Different Views

Motorcycle Headlight-Use Laws and Fatal Motorcycle Crashes in the US, 1975–83

PAUL L. ZADOR, PHD

Abstract: Fatal motorcycle crashes in the United States from 1975 to 1983 were analyzed. In the 14 states that had motorcycle headlight-use laws during the study period, about 600 daytime crashes of the type included in the study were prevented by these laws. This reduction corresponds to a 13 per cent reduction in fatal daytime crashes and to an average reduction of about five fatal crashes per year for each of the 14 states. About 30 states did not have motorcycle daytime headlight laws in effect during the study period. If all of these states had such laws, in an average year, approximately 140 additional fatal motorcycle crashes would have been prevented. (*Am J Public Health* 1985; 75:543–546.)

Introduction

During 1975–83, 14 states in the United States had laws in effect requiring motorcycle headlights and taillights to be turned on at all times when the motorcycle is in operation. The adoption of these laws beginning in 1967 was prompted by large increases in motorcycle usage accompanied by large increases in motorcycle crashes and by mounting evidence that the increased conspicuousness of motorcycles from daytime use of headlights and taillights can reduce crashes. In 1972, California adopted a law requiring all newly sold motorcycles in the state to have their lighting system permanently wired so that these motorcycles could be operated only with their lights lit. Although this law did not become effective until 1978, motorcycles with lighting systems wired to ignition have been marketed throughout the United States since 1975, and most newly sold motorcycles now have this feature.

The effectiveness of these laws in reducing motorcycle crashes has been assessed in several studies.[1–7] Janoff, *et al,* in 1970, concluded that both the use of headlights and the use of taillights reduced daytime crashes.[1] The reduction in multi-vehicle crashes was reported to exceed the reduction in single vehicle crashes. More multi-vehicle crashes in which the motorcycle headlight was in the field of view of the other driver were reduced than multi-vehicle crashes in which the taillight was in the field of view. The data reported by Janoff, *et al,*[1] indicated that the average rate of daytime crashes per 10,000 registered motorcycles was reduced by 7 per cent after the adoption of daytime headlight laws in the four states studied.* Other studies by Robertson,[2] Waller and Griffin,[3,4] and Muller[5–7] all reported some reductions in all daytime crashes[2] or in daytime single vehicle as compared to daytime multi-vehicle crashes.[3–7]

Although most of these studies have been criticized on methodological grounds by one or more authors,[5–8] there appears to be a consensus that these laws do reduce daytime motorcycle crashes. Because about one-fifth of all single vehicle crashes result from attempts by motorcyclists to avoid other vehicles, it is likely that single vehicle crashes as well as multivehicle crashes are reduced.[9] The magnitude of this reduction, however, is uncertain. The present study was undertaken to provide additional evidence of the effect of daytime headlight laws on fatal motorcycle crashes in the United States during 1975–1983.

Materials and Methods

Data

Data on fatal motorcycle crashes in the United States from 1975 to 1983 were obtained from the Fatal Accident Reporting System (FARS).** Only crashes with one motorcycle and no more than two other vehicles were analyzed. Pedestrian crashes and crashes involving bicycles, mopeds, and motor scooters were excluded as were crashes coded in the FARS data as occurring during dawn or dusk. Crashes were restricted to those with one or two fatally injured riders.

States were classified according to daytime headlight-use law status as shown in Appendix A. Only states whose status did not change throughout the entire study period of nine years were analyzed.

The crashes were classified according to daytime headlight-use law status (with versus without), light condition (day versus other), driver age (25 and under versus other),

*The rate of crashes per 10,000 registered motorcycles before the law was 194 in daylight and 66 in darkness. The comparable figures were 109 and 40 after the law. Had the daylight to darkness ratio been unaffected by the law there would have been $(194/66) \times 40 = 117.6$ daytime crashes after the law, but there were only $0.93 \times 117.6 = 109$ such crashes per 10,000 motorcycles. The difference between observed and estimated crash frequency corresponds to a 7 per cent reduction in daytime crashes.

**Contrary to Muller's claim (Appendix C in reference 4) if use laws reduced single vehicle crashes in the day then the total reduction during the day is underestimated by his procedures for at least two reasons. First, Muller excluded the reduction in single vehicle crashes themselves from his estimate for the total reduction. Second, if the ratio of multi-vehcile crashes (x) to single vehicle crashes (y) was x/y before the law and it became $(\alpha x)/(\beta y)$, with $0 < \alpha,\beta < 1$, after the law, then the reduction in multivehicle crashes was $(1 - /\beta)x$ according to Muller's method. However, in reality it was $(1 - \alpha)x > (1 - \alpha/\beta)\chi$ because $\beta < 1$; the total reduction is $(1-\alpha)x + (1 - \beta)y$.

Address reprint requests to Paul L. Zador, PhD, Research Scientist, Insurance Institute for Highway Safety, Watergate 600, Suite 300, Washington, DC 20037. This paper, submitted to the Journal July 11, 1984, was revised and accepted for publication November 7, 1984.

Editor's Note: See also Different View p 547 this issue.

and crash type. The crash type classification is shown in Appendix B. Crashes of two vehicles were classified in terms of the points of first impact. Frontal, right-side, left-side, and rear impacts were distinguished for both vehicles, but because of low cell frequencies some of the resulting 16 classifications were combined into 12 classifications. Thus, with the inclusion of the single vehicle crashes, 13 crash types were distinguished, resulting in a four-way classification of crashes in terms of law (L), ambient light condition (T), type (C), and age (A).***

Analysis

The analysis was begun by fitting a parsimonious hierarchical loglinear model to the four-way table to crash frequencies. Starting with the most complete model that excludes the two-way law by light condition interaction (LT), and all higher order interactions containing it, the model was improved by adding simple terms in a stepwise manner until an adequate model was found. Simple terms were then deleted from this model, again in a stepwise manner, until all terms that made no statistically significant contribution to the model were eliminated. Because the resulting model contained all two-factor effects, collapsing any single variable was not permissible.[10] Therefore, the effect of headlight laws on daytime crashes were calculated separately for each of the 26 2 × 2 tables obtained by classifiying crashes on both crash type and driver age. (For details, see Appendix C.)

All calculations were performed using SASBMDP.[11,12] The statistical methods used are described by, for example, Fleiss[13] and Bishop, *et al.*[10]

Results

In comparison with nighttime crashes, the risk of daytime crashes was 13 per cent lower in states with motorcycle daytime headlight laws than in states without such laws. This corresponds to an estimated reduction of 595 daytime crashes in the 14 headlight-use law states during the nine-year study period, or 4.7 crashes per state per year. The 95 per cent confidence limits on the estimated reduction ranged from 355 to 822 crashes, 2.8 to 6.5 crashes per state per year.

The joint effect of driver age and crash type on daytime crashes was further investigated by identifying the simplest hierarchical loglinear model that fit the data. As the results in Table 1 show, the parsimonious model that fits the data includes a three-way interaction, TCA, between light condition (T), crash type (C), and driver age (A), and all two-way interactions that contain the headlight use law (LC, TL, and LA). This model provides an adequate fit ($\chi^2 = 48.6$, df = 37, $p = 0.097$). The inclusion of the light condition by headlight-use law interaction (TL) is very important ($\chi^2 = 21.2$, d.f. = 1, $p < 0.0001$), and the inclusion of effect of the law, as measured by the three-way interaction containing crash type (TLC) is of no significance ($\chi^2 = 16.9$, d.f. = 12, $p = 0.15$).

Table 2 displays the risk reduction estimates by driver age and crash type. It is of interest to note that the risk to young drivers was reduced by about 16 per cent and that this reduction exceeds the observed reduction of 8 per cent among older drivers by a factor of two. The reduction in front-to-front crashes was about 24 per cent, which is approximately twice the average reduction of 12 per cent. Single vehicle crashes were reduced by 5 per cent only.

***A table of the four-way classification of crashes by law, ambient light condition, type, and age is available from the author upon request.

TABLE 1—Step-by-Step Identification of Simplest Hierarchical Loglinear Model for Fatal Motorcycle Crashes in the United States from 1975 to 1983 by Headlight-Use Law Status (L), Ambient Light Condition (T), Crash Type (C), and Driver Age (A)

Model	Difference Due to	Simple Effect*	D.F.	Likelihood Ratio Chi-Square	Likelihood Ratio Prob.
TCA,LCA			26	52.21	0.0017
	Adding	TL	1	21.23	0.0000
TL,TCA,LCA			25	30.98	0.1895
	Adding	TLC	12	16.88	0.1543
TLC,TCA,LCA			13	14.11	0.3664
	Deleting	LCA	12	16.54	0.1679
TLC,TCA,LA			25	30.64	0.2011
	Deleting	TLC	12	17.90	0.1186
LC,TL,TCA,LA**			37	48.55	0.0969

*At each step the simple effect for addition or deletion was chosen so that the resulting model is the best possible.

**As judged by the Freeman-Tukey deviates of estimates based on the model LC, TCA, LA, TL *is adequate in every cell* of the four-way table. Moreover, the loglinear parameter corresponding to the LT interaction is $\lambda = -.031$ ($Z = -4.66$, $p < 0.0001$) so that the risk reduction estimate based on this model is about 12 per cent.

Discussion and Summary

It should be noted that in recent years most new motorcycles were sold with lighting systems wired to the ignition. Therefore, the effect of the laws was likely to be larger at the beginning of the study period than at the end of it. Clearly, the effects attributable to laws requiring daytime headlight use will diminish in the future as the number of older motorcycles without this feature is reduced.

A recent study of motorcyclist fatalities in the United States between 1976 and 1981 reported that the total effect of headlight-use laws was at most a 5 per cent reduction in daytime multi-vehicle fatalities; the effect used in calculating this estimate was not statistically significant at the 5 per cent confidence level.[7] To reach this conclusion, the odds ratio for measuring the association between two factors—the number of vehicles in the crash (single versus multiple

TABLE 2—Estimated Frequency (Per Cent) of Fatal Daytime Motorcycle Crashes Prevented by Headlight Use Laws in 14 States from 1975 to 1983 by Crash Type and Driver Age*

Crash Type: Motorcycle	Crash Type: Other Vehicle	Driver Age: 25 and under	Driver Age: 26 and over	Driver Age: All
Single		−117** (−12)	28 (4)	−87 (−5)
Front	Front	−201† (−26)	−100** (−21)	−304† (−25)
	Right	−36 (−11)	1 (1)	−37 (−7)
	Rear	−25 (−13)	4 (3)	−20 (−7)
	Left	−51 (−17)	−57** (−32)	−108** (−23)
Right	Front	−46 (−36)	−18 (−27)	−65** (−33)
	Right	13 (908)	−5 (−38)	10 (8)
Right/Left	Rear	−4 (−38)	3 (50)	−1 (−4)
Right	Left	3 (32)	6 (59)	10 (54)
Rear	All	−9 (−23)	−6 (−15)	−20 (−23)
Left	Front	−7 (−4)	4 (5)	−4 (−2)
	Right	5 (−56)	−12 (−64)	−7 (−24)
	Left	4 (41)	−8 (−61)	−4 (−21)
All††	All	−474† (−16)	−161 (−8)	−635† (−13)

*See text for excluded crashes.
**Statistical significance at level of .05.
†Statistical significance at level of .0001.
††Results based on pooled table.

vehicle) and light condition (day versus night)—was compared between states with and states without headlight-use laws, and the effect was estimated from the logarithms of these odds ratios, i.e., from the three-way interaction between law, light condition, and crash type. The validity of this method depends critically on the assumption that headlight-use laws do not reduce single vehicle crashes.† However, both the present study and the earlier study by Janoff, *et al,*[1] found that headlight-use laws do reduce single vehicle crashes as well. It was estimated in the present study that single vehicle crashes are reduced by 5 per cent. This is just under 30 per cent of the 17 per cent reduction found for multi-vehicle crashes. This finding parallels the earlier finding by Hurt, *et al,*[9] that about 20 per cent of all single vehicle crashes are the result of attempts by motorcyclists to avoid other vehicles. Moreover, according to Muller's own Table 4,[7] a higher proportion of the single vehicle fatal crashes occurred during daytime in states without headlight-use laws than in states with such laws. These considerations demonstrate that the three-way interaction method used by Muller leads to biased estimates for the effects of headlight-use laws. The 13 per cent reduction in fatal crashes found in the present study is below the 18 per cent estimated reduction in all multi-vehicle crashes in North Carolina,[4] but it is above the estimated 7 per cent reduction in all crashes based on Janoff's four-state study.[1]

It should be noted in conclusion that about 30 states had no motorcycle daytime headlight laws in effect during the study period. Had all of these states had such laws, in an average year, an estimated 140 additional fatal motorcycle crashes would have been prevented.

†The Fatal Accident Reporting System (FARS) is a census of almost all fatal motor vehicle crashes in the US. FARS is maintained by the National Highway Safety Administration, and is based on data provided by state governments.

REFERENCES

1. Janoff JS, Cassell A, Fertner KS, Smierciak ES: Daytime Motorcycle Headlight and Taillight Operation. Philadelphia: Franklin Institute, (Rep. No. F-C2588) 1970.
2. Robertson LS: An instance of effective legal regulation: motorcyclist helmet and daytime headlamp laws. Law and Society Rev 1976; 10:467–488.
3. Waller PF, Griffin LI: The impact of a motorcycle lights-on law. Proc Am Assoc Automotive Med, Vancouver, 1977; 14–25.
4. Waller PF, Griffin LI: The impact of a motorcycle lights-on law: an update. Paper presented to the National Safety Council Symposium on Traffic Safety Effectiveness (Impact) Evaluation Projects. Chicago, IL, 1981; 1–18.
5. Muller A: An evaluation of the effectiveness of motorcycle daytime headlight laws. Am J Public Health 1982; 72:1136–1141.
6. Muller A: How effective are motorcycle daytime headlight laws? a response to Zador's criticism. Am J Public Health 1983; 73:809–810.
7. Muller A: Daytime headlight operation and motorcyclist fatalities. Accid Anal Prev 1984; 16:1–18.
8. Zador P: How effective are motorcycle daytime headlight laws? Am J Public Health 1983; 73:808.
9. Hurt HH, Ouellet JV, Thom DR: Motorcycle Accident Cause Factors and Identification of Countermeasures. Vol. 1. Technical Report No. DOT-HS-805-862. Springfield, VA: NTIS, 1981.
10. Bishop YMM, Fienberg SE, Holland PW: Discrete Multivariate Analysis: Theory and Practice. Cambridge: MIT Press, 1975.
11. Dixon WJ, Brown MB, Engelman L, Frane JW, Hill MA, Jennrich RI, Toporek JD: BMDA Statistical Software 1981. Berkeley: University of California Press, 1981.
12. SAS Institute Inc. *SAS User's Guide: Statistics 1982 Edition*. Cary, NC: SAS Institute Inc, 1982.
13. Fleiss JL: *Statistical Methods for Rates and Proportions*. New York: Wiley and Sons, 1981.

ACKNOWLEDGMENTS

The author wishes to thank Karen Weinberg and Michele Fields for legal research, Deborah Sandroni for data processing, and Sharon J. Rasmussen for editorial assistance. This work was supported by the Insurance Institute for Highway Safety.

APPENDIX A

Classification of States According to Daytime Headlight Use Laws for Motorcycles

States with Motorcycle Daytime Headlight Laws	Effective Date
Arkansas	July 1, 1967
Florida	September 1, 1971
Georgia	July 1, 1973
Illinois	July 1, 1970
Indiana	September 1, 1967
Maine	June 28, 1974
Montana	October 1, 1967
New York	January 1, 1971
North Carolina	October 1, 1973
Oregon	September 12, 1967
South Carolina	June 22, 1973
Washington	July 24, 1974
Wisconsin	January 11, 1968
Wyoming	May 26, 1973

States with no Daytime Headlight Laws during 1975–83
Alabama, Alaska, Arizona, Colorado, Delaware, District of Columbia, Hawaii, Idaho, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Mississippi, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Dakota, Texas, Utah, Vermont, Virginia.

States Excluded from Study
California, Connecticut, Iowa, Kansas, Minnesota, Tennessee, West Virginia.

APPENDIX B

Classification of Two-Vehicle Motorcycle Crashes by First Impact Point

	Other Vehicle			
Motorcycle	Front	Right	Left	Rear
Front*	Front/Front (4,497)††	Front/Right (2,111)	Front/Left (1,651)	Front/Rear (1,449)
Right	Right/Front (500)	Right/Right (59)	Right/Left (105)	Right or Left/Rear† (57)
Left	Left/Front (830)	Left/Right (99)	Left/Left (93)	Right or Left/Rear (57)
Rear	Rear/All** (598)	Rear/All (598)	Rear/All (598)	Rear/All (598)

*11, 12, 1 o'clock = Front; 2–4 o'clock = Right; 5–7 o'clock = Rear; 8–10 o'clock = Left.
**Rear into Front, Right, Left and Rear were combined.
†Right and Left into Rear were combined.
††Sample sizes given in parentheses. There were 10,597 single motorcycle crashes.

APPENDIX C

The frequency of daytime crashes that would have occurred in states with daytime headlight laws in the absence of those laws can only be estimated. The maximum likelihood (ML) estimate ($\hat{a}_{11}$) for the expected value of this frequency is

$$\hat{a}_{11} = a_{12} R_2, \tag{1}$$

where a_{12} is the observed frequency of night crashes in states with daytime headlight-use laws, and $R_2 = a_{21}/a_{22}$ is equal to the ratio of day crashes (a_{21}) and night crashes (a_{22}) in the other states. The per cent difference between the observed (a_{11}) and the estimated ($\hat{a}_{11}$) frequency then is

$$\% \text{ DIFF} = \frac{100 \times (a_{11} - \hat{a}_{11})}{\hat{a}_{11}} = 100 \times (\alpha - 1)$$

$$\simeq 100 \times \ln(\alpha), \tag{2}$$

where $\alpha = a_{11}a_{22}/a_{12}a_{21}$ is the odds ratio for the 2 × 2 table of crashes classified by law status and light condition (in a_{ij}, $i = 1$ for states with laws and $i = 2$ for states without laws; $j = 1$ for day and $j = 2$ for night). Thus 100 ln(α) is approximately equal to the effect of headlight laws expressed as a percentage difference between observed and estimated crashes.

The variance of the log (odds ratio) is, approximately,

$$s^2 = 1/a_{11} + 1/a_{12} + 1/a_{21} + 1/a_{22}. \tag{3}$$

Hence $\ln(\alpha) + 2s$ and $\ln(\alpha) - 2s$ provide 95 per cent confidence intervals for $\ln(\alpha)$.

A Survey of the Problems of Childbirth, 1911–16

In 1913 in this country at least 15,000 women, it is estimated, died from conditions caused by childbirth; about 7,000 of these died from childbed fever, a disease proved to be almost entirely preventable, and the remaining 8,000 from diseases now known to be to a great extent preventable or curable. Physicians and statisticians agree that these figures are a great underestimate.

In 1913 the death rate per 100,000 population from all conditions caused by childbirth was little lower than that from thyphoid fever; this rate would be almost quadrupled if only the group of the people which can be affected, women of childbearing age, were considered.

In 1913 childbirth caused more deaths among women 15 to 44 years old than any disease except tuberculosis.

The death rate due to this cause is almost twice as high in the colored as in the white population.

Only 2 of a group of 15 important foreign countries show higher rates from this cause than the rate in the registration area of the United States. The rates of 3 countries, Sweden, Norway, and Italy, which are notably low, show that low rates for these diseases are attainable.

The death rates from childbirth and from childbed fever for the registration area of this country apparently are not falling to any great extent; during the 13 years from 1900 to 1913 they have shown no demonstrable decrease. These years have been marked by a revolution in the control of certain other preventable diseases, such as typhoid, diphtheria, and tuberculosis. During that time the typhoid rate has been cut in half, the rate from tuberculosis markedly reduced, and the rate from diphtheria reduced to less than one-half. During this period there has been a decrease in the death rate from childbirth per 1,000 live births in England and Wales, Ireland, Japan, New Zealand and Switzerland.

These facts point to the need in this country . . . of higher standards of care for women at the time of childbirth.

The low standards at present existing in this country result chiefly from two causes: (1) General ignorance of the dangers connected with childbirth and of the need for proper hygiene and skilled care in order to prevent them; (2) difficulty in the provision of adequate care due to special problems characteristic of this country. Such problems vary greatly in the city and in the rural districts. In the country inaccessibility of any skilled care is a chief factor.

–Meigs GL: *Maternal Mortality from All Conditions Connected with Childbirth in the United States.* Washington, DC: US Children's Bureau, Pub. No. 19, 1917. Excerpted in: *Children and Youth in America: A Documentary History,* Vol II Cambridge: Harvard University Press, 1970; 994–995.