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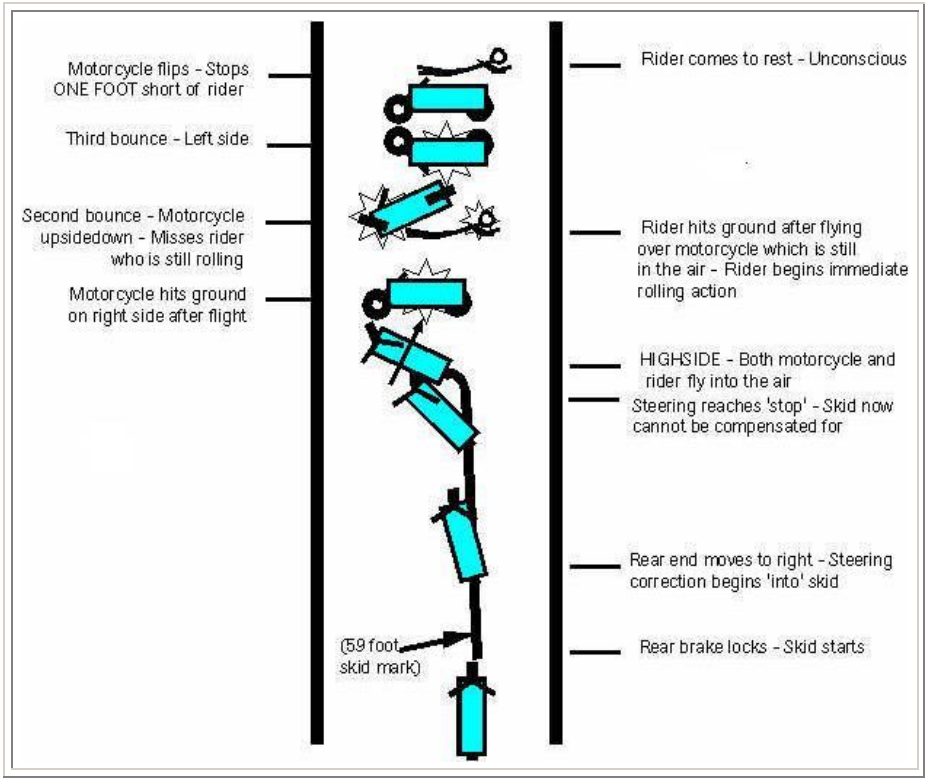
Technical Report

Motorcycle Helmet Effectiveness Revisited



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16. Abstract

This report looks at the measurement of how effective motorcycle helmets are in preventing fatalities in motorcycle crashes. Based on a comparison of crashes involving motorcycles with two occupants, at least one of whom was killed, the method uses data from the Fatality Analysis Reporting System (FARS) to estimate helmet effectiveness. Technological changes over the past 15 years have led to improvements in helmet design and materials. Recalculating the effectiveness of helmets in preventing fatalities, using more recent data, shows that helmets have indeed improved in this respect. The effectiveness of helmets has increased from 29 percent in 1982 through 1987 to 37 percent over the years 1993 through 2002. The significance of this improvement is that over the same period, helmets have saved the lives of 7,808 riders. The potential number of lives saved over the period is even higher, at 11,915. Unfortunately, the declining rate of helmet use among motorcyclists has contributed to rising numbers of rider fatalities despite the improved life saving qualities of helmets.

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Executive Summary

Using Fatality Analysis Reporting System (FARS) data from 1993 through 2002, this report recalculates the "effectiveness " of helmets in preventing fatalities in motorcycle crashes. The resulting effectiveness of 37 percent represents a significant improvement over the previous estimate of 29 percent obtained using data from 1982 through 1987. The 37 percent effectiveness would mean that from 1993 through 2002 helmets saved 7,808 lives, a substantial increase compared with the estimate of 5,430 lives saved using the old effectiveness measure.

The past fifteen years have seen significant advances in motorcycle helmet design and materials. As a result, the newer helmets afford a much greater degree of protection against potentially fatal head injuries.

Based on a comparison of fatal crashes involving motorcycles with two occupants, at least one of whom was killed, NCSA calculates the "effectiveness" of helmets in preventing fatalities. Recalculating the effectiveness of helmets in preventing fatalities using more recent data shows that helmets have indeed improved in their ability to protect the wearer. Unfortunately, the potential benefits of improved helmets are not being realized, as fatalities continue to rise in response to declining helmet usage rates. Had all motorcyclists consistently worn proper helmets over the 1993 to 2002 time period, the number of lives saved would have been much higher at 11,915.

Despite the fact that less than 3 percent of registered passenger vehicles are motorcycles, motorcyclist fatalities represent about nine percent of all passenger vehicle occupant fatalities. Considering that passenger car occupant fatalities are trending downward, policies that result in raising public acceptance of the protective value of helmets can have a significant impact on reducing the total number of lives lost annually on America's highways.

Highlights

- The state of the art in helmet design and materials has improved significantly over the past fifteen years, and their effectiveness in preventing fatalities is greater than previous estimates indicated.

- As a result of these improvements, motorcycle helmets are currently estimated to be 37 percent effective in preventing rider fatalities, compared with the 1989 estimated effectiveness of 29 percent.

- The higher effectiveness means that over the ten-year period from 1993 through 2002, motorcycle helmets have saved 7,808 lives, 2,378 more than was previously thought.

- Effectiveness of 37 percent means that a rider can reduce his or her risk of suffering a fatal injury in a crash by over one-third simply by wearing a proper helmet.

- Despite the improved performance of helmets, the incidence of fatal motorcycle crashes in the United States has been increasing in recent years, as the percentage of riders who use helmets has fallen from 71 percent to 58 percent nationally.

Motorcycle Helmet Effectiveness Revisited

1.0 Introduction

The past fifteen years have seen significant advances in motorcycle helmet design and materials. As a result, the newer helmets afford a much greater degree of protection against potentially fatal head injuries. Despite these technological improvements, NHTSA is still using the 29 percent helmet effectiveness calculated from observed fatality data from the 1980's.

This report uses more recent data from the Fatality Analysis Reporting System (FARS) to update the estimated protective value of motorcycle helmets in the prevention of fatal head injuries and to estimate the total number of lives saved by helmets. An "effectiveness" of 29 percent means that use of a proper helmet can improve a rider's chances of surviving a potentially fatal crash by almost one-third. The fact that motorcyclist fatalities represent about nine percent of all passenger vehicle occupant deaths, despite the relatively low numbers of motorcycles vis-à-vis other passenger vehicles traveling the nation's highways, underscores the protective value of motorcycle helmets.

In terms of lives saved, the 29 percent effectiveness means that over the recent ten-year period from 1993 through 2002, motorcycle helmets have saved 5,430 lives. This estimate is conservative, given the known improvements in helmet technology over the same period. If effectiveness were recalculated based on more recent mortality data, one would expect to see a higher effectiveness and a concomitant increase in the number of lives saved.

While helmets have improved, the proportion of riders who actually use them has declined. In the United States in 2002, motorcycle crashes claimed the lives of 3,244 motorcyclists and injured another 65,000. Many of these riders were not wearing helmets. In fact, the 2002 National Occupant Protection Use Survey (NOPUS) data on helmet usage shows that only 58 percent of motorcyclists wear helmets when they ride, a sharp drop from the 71 percent usage rate in 2000. With the repeal or watering down of helmet laws in many states, both the percentage of non-users and the number of fatalities have grown.

Since 1974, motorcycle helmets are required to meet or exceed the Department of Transportation's Federal Motor Vehicle Safety Standard (FMVSS) No. 218. In addition, many helmet manufacturers voluntarily submit their products for testing and certification under the standards developed and periodically updated by private testing laboratories. In particular, the requirements of FMVSS 218, together with changes in design and materials used in manufacturing helmets, are the driving force behind the improved effectiveness of helmets. One of the more significant innovations introduced in the early 1990s has been the use of materials such as Kevlar, expanded polypropylene, and carbon fiber in the manufacture of helmet shells and protective linings.

Of course, head injuries are not the only cause of crash fatalities. When we speak of "effectiveness" of helmets in reducing the risk of death in fatal motorcycle crashes, all types of injuries suffered by riders are included by implication. For example, if a helmet were absolutely certain to prevent a severe head injury, the rider could still die from other traumatic injuries suffered in a crash. Clearly, motorcycle helmets cannot prevent all fatal injuries, but in the case of head injuries in particular, helmets do provide a measure of preventive protection to the wearer. Just how effective helmets are in preventing fatalities is a function of both their performance in crashes and the incidence of fatal injuries other than head injuries. While it would be useful to know the effectiveness of helmets in preventing potentially fatal head injuries alone, the purpose of effectiveness as calculated here is to provide a measure of the overall difference in survival value in a potentially fatal crash that is attributable to the proper use of a helmet.

A number of studies have shown helmets to be an important factor in preventing death or serious injury in motorcycle crashes. Braddock, Schwartz et al. (1992), found that un-helmeted motorcyclists were 3.4 times more likely to die than were helmeted riders. A study by Kelly, Sanson et al. (1991) found that injured non-helmeted riders had higher injury severity scores and sustained more head and neck injuries. Of the 26 fatally injured riders in this study, 25 were un-helmeted. A three year study of helmet use in Colorado found that following repeal of a helmet law in 1977, helmet usage declined from 99 percent to as low as 49 percent, while the motorcycle fatal crash rate increased by more than 100 percent and the injury crash rate increased by 13 percent. More recently, a 2003 evaluation of the repeal of helmet laws in Kentucky and Louisiana found that in both states, the helmet use rate declined rapidly in the years following repeal, from 96 percent to 56 percent in Kentucky and from about 100 percent to 52 percent in Louisiana, while the fatalities increased correspondingly in both states.

In support of revisiting motorcycle helmet effectiveness in saving lives, an analysis of data from the Department of Transportation's Crash Outcome Data Evaluation System (CODES) in 1996 showed that "…motorcycle helmets are 35 percent effective in preventing fatality, 26 percent effective in preventing injuries at least serious enough to require transport to the hospital ED [Emergency Department], and 9 percent effective in preventing all injury."

There is an inescapable irony in all these statistics: On the one hand, real world crash experience and destructive testing both suggest that the protective value of helmets has improved over the years. On the other hand, NCSA's studies of helmet use indicate that the usage rate is falling as more riders choose not to wear helmets and existing helmet laws are repealed or weakened.

2.0 Methodology

In 1989, using Fatality Analysis Reporting System (FARS) data for 1982 through 1987, Wilson estimated that motorcycle helmets were 29 percent effective in preventing occupant fatalities in motorcycle crashes. She based her calculation on a paired comparison study of crashes resulting in at least one fatality and involving one or more motorcycles each of which carried one rider and one passenger. The methodology was based on previous work by Evans on the effect of vehicle mass on driver fatalities (1984); Kahane (1986) and Partyka (1987, 1988) on the effectiveness of seat belts and other restraint systems; and Evans and Frick (1988), on the effectiveness of motorcycle helmets. Since 1989, NHTSA has used the 29 percent effectiveness to calculate the number of lives saved through the use of motorcycle helmets.

Motorcycle crashes with fatal outcomes involving one rider and one passenger were compared using a matched pairs procedure. Limiting the crashes to those involving a rider and passenger combination gives the following four possibilities:

Table 1. - Rider/Passenger Helmet Use Combinations

	Passenger Not Helmeted	Passenger Helmeted
Rider Not Helmeted	*Neither rider nor passenger helmeted*	*Rider not helmeted, passenger helmeted*
Rider Helmeted	*Rider helmeted, passenger not helmeted*	*Both rider and passenger helmeted*

For each of the four possible combinations, ratios were calculated for rider to passenger fatalities and passenger to rider fatalities in a given year. For example, in those cases in which neither the rider nor the passenger used a helmet, the Fatality Ratio (FR) of rider to passenger deaths, is:

$$FR_{(RNH)} = Rider_{(NH)} / Psgr_{(NH)}$$

And in those cases where only the rider was helmeted, the Fatality Ratio is:

$$FR_{(RH)} = Rider_{(H)} / Psgr_{(NH)}$$

The fatality ratios were used to calculate separate helmet effectiveness, expressed as a percentage, for riders and passengers. It is assumed that any difference between the fatality ratios for unhelmeted and helmeted motorcycle occupants in each of the possible

scenarios is due to the effectiveness of the helmet. For example, the effectiveness of a helmet in preventing fatal injuries to a rider accompanied by an unhelmeted passenger would be:

$$\text{Effectiveness} = (FR_{(RNH)} - FR_{(RH)}) / FR_{(RNH)}$$

Wilson calculated the fatality ratios and effectiveness for each year of the six-year period from 1982 through 1987 (Table 2) to show the variation that occurs from year to year as the result of the small number of cases in some of the cells. To control for this variation, multiple years of data were used to calculate the overall effectiveness for the different combinations of riders and passengers. Aggregating data over the 5-year period from 1982 through 1987 results in an overall 29 percent effectiveness of helmets in preventing fatal injuries in otherwise fatal motorcycle crashes (lower right hand cell in Table 3).

Table 2 - Rider/Passenger Fatalities in Motorcycle Crashes* By Helmet Use Status 1982-1987						
Year	Helmet Used		No of Deaths		Fatality Ratios	
	Rider	Passenger	Rider	Passenger	Rider/Psgr	Psgr/Rider
1982	No	No	297	237	1.253	0.798
	No	Yes	19	15	1.267	0.789
	Yes	No	37	44	0.841	1.189
	Yes	Yes	183	155	1.181	0.847
1983	No	No	263	224	1.174	0.852
	No	Yes	25	12	2.083	0.480
	Yes	No	24	31	0.774	1.292
	Yes	Yes	160	131	1.221	0.819
1984	No	No	243	232	1.047	0.955
	No	Yes	21	13	1.615	0.619
	Yes	No	30	36	0.833	1.200
	Yes	Yes	147	123	1.195	0.837
1985	No	No	265	236	1.123	0.891
	No	Yes	17	9	1.889	0.529
	Yes	No	31	36	0.861	1.161
	Yes	Yes	144	143	1.007	0.993
1986	No	No	263	247	1.065	0.939
	No	Yes	20	12	1.667	0.600
	Yes	No	26	31	0.839	1.192
	Yes	Yes	158	125	1.264	0.791
1987	No	No	279	251	1.112	0.900
	No	Yes	20	11	1.818	0.550
	Yes	No	20	19	1.053	0.950
	Yes	Yes	125	102	1.225	0.816
Total	No	No	1610	1427	1.128	0.886
	No	Yes	122	72	1.694	0.590
	Yes	No	168	197	0.853	1.173
	Yes	Yes	917	779	1.177	0.850

*Crash must involve both a rider and a passenger on the same motorcycle.
Source: National Center for Statistics and Analysis, NHTSA - FARS 1982-1987

Table 3 - Helmet Use Effectiveness (Percent) For Motorcycle Riders and Passengers 1982 through 1987								
Effectiveness For:	**Control**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**All Years**
Rider	Unhelmeted Passenger	33	34	20	23	21	05	24
	Helmeted Passenger	07	41	26	47	24	33	31
	Average	20	38	23	35	26	19	27
Passenger	Unhelmeted Rider	01	44	35	41	36	39	33
	Helmeted Rider	29	37	30	14	34	14	28
	Average	15	40	33	28	35	26	30
Rider And Passenger	Unhelmeted Control	17	39	28	32	29	22	29
	Helmeted Control	18	39	28	31	29	23	29
	Average	17	39	28	31	29	23	**29**
Source: National Center for Statistics and Analysis, NHTSA - FARS 1982-1987								

3.0 Revising Estimated Effectiveness

Since 1987 there have been changes in the design and materials used to manufacture motorcycle helmets. Has the effectiveness of motorcycle helmets in reducing fatalities also changed and, if so, is the effectiveness higher or lower than it was in 1987?

3.1 Updating The Data

Table 4 shows the annual and total fatality ratios recalculated using the ten most recent years of FARS data to reflect technological changes since 1987. The ten-year time period was selected in order to increase the number of cases available and to control for the effects of years with outlying data. As was the case for the 1982 through 1987 data, the individual years are shown for comparison purposes only -- the overall totals were used to calculate effectiveness.

Table 4 - Rider/Passenger Fatalities in Motorcycle Crashes* By Helmet Use Status 1993 - 2002						
Year	Helmet Used		No of Deaths		Ratios	
	Rider	Psgr	Rider	Psgr	Rider/Psgr	Psgr/Rider
1993	No	No	110	105	1.048	0.955
	No	Yes	13	1	13.000	0.077
	Yes	No	8	12	0.667	1.500
	Yes	Yes	105	93	1.129	0.886
1994	No	No	89	95	0.937	1.067
	No	Yes	13	3	4.333	0.231
	Yes	No	8	11	0.727	1.375
	Yes	Yes	87	100	0.870	1.149
1995	No	No	105	95	1.105	0.905
	No	Yes	12	5	2.400	0.417
	Yes	No	9	14	0.643	1.556
	Yes	Yes	104	82	1.268	0.788
1996	No	No	95	94	1.011	0.989
	No	Yes	13	1	13.000	0.077
	Yes	No	7	9	0.778	1.286
	Yes	Yes	106	86	1.233	0.811
1997	No	No	94	83	1.133	0.883
	No	Yes	11	5	2.200	0.455
	Yes	No	9	5	1.800	0.556
	Yes	Yes	92	78	1.179	0.848
1998	No	No	100	97	1.031	0.970
	No	Yes	11	3	3.667	0.273
	Yes	No	4	2	2.000	0.500
	Yes	Yes	100	82	1.220	0.820
1999	No	No	107	89	1.202	0.832
	No	Yes	15	4	3.750	0.267
	Yes	No	7	9	0.778	1.286
	Yes	Yes	81	86	0.942	1.062
2000	No	No	111	115	0.965	1.036
	No	Yes	14	12	1.167	0.857
	Yes	No	7	8	0.875	1.143
	Yes	Yes	111	97	1.144	0.874

Table 4 - Rider/Passenger Fatalities in Motorcycle Crashes* By Helmet Use Status 1993 - 2002						
Year	Helmet Used		No of Deaths		Ratios	
	Rider	Psgr	Rider	Psgr	Rider/Psgr	Psgr/Rider
2001	No	No	142	130	1.092	0.915
	No	Yes	27	17	1.588	0.630
	Yes	No	8	8	1.000	1.000
	Yes	Yes	100	82	1.220	0.820
2002	No	No	154	124	1.242	0.805
	No	Yes	12	8	1.500	0.667
	Yes	No	4	7	0.571	1.750
	Yes	Yes	105	83	1.265	0.790
Total	No	No	1,107	1,027	1.078	0.928
	No	Yes	141	59	2.390	0.418
	Yes	No	71	85	0.835	1.197
	Yes	Yes	991	869	1.140	0.877
Source: National Center for Statistics and Analysis, NHTSA, FARS 1993-2002 * Crash must involve both a rider and a passenger on the same motorcycle.						

Table 5 - Helmet Use Effectiveness (Percent) For Motorcycle Riders and Passengers 1993 through 2002												
Effectiveness For:	**Control**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**All Years**
Rider	Unhelmeted Passenger	36	22	42	23	-59	-94	35	09	08	54	23
	Helmeted Passenger	91	80	47	91	46	67	75	02	23	16	52
	Average	64	51	45	57	-07	-14	55	06	16	35	37
Passenger	Unhelmeted Rider	92	78	54	92	48	72	68	17	31	17	55
	Helmeted Rider	41	16	49	37	-53	-64	17	24	18	47	27
	Average	67	47	52	65	-03	04	43	21	25	32	41
Rider And Passenger	Unhelmeted Control	64	50	48	58	-06	-11	52	13	20	36	39
	Helmeted Control	66	48	48	64	-04	02	46	13	21	32	40
	Average	65	49	48	64	-05	-05	49	13	21	34	**39**
Source: National Center for Statistics and Analysis, NHTSA - FARS 1993-2002												

In Table 5, a motorcycle helmet effectiveness of 39 percent was calculated using the cumulative data from 1993 through 2002, compared with the 29 percent calculated with data from 1982 through 1987. As in the 1989 report, multiple years of data were used in order to control for the small numbers of crashes meeting the criteria in any particular year. In the case of riders accompanied by unhelmeted passengers in 1997, for example, 9 helmeted riders and 5 unhelmeted passengers were killed in fatal crashes involving both a rider and a passenger. This may indicate not only that more motorcyclists are wearing helmets, but that passengers accompanying riders wearing helmets are more likely to be helmeted as well. One problem in using the paired comparison method to estimate effectiveness of protective equipment is that survivors may tend to exaggerate their use in order to avoid being cited for non-use. In the case of motorcycle helmets, this effect is offset both by the high visibility of motorcycle riders in comparison with motor vehicle occupants and the fact that only 20 states and the District of Columbia require all riders to wear helmets. There are currently 3 states that do not require helmets and 27 states that require helmets only for certain classes of riders.

Effectiveness is used to estimate the number of lives saved as follows:

$$\text{Lives Saved} = \text{Fatalities}_{\text{Helmeted}} * \text{Effectiveness} / (1-\text{Effectiveness})$$

And the potential number of lives saved as:

$$\text{Potential Lives Saved} = (\text{Fatalities}_{\text{Total}} + \text{Lives Saved}_{\text{Total}}) * \text{Effectiveness}$$

Tables 5 and 6 show the numbers of lives saved and the potential lives saved in 2002 using 29 percent effectiveness (Table 6) and effectiveness as derived from more recent data (Table 7).

Table 6 – Motorcyclists Saved by Helmets In 2002 Using Un-weighted Average for Total Effectiveness (Effectiveness Based on 1982-1987 Data)

Motor Cyclists	Effectiveness (%)	Fatalities			Lives Saved	Potential Lives Saved
		Total	Helmeted	Unhelmeted		
Riders	27	3,010	1,598	1,412	591	972
Passengers	30	234	95	139	41	83
Total	29	3,244	1,693	1,551	692	1,141
Source: National Center for Statistics and Analysis, NHTSA – FARS 2002						

Table 7 – Motorcyclists Saved by Helmets In 2002 Using Un-weighted Average for Total Effectiveness (Effectiveness Based on 1993-2002 Data)

Motor Cyclists	Effectiveness (%)	Fatalities			Lives Saved	Potential Lives Saved
		Total	Helmeted	Unhelmeted		
Riders	37	3,010	1,598	1,412	939	1,461
Passengers	41	234	95	139	66	123
Total	39	3,244	1,693	1,551	1,082	1,687
Source: National Center for Statistics and Analysis, NHTSA – FARS 2002						

3.2 The Weighted Average Effectiveness

One problem with the calculation is obvious from the two tables. If one were to apply the separate rates for riders and passengers to obtain the numbers of lives saved and sum the results, the total lives saved would be less than the figure obtained using the average total rate. The overall rate is a straight, un-weighted average of the component rates, and fails to account for differences in the numbers of riders and passengers involved.

The second proposed change is to use the weighted average of the effectiveness rates calculated for riders and passengers separately. Weighted average effectiveness was obtained by using the effectiveness rates for riders and passengers to calculate Potential Lives Saved for each group over the time periods 1982 through 1987 and 1993 through 2002. The results were summed to obtain Total Potential Lives Saved as shown earlier in Table 7. Total Potential Lives Saved was then used to solve for the total or overall effectiveness rate, ER, (Tables 8 and 9).

$$ER_{Total} = \text{Potential Lives Saved}_{Total} \; / \; (\text{Lives Saved}_{Total} + \text{Fatalities}_{Total})$$

For example, in Table 8,

$$ER_{Total} = 1{,}055 / (632+3{,}244)$$
$$= .27$$

And in Table 9,

$$ER_{Total} = 1{,}584 / (1{,}005+3{,}244)$$
$$= .37$$

Table 8 – Motorcyclists Saved by Helmets In 2002 Using Weighted Average for Total Effectiveness (Effectiveness Based on 1982-1987 Data)

Motor Cyclists	Effectiveness (%)	Fatalities			Lives Saved	Potential Lives Saved
		Total	Helmeted	Unhelmeted		
Riders	27	3,010	1,598	1,412	591	972
Passengers	30	234	95	139	41	83
Total	27	3,244	1,693	1,551	632	1,055
Source: National Center for Statistics and Analysis, NHTSA – FARS 2002						

Table 9 – Motorcyclists Saved by Helmets In 2002 Using Weighted Average for Total Effectiveness (Effectiveness Based on 1993-2002 Data)						
Motor Cyclists	**Effectiveness (%)**	**Fatalities**			**Lives Saved**	**Potential Lives Saved**
		Total	**Helmeted**	**Unhelmeted**		
Riders	37	3,010	1,598	1,412	939	1,461
Passengers	41	234	95	139	66	123
Total	37	3,244	1,693	1,551	1,005	1,584
Source: National Center for Statistics and Analysis, NHTSA – FARS 2002						

Table 10 shows the impact of the higher effectiveness of helmets on the number of lives saved over the ten-year period from 1993 through 2002.

Table 10 – Motorcyclists Saved by Helmets 1993 through 2002						
Effectiveness		**Fatalities**			**Lives Saved**	**Potential Lives Saved**
		Total	**Helmeted**	**Unhelmeted**		
Current	29	24,396	13,294	11,102	5,430	8,650
Revised	37	24,396	13,294	11,102	7,808	11,915
Difference	-	-	-	-	2,378	3,265
Source: National Center for Statistics and Analysis, NHTSA – FARS 2002						

3.0 Conclusions

Both the design and materials used in manufacturing motorcycle helmets have improved throughout the 1990's, resulting in a significant improvement in their effectiveness in protecting against fatal head injuries. Despite the improvement in effectiveness, from 29 percent to 37 percent, motorcycle fatalities continue to increase as riders choose not to take advantage of the protection afforded by helmets. The weakening or repeal of compulsory helmet use laws in many states has been shown to be associated with a dramatic drop in the percentage of motorcyclists who wear helmets.

Using the new, recomputed effectiveness to calculate the number of lives saved over the ten-year period from 1993 through 2002 shows that motorcycle helmets have saved 7,808 lives, 2,378 more than was previously thought. Unfortunately, with the declining use rates in some states more riders are dying unnecessarily. If all riders consistently wore proper helmets, the number of additional fatalities that could have been prevented over the same ten-year period would have raised the total lives saved to 11,915 persons.

Policies directed toward increasing acceptance of helmets as a protective device can have a significant impact on reducing our overall traffic fatality count. Motorcycles compose less than three percent of all registered passenger vehicles in the United States, but motorcyclist fatalities account for nine percent of all passenger vehicle occupant fatalities. In recent years, passenger car fatalities have been trending downward – the annual rise in overall passenger vehicle fatalities is due to fatal motorcycle and light truck crashes.

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