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Risk factors for causing road crashes involving cyclists: An application of a quasi-induced exposure method

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ABSTRACT

A quasi-induced exposure approach was applied to the Spanish Register of Traffic Crashes to identify driver- and vehicle-related factors associated with the risk of causing a road crash involving a cyclist in Spain from 1993 to 2009. We analyzed 19,007 collisions between a bicycle and another vehicle in which only one of the drivers committed an infraction, and 13,540 records that included the group of non-infractor cyclists in the above collisions plus cyclists involved in single-bicycle crashes. Adjusted odds ratios were calculated for being responsible for each type of crash for each factor considered. Age from 10 to 19 years, male sex, alcohol or drug consumption and non-helmet use were cyclist-related variables associated with a higher risk of crash, whereas cycling more than 1 h increased only the risk of single crashes. Bicycles with brake defects and ridden by two occupants were also at higher risk of involvement in a crash, whereas light defects were associated only with collisions with another vehicle. For drivers of the other vehicle, age more than 60 years, alcohol, not using safety devices and nonprofessional drivers were at higher risk. The risk of colliding with a bicycle was higher for mopeds than for passenger cars.

1. Introduction

Road crashes involving cyclists are a non-negligible health problem, especially in countries where bicycles are used frequently as a mode of transport (Bacchieri et al., 2010; Schepers and den Brinker, 2011; Tin Tin et al., 2010; Veisten et al., 2007; Wang and Nihan, 2004). Compared to other road users, cyclists run a higher risk of being injured in a road crash (Wegman et al., 2012). Furthermore, efforts to encourage the use of bicycles for commuting or for sports and leisure activities in many developed countries (Heinen et al., 2010; Morgan et al., 2010; Pucher et al., 2011) make it necessary to devote greater resources to the prevention of cycling-related crashes. Epidemiological studies of cycling-related road crashes are usually designed with a focus on exploring the most frequent patterns of accidents, their circumstances and environment-related factors (Johnson et al., 2010; Loo and Tsui, 2010; Lusk et al., 2011; Morgan et al., 2010; Nicaj et al., 2009; Räsänen and Summala, 1998; Schepers et al., 2007; Wang and Nihan, 2004; Wood et al., 2009), or describing the characteristics of injured cyclists and the factors related with the severity of injuries (Amoros et al., 2011, 2012; Attewell et al., 2001; Bíl et al., 2010; Elvik, 2011; Moore et al., 2011; Rivara et al., 1997; Simon-Tov et al., 2012; Thompson et al., 1999; Wessels, 1996). However, few studies have assessed the driver- and the vehicle-related factors associated with the risk of causing a crash involving a cyclist, adjusted by the intensity of exposure (Bacchieri et al., 2010; Maring and van Schagen, 1990), from the perspective of both the cyclist and the other driver or vehicle involved in the crash. This oversight leads to a major methodological challenge: how to assess exposure to the risk of causing a crash. Unfortunately, there are no valid exposure estimates of distance or time driven by cyclists in Spain stratified according to individual and environmental-related characteristics.

The quasi-induced exposure method constitutes a potentially useful tool to deal with this problem. This approach compares the characteristics of responsible and non-responsible drivers involved in road crashes (Lardelli-Claret et al., 2006; Lenguerrand et al., 2008). Although quasi-induced exposure methods have been widely used in previous decades to explore the effect of factors potentially related with the risk of road crashes (Jiang and Lyles, 2010), there appear to be no studies that have used this approach to investigate the factors that cause cycling-related road crashes.

The aim of the present study was to identify driver-related and vehicle-related factors associated with the risk of causing a road crash involving a cyclist in Spain. We analyzed two groups of

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crashes: those involving a single cyclist, and collisions between a bicycle and another vehicle.

2. Materials and methods

The initial source population from this study comprised the 46,076 cyclists involved in road crashes from 1993 to 2009 in Spain, recorded in the database of the Spanish Register of Traffic Crashes with Victims maintained by the Spanish Traffic General Directorate (*Dirección General de Tráfico*, DGT). For each traffic crash resulting in injury or death, the register contains information about the nature of the crash and about the vehicles and persons involved. This information is taken from the statistical report and checklist filed for each accident, an official document that the Spanish Traffic Police must complete at the scene of all accidents with victims (Lardelli-Claret et al., 2003). From the original population of cyclists we initially selected two different groups: cyclists involved in collisions with another (non-bicycle) vehicle (34,179 cyclists) and cyclists involved in single-bicycle crashes, i.e., crashes in which only a cyclist was involved and no other vehicle or pedestrian was involved (4520 cyclists). Each record of cyclists in the first group was matched with the corresponding record for the driver of the other vehicle involved in the same collision.

The analysis of these two groups of cyclists was based on a quasi-exposure method. The aim of this method is to estimate the increase in risk of being involved in a road crash associated with different driver- or vehicle-related characteristics, when no direct measurements of the intensity of exposure are available for these characteristics. Briefly, the method is based on selecting two-vehicle collisions in which only one of the two drivers involved was considered responsible for the crash ("clean collisions"). Non-responsible drivers involved in these collisions may be considered an approximately random sample of the road-user population; this assumption means that estimating the risk of involvement in a collision for a certain type of driver or vehicle (i) requires simply comparing the frequency of this particular driver's or vehicle's appearing in the population of responsible drivers with the frequency of the same driver's or vehicle's appearing in the sample of non-responsible drivers. Furthermore, if the intensity of exposure to the risk of involvement in a crash is the same for single-vehicle crashes and crashes involving two vehicles, the relative propensity to cause a single crash can also be estimated for type i drivers or vehicles by comparing the frequency of appearance of a given driver in the population of drivers involved in single-vehicle crashes with the frequency of appearance of the same type of driver in the sample of non-responsible drivers (Lardelli-Claret et al., 2006).

The Spanish Traffic Crash Register does not contain information about responsibility for the crash; however, it records the commission of infractions (including speed-related infractions) for all drivers involved in the crash (see Appendix for the infractions coded in the DGT register). Therefore, we defined a clean collision between a bicycle and another vehicle as a collision in which one of the drivers committed an infraction and the other did not. The underlying assumption is that in these clean collisions, the infractor driver was much more likely to have been responsible for the crash than the driver of the other vehicle. It is important to emphasize here that we are not using the word "responsibility" in a legal sense, but in a epidemiological one. From an epidemiological point of view, almost all health outcomes (including, of course, road crashes) are multicausal, and no single necessary or sufficient cause can be identified. This is particularly true for road crashes, in which the only necessary cause is exposure to the risk, i.e., it is necessary to ride a bicycle in order to be at risk of having a road crash while riding a bicycle. Instead, we used the multicausal modified deterministic model proposed by Rothman (Rothman and Greenland, 2005) according to which a given health event is the outcome of the combination of a (usually large) set of component causes which result in a specific sufficient cause. In our clean collisions (in which one of the drivers committed an infraction and the other did not), the use of the word "responsible" specifically means that among the set of component causes of the sufficient cause which led to a given collision, the infractor driver was much more likely to be one of the components of this specific sufficient cause than the non-infractor driver.

Based on the assumptions explained above, we determined whether an infraction was committed by all cyclists included in the present analysis as well as by any of the 34,179 drivers of the other vehicle involved in the same collision. After excluding crashes for which there was no information regarding the commission of an infraction by either of the involved drivers, we built a first dataset comprising 19,007 collisions between a bicycle and another vehicle (55.6% of all collisions) in which only one of the involved drivers (the cyclist or the driver of the other vehicle) committed an infraction. For each of these "clean" collisions, we created a data file containing the following information, taken from the DGT record:

- *Dependent variable*: infractor driver: a value of 0 was assigned if the cyclist committed an infraction ($n = 9294$, 48.9%), and a value of 1 if the other driver was the infractor ($n = 9713$). We assumed that in clean collisions, the infractor driver was highly likely to have been responsible for the crash.
- *Independent variables, grouped in the following categories*: type of crash; variables for both drivers (the cyclist and the driver of the other vehicle): age group (see tables for categories), sex, use of protective devices (helmet or seat belt), psychophysical circumstances (none, driving under the effect of alcohol or drugs, others), hours driving without a rest (less than 1, 1–3, more than 3), type of driver (professional or nonprofessional), and driver's maneuver before the crash (no particular maneuver, i.e., traveling normally with the direction of traffic, passing, turning, joining the traffic flow, crossing an intersection, stopped/parked, other); variables for the vehicle: previous defects of the bicycle (none, lights, brakes, others); number of occupants of the bicycle (one, more than one), type of the other vehicle (passenger car, moped, motorcycle, van, truck less than 3500 kg, truck 3500 kg or more, bus, tractor or heavy machinery, other); age and number of occupants in the other vehicle (1, 2, more than 2). The environmental variables used as independent variables were: type of road (highway, two-lane road, rural road, etc.); place (highway, urban street, urban through-road), hour; type of day (working day, holiday, day before a holiday, day after a holiday); month; year; visibility conditions (good, diminished); surface (normal, altered); weather conditions (good, adverse); and light conditions (daylight, sundown, night with good lighting, night with insufficient lighting, night without lighting).

In the next step, a second data dataset was created comprising 13,540 cyclists classified in three subgroups: non-infractor cyclists involved in clean collisions with another vehicle ($n = 9713$), non-infractor cyclists involved in single crashes ($n = 1322$) and infractor cyclists involved in single crashes ($n = 2505$). In this dataset we assumed that the first subgroup comprised mainly non-responsible cyclists, and therefore hypothesized that their characteristics would resemble those of all cyclists on the road. In the second group, responsibility was uncertain: although none of the cyclists committed an infraction, no other driver or pedestrian was involved in the crash. Cyclists in the last subgroup were considered responsible for the single crash they were involved in. In this data set, the dependent variable was the subgroup of cyclists under consideration. Independent variables were the same as in