost figures was adjusted as shown in Table 1 using the Consumer Price Index that was available at the U.S. Bureau of Labor Statistics Web site, www.bls.gov (accessed August 15, 2008). The injury costs for different levels of severity were based upon MAIS coding for automobile incidents.[16] The inflation-adjusted costs for codes 6 through 0 were, respectively, $4,300,140; $3,069,529; $934,438; $401,356; $201,772; $19,183; and $0.

These costs included both direct and indirect costs. Direct costs included medical and emergency services, and indirect costs included productivity losses, insurance administration, workplace and legal expenses, and property damage. The costs also included intangibles based upon quality-adjusted life years determined from the duration and severity of the injury.[14] We did not use costs incurred with a *Pr_0* assumed to be $0, because property damage for automobile crashes can be more expensive than ATV damage. Thus, our calculations took a conservative stance by excluding this cost factor.

Sensitivity Analyses

The base case for this analysis was established with a 50-year analytic horizon, a 5% discount rate, an intervention cost of US$6773 per ATV, and an outcome cost profile as described above and shown on Table 1. Uncertainties used within the model were analyzed by varying values within a range drawn to test the sensitivity of the parameters to change. As each parameter was varied to test its sensitivity, the other parameters were held constant against the base case. From the decision analysis measured by injuries averted, five parameters evaluated were the adjustments to the CPSC base data for helmet use and effectiveness by removal, and, likewise, adjustments for the cases not treated at the ED were evaluated by removal. In addition, analyses were conducted by modifying the helmet effectiveness for reducing both fatal and nonfatal risk to 75%, doubling *Pr_c* to reflect the use of the Australian multiplier, and adjusting the 145-hour average annual driving time to the equivalent 2000-hour work year. From the economic analysis measured by savings per injury averted, five parameters were tested. First and second, the time frame for the analytical horizon was changed to 25 then 10 years; third, the discount rate was changed to 0% (no discounting); and fourth and fifth, the same two modifications to *Pr_c* applied to the decision analysis were evaluated in the economic analysis.

RESULTS

Universal helmet use when operating an ATV in this analysis resulted in an annual reduction of 2 fatalities and 237.5 nonfatal head injuries per 100,000 drivers. An unhelmeted rider was 2.4 times as likely to die from an ATV collision as someone wearing a helmet during a collision. Of the nonfatal injuries averted, 18.9, 33.8, 38.2, 48.0, and 97.0 head injuries per 100,000 drivers were critical, severe, serious, moderate, and minor, respectively. Table 3 shows the distribution of the averted injuries across these AIS categories.

We conducted a sensitivity analysis on the effect of the adjustments to the CPSC base data upon these results in our model. When we removed the adjustment for helmet wearing in the CPSC base data, the result dropped by 17.7% to 195.4 injuries averted. Likewise, removal of the adjustment for patients who did not seek ED treatment reduced by 12.6% to 207.6 injuries averted. When the helmet effectiveness was increased to 75% for both fatal (an effectiveness increase of 0.33) and nonfatal injuries (an increase of 0.11), injuries averted were increased by 14.0% to 270.7 cases. Although significant, the sensitivity of these results pales in comparison to the next two parameters evaluated. By doubling the Australian multiplier from 2.03 to 4.06, the resulting injuries averted increased by 3254.3% to

TABLE 3. Results From the Decision Analysis, Economic Analysis, and Sensitivity Analyses of the Cost Effectiveness Analysis of Helmet Use on ATVs (US$)

Parameter	Result	Base case deviation
Injuries Averted/yr—base case/100,000 riders*	237.5	—
AIS 1 Minor*	97.0	—
AIS 2 Moderate*	48.0	—
AIS 3 Serious*	38.2	—
AIS 4 Severe*	33.8	—
AIS 5 Critical*	18.9	—
AIS 6 Fatal*	1.7	—
Injuries Averted/yr—helmet adjustment	*195.4*	*–42.1 (–17.7%)*
Injuries Averted/yr—no ED adjustment	*207.6*	*–29.9 (–12.6%)*
Injuries Averted/yr—75% helmet effectiveness	*270.7*	*33.2 (14.0%)*
Injuries Averted/yr—Australian multiplier times 2	*7967.7*	*7730.7 (3254.3%)*
*Injuries Averted/yr—*Pr_c *@ 2000 hr = 0.97802*†	*3276.3*	*3092.2 (1279.3%)*
Savings/injury averted, 50 yr, 5% discount rate*	$364,306	–
Savings/injury averted, 25 yr	*$318,183*	*$46,123 (–12.7%)*
Savings/injury averted, 10 yr	*$151,229*	*$213,077 (–58.5%)*
Savings/injury averted, 0% discount rate	*$463,468*	*$99,162 (27.2%)*
Savings/injury averted, $53 unit intervention cost	*$519,273*	*$154,967 (42.5%)*
Savings/injury averted, Australian multiplier times 2	*$259,740*	*$104,566 (–28.7%)*
Savings/injury averted, Pr_c *@ 2000 hr = 0.97802*†	*$509,172*	*$144,866 (39.76%)*

*Base case.
†This probability is based upon an adjustment from 145 hours driving/ATV/year to 2000 hours/year, which is a work-year (50 weeks times 40 hours).
‡The results from the sensitivity analyses are shown in italics.

7967.7/100,000, which explodes into the irrational, thus the multiplier that we used appears reasonable. When we raised the annual exposure to a 2000-hour work year from 145 hours of average ATV driving per year, the probability rose to 0.978, i.e., to a point that nearly every ATV could be expected to crash once per year (if driven full-time). If this were to be the case, then a staggering 7967.7 head injuries could be averted —a 3254.3% increase— including 23 fatalities, by the universal use of a helmet during ATV riding.

The cost-effectiveness of wearing a helmet in the event of a crash provided a social cost savings for the base case of US$364,306 per helmet worn at a 5% discount rate that extended over the 50-year period. A sensitivity analysis was conducted by modifying the analytic horizon to 25 years and to 10 years. The horizon of 25 years decreased the savings by 12.7% to US$318,183, and when reduced to 10 years, the savings diminished by 58.5% to US$151,229. The cost-effectiveness of helmet use is sensitive to the shorter-term durations of the analytic horizon, averaging the intervention cost over a short period of time. The discount rate was also evaluated by removing discounting, resulting in a 21.4% increase to US$463,468 in cost-effectiveness, thus the 5% discount rate cost nearly a US$100,000, representing the time value of money. The intervention cost of US$6773 (undiscounted) included supervision, but when this cost was reduced to the price of a helmet at US$53.00, the cost-effectiveness was increased by 42.5% to US$519,273 per injury averted. Increased helmet use and effectiveness is significant for increasing cost-effectiveness, for all parameters tested resulted in cost savings per injury averted.

Two parameters evaluated for sensitivity under the decision analysis were also evaluated in our economic analysis. Although the deviations in injuries averted by the intervention were gigantic, the sensitivities regarding cost-effectiveness were modest. Doubling the value of the Australian multiplier decreased the cost-effectiveness of the helmet intervention by 28.7% to US$259,740, and, conversely, adjusting

Pr_0 to a 2000-hour work year increased the cost-effectiveness by 39.7% to US$509,172 per injury averted. Although significant, the relative modesty of these figure compared to the sensitivity of the result from the decision analysis is governed by the division of the cost savings by the injuries averted, both of which are highly affected within our sensitivity analysis, demonstrating a canceling affect because of the division of one variable by another. Nevertheless, understanding exposure to noninjury crashes is an important knowledge gap, and the cost-effectiveness increased when evaluating the hours of ATV use argues for increased helmet use.

DISCUSSION

Helmet use was found to be extremely cost-effective no matter the input variations conducted in the sensitivity analyses. Striking was the adjustment in annual hours of ATV operation in the sensitivity analysis to an equivalent work year, which indicated that an ATV has the likelihood of crashing once per 2000-hour work year. Furthermore, this analysis was conservative in many ways. It did not include occupational injuries related to ATV operation, ATV use is increasing beyond the time addressed in this study as does the potential for more injuries, and additional benefits would accrue from donning helmets in reducing the severity of facial injuries. Our study included only head injuries, but helmets also provided some facial protection, and data showed that 63.5% of patients had facial injuries.[1]

Although property damage may be small in an ATV crash, and thus not counted in our analysis, the high number of crashes can result in a substantial cost. In addition, head injuries are more lethal than many other injuries and may result in long-lasting brain damage, which is underrepresented in this study. Many fatalities not seen at hospitals may not be counted; for each ED reported death from an ATV-related crash, a coroner over the same 2-year period reported five ATV-related deaths.[8]

Missing from the literature was any study except one of ATV riders (drivers and passengers) who had experienced a crash, but were not injured.[19] The characteristics of these noninjury events could inform designers of ATVs and helmets to help them in averting injuries.

Fortunately, CPSC had determined the effectiveness of helmets in preventing fatal and nonfatal injuries, which was used in our analysis. Nevertheless, helmets have limitations in their efficacy even though they will reduce the severity of an injury.[11] Trauma is the result of energy transfer to the body, and to mediate injury severity from a crash, the energy must be dissipated; however, the effectiveness of helmets decreased with impact speed.[23]

A study of ATV-related injuries in New Zealand resulted in a recommendation to conduct further research into the effectiveness and design of roll-over protective structures (ROPS) or roll bars for ATVs and design of ATVs that are more stable. Even though most serious injuries, 70%, were incurred as a result of ATV overturns, manufacturers have been "adamant" that ROPS not be placed on ATVs, but arguments exist that this assumption should be challenged, for ROPS may have the greatest potential for reducing ATV-related injuries and fatalities.[23] Noteworthy is that one fatality was attributed to chest trauma resulting from a protective roll bar in an overturn incident,[6] but no details of the incident were addressed. Thus, the effectiveness of a roll bar (or roll cage) also requires adequate restraint systems.[24]

The New Zealand study recommended implementing farm safety programs in rural schools with an emphasis on ATVs.[25] *Brad's Last Ride* came from one such program in which the narrative-based training embeds safety stories into economics instruction curricula.[13] The narratives were used to change the attitudes of participating students and to establish the relevance of safe actions by involving participants in making critical decisions as the story unfolded. The narrative simulation exercise approach has proved more effective than the recitation or review of statistics when the participant is reluctant to accept the message. These narratives spanned the range from the pre-event, through the event circumstances and decisions, to the post-event phase. As students worked through the narrative, they made decisions as the story unfolded. This differed from

passive story-telling by engaging the student actively in making decisions, and then vicariously experiences the consequences of the decisions. The students also engaged in critical thinking about safety within the classroom setting.

The story continued with an analysis of the case to determine cost factors that related to the injury incident and identified one or more interventions that would have prevented the injury and the associated costs of the injury event. The case analysis also examined the different cost perspectives associated with the injury. Fundamentally, economics demonstrated the catastrophic significance of low probability injury events through calculations of expected value.[11]

The specter of hundreds of deaths and thousands of ATV-related injuries remains very real. As seen in Figure 1, injuries dropped during the 10-year consent decree period but rose following the expiration of the decree in 1998. Moreover, the inadequacy of voluntary standards was underscored by the following quote from the *Wall Street Journal*:

> *"David Murray, outside counsel to Yamaha Motor Corp., U.S.A., a U.S. distributor for Yamaha Motor Co. of Japan, says 'the company has spent lots of time and money to put safe all-terrain vehicles on the U.S. market. But the arrival of substandard ATVs from China and Taiwan has bruised the reputation of the entire industry,' he says. 'These imports, estimated to account for more than one-third of the U.S. market, are primarily sold online or through shops in rural areas. Just looking at them visually, you could tell that they were not in compliance with the voluntary standards. Some manufacturers thought voluntary really meant voluntary. There's been virtually no enforcement,' he said."*[26]

Reading of warning labels and manuals and participation in training courses are minimally related to helmet use when riding ATVs but is significantly higher when required by law.[27] However, helmet use during ATV operation is mandated in only 21 states.[24] Nonetheless, results show clearly that states with some level of safety legislation like mandated helmet use have substantially fewer fatalities than do states that have no ATV safety laws.[28]

To intervene against the epidemic of ATV-related death and injury, policy changes are in order regarding import controls on dangerous machines and increasing domestic ATV safety. Moreover, a system of prevention is needed that improves surveillance to better understand risk factors and ATV and injury trends, better targeting of populations-at-risk whether occupational or recreational, and improved and targeted interventions that have lasting value and effectively eliminate hazards or reduce risks. Improved frequency of helmet use is a barometer for improved risk reduction.

CONCLUSIONS

Several conclusions are drawn from this analysis. Foremost among these is that universal helmet use when riding on an ATV would save lives, reduce nonfatal head injury frequency and severity, and allay cost burdens on society. Indeed, helmet use has been shown to be extremely cost-effective, ranging from about US$150,000 to more than US$500,000 in savings to society per head injury averted across all of the parameters considered.

The potential for ATV crashes is very high. If adjusted to full-time operation at 2000 hours per year, each involved ATV has the potential to crash once per year. Interventions are needed to reduce the toll of head injuries incurred by ATV riders, including increased helmet use and perhaps some kind of overturn protection and restraint system. Import controls are needed to stop dangerous ATV designs from entering the country. Research is needed to understand the frequency and rates of close calls. Injury studies are needed to document levels of injury severity consistent with cost factors that can be applied to them. Cost factor development for ATV-related injuries is needed, and both occupational and recreational ATV-related injury data need to be integrated to better structure interventions.

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