Accident Analysis and Prevention 38 (2006) 142–147

ACCIDENT ANALYSIS & PREVENTION

www.elsevier.com/locate/aap

Generalized linear regression analysis of association of universal helmet laws with motorcyclist fatality rates

C. Craig Morris *

Bureau of Transportation Statistics, Research and Administrative Technology Administration, U.S. Department of Transportation, 400 Seventh Street, SW, Room 3430, Washington, DC 20590, USA

Received 19 January 2005; accepted 19 May 2005

Abstract

This study evaluates the association of universal helmet laws with U.S. motorcyclist fatality rates from 1993 through 2002 using climate measures as statistical controls for motorcycling activity via quasi-maximum likelihood generalized linear regression analyses. Results revealed that motorcyclist fatalities and injuries are strongly associated with normalized heating degree days and precipitation inches, and that universal helmet laws are associated with lower motorcyclist fatality rates when these climate measures, and their interaction, are statistically controlled. This study shows that climate measures have considerable promise as indirect measures (proxies) of motorcycling activity in generalized linear regression studies.

Published by Elsevier Ltd.

Keywords: Motorcycle; Safety; Climate; Seasonality

1. Introduction

According to the National Center for Statistics and Analysis (NCSA) of the National Highway Traffic Safety Administration (NHTSA), recent data indicate that only about half of all fatally injured motorcyclists in the United States were wearing helmets (NCSA, 2001). While there is evidence that wearing a compliant motorcycle helmet reduces the likelihood and severity of severe head injury and death (Deutermann, 2004; NCSA, 1996; NHTSA, 2003a; Sass and Zimmerman, 2000), several states have recently relaxed motorcycle helmet laws, and helmet use has declined (NCSA, 2002). At the end of 2002, only 20 states had a *universal helmet law* requiring that all motorcyclists wear helmets; the remaining states, except for three, had laws requiring that some riders wear helmets (NHTSA, 2003b). States with a universal helmet law require all motorcycle riders to wear helmets at all times while riding on public roads. Most states without a universal helmet law still require some riders to wear helmets, e.g. riders under 15, 18, 19, or 21; riders with an instruction permit or less than 1 year of experience; riders who have not completed a training course; riders without US$ 10,000 of medical insurance, etc. During the 10-year period from 1993 through 2002, 25 states never had a universal helmet law, 20 states always had a universal helmet law, and five states started with a universal helmet law but eliminated it during that decade (NCSA, 1993–2002).

To evaluate the effectiveness of universal helmet laws, one approach is to compare motorcyclist fatalities in states with a universal helmet law to those in states without it, adjusting for differences in motorcyclist activity between the states. Unfortunately, while the number of motorcycle registrations is available for individual states, the number of motorcycle miles traveled is not. Although the number of motorcycle registrations is partially related to exposure, this measure neglects variation in the amount of activity of the registered motorcycles—a key quantitative measure needed to assess the association of fatality rates with helmet laws. However, since motorcycle activity is highly seasonal, with more activity on warm or dry days than on cold or rainy days, and climates vary markedly across states in the U.S., fatalities per registered motorcycle can be compared between states with and without universal helmet laws while controlling for climate measures correlated with motorcyclist activity.

In a careful study with controls for various factors known or expected to be associated with motorcyclist fatality rates, such as average temperature, precipitation, population density, alcohol use, speeding, and engine size, Branas and Knudson (2001)

* Tel.: +1 202 366 5533; fax: +1 202 493 0568; mobile: +1 703 606 9308.
E-mail addresses: Craig.Morris@RITA.gov, craig.morris@bts.gov.

0001-4575/$ – see front matter. Published by Elsevier Ltd.
doi:10.1016/j.aap.2005.08.004

found no significant difference in fatality rates between states with versus without universal helmet laws from 1994 through 1996. While their findings demonstrate the importance of statistical controls in the comparison of state fatality rates, the null results raise questions about the statistical power of their study and leave open the question of a potential benefit of universal helmet laws. In a panel study spanning the 22 years from 1976 to 1997, Sass and Zimmerman (2000) reported an average 29–33% decrease in per capita motorcyclist fatalities associated with state laws mandating helmet use by motorcyclists. They also found similar results in a set of 22 separate cross-sectional single-year analyses. Of many interesting features of their study, one was the use of a climate measure, heating degree days, as both an indirect measure of motorcyclist activity as well as a factor thought to interact with motorcycle helmet usage (i.e. with more helmet usage in states with harsher climates). Their study also included many other factors in complex structural models, some of which simultaneously estimated over 80 parameters under strict covariance assumptions required by panel studies. While the strict covariance assumptions of panel studies are irrelevant to model parameter estimates, violation of the assumptions causes underestimation of standard errors of the parameter estimates, making the true likelihood of erroneously rejecting null hypotheses much greater than the nominal (α) levels. Unfortunately, as noted by Sass and Zimmerman (2000, p. 208), the available tests of such assumptions often lack sufficient power to reliably detect violations.

An association of state universal helmet laws with reduced state fatality rates is likely to be hard to detect statistically for several reasons: all but three states require at least some riders to wear helmets; some riders wear helmets even when they are not legally required; motorcyclist fatalities are not only attributable to head injuries; many factors influence motorcyclist fatalities; and direct motorcyclist activity data do not exist. Statistical power – the likelihood a study will detect an existing association – is an increasing function of both the proportion of variance explained by a set of explanatory variables and the degrees of freedom for the model; however, while increasing the number of linearly independent explanatory variables increases the proportion of explained variance (with diminishing returns), it also decreases the degrees of freedom (with an accelerated effect the fewer the degrees of freedom)—which with only the 50 independent (multivariate) observations available for U.S. state comparisons, quickly costs more statistical power than is gained by additional explanatory variables.

Since climate measures are strongly associated with motorcyclist activity, the strongest factor associated with fatality risk, the present study examines the association of universal helmet laws with motorcyclist fatality rates using pertinent climate measures to control for motorcyclist activity in quasi-maximum likelihood generalized linear regression analyses. While the states undoubtedly still differ in minor ways aside from climates and the presence or absence of universal helmet laws, the multitude of such independent minor factors mitigates against the likelihood of severe bias attributable to them. The analytic objective is to maintain scientific parsimony and statistical power, with minimal reliance on stringent statistical assumptions, by modeling fatality rates as a function of one explanatory variable (universal helmet law) and two climate-related activity measures (heating degree days, precipitation) along with pertinent quadratic and interaction terms. Quasi-maximum likelihood generalized linear modeling provides crucial flexibility in modeling the relation between a function of the mean and the covariates, the relation between the mean and variance, and the error distribution.

2. Methods

Motorcyclist fatality data are from NHTSA's Fatality Analysis and Reporting System (FARS-NCSA, 2005). FARS is a database of information about the scenarios, vehicles, drivers, and passengers involved in all fatal motor vehicle crashes on public highways and roads in the U.S. Data on hospital emergency room-treated injuries are from the U.S. Consumer Product Safety Commission's (CPSC) National Electronic Injury Surveillance System-All Injury Program (NEISS-AIP) (Schroeder and Ault, 2001). Data on number of registered motorcycles by states are from the Federal Highway Administration (FHWA, 1992–2002).

Normalized state climate data, including population-weighted annual heating degree days and precipitation inches, are from the National Oceanic and Atmospheric Administration (NOAA-NCDC, 2002a,b). The heating degree days statistic is a measure of cold weather energy consumption and is defined as the annual sum of daily differences in mean daily temperature from a 65 °F base (with the difference set to 0 if the mean daily temperature exceeds the 65° base temperature), averaged across all stations within the state, with the average weighted by population distribution in the area. At one station in a given year, for example, 5 days with a mean daily temperature of 64 °F would result in 5 degree days, as would 1 day with a mean daily temperature of 60 °F. NOAA's normalized heating degree day measure, an annual average derived over the 30-year period 1971–2000, is a climate measure that estimates the annual average heating degree days for each state during the normalization period. The advantage of heating degree days over average temperature as a measure of motorcyclist activity consists both in its theoretical utility for ratio-scale measurement of the change in thermal energy necessary to maintain a comfortable ambient temperature and in its empirical utility in accounting for substantial nuisance variation in fatality rates.

For each state, the annual average fatality rate was estimated by dividing the sum of fatalities across the decade from 1993 to 2002 by the sum of motorcycle registrations each year across the same period. The annual average heating degree days and precipitation were obtained likewise.

Generalized linear regression analysis compared fatality rates in states with and without universal helmet laws adjusting for exposure as indexed by normalized state climate data. To include all 50 states in the present analysis, the five states that repealed a universal helmet law sometime during the decade of 1993–2002 (three in 1997, one in 1999, and one in 2000) were grouped with states that never had a universal helmet law during that decade. Also, following NOAA, data for the District of Columbia were combined with those for Maryland, both of which had a universal