"BORN TO BE WILD"

The Effect of the Repeal of Florida's Mandatory Motorcycle Helmet-Use Law on Serious Injury and Fatality Rates

LISA STOLZENBERG
STEWART J. D'ALESSIO
Florida International University

In response to political pressure, the state of Florida repealed its mandatory motorcycle helmet-use law for all operators and passengers older than the age of 21, effective July 1, 2000. Using monthly data and a multiple time-series design, the authors assessed the effect of this law change on serious injury and fatality rates for motorcycle riders aged 21 and older. Controls for serious injury and fatality rates for motorcycle riders younger than 21 years of age were included in the analyses. Maximum-likelihood results showed that the repeal of the mandatory helmet-use law in Florida had little observable effect on serious injuries or on fatalities that resulted from motorcycle crashes. Policy implications of these findings are discussed, and explanations are given as to why the repeal of the mandatory motorcycle helmet-use law in Florida was inconsequential.

Keywords: *mandatory motorcycle helmet-use law; motorcycle crashes; motorcycle injuries; motorcycle fatalities*

Mandatory motorcycle helmet-use laws have become a popular strategy to improve public safety. The primary purpose of these laws is to reduce serious injuries and fatalities that result from motorcycle crashes by requiring operators of motorcycles and their passengers to wear protective helmets. The underlying rationale for mandatory motorcycle helmet-use laws emanates from research that finds that motorcycle riders wearing protective helmets are much less likely to suffer injuries, particularly head injuries, and are less apt to be killed in a crash (Evans and Frick 1988; Fleming and Becker 1992; Gabella et al. 1995; Sarkar, Peek, and Kraus 1995; Weiss 1992). Helmet use is also reported to decrease the overall cost of medical care (Rowland et al. 1996).

EVALUATION REVIEW, Vol. 27 No. 2, April 2003 131-150
DOI: 10.1177/0193841X02250524

Twenty-one states currently have full helmet-use laws, while another 25 states have limited helmet-use laws that exempt adult riders from wearing helmets (see the appendix). Adult riders are usually defined as persons older than 18 or 21 years of age. Only 4 states do not have any helmet-use laws. These states include Colorado, Illinois, Iowa, and New Hampshire. Five states also require motorcyclists to be covered by an insurance policy providing for at least \$10,000 in medical benefits for injuries incurred as a result of a crash while operating or riding as a passenger on a motorcycle.

Despite a plethora of studies that report that mandatory motorcycle helmet-use laws are effective in reducing motorcycle crash injuries and fatalities (Chenier and Evans 1987; Chiu et al. 2000; Fleming and Becker 1992; Graham and Lee 1986; Hartunian et al. 1981; Kraus et al. 1994; Robertson 1976; Sosin and Sacks 1992; Sosin, Sacks, and Holmgreen 1990; Watson, Zador, and Wilks 1980, 1981), a public backlash has developed against these laws. Opponents of mandatory motorcycle helmet-use laws maintain that protective helmets hinder a motorcycle operator's vision (Gordon and Prince 1975) and hearing (Purswell and Dorris 1977), thereby making accidents more likely to occur. They also argue that motorcycle helmet use increases the probability of certain types of injuries that transpire during a crash, primarily neck and spinal cord injuries (Cooter et al. 1988; Goldstein 1986; Huston and Sears 1981; Konrad et al. 1996; Krantz 1985).

It is also proffered that the repeal of mandatory helmet-use laws, by offering individuals a choice in whether to wear protective helmets, increases the attractiveness and convenience of motorcycle use. This in turn affects miles traveled and sales of motorcycles. For example, Kraus, Peek, and Williams (1995) reported that after an unrestricted helmet-use law went into effect in California in 1992, there was a substantial decrease in the number of motorcycles observed traveling on roads in various California cities. Finally, many empirical evaluations of helmet-use laws are thought to be methodologically flawed (Adams 1983; American Motorcyclist 1991; Perkins 1981). Problems include small unrepresentative samples, specification error, a myopic focus on head injuries resulting from motorcycle crashes, and a continued failure to employ multivariate statistical procedures, to name a few.

Determined and sustained political pressure from motorcycle enthusiasts and advocacy groups has led a number of states to repeal their mandatory helmet-use laws. Florida is one such state. Florida repealed its mandatory motorcycle helmet-use law on July 1, 2000, by authorizing that an individual older than 21 years of age could operate or ride a motorcycle without wearing protective headgear securely fastened on his or her head if such person is covered by an insurance policy providing for at least \$10,000 dollars in medical benefits for injuries incurred as a result of a crash while operating or riding on a motorcycle. Individuals younger than 21 are still required to wear protective helmets when riding a motorcycle.

A continuing concern among the medical community is whether the repeal of Florida's mandatory helmet-use law has increased serious injuries and fatalities resulting from motorcycle crashes. To our knowledge, the only study conducted to date that examines the impact of the repeal of Florida's mandatory helmet-use law is a simple pretest-posttest analysis of head injuries and fatalities that occurred before and after the law's repeal undertaken by Hotz et al. (2002) at the University of Miami.

In this study, Hotz et al. (2002) gathered data on all motorcycle-related cases that were admitted at either the Ryder Trauma Center or at the University of Miami/Jackson Memorial Medical Center's Surgical Emergency Room for a 6-month period prior to the law's repeal (July 1, 1999, to December 31, 1999) and for a 6-month period following the law's repeal (July 1, 2000, to December 31, 2000). Information was obtained on 54 subjects prior to the law's repeal and on 94 subjects after the law's repeal. Motorcycle-related cases taken to other trauma centers or directly taken to the morgue by paramedics were not included in the study. Using bivariate statistical procedures, Hotz et al. found that the repeal of Florida's mandatory helmet-use law engendered a substantial decrease in helmet use among motorcycle riders and a sizable increase in the number of brain injuries and motorcycle fatalities. They also noted an 81% increase in the number of motorcycle crash victims admitted to the two trauma centers following the repeal of the helmet-use law.

Although the results generated from this study appear to support the position that the repeal of Florida's mandatory motorcycle helmet-use law increased motorcycle crash injuries and fatalities, it is important to recognize that simple comparisons of prelaw and postlaw repeal means are only suggestive. Further evidence is needed before accepting these findings as definitive because it is not possible to say whether the observed changes in motorcycle crash injuries and fatalities were due to the repeal of the law or whether they resulted from a preexisting trend or some other salient factor. As Charles Branas and C. William Schwab (2002) of the University of Pennsylvania Medical Center pointed out,

> Numerous shortcomings in this work should probably limit its interpretation to, at best, a very rough, unadjusted guide to the impact of repealing Florida's helmet law. Changes in numerous other variables (i.e., the number of registered motorcycles, roadway types, alcohol consumption, weather, available police resources) . . . might have also affected the occurrence of motorcycle helmet crash victims presenting to the University of Miami Medical Center. (Pp. 473-74)

In this article, we investigate further the impact of Florida's repeal of its mandatory motorcycle helmet-use law, correcting for the methodological problems encountered in earlier research. We do not, however, aim to replicate the Hotz et al. (2002) study that analyzed clinical data. Rather, for analytical and practical reasons, we contribute to the literature by using monthly data over a 192-month period and a multiple time-series design to better estimate the effect of Florida's repeal of its mandatory helmet-use law on motorcycle crash injuries and fatalities.

The type of data and the analytic strategy used in this study have several methodological advantages. First, although no research design guarantees correct inferences, the multiple time-series design is considered an effective quasi-experimental design for drawing causal inferences (Johnson and Christensen 2000). This design, which is depicted below, involves comparisons of series of observations (O) over time expected to be affected by an intervention (X) with a control series not expected to be influenced by the same intervention:

$$O_{A1}O_{A2}O_{A3}O_{A4}O_{A5} \times O_{A6}O_{A7}O_{A8}O_{A9}O_{A10}$$
$$O_{B1}O_{B2}O_{B3}O_{B4}O_{B5} \times O_{B6}O_{B7}O_{B8}O_{B9}O_{B10}.$$

This design helps to rule out a large number of plausible alternative explanations for a hypothesized causal relationship because the comparison series acts to reduce the possibility of history effects.

In addition, although the simple diagram shown above depicts only one experimental and one control series, multiple experimental and control series are examined in this study. Specifically, we compare the trends in the serious injury and fatality rates for motorcycle riders aged 21 and older before the helmet-use law was repealed with trends after the law was repealed. If the differences between the preintervention and postintervention series are positive and greater than one should expect from chance, then a significant effect of the law's repeal on serious injuries and fatalities can be inferred. Of course, because the repeal of the motorcycle helmet-use law applied only to motorcycle operators and passengers older than 21 years of age, the repeal of the law should have little if any effect on the serious injury and fatality rate series for motorcycle riders younger than 21 years of age. The use of the younger-than-21 serious injury and fatality rates as statistical controls in the analyses helps us to avoid attributing significance to the repeal of the law that should, more accurately, be attributed to some other independent but coincidental event such as a change in weather conditions.

We also use month rather than year as our unit of analysis because monthly data are considered superior for interpreting change and for reducing the confounding of history effects (Tiao and Wei 1976). Analyzing monthly data also permits greater flexibility in applying more sophisticated and efficient statistical procedures because of the increased number of observations. Finally, because this analysis compares changes in serious injury and fatality rates in one state over time and does not predict changes across different states, potential biases resulting from dissimilarities in state accident-reporting practices are minimized.

The policy implications of this study are noteworthy. If the repeal of Florida's mandatory motorcycle helmet-use law is related positively to serious injuries and fatalities that result from motorcycle crashes, once trend and seasonal fluctuations are taken into account, then we can conclude that mandatory helmet-use laws are effective in improving motorcycle safety. Yet if the repeal of Florida's mandatory helmet-use law has no observable impact on motorcycle crash injuries and fatalities, then motorcycle safety might be improved more effectively through alternative mechanisms.

DATA

The data used in this study were obtained from the Traffic Crash Database maintained by the Florida Department of Highway Safety and Motor Vehicles, Office of Management and Planning Services (OMPS). The OMPS Traffic Crash Database encompasses data from 1986 through 2001. This database contains information on motor vehicle crashes that occur on public roads in the state of Florida.

Two dependent variables are used in the analysis. The first endogenous variable of theoretical import is the serious injury rate for motorcycle riders older than 21 years of age. This variable is operationalized as the monthly number of motorcycle crashes with serious injuries involving operators and passengers aged 21 and older occurring on interstates, highways, county roads, and municipal roads divided by motorcycle registrations and multiplied by 100,000. Serious motorcycle crash injuries are defined as incapacitating injuries in which there are visible sign(s) of injury from the crash (e.g., bruises, abrasions, limping, etc.) and the person(s) was assisted from the crash scene.

The second dependent variable of interest, the fatal motorcycle crash rate, is measured as the monthly number of fatal motorcycle crashes involving operators and passengers aged 21 and older occurring on interstates, highways, county roads, and municipal roads divided by motorcycle registrations and multiplied by 100,000. A fatal injury occurs when an injury sustained in a motorcycle crash results in the death of the individual within 90 days.

We analyze the effect of Florida's repeal of its mandatory motorcycle helmet-use law with a dummy variable coded 0 before July 2000 and 1 otherwise. The two control variables are measured as the monthly number of motorcycle crashes with serious injuries or fatalities involving operators and passengers younger than 21 occurring on interstates, highways, county roads, and municipal roads divided by motorcycle registrations and multiplied by 100,000.

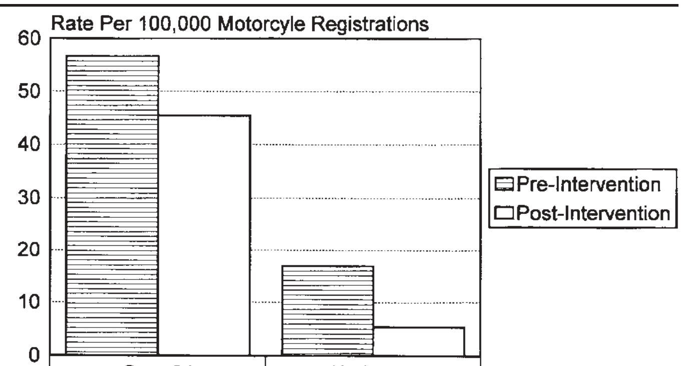
DESCRIPTIVE ANALYSIS

Figures 1 and 2 compare the mean changes between preintervention and postintervention periods for the serious injury and fatality rate series. For these comparisons, we use the 174 months preceding the repeal of the helmet-use law (January 1, 1986, to June 30, 2000) and the 18 months following the repeal of the law (July 1, 2000, to December 31, 2001).

A cursory glance at Figure 1 indicates little support for the assertion that the repeal of Florida's mandatory helmet-use law caused an increase in the serious injury rate. In fact, serious injuries actually decreased following the repeal of the law. The mean level of the preintervention serious injury rate for motorists older than 21 was 56.61; the mean level of this series after the helmet-use law's repeal decreased to 45.52. Further examination of Figure 1 shows that the mean level of the serious injury rate for motorists younger than 21 also decreased substantially following the repeal of the helmet-use law. The preintervention serious injury rate for motorists younger than 21 was 16.95. After the helmet-use law's repeal, the mean level of the series was reduced to 5.37. The exact reasons for these decreases are not readily apparent.

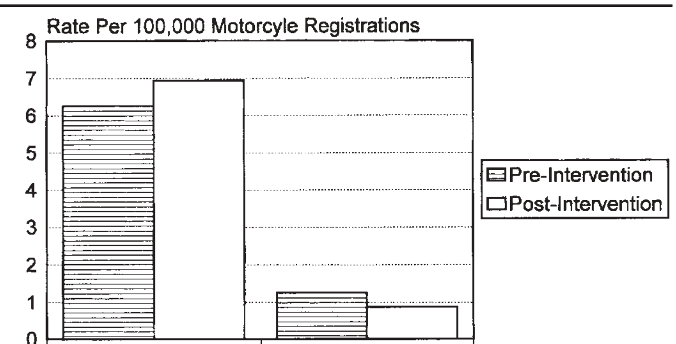
Figure 2 depicts mean changes between the preintervention and postintervention periods for the two fatality rate series. The overall means for the 21 and older series and for the younger than 21 series during the preintervention period were 6.25 and 1.25, respectively. After the repeal of the law, the fatality rate for riders aged 21 and older increased to 6.94, and the fatality rate for motorists younger than 21 years of age decreased to 0.87. However, both of these rate changes are small and appear to be the result of random fluctuations.

Although these initial results appear to support the position that the repeal of the mandatory motorcycle helmet-use law did not increase the serious injuries and fatalities substantially in Florida, it is important to recognize that



	Over 21	Under 21
Pre-Intervention	56.61	16.95
Post-Intervention	45.52	5.37

Figure 1: Means for Preintervention and Postintervention Motorcycle Serious Injury Rates in Florida



	Over 21	Under 21
Pre-Intervention	6.25	1.25
Post-Intervention	6.94	0.87

Figure 2: Means for Preintervention and Postintervention Motorcycle Fatality Rates in Florida

simple comparisons of preintervention and postintervention means are only suggestive at best. Further empirical evidence is necessary before accepting these findings as definitive because it is not possible to say whether these observed changes in motorcycle crash injuries and fatalities are due to the repeal of the law or whether they are simply the result of preexisting trends.

To illustrate this point, we constructed graphical charts that depict the serious injury and fatality rates over time (see Figures 3 and 4). The vertical line depicted in each of the figures represents the repeal of the helmet-use law in Florida. A visual examination of Figure 3 suggests that the serious injury rates were trending downward slightly prior to the repeal of law. Consequently, a question remains as to whether the large observed reductions in the serious injury rates during the postintervention period, as depicted in Figure 1, resulted from the repeal of the helmet-use law or from a preexisting downward trend. In contrast, both fatality rate series appear to have remained relatively stable over time.

MULTIVARIATE TRANSFER FUNCTION ANALYSES

We began the multivariate transfer function analyses by constructing univariate autoregressive integrative moving-average (ARIMA) models for the each of the four series for the 174-month period preceding the repeal of the mandatory helmet-use law. The univariate ARIMA, which typically is developed through an iterative model-building strategy, accounts for the stochastic processes associated with a series (Box, Jenkins, and Reinsel 1994). Several factors must be considered in selecting an appropriate univariate ARIMA model. One important consideration is whether the series has a single constant variance throughout its course. A nonstationary variance is engendered by dramatic fluctuations in variation between observations in a series. To determine whether each of the four series was stationary in variance, we consulted a rule-based expert system in the statistical software program Forecast Pro (Stellwagen and Goodrich 2000). This system, which uses a goodness-of-fit measure to compare competing models, recommended that a natural logarithm transformation was necessary to stabilize the variance of the older-than-21 fatality rate series.

Another salient consideration is whether a series has a single constant level throughout its course. That is, a series should not “trend” or “drift” upward or downward over time. A commonly used test for the presence of an unstable level is the “augmented” Dickey-Fuller test (Dickey, Bell, and Miller 1986). This test, which assesses whether a series has a unit root, indicated that the younger-than-21 serious injury and fatality rate series were trended and required first-order differencing.

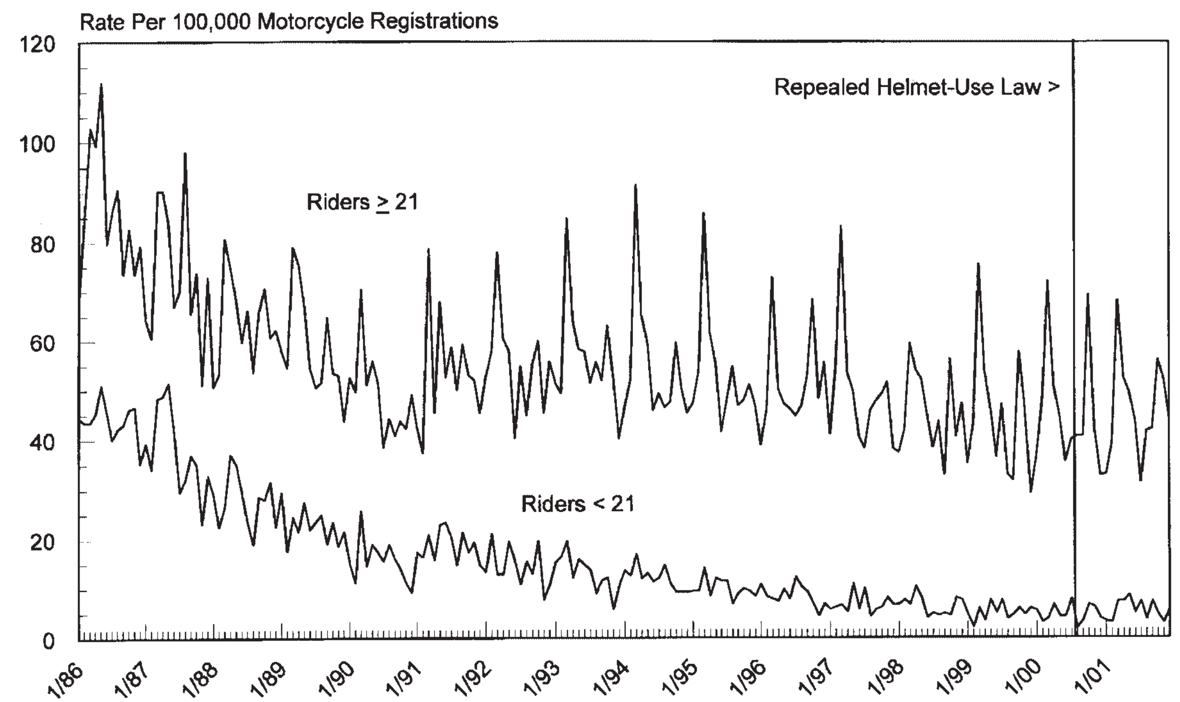


Figure 3: Motorcycle Serious Injury Rates in Florida
NOTE: Florida's repeal of its mandatory helmet-use law became effective on July 1, 2000.

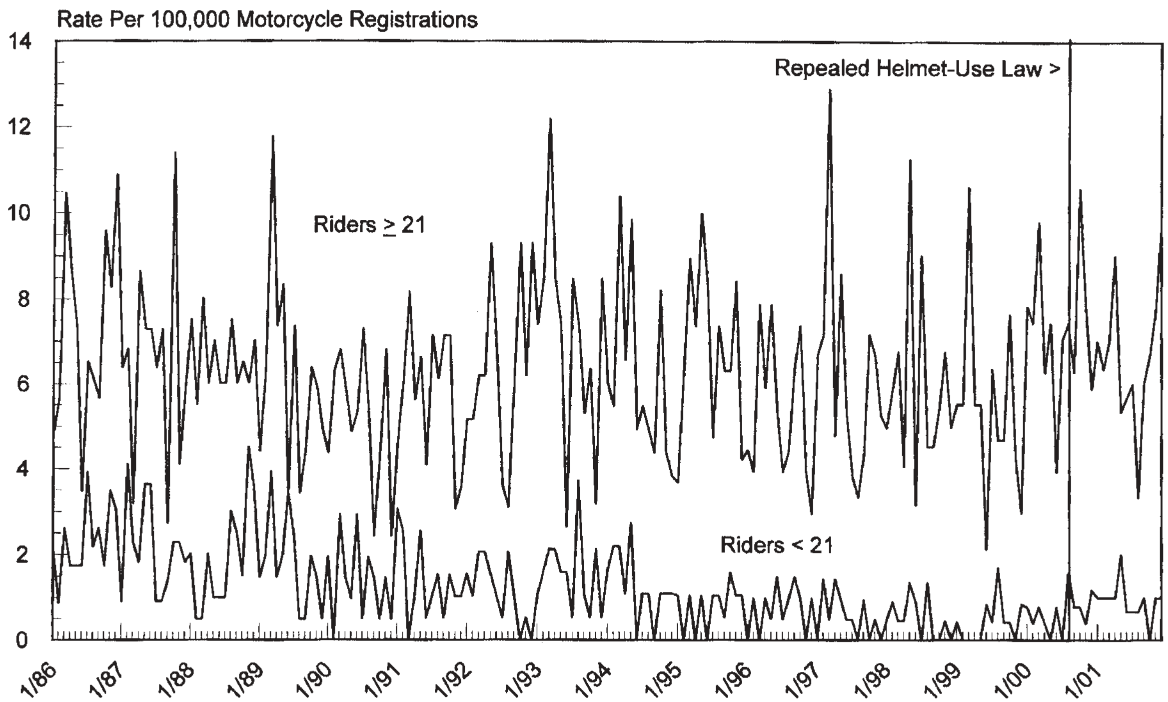


Figure 4: Motorcycle Fatality Rates in Florida
NOTE: Florida's repeal of its mandatory helmet-use law became effective on July 1, 2000.

A third consideration is whether a series has any cyclical or periodic fluctuation that repeats itself each time at the same phase of the cycle or period. This repetitive variation, commonly known as seasonality, is most likely to occur at yearly intervals with monthly data. Our examination of each of the series autocorrelation functions (ACFs) at lags of 12 months, 24 months, 36 months, and 48 months indicated that none of the series needed to be seasonally differenced.

Once the four series were determined to be stationary in variance and level, we examined each series ACF and partial autocorrelation function for autoregressive and for moving-average processes. In an autoregressive process, the current value in a series is influenced by an exponentially weighted sum of one or more previous values. That is, the effect of one or more prior observations (i.e., the order of the autoregressive parameter) on the current observation diminishes over time: $Y_t = \phi_1 Y_{t-1} + \ldots + \phi_p Y_{t-p} + a_t$. In contrast, each value in a moving-average process is determined by the average of the current disturbance and one or more previous disturbances. The effect of a moving-average process lasts for a finite number of periods (i.e., the order of the moving-average parameter) and then vanishes abruptly: $Y_t = a_t - \theta_1 a_{t-1} - \ldots - \theta_q a_{t-q}$.

After constructing the univariate ARIMA models, we used the automatic multivariate transfer function procedure in Autobox (Reilly 1999) to assess the impact of the mandatory motorcycle helmet-use law's repeal on the serious injury and fatal crash rates for operators older than 21 years of age.[1] Both of the younger-than-21 series were employed as control variables in these equations. Three different intervention models were assessed. First, we considered the possibility that the older-than-21 motorcycle crash injury and fatality rates declined sharply after the repeal of the mandatory motorcycle helmet-use law went into effect and then remained at these lower levels over time. We also investigated the possibility that the repeal of the law had a small initial impact on the serious injury and fatality rates that grew larger over time. This transfer function has two effect parameters. The intervention or omega parameter (ω) measures the degree of change in the level of the serious injury and fatality series; the delta parameter (δ) estimates the amount of time required for these changes to be actualized. The larger the value of the delta parameter, the more gradual the impact of the law's repeal. Conversely, a small delta coefficient would suggest that the effect of the law's repeal occurred more rapidly. Finally, we tested whether serious injuries and fatalities were reduced initially by the law's repeal but then returned to preexisting levels as time passed.[2]

Our analyses indicated that for the older-than-21 serious injury and fatality rate series, the abrupt permanent change model provided the best fit to the data. The zero-order transfer function models the law's repeal as having an abrupt and permanent effect on motorcycle crash injuries and fatalities. If the intervention coefficients are positive and statistically significant, the proposition that the repeal of Florida's mandatory motorcycle helmet-use law increased the serious injury and fatality rates above that expected on the basis of preexisting trends would be supported.

Tables 1 and 2 present the maximum-likelihood coefficients along with *t* values to evaluate statistical significance. A Box-Ljung Q statistic (Ljung and Box 1978), which tests the null hypothesis that a set of sample autocorrelations is associated with a random process, indicated that the residuals for the models were uncorrelated (i.e., constituted "white noise").[3] The results displayed in Table 1 indicate that the repeal of the helmet-use law did not increase the serious injury rate above that expected on the basis of preexisting trends. The intervention coefficient is negative and is not statistically significant. Visual examination of Table 1 also shows that the serious injury rate for motorcycle riders younger-than-21 years of age has a substantive effect. Both the omega and the delta coefficients are statistically significant, thereby indicating that the younger-than-21 control series has a permanent but gradual effect on the older than 21 serious injury motorcycle crash rate. However, as correctly noted by an anonymous reviewer, it is possible that the relationship between the younger-than-21 series and the older-than-21 series is spurious; both series may be affected by one or more common causes such as weather conditions.

Table 2 also reveals little evidence that the repeal of the mandatory helmet-use law affected the fatal motorcycle crash rate. Although the intervention variable is related positively to the fatal crash rate, its effect is not statistically significant. This finding runs counter to the prediction that the repeal of the helmet-use law in Florida influenced motorcycle crash fatalities above that predicted on the basis of preexisting trends. Our analysis also demonstrates that the effect of the younger-than-21 fatality rate control series is inconsequential. In sum, our results indicate that preexisting trends rather than the repeal of the motorcycle helmet-use law account for the changes in the serious injury and fatality rates observed initially in Figures 1 and 2.

DISCUSSION AND CONCLUSION

We began this article by noting that although the state of Florida recently repealed its mandatory motorcycle helmet-use law, only one study has been published to our knowledge that evaluates its impact. This study found that

TABLE 1: Maximum-Likelihood Coefficients for the Motorcycle Serious Injury Rate (Age > 21) Equation

Model Component	*Coefficient*	*Standard Error*	p *Value*	t *Value*
Constant	1.290	0.775	.098	1.66
AR(1)	0.194	0.065	.003	2.98
Δ serious injury rate (age < 21)				
Delta	0.970	0.014	.000	69.92
Omega	0.678	0.142	.000	4.78
Law change				
Omega	–1.150	2.420	.636	–0.47

NOTE: The equation for the full model is *Y*(*T*) = 1.597 + [*X*1(*T*)][(1 – *B***1)][(1 – .970B** 1)]**–1 [(+ .678)] + [*X*2(*T*)][(–1.150)] + [(1 – .194B** 1)]**–1 [*A*(*T*)], where *Y* = serious injury rate (age > 21), *X*1 = serious injury rate (age < 21), and *X*2 = law change. Δ = first difference. To produce more robust models, Autobox's outlier detection procedure was used to identify potential interventions (i.e., level shifts, seasonal pulses, and single-point outliers). Although not shown in the table, dummy variables were included in the analyses to model these interventions.

TABLE 2: Maximum-Likelihood Coefficients for the LN Motorcycle Fatality Rate (Age > 21) Equation

Model Component	*Coefficient*	*Standard Error*	p *Value*	t *Value*
Constant	1.734	0.025	.000	67.83
Δ fatality rate (age < 21)				
Omega	0.009	0.022	.675	0.42
Law change				
Omega	0.133	0.085	.119	1.57

NOTE: The equation for the full model is *Y*(*T*) = 1.734 + [*X*1(*T*)][(1 – *B***1)][(+.009)] + [*X*2(*T*)][(+.133)] + [*A*(*T*)], where *Y* = natural logarithmetic fatality rate (age > 21), *X*1 = fatality rate (age < 21), and *X*2 = law change. Δ = first difference. To produce more robust models, Autobox's outlier detection procedure was used to identify potential interventions (i.e., level shifts, seasonal pulses, and single-point outliers). Although not shown in the table, dummy variables were included in the analyses to model these interventions.

the repeal of Florida's mandatory helmet-use law engendered a substantial decrease in helmet use among motorcycle riders and a large increase in the number of brain injuries and motorcycle crash fatalities. However, because this study failed to account for differences between preintervention and postintervention periods, its findings are questionable. The factors engendering injury and death in motorcycle crashes are much more complex than simply whether the motorcycle rider was wearing a protective helmet during the crash.

Against this backdrop, we analyzed time-series data drawn from the entire state of Florida to determine the effect of Florida's repeal of its mandatory motorcycle helmet-use law on serious injuries and fatalities resulting from motorcycle crashes. Our results indicate that the law's repeal had little observable influence on the serious injury or fatality rate for motorcycle riders older than 21 years of age. The absence of an effect is rather surprising, considering the findings published in previous research studies.

The question that begs answering is why the repeal of Florida's mandatory helmet-use law had no substantive effect on motorcycle crash injuries and fatalities. We offer a few explanations that warrant discussion. One possibility is that because motorcycle crashes are often very severe, a diminishing marginal return can be expected by further increases in levels of motorcycle safety. An example drawn from the airline industry may be instructive. An airliner suffers engine trouble at 30,000 feet and is spiraling out of control toward the ground. A stewardess informs the passengers to fasten their safety belts. However, whether the passengers obey the stewardess's instructions is relatively meaningless because the odds of surviving the plane crash are extremely low notwithstanding whether a passenger is wearing his or her safety belt. Because many fatal motorcycle crashes are extremely severe, it seems unlikely that the repeal of a motorcycle helmet-use law would have any statistically discernible effect on serious injury or fatality rates simply because it raised the level of driver safety slightly further. Supporting this logic, it has been shown that motorcycle helmets are "most effective in less severe collisions that result in mild to moderate injuries" (Offner, Rivara, and Maire 1992, 640).

By the same token, the effectiveness of protective helmets in reducing serious injury and fatality rates depends on the proportion of motorcycle crash fatalities that result from head injuries. That is, for helmet use to be effective in saving lives, head injuries in motorcycle crashes must account for a large percentage of all motorcycle crash fatalities. However, this appears not to be the case. Although Sosin and Sacks (1992) found that helmet-use laws were effective in preventing nonfatal head injuries in nonfatal motorcycle crashes, they did not observe any difference between states with and without mandatory helmet-use laws in reference to overall fatality rates from motorcycle crashes. Their findings suggest that although motorcycle helmets may save lives, the number of lives saved is so small that it has no statistically discernable impact on the overall number of motorcycle crash deaths.

A third possibility relates to the relationship between helmet use and motorcycle crashes. Let us accept for the moment that motorcycle helmets are effective in saving lives in motorcycle crashes as reported in many clinical studies. However, if motorcycle helmets also impair the vision and/or hearing of motorcycle operators, helmeted motorcycle riders may also have a greater chance of getting into crashes than do unhelmeted drivers. Consequently, any beneficial effect of motorcycle helmets in saving riders' lives would be counterbalanced by making motorcycle accidents more likely for helmeted riders. In a similar vein, it is also plausible that the adverse consequences of helmet nonuse in crashes is being negated by increased care on the part of the individual when riding a motorcycle. Sosin and Sacks (1992) reported a substantially higher motorcycle crash rate in states that have mandatory helmet-use laws, whereas Lin, Hwang, and Kuo (2001) noted that unhelmeted riders have fewer collisions with moving cars than do helmeted motorcycle riders. We also observed that the motorcycle crash rate for riders older than 21 decreased by approximately 21% following the repeal of the helmet-use law in Florida.

A fourth possibility is that the repeal of the motorcycle helmet-use law had little effect on whether motorcyclists wore their protective helmets. It is estimated that even without a motorcycle helmet-use law, between 40% and 60% of motorcycle riders still wear helmets (Kraus, Peek, and Williams 1995). Following the repeal of Florida's mandatory helmet-use law, approximately 46% of the individuals older than age 21 involved in motorcycle crashes were still wearing protective helmets.

Although our results have important policy implications, it would be premature to accept them as definitive and final. Certain caveats must be entertained. First, our finding of a null effect of the law's repeal asks the question "Why?" How can it be that the repeal of the mandatory motorcycle helmet-use law in Florida had no observable effect on serious injury and fatality rates, when many other empirical studies report precisely the opposite? The most likely explanation relates to methodological considerations. Previous research has been handicapped by a continued reliance on small and unrepresentative samples, specification problems, and a failure to use multivariate statistical procedures. The current study addressed most of these problems. The weak influence of the law's repeal on serious injury and fatality rates might also be attributable to our multivariate transfer function (ARIMA) analysis, which is considered to be a relatively conservative statistical procedure.

Second, there will always remain a question as to whether the evidence presented here suffices to sufficiently discredit the utility of mandatory motorcycle helmet-use laws. For example, one could make a reasonable argument that a longer postintervention would be needed to evince an intervention effect. Although it would have been desirable to extend the period of analysis, difficulties in obtaining additional data precluded extending the series. Nevertheless, other studies that use even shorter postintervention periods report that either the implementation or the repeal of mandatory helmet-use laws influence motorcycle crash injuries and/or fatalities (Chiu et al. 2000; Fleming and Becker 1992; Hotz et al. 2002; Kraus et al. 1994). In addition, because the monthly number of motorcycle fatalities in Florida is rather small, the fatality rate series is somewhat unstable. Thus, it is important that readers view our findings in reference to the impact of the law's repeal on the fatality rate for motorcycle riders older than 21 years of age with some healthy skepticism.

Third, the data analyzed here were drawn from one large state. Would our failure to find a strong positive effect of the repeal of the mandatory motorcycle helmet-use law on serious injuries and fatalities in Florida hold for other states? Does state size or state demographics play a role in determining the impact of motorcycle helmet-use legislation? Others should consider replicating this study in other states that have recently repealed their mandatory helmet-use laws. The more frequently such research is conducted, the greater confidence we can place in the generalizability of our findings.

Notwithstanding these caveats, the implications of our findings for policy are clear. The notion that Florida's repeal of its mandatory helmet-use law increased significantly serious injuries and fatalities resulting from motorcycle crashes has been assumed implicitly by policy makers and social scientists alike, but such a belief is not supported by this study. When motorcycle registrations, preexisting trends, and seasonal factors are taken into account, the repeal of Florida's helmet-use law has little observable effect on serious injury and fatality rates.

It would seem particularly fruitful for other researchers to identify more precisely the specific mechanisms responsible for our findings. It also seems clear that those who share our interest in improving motorcycle safety might be better served by shifting their attention away from mandatory helmet-use laws to other potentially more effective measures. Driver training and educational programs might be considered a viable alternative. As Perkins (1981, 295) asserted, "Prevention through rider and driver education may be considerably more cost-effective and save many more lives than mandatory helmet laws." Other measures that help increase the visibility of motorcyclists in traffic may also prove effective.

The effect of mandatory helmet-use laws on motorcycle crash injuries and fatalities is an important question that is raised frequently, with scant and often questionable empirical evidence on which to base definitive answers. The purpose of this study was to shed additional light on this issue. Because our findings show that Florida's repeal of its mandatory motorcycle helmet-use law did not increase the serious injury or fatality rates, we conclude that policy makers should probably consider revising or repealing these types of laws. We fully expect that our findings and conclusions will be elaborated and challenged in future empirical work.

APPENDIX
Helmet-Use Law Statutes by State

State	*Type of Helmet-Use Law*
Alabama	Helmet law, all riders
Alaska	Helmet law, age exemptions
Arizona	Helmet law, age exemptions
Arkansas	Helmet law, age exemptions and insurance requirement
California	Helmet law, all riders
Colorado	100% helmet law free
Connecticut	Helmet law, age exemptions
Delaware	Helmet law, age exemptions
Florida	Helmet law, age exemptions and insurance requirement
Georgia	Helmet law, all riders
Hawaii	Helmet law, age exemptions
Idaho	Helmet law, age exemptions
Illinois	100% helmet law free
Indiana	Helmet law, age exemptions
Iowa	100% helmet law free
Kansas	Helmet law, age exemptions
Kentucky	Helmet law, age exemptions and insurance requirement
Louisiana	Helmet law, age exemptions and insurance requirement
Maine	Helmet law, age exemptions
Maryland	Helmet law, all riders
Massachusetts	Helmet law, all riders
Michigan	Helmet law, all riders
Minnesota	Helmet law, age exemptions
Mississippi	Helmet law, all riders
Missouri	Helmet law, all riders
Montana	Helmet law, age exemptions
Nebraska	Helmet law, all riders
Nevada	Helmet law, all riders
New Hampshire	100% helmet law free
New Jersey	Helmet law, all riders
New Mexico	Helmet law, age exemptions
New York	Helmet law, all riders
North Carolina	Helmet law, all riders
North Dakota	Helmet law, age exemptions
Ohio	Helmet law, age exemptions
Oklahoma	Helmet law, age exemptions
Oregon	Helmet law, all riders

Appendix (continued)

State	*Type of Helmet-Use Law*
Pennsylvania	Helmet law, all riders
Rhode Island	Helmet law, age exemptions
South Carolina	Helmet law, age exemptions
South Dakota	Helmet law, age exemptions
Tennessee	Helmet law, all riders
Texas	Helmet law, age exemptions and insurance requirement
Utah	Helmet law, age exemptions
Vermont	Helmet law, all riders
Virginia	Helmet law, all riders
Washington	Helmet law, all riders
West Virginia	Helmet law, all riders
Wisconsin	Helmet law, age exemptions
Wyoming	Helmet law, age exemptions

Notes

1. Box, Jenkins, and Reinsel (1994) provided a comprehensive discussion of the iterative procedures used in estimating multivariate transfer function models. Suffice it to say that once the univariate autoregressive integrative moving-average model for each stochastic series is identified, each of the stochastic series is then prewhitened. Prewhitening is a process that applies a given set of autoregressive and moving-average factors to a stationary series. Each stochastic input series is prewhitened by its own autoregressive and moving-average factors. The output series is then prewhitened by the input series autoregressive and moving-average factors. If there are multiple input series, than the stationary output series is prewhitened once for each different input series. Prewhitening is advantageous because it helps to remove the intrarelationship in a series, thereby allowing a more accurate appraisal of the interrelationship between the input and output series.

2. The intervention variables were coded as pulse functions in these analyses.

3. Although reported in Table 1, the nonsignificant parameters were eliminated from the models prior to the calculation of the Box-Ljung Q statistics.

REFERENCES

Adams, J. G. U. 1983. Public safety legislation and the risk compensation hypothesis: The example of motorcycle helmet legislation. *Environment and Planning C: Government Policy* 2:193-203.

American Motorcyclist. 1991. New helmet study; same old flaws. *American Motorcyclist* 45:34-35.

Box, G. E. P., G. M. Jenkins, and G. C. Reinsel. 1994. *Time series analysis: Forecasting and control*. 3d ed. Englewood Cliffs, NJ: Prentice Hall.

Branas, C. C., and C. W. Schwab. 2002. Motorcycle helmet laws require careful study. *Journal of Trauma, Injury, Infection, and Critical Care* 52:437-74.

Chenier, T. C., and L. Evans. 1987. Motorcyclist fatalities and the repeal of mandatory helmet wearing laws. *Accident Analysis and Prevention* 19:133-39.

Chiu, W., C. Kuo, C. Hung, and M. Chen. 2000. The effect of the Taiwan motorcycle helmet use law on head injuries. *American Journal of Public Health* 90:793-96.

Cooter, R. D., A. J. McLean, D. J. David, and D. A. Simpson. 1988. Helmet-induced skull base fracture in a motorcyclist. *Lancet* 1:84-85.

Dickey, D. A., W. R. Bell, and R. B. Miller. 1986. Unit roots in time series models: Tests and implications. *American Statistician* 40:12-26.

Evans, L., and M. C. Frick. 1988. Helmet effectiveness in preventing motorcycle driver and passenger fatalities. *Accident Analysis and Prevention* 20:447-58.

Fleming, N. S., and E. R. Becker. 1992. The impact of the Texas 1989 motorcycle helmet law on total and head-related fatalities, severe injuries, and overall injuries. *Medical Care* 30:832-42.

Gabella, B., K. L. Reiner, R. E. Hoffman, M. Cook, and L. Stallones. 1995. Relationship of helmet use and head injuries among motorcycle crash victims in El Paso County, Colorado, 1989-1990. *Accident Analysis and Prevention* 27:363-69.

Goldstein, J. P. 1986. The effect of motorcycle helmet use on the probability of fatality and the severity of head and neck injuries. *Evaluation Review* 10:355-75.

Gordon, S., and J. Prince. 1975. Field of view with and without motorcycle helmets. Technical report DOT HS-801-75. Washington, DC: National Highway Traffic Safety Administration.

Graham, J. D., and Y. Lee. 1986. Behavioral response to safety regulation: The case of motorcycle helmet-wearing legislation. *Policy Sciences* 19:253-73.

Hartunian, N. S., C. N. Smart, T. R. Willemain, and P. L. Zador. 1981. The economics of safety deregulation: An analysis of excess death and costs due to motorcycle helmet law repeal in the United States. *Journal of Health Politics, Policy and Law* 8:86-78.

Hotz, G. A., S. M. Cohn, C. Popkin, P. Ekeh, R. Duncan, E. W. Johnson, F. Pernas, and J. Selem. 2002. The impact of a repealed motorcycle helmet law in Miami-Dade County. *Journal of Trauma, Injury, Infection, and Critical Care* 52:469-74.

Huston, R. L., and J. Sears. 1981. Effect of protective helmet mass on head/neck dynamics. *Journal of Biomedical Engineering* 103:18-23.

Johnson, B., and L. Christensen. 2000. *Educational research: Quantitative and qualitative approaches*. Boston: Allyn & Bacon.

Konrad, C. J., T. S. Fieber, G. K. Schuepfer, and H. R. Gerber. 1996. Are fractures of the base of the skull influenced by mass of the protective helmet? A retrospective study in fatally injured motorcyclists. *Journal of Trauma* 41:854-58.

Krantz, K. P. G. 1985. Head and neck injuries to motorcycle and moped riders with special regard to the effect of protective helmets. *Injury* 16:253-58.

Kraus, J. F., C. Peek, and A. Williams. 1995. Compliance with the 1992 California motorcycle helmet use law. *American Journal of Public Health* 85:96-99.

Kraus, J. F., C. Peek, D. L. McArthur, and A. Williams. 1994. The effect of the 1992 California motorcycle helmet-use law on motorcycle crash fatalities and injuries. *Journal of the American Medical Association* 272:1506-11.

Lin, M., H. Hwang, and N. Kuo. 2001. Crash severity, injury patterns, and helmet use in adolescent motorcycle riders. *Journal of Trauma* 50:24-30.

Ljung, G. M., and G. E. P. Box. 1978. On a measure of lack of fit in time series models. *Biometrika* 65:297-303.

Offner, P. J., F. P. Rivara, and R. V. Maire. 1992. The impact of motorcycle helmet use. *Journal of Trauma* 32:636-41.

Perkins, R. J. 1981. Perspectives on the public good. *American Journal of Public Health* 71:294-95.

Purswell, J. L., and A. L. Dorris. 1977. Auditory and biomechanical performance requirements for motorcycle helmets. In *Proceedings of human factors society—21st annual meeting*, 226-30.

Reilly, D. P. 1999. Autobox for Windows, 5.0. Hatboro, PA: Automatic Forecasting Systems.

Robertson, L. S. 1976. An instance of effective legal regulation: Motorcycle helmet and daytime headlamp laws. *Law and Society* 10:476-77.

Rowland, J., F. Rivara, P. Salzberg, R. Soderberg, R. Maier, and T. Koepsell. 1996. Motorcycle helmet use and injury outcome and hospitalization costs from crashes in Washington State. *American Journal of Public Health* 86:41-45.

Sarkar, S., C. Peek, and J. F. Kraus. 1995. Fatal injuries in motorcycle riders according to helmet use. *Journal of Trauma* 38:242-45.

Sosin, D. M., and J. J. Sacks. 1992. Motorcycle helmet-use laws and head injury prevention. *Journal of the American Medical Association* 267:1649-51.

Sosin, D. M., J. J. Sacks, and P. Holmgreen. 1990. Head injury-associated deaths from motorcycle crashes: Relationship to helmet-use laws. *Journal of the American Medical Association* 264:2395-99.

Stellwagen, E. A., and R. L. Goodrich. 2000. *Forecast Pro*. Belmont, MA: Business Forecast Systems.

Tiao, G. C., and W. W. S. Wei. 1976. Effect of temporal aggregation on the dynamic relationship of two time series variables. *Biometrika* 63:513-23.

Watson, G. S., P. L. Zador, and A. Wilks. 1980. The repeal of helmet use laws and increased motorcycle mortality in the United States, 1975-1978. *American Journal of Public Health* 70:579-85.

———. 1981. Helmet use, helmet use laws, and motorcyclist fatalities. *American Journal of Public Health* 71:297-300.

Weiss, A. A. 1992. The effects of helmet use on the severity of head injuries in motorcycle accidents. *Journal of the American Statistical Association* 87:48-56.

Lisa Stolzenberg is an associate professor in the School of Policy and Management at Florida International University. Her work has appeared in a variety of journals, including the American Sociological Review, Social Forces, Social Problems*, and* Criminology. *Her research has been supported by the National Institute of Justice and several other funding agencies.*

Stewart J. D'Alessio is an associate professor in the School of Policy and Management at Florida International University. His current research focuses on economic inequality and crime.