Memorandum

U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

Subject: ACTION: Submission of Report on Antilock Brakes

Date: JUL 16 2010

From: Dennis Utter, Director
Office of Traffic Records and Analysis

Reply to Attn. Of: NVS-421
Sue Partyka

To: Docket NHTSA 2002-11950

Thru: Marilena Amoni
Associate Administrator
National Center for Statistics and Analysis

Please place the following agency report in docket number NHTSA 2002-11950.

Published research suggests that antilock braking systems (ABS) may be effective in preventing fatal motorcycle crashes. The National Highway Traffic Safety Administration's (NHTSA) National Center for Statistics and Analysis (NCSA), performed case-control comparisons for motorcycles with and without antilock braking systems (ABS) using two sets of data (fatal crashes and, separately, all police-reported crashes). Using this methodology, we did not find statistically-significant results to suggest that ABS affects motorcycle crash risk.

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Attachments:
Motorcycle Antilock Braking Systems and Crash Risk Estimated from Case-Control Comparisons, Mathematical Analysis Division, July 7, 2010

cc: Associate Administrator, Rulemaking
Director, Office of Crash Avoidance Standards
Chief, Vehicle Dynamics Division
Mike Pyne

Motorcycle Antilock Braking Systems and Crash Risk

Estimated from Case-Control Comparisons

Mathematical Analysis Division
National Center for Statistics and Analysis
National Highway Traffic Safety Administration
July 7, 2010

Summary

The National Highway Traffic Safety Administration's National Center for Statistics and Analysis performed case-control comparisons for motorcycles with and without antilock braking systems (ABS), using two sets of data (fatal crashes and, separately, all police-reported crashes). Using this methodology, we did not find statistically-significant results to suggest that ABS affects motorcycle crash risk.

We did find three differences between non-ABS and ABS motorcycle crash conditions. First, the police were less likely to report pre-crash braking in fatal crashes for ABS (compared to non-ABS) motorcycle riders. Second, riders in all police-reported crashes were more likely to be male when the motorcycle had ABS (compared to when it did not). And third, police-reported crashes were more likely to involve multiple vehicles when the motorcycle was equipped with ABS (compared to when it was not). The interpretation of these findings is unclear, and the estimates may change as more data from a wider range of motorcycle models become available.

Background

Published comparisons of fatalities per registered vehicle-year suggest that ABS may be effective in preventing fatal motorcycle crashes.[1] Teoh studied motorcycles with optional ABS for which the ABS status (that is, whether the individual motorcycle had ABS) could be identified from patterns in the vehicle identification number (VIN), and he found differences in the fatal-crash involvement rates between motorcycles with ABS and motorcycles without ABS. He estimated that there were 6.4 fatal crashes per 10,000 registered vehicle-years for the non-ABS group compared to 4.1 for the ABS group, which is a reduction of 37 percent associated with selecting ABS. However, we need to consider possible confounding factors when interpreting these results. For example, we do not know whether riders who select the ABS option travel more or fewer miles per year or whether the availability of ABS is related to how they use their motorcycle.

We lack data to address these questions directly, but other analytical approaches may be less subject to selection bias and do not depend on accepting registrations as a valid measure of exposure to crash risk. One approach that the agency has used to address crash-avoidance issues is based on case-control comparisons.[2,3] We define "case" crashes as those that might be prevented (or otherwise affected) by a specific countermeasure, and we define "control" crashes as those that are unlikely to be affected by that countermeasure. The control crashes are used as a measure of crash exposure, and the ratio of case to control crashes is interpreted as a measure of crash risk. The case-control analytical approach is sometimes referred to as an "induced exposure" method, with the number control crashes interpreted as a measure of exposure to crash involvement. This report describes the application of this technique to motorcycle ABS using fatal and other police-reported crash data.

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[1] Teoh, E.R. (2010) *Effectiveness of Antilock Braking Systems in Reducing Motorcycle Fatal Crashes*, Arlington, VA: Insurance Institute for Highway Safety.

[2] Dang, J.N. (2007) *Statistical Analysis of the Effectiveness of Electronic Stability Control (ESC) Systems – Final Report*, NHTSA Technical Report No. DOT HS 810 794, Washington, DC.

[3] Kahane, C.K. and Dang, J.N. (2009) *The Long-Term Effect of ABS in Passenger Cars and LTVs*, NHTSA Technical Report No. DOT HS 811 182, Washington, DC.

Data and Definitions

We used two of the agency's data programs in this analysis. Our comparisons of motorcycles in fatal crashes are based on the 2001-2008 Fatality Analysis Reporting System (FARS).[4] Our comparisons of motorcycles in all police-reported crashes are based on 2001 and later crash years for States that had the VIN on files that were available to us in the State Data System (SDS) at the end of March 2010. We used the motorcycle models and model years identified by Teoh as having ABS available as an option that was identifiable from the VIN.[5] These are the:

2008 Harley-Davidson V-Rod,
2001-2008 Honda Gold Wing 1800,
2002-2008 Honda Interceptor 800,
2001-2007 Honda Reflex,
2003-2008 Honda ST1300,
2003-2008 Honda Silver Wing,
2008-2009 Kawasaki Concours 14,
2007-2008 Suzuki Bandit 1250,
2006-2008 Suzuki Burgman 650,
2007-2008 Suzuki SV650,
2007-2008 Suzuki V-Strom 650,
2006-2008 Triumph Sprint ST, and
2004-2005 Yamaha FJR1300.

We classified crashes as either case or control using two alternative definitions of a non-culpable vehicle. What we will refer to here as the "strict" definition of the control group includes stationary motorcycles and those moving very slowly. These had the police-reported travel speed no greater than 10 mph or the pre-crash vehicle maneuver reported as stopped, parked, entering a parked position, leaving a parked position, starting in traffic, backing, being pushed by a person, or driverless. The strict definition of crashes of interest includes all other crash-involved motorcycles.

What we will refer to here as the "relaxed" definition of the control group also considers whether any driver was "at fault." Fault was defined from driver contributing circumstances, using those that suggest a possible moving violation. Drivers at fault are those identified by the police with "improper" actions, a "failure" to act properly, or under the influence of alcohol or drugs. All other drivers are considered to be "not at fault" for this application. The relaxed definition of the control group includes motorcycle crashes covered by the strict definition plus multi-vehicle crashes in which the motorcyclist was not at fault but another driver in the crash was at fault. The "relaxed definition of crashes of interest" includes all other crash-involved motorcycles.

Under the null hypothesis that ABS does not affect crash risk, we would expect a similar ratio of case to control crashes for both groups. Under the hypothesis that ABS prevents crashes,

[4] Teoh based his analysis on 2003-2008 FARS data, the calendar years for which he had matching registration data.
[5] We interpreted VINs using PC VINA (Personal Computer Vehicle Identification Number Analysis) software, developed by R. L. Polk & Co., supplemented with the annual publication, *Passenger Vehicle Identification Manual*, National Insurance Crime Bureau, Des Plaines, IL.

we would expect a lower ratio of case to control crashes for the ABS group than for the non-ABS group. This paper describes the results of these comparisons.

Case-Control Comparisons for Fatal Crashes

The 2001-2008 FARS data include 356 motorcycles with optional ABS that was identifiable from the VIN. There were 302 non-ABS and 54 ABS motorcycles in fatal crashes available for this study. A simple comparison using the strict definition of the control group shows that the ratio of crashes of interest to control-group crashes is:

294 / 8 = 36.75 without ABS and
50 / 4 = 12.50 with ABS.

There were too few control-group crashes for a statistical test of the significance of the difference between non-ABS and ABS motorcycles.[6] There were more control-group crashes using the relaxed definition, and the ratio of crashes of interest to control-group crashes is:

243 / 59 = 4.12 without ABS and
44 / 10 = 4.40 with ABS.

If we interpret the ratios as crash rates (with control-group crashes acting as a normalizing or exposure measure for the crashes of interest), then the point estimate for the crash rate for ABS motorcycles is slightly higher than the rate for non-ABS motorcycles. This is not the direction we would expect if ABS were effective in preventing fatal-crash involvements. However, the chi-square for the comparison is small (χ^2=0.0304), and the probability of a value this high occurring by chance is large (p=0.8616). A common definition of a statistically-significant result is that the probability that it occurred by chance does not exceed 0.05 (and a finding is significant when $p \leq 0.0500$). The difference between non-ABS and ABS motorcycles in fatal crashes is not statistically significant at this level.

We also explored police-reported pre-crash braking as a function of ABS availability. The police reported braking for 31.28 percent of non-ABS motorcycles (56 of 179 crashes with information on attempted avoidance maneuvers) and for 6.45 percent of ABS motorcycles (2 of 31 cases with the information). The difference is statistically significant (χ^2=8.1514, p=0.0043), but its interpretation is unclear. For example, ABS may eliminate skid marks and other evidence of braking, or ABS may prevent fatal crashes when brakes are used.[7]

Case-Control Comparisons for All Police-Reported Crashes

The comparisons described above were limited to motorcycles in fatal crashes. We gain a broader perspective by considering motorcycles in all types of police-reported crashes. The SDS includes 18 States with the VIN on their electronic crash records and for which we had a

[6] The expected count in one or more cells, under an assumption that the factors being compared were statistically independent, was less than five.
[7] The agency's Crash Investigation Division reviewed the available police reports for the crashes that occurred in 2007. The reviewers found a positive indication of braking by the motorcycle rider before the first harmful event in 12 of 57 reports, and no indication of braking or attempted braking in the others. They found pre-crash braking for 12 of 49 non-ABS motorcycles and none of the 8 ABS motorcycles in their review.

2001 or later analysis file at the end of March 2010. The following data were available for this analysis.

2001-2007 Alabama
2001-2007 Florida
2001-2006 Georgia
2001-2007 Illinois
2002-2007 Kansas
2001-2007 Kentucky
2001-2007 Maryland
2004-2007 Michigan
2001-2007 Missouri
2003-2007 Nebraska
2006-2008 New Jersey
2001-2007 New Mexico
2001-2006 North Carolina
2001, 2003-2005 Pennsylvania
2001-2004 Utah
2002-2007 Washington
2001-2006 Wisconsin
2002-2007 Wyoming

These 105 State-years of data include 2,653 motorcycles with optional ABS that was identifiable from the VIN. There were 2,255 non-ABS motorcycles and 398 ABS motorcycles available for this study. Using the strict definition of the control group, the ratio of crashes of interest to control-group crashes is:

1,958 / 297 = 6.59 without ABS and
343 / 55 = 6.24 with ABS,

and the difference is not statistically significant (χ^2=0.1236, p=0.7252). Using the relaxed definition of the control group, the ratio of crashes of interest to control-group crashes is:

1,629 / 626 = 2.60 without ABS and
280 / 118 = 2.37 with ABS,

and the difference is not statistically significant (χ^2=0.5974, p=0.4396). The difference between non-ABS and ABS motorcycles in all police-reported crashes is not statistically significant using either control group.

We can also use the State data for comparisons that may suggest differences in vehicle use. The non-ABS and ABS motorcycles in the crashes available for this study seem similar in terms of the posted speed limit, vehicle age, rider age, light condition, and helmet use. The mean posted speed limit (in miles per hour, for those States that include the variable on the files provided to the agency) was 44.485 for non-ABS motorcycles and 44.549 for ABS motorcycles. The absolute value of the t-statistic for the comparison is small (t=-0.07) and the probability of a

value this high occurring by chance is large (p=0.9462). The mean vehicle age[8] was 2.7268 years for non-ABS motorcycles and 2.7588 years for ABS motorcycles (t=-0.37, p=0.7103). The mean age of the riders was 50.169 years for non-ABS motorcycles and 50.209 years for ABS motorcycles (t=-0.06, p=0.9558). Crashes after dark accounted for 14.95 percent of non-ABS motorcycle crashes and 14.94 of ABS motorcycle crashes (χ^2=0.0000, p=0.9951). Riders with helmets were 79.44 percent of those on non-ABS motorcycles and 80.43 percent of those on ABS motorcycles (χ^2=0.1683, p=0.6817). None of these five comparisons suggests pre-crash differences between the two groups of motorcycles.

There did appear to be a difference in the mix of male and female riders in crashes as a function of ABS availability. Male riders were 94.60 percent of those on non-ABS motorcycles and 97.04 percent of those on ABS motorcycles (χ^2=3.9257, p=0.0476). The difference is statistically significant. A simple way to address the potential bias associated with the mix of riders is to perform the case-control comparisons separately for male and female riders. Using the strict definition of the control group, the ratio of crashes of interest to control-group crashes for male riders is:

1,803 / 228 = 7.91 without ABS and
318 / 42 = 7.57 with ABS,

and the difference is not statistically significant (χ^2=0.0593, p=0.8076). Using the relaxed definition of the control group, the ratio of crashes of interest to control-group crashes for male riders is:

1,484 / 547 = 2.71 without ABS and
258 / 102 = 2.53 with ABS,

and the difference is not statistically significant (χ^2=0.3034, p=0.5817). The difference between non-ABS and ABS motorcycles with male riders in police-reported crashes is not statistically significant using either control group. There were too few crashes with female riders for statistically-valid case-control comparisons.

We considered two other factors that Kahane and Dang found to be relevant to ABS performance for passenger vehicles. We tested the difference in the mix of single-vehicle and multiple-vehicle crashes as a function of ABS availability. Single-vehicle crashes were 41.64 percent of those for non-ABS motorcycles and 35.93 percent of those for ABS motorcycles. The difference is statistically significant (χ^2=4.5689, p=0.0326). Differences in the number of vehicles in the crash as a function of ABS availability may reflect differences in road use (how, when, and where motorcycles are used) or real differences in vehicle performance (such as the ability to avoid severe crashes).

We also tested the difference in the mix of wet and dry crash conditions as a function of ABS availability. The road was wet[9] in 8.29 percent of crashes with non-ABS motorcycles and in 10.33 percent of crashes with ABS motorcycles, but the difference is not statistically significant (χ^2=1.7845, p=0.1816). It may still be useful to perform case-control comparisons separately for each road surface condition because of the implications for brake performance.

[8] We defined vehicle age as crash year – model year + 1.
[9] "Wet" was defined from variables for road surface condition and weather, and it includes water, ice, sleet, and snow.

Using the strict definition of the control group, the ratio of crashes of interest to control-group crashes on wet roads is:

161 / 25 = 6.44 without ABS and
39 / 2 = 19.50 with ABS,

but there were too few control-group crashes for a statistical test of the significance of the difference between non-ABS and ABS motorcycles on wet roads. Using the relaxed definition of the control group, the ratio of crashes of interest to control-group crashes on wet roads is:

144 / 42 = 3.43 without ABS and
37 / 4 = 9.25 with ABS,

and the difference approaches statistical significance (χ^2=3.4196, p=0.0644).

The results on dry roads did not approach statistical significance. Using the strict definition of the control group, the ratio of crashes of interest to control-group crashes on dry roads is:

1,789 / 269 = 6.65 without ABS and
303 / 53 = 5.72 with ABS,

and the difference is not statistically significant (χ^2=0.8665, p=0.3519). Using the relaxed definition of the control group, the ratio of crashes of interest to control-group crashes on dry roads is:

1,477 / 581 = 2.54 without ABS and
242 / 114 = 2.12 with ABS.

The difference is not statistically significant (χ^2=2.1278, p=0.1447), but we would like to update the comparison when additional data are available.

Another consideration reported by Teoh is that all Honda motorcycles in his study had combined braking systems (CBS) as standard equipment and CBS was not available on other models. ABS may perform differently depending on whether it is used alone or with CBS, so we performed the case-control comparisons separately for non-CBS and CBS motorcycles. There are 208 non-CBS motorcycles in our study data, which is 8 percent of the available data. Using the strict definition of the control group, the ratio of crashes of interest to control-group crashes for non-CBS (that is, other than Honda) motorcycles is:

145 / 19 = 7.63 without ABS and
38 / 6 = 6.33 with ABS,

and the difference is not statistically significant (χ^2=0.1380, p=0.7103). Using the relaxed definition of the control group, the ratio of crashes of interest to control-group crashes for non-CBS motorcycles is:

117 / 47 = 2.49 without ABS and

30 / 14 = 2.14 with ABS,

and the difference is not statistically significant (χ^2=0.1671, p=0.6827). Using the strict definition of the control group, the ratio of crashes of interest to control-group crashes for CBS (that is, Honda) motorcycles is:

1,813 / 278 = 6.52 without ABS and
305 / 49 = 6.22 with ABS,

and the difference is not statistically significant (χ^2=0.0781, p=0.7799). Using the relaxed definition of the control group, the ratio of crashes of interest to control-group crashes for CBS motorcycles is:

1,512 / 579 = 2.61 without ABS and
250 / 104 = 2.40 with ABS,

and the difference is not statistically significant (χ^2=0.4287, p=0.5126). There were no statistically-significant differences between non-ABS and ABS motorcycles found for either non-CBS or CBS models, using either control group.

There may be other biases associated with the mix of motorcycle models with and without ABS. A simple way to address this possibility is to limit the comparisons to the most-common make-model. Sixty-three percent of the motorcycles in our study (1,684 of 2,653) were Honda Gold Wing 1800 models (all with CBS). Using the strict definition of the control group, the ratio of crashes of interest to control-group crashes for the Honda Gold Wing 1800 is:

1,225 / 206 = 5.95 without ABS and
220 / 33 = 6.67 with ABS,

and the difference is not statistically significant (χ^2=0.3227, p=0.5700). Using the relaxed definition of the control group, the ratio of crashes of interest to control-group crashes for the Honda Gold Wing 1800 is:

1,010 / 421 = 2.40 without ABS and
178 / 75 = 2.37 with ABS,

and the difference is not statistically significant (χ^2=0.0052, p=0.9425). The difference between non-ABS and ABS Honda Gold Wing 1800 motorcycles is not statistically significant using either control group.

Discussion

The estimates in this report may change as data from a wider range of motorcycle models and data from more crashes become available. However, none of the simple comparisons presented here (for case and control motorcycles, with and without ABS) suggests an effect of ABS on crash risk.

We used an induced-exposure (or case-control) method to estimate effects associated with ABS, and any conclusions from these comparisons would depend on three assumptions. First, drawing conclusions from these comparisons would require assuming that crashes involving non-culpable motorcycles (using either the strict or the relaxed definition) are an adequate control group, representing exposure to crashes. However, it is important to remember that there are alternative ways to define non-culpable vehicles, opinions differ, and the choice of the control group will affect the results of the comparisons.

Second, drawing conclusions from this approach would require assuming that the ABS itself was the only difference between the case and control motorcycles. That is, the comparison is simplest if vehicle design (aside from ABS availability) and vehicle use are the same for both groups of motorcycles. While it is true that the same models and model years were used as case and control vehicles, there may be biases associated with the owner's decision to purchase the optional ABS that affect how the vehicles are used.

And third, extending any conclusions beyond the motorcycle makes and models used in the analysis would require assuming that the experience on the motorcycles that were available with optional ABS that was identifiable from the VIN was typical of the experience that could be expected on a wider range of models (including a variety of makes, for motorcycles with and without CBS).

The null results reported here should be treated with caution because of the small numbers of control-group motorcycle crashes available for many of the comparisons. With small numbers as denominators, the ratios could change considerably with a small amount of variability in the control numbers. More data (and, especially, data from a wider range of motorcycle models) should help us better assess the effects of ABS on motorcycle-crash risk.