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The association of age, sex and helmet use with the risk of death for occupants of two-wheeled motor vehicles involved in traffic crashes in Spain

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ABSTRACT

Background: This study was designed to separate the association of age, sex and helmet use with the risk of death for occupants of two-wheeled motor vehicles (TWMV) involved in crashes into its two theoretical components: severity of the crash and occupant resilience.
Methods: We analyzed the retrospective cohort comprising all 48 016 pairs of drivers and passengers aged 14 years or more in TWMV involved in crashes with victims in Spain from 1993 to 2007 recorded in the Spanish traffic crash registry. The outcome (death or survival), age, sex and helmet use was known for both occupants. Adjusted relative risks (RR) for the association of age, sex and helmet with the risk of death were calculated with Poisson regression models.
Results: Each 1-year increase in age was related with a 3% increase in the risk of death related with lower resilience. The severity-dependent RR of death was 1.84 for male sex and 0.86 for non-helmet use, and the resilience-dependent RR was 0.72 and 2.53, respectively.
Conclusions: The direction and magnitude of the association between age, sex and helmet use and the risk of death of an occupant of a TWMV involved in a crash changed depending on which component of risk was considered: crash severity or occupant resilience. Specifically, female sex and non-helmet use seemed to be associated with crashes of lower severity, but together with increased age they were also related with lower resilience to the energy released in the crash, and therefore with a higher risk of death after adjustment for crash severity. This should be taken into account when assessing the association of individual factors with the risk of death after a crash.

1. Introduction

The association between occupant-dependent factors and the risk of death after a traffic crash involving two-wheeled motor vehicles (TWMV) has been investigated in several contexts (Chang and Yeh, 2006; Evans and Frick, 1988; Lapparent, 2006; Lin et al., 2001; Norvell and Cummings, 2002; Quddus et al., 2002; Rowland et al., 1996; Shankar and Mannering, 1996; Yau, 2004; Zambon and Hasselberg, 2006). From a theoretical viewpoint, this relationship may be broken down into two main elements: (1) the association between individual factors and the *severity* of the crash (mainly related with the type of crash and the amount of energy released), and (2) the association between individual factors and the *resilience* of the occupant to the effect of the released energy, which is related in turn with the fraction of energy released which is transferred to the occupant, the occupant's resistance to the immediate effect of the transferred energy, and the prognosis for injuries sustained as a direct result of the crash.

The direction and magnitude of the two types of association between individual factors and the risk of death (severity- and resilience-dependent associations) may differ and may even be opposite. Therefore each component should be considered individually. Moreover, the association of a given factor with one component may confound the association between this factor and the other component. For example, regarding the effectiveness of helmet use for TWMV occupants (Shankar and Mannering, 1996), estimation of the decrease in risk of death due to increased resilience provided by helmets (by reducing the amount of energy transferred to the head) may be confounded if helmet use is also related with crash severity (Lin et al., 2001; Rutledge and Stutts, 1993). This assumption may hold if helmet use is associated with more cautious driving, including driving at lower speeds. But the opposite may also be the case if, in accordance with the hypothesis of risk homeostasis (Hedlund, 2000) helmeted drivers offset their

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perceived lower risk by acquiring other riskier habits such as driving at higher speeds. Both associations may affect the estimated true effectiveness of helmet use in reducing the risk of death after a crash.

In the light of these considerations, we aimed in this study to find a model able to shed light on the global associations of age, sex and helmet use with the risk of death of occupants of TWMV after a crash, and able to separate the former associations into the two components of risk of death, i.e., severity of the crash and occupant resilience.

2. Methods

From the Spanish traffic crash registry we selected a retrospective cohort of 48 016 TWMV drivers at least 14 years old involved in a traffic crash with victims from 1993 to 2007. Additional criteria for inclusion in the analysis were traveling with a passenger at least 14 years old, and information in the registry on the outcome (death or survival) in the first 24 h after the crash, age, sex and helmet use for both the driver and the passenger. The main characteristics of this police-based registry, which theoretically covers all crashes with victims taking place in Spain, were described in previous papers (Lardelli et al., 2003a; Lardelli-Claret et al., 2003b). Information was obtained from the registry for variables for both drivers and passengers, e.g., death, age, sex, position and helmet use. Other driver-related variables were psychophysical conditions (none, driving under the influence, others), hours driving (<1, ≥1), and administrative infractions prior to the crash (none, driving without a valid license, others).

As vehicle-related variables we recorded the code identifier of the vehicle, the type of vehicle (moped or motorcycle), and the presence of previous defects in the vehicle (no, yes). Environment-related variables were year, month, weekday, type of day (work day, eve of a Sunday or holiday, Sunday or holiday, day after a Sunday or holiday), time, zone (road, built-up area with >100 000 inhabitants, built-up area with 50 000–100 000 inhabitants, built-up area with 5000–50 000 inhabitants, built-up area with <5000 inhabitants), characteristics of the road (straightaway, wide curve, unsignposted tight curve, signposted tight curve with no speed limit, signposted tight curve with speed limit, T intersection, 4-leg intersection, entrance ramp, exit ramp, traffic circle, other), traffic density (light, heavy, congested), road surface conditions (normal, altered), weather conditions (good, adverse), visibility (good, restricted), and light conditions (daylight, twilight, night with good illumination, night with insufficient illumination, night without illumination). Variables related to the severity of the crash were the type of crash (frontal collision, frontolateral collision, lateral collision, front-to-rear collision, overturned vehicle, collision with an obstacle in the road, collision with a pedestrian, running off the road, other), driver maneuver just before the crash (following planned route, passing on the right, passing on the left, turning, merging from other street or road, crossing an intersection, swerving to avoid an obstacle or a pedestrian/sudden braking, stopped, other actions), speed-related infractions (none, traveling above the speed limit, inappropriate speed for existing conditions), other infractions committed by the driver (none, distracted, others), the number of vehicles involved (one, two, three or more), the number of injured persons (one, two, three, four or more), and the number of deaths in the crash excluding those of the TWMV occupants (none, one or more).

3. Analysis

A detailed description of the analysis can be found in a previous paper (Lardelli-Claret et al., 2009) in which we assessed the effect of age, sex and seat belt use on the risk of death after a crash for drivers of passenger cars. Briefly, we used Poisson regression analysis (Hardin and Hilbe, 2001) to obtain adjusted relative risks (RR) and their 95% confidence interval for the association between age, sex and helmet use with the risk of death. Previously, we used a multiple imputation process with switching regression (multiple imputation by chained equations) (Van Buuren et al., 1999) to construct ten files in which missing values for the variables psychophysical circumstances, hours driving without a break, presence of previous defects in the vehicle, administrative infractions and speed-related infractions (the only co-variables with missing values) were replaced by their corresponding imputed values. We fitted a model for each file, and coefficients of each model were combined according to the combination rules of Rubin (Li et al., 1991). These operations were done with the Ice (Royston, 2005) and Mim programs from Stata v. 10.

To achieve the study objectives we designed four different Poisson regression models. Table 1 summarizes the main characteristics of each one.

In the first model (model 1), the dependent variable was death of the driver. As independent terms of the model we included the remaining driver-related characteristics as well as all vehicle- and environment-related variables. Theoretically, this model (called the joint model here) allows us to estimate the joint association of each driver-related factor on risk of death (i.e., the association dependent on both crash severity and driver resilience), adjusted for the possible confounding bias introduced by the type of vehicle and the environment.

Model 2 was constructed to assess the association of passenger's age, sex and helmet use (included as independent terms of the model) with the passengers' risk of death (the dependent variable). Theoretically, passenger characteristics are not directly related with crash severity, thus their relationship with passengers' risk of death is assumed to be dependent on resilience only. However, passenger characteristics may be indirectly related with crash severity through their possible relationship with drivers' characteristics, type of vehicle and environment. Therefore, we also included these variables as independent terms in the model. Additionally, in order to control for residual confounding related with crash severity, we included as independent terms in the model all other variables related with the severity of the crash.

In model 3 we tried to determine whether the driver's age, sex and helmet use (chosen here as the independent terms in the model) were related with the passenger's risk of death (the dependent variable). Theoretically, if this association exists it would be mediated only by the association of the above driver-related characteristics with crash severity. However, because the characteristics of the driver and passenger occupying the same TWMV may be related, we also included the former in the model as confounders. Finally, to adjust for confounding related with the type of vehicle and environment-related variables, all of these variables were also included as independent terms of the model.

Model 4 was a conditional regression model that considered driver-passenger pairs occupying the same TWMV. In this model only the 1712 pairs in which at least one death occurred were included, as the remaining pairs were non-informative. The dependent variable was death of either or both of the occupants. As independent terms in the model we used age, sex, helmet use and position on the vehicle (the four variables for which data were available for both drivers and passengers). The paired design provided almost perfect control for the variability in the risk of death related with crash severity and the association between death and the independent terms was assumed to be mediated entirely by resilience of the TWMV occupants. Therefore, we used this model as our gold standard for comparison to the results obtained with model 2. If the association of age, sex and helmet use with the risk of death