Exposure to Traffic and Risk of Hospitalization Due to Injuries

Maria Segui-Gomez,[1,*] **Francisco J. Lopez-Valdes,**[1,3] **Francisco Guillen-Grima,**[4] **Ernesto Smyth,**[5] **Javier Llorca,**[6] **and Jokin de Irala**[2]

Research on the risk of motor vehicle injuries and their relationship with the amount of travel has been only partially analyzed. The few individual exposure assessments are related to very specific subsets of the driving and traveling populations. This study analyzes the relationship between kilometers traveled and hospitalization due to motor vehicle injuries. Twelve thousand three hundred and sixty nine Spanish university graduates from the Seguimiento Universidad de Navarra multipurpose cohort study were evaluated. They had not been hospitalized due to motor vehicle injuries at baseline and were followed up to eight years. Biannual questionnaires allowed for self-reporting of kilometers traveled in motor vehicles, together with incidence of hospitalization. Covariates in the Cox regression models included age and gender and baseline use of safety belt while driving, driving a vehicle with driver-side airbag, driving a motorcycle, and drinking and driving. There were 49,766 participant-years with an average yearly travel of 7,828 km per person-year. Thirty-six subjects reported a first hospitalization event during this time. The adjusted hazard ratio per additional kilometer traveled was 1.00005 (95% confidence interval 1.000013 to 1.000086). Even the smallest of reductions in the amount of kilometers traveled (from an average of 3,250 km per year to 1,000) has a statistically significant protective effect on the likelihood of sustaining hospitalization due to motor vehicle injury (aHR 0.9, 95% CI 0.78 to 0.98). In light of current policies aimed to reduce motorized traffic due to environmental concerns, it may be appropriate to consider the additional health benefit related to reductions in injuries.

KEY WORDS: Hospitalization; injuries; longitudinal studies; motor vehicle crashes; risk

[1]European Center for Injury Prevention, Universidad de Navarra, Pamplona, Spain.
[2]Department of Preventive Medicine and Public Health, Universidad de Navarra, Pamplona, Spain.
[3]Center for Applied Biomechanics, University of Virginia, Charlottesville, VA, USA.
[4]Department of Preventive Medicine, Clínica, Universidad de Navarra, Pamplona, Spain.
[5]Department of Preventive Medicine and Public Health, Universidad de Santiago de Compostela, Santiago de Compostela, Spain.
[6]Department of Preventive Medicine and Public Health, Universidad de Cambria, Santander, Spain.
*Address correspondence to Maria Segui-Gomez, European Center for Injury Prevention, Universidad de Navarra, Ed. Los Costaños, Irunlarrea 1, 31080 Pamplona, Spain; tel: 34 948 425600 ext. 6575; fax: 34 948 425649; msegui@unav.es, mruizp@unav.es.

1. INTRODUCTION

Though the benefits brought in by economic development and better transportation systems are unquestionable, there is also a growing burden of illness through pollution and climate change.[1,2] Many of these health problems have been discussed elsewhere and they range from, for example, asthma and allergic sensitization in children[3] to overall mortality among U.S. military veterans.[4] Although some of the specific health impacts are still debatable,[5] the 2006 article by McMichael[6] summarizes well the breadth and depth of health risks imposed by this environmental change.

The magnitude of this impact is such that stronger policies to reduce global warming need to be implemented. As an example, the Intergovernmental Panel on Climate Change has called for reductions of global greenhouse gas emissions by as much as 80% by 2050.[7] Motor vehicle usage is the second biggest contributor to these emissions in the transport sector, a sector that is second in global carbon dioxide emissions and the only sector where emissions continue to grow.[8] In a recent analysis aimed to develop policies to reach such an objective in the State of Minnesota, and among other complementary strategies, a 50% reduction of vehicle miles driven from 2005 levels has been targeted for 2050.[9]

Besides preventing the health burden associated with emissions, there is an often forgotten health benefit to reducing motorized transport: the reduction of motor vehicle injuries. As stated by the World Health Organization (WHO), "road traffic injuries are a major but neglected public health challenge."[10] Motor vehicle crashes are responsible for the death of more than 1.2 million deaths a year and predictions for 2020 place them as the third leading contributor to the global burden of disease and injury.[11]

Yet, the injury risks associated with the amount of travel have been only partially analyzed.[12,13] Much of the existing research has been purely descriptive, based on police reports that lack information about exposure,[14] ecologic studies that use aggregated travel exposure data as derived from fuel consumption estimates,[15] or, exceptionally, representative interviews such as the U.S. National Household Travel Survey.[16] A number of transverse descriptive studies and case-control studies have relied on creative approaches such as the so-called induced exposure method to control for the confounding effect of exposure.[17,18] Most of these empirical analyses and a few theoretical reviews[19] point to a positive relationship with increased travel relating to higher accident and injury rate. However, a few such studies identify decreased fatality rates with increased exposure to traffic, an issue that they always link to traffic density and the slowdown of travel speeds, which may not affect crash rates but affects the severity of those crashes and their fatal consequences.[20] Individual-level injury and exposure (i.e., distance traveled) data have rarely ever been available except for subsets of the population,[16,21,22] an issue deemed challenging but necessary.[13]

The importance of individual versus population-based exposure data and the damaging effect of the so-called ecological fallacy can be best learnt through the example of the relationship between per capita income and the risk of motor vehicle injuries portrayed in one of the classical epidemiological textbooks for physician and public health researchers.[23] There, it is shown how an association observed between variables on an aggregate level (in the example, the mean income of several populations where the higher the mean income the higher the crash rates) does not necessarily represent the association that exists at the individual level (in, the example, it is only the poorer individuals suffering the crashes—regardless of where they live).

Our goal was to evaluate the individual-level relationship between changes in kilometers traveled by motor vehicle and the risk of hospitalization due to crash-related injuries.

2. METHODS

2.1. Study Population

The Seguimiento Universidad de Navarra (SUN) study is a multipurpose open enrollment prospective cohort managed from the University de Navarra (Navarra, Spain) in collaboration with other universities in the country. The cohort has been described in more detail elsewhere.[24] Briefly, after a pilot period in 1999, university graduates from all over the country are continuously invited to participate in the study. Participants are contacted every other year to complete a questionnaire where exposure to a number of factors and incidence of a number of diseases and injuries are monitored. Follow-up losses are less than 20% and they seem to bear no bias in the reported outcomes.[25] (Please visit http://www.unav.es/departamento/preventiva/sun for additional information.)

Since the questionnaires are sent at study enrollment (baseline questionnaire, herein called C0) and biennially thereafter, we refer to the two-year, four-year, and subsequent follow-up questionnaires as C2, C4, and C6.... However, actual dates of completion are recorded, allowing for actual follow-up periods to range from individual to individual.

2.2. Data Collection

At C0, invited participants are asked about their prior experience of being hospitalized during a minimum of 24 hours because of motor vehicle injuries, and this is asked again in subsequent questionnaires. The repeatability and validity of this question have

been published elsewhere.[26,27] In every subsequent follow-up questionnaire, whether there has been an incident of hospitalization related to motor vehicle injuries over the preceding period is asked.

Exposure to road traffic as in kilometers traveled per year(s) is asked in every questionnaire. In the baseline questionnaire, this datum is collected through two categorical variables that allow participants to express their average travel in passenger cars in km/year (<1,000, 1,001–10,000, 10,001–20,000, 20,001–50,000, and ≥ 50,001) or on mopeds or motorcycles (never, <1,000, 1,001–5,000, 5,001–10,000, ≥ 10,001 km/year). In later questionnaires, both questions were merged and categories were shifted to allow for a better distribution of responses into <1,500, 1,501–5,000, 5,001–10,000, 10,001–20,000, and ≥ 20,001). For this article, travel information per each contributing to the cohort was combined into a five-category variable to summarize mid-point range average distances traveled of 1,000, 3,250, 7,500, 15,000, or 25,000 km/per year. For descriptive purposes, variations in the amount of kilometers traveled over the years were documented as one-, two-, three-, or four-category increases or decreases or "no changes."

Other motor-vehicle-safety-related questions include use of safety belts, driving a frontal driver side airbag-equipped vehicle, ever riding a motorbike at enrollment, using a helmet when riding it, and "on occasion" driving while intoxicated. Although changes in many of these practices are monitored over time, in this analysis we used the information reported at baseline together with information on the subject's age (at time of enrollment) and gender.

2.3. Statistical Analysis

Data for this analysis included the participants who completed follow-up questionnaires by August 2007 and who reported not having been hospitalized due to motor vehicle injuries prior to cohort enrollment (i.e., we excluded prevalent cases). Descriptive and analytical statistics (χ^2 and t est) were used to evaluate differences in the distributions of sociodemographic and travel characteristics between subjects reporting or not hospitalization episodes in relation to motor vehicle crashes. Their individual person-years contribution to the cohort and whether or not they reported sustaining a hospitalization episode in relation to motor vehicles were used to develop proportional hazard ratio regression models.[28] The outcome variable was whether and how early into the follow-up period had any partici-

pant reported requiring hospitalization in relation to motor vehicle injuries. The main independent variable was the kilometers traveled as reported during each year of the years any participant contributed to the cohort. In addition, the multivariate models allowed us to investigate the possible confounding effect of the person's age, gender, drinking and driving habit, driving of vehicles equipped with airbags, use of safety belts, and their riding on motorcycles. Equation (1) shows the model used:

$$
\begin{aligned}
&\text{Log (hazard hospitalization}(t)) \\
&= \text{ baseline hazard hospitalization }(t) \\
&\quad + \beta_1 \text{ kilometers travel}(t) + \beta_2 \text{ sex } t_0 \\
&\quad + \beta_3 \text{ age } t_0 + \beta_4 \text{ rides motorcycle } t_0 \\
&\quad + \beta_5 \text{ airbag } t_0 + \beta_6 \text{ safety belt } t_0 \\
&\quad + \beta_7 \text{ drinking \& driving } t_0.
\end{aligned}
\tag{1}
$$

Hazard ratios (HR) are presented together with their 95% confidence intervals (CI). When appropriate, probabilities of being hospitalized due to motor-vehicle-related injuries were calculated using Equation (2):

$$
P = \text{HR}/(1 + \text{HR}).^{(29)}
\tag{2}
$$

In addition, adjusted hazard ratios (HR) and their corresponding 95% CI for particular reductions in the number of kilometers traveled were calculated using Equation (3):

$$
\text{HR} = e^{\beta * (\text{difference in average kilometers traveled per year})}.
\tag{3}
$$

Analyses were done using Stata/SE v.9.2 (Stat Corp.).

3. RESULTS

The 17,925 subjects who had agreed to participate in the cohort by submitting their questionnaires prior to August 1, 2007 were eligible for the study. Of those, 5,556 were excluded because either they responded to the baseline questionnaire only (and, therefore, did not contribute with follow-up information), they reported at baseline having had a motor-vehicle-related hospitalization (i.e., prevalent cases), or had missing information either regarding kilometers traveled or hospitalization status. Thus, 12,369 participants were evaluated. Though they were at most eligible to have responded to the six-year follow-up questionnaire (i.e., C6), actual follow-up times ranged from one year (2.1%) to eight years (<1%), and the average follow-up time was four years. In fact, some 25% of the participants contributed two, four, or six years each, another 12% of

Table I. Sociodemographic and Travel Characteristics of Eligible SUN Participants by Motor-Vehicle-Related Hospitalization Status (n = 12,369)

	Never Hospitalized n = 12,333	At Least One Incident Hospitalization n = 36	P
Age (average (*SD*))	38.0 (12.0)	36.7 (13.6)	<0.001
Gender (male)	40.1%	47.2%	0.384
Drinking & driving (yes, sometimes)	29.6%	23.5%	0.228
Travel on motorbikes at baseline	9.6%	26.5%	<0.001
Safety belt use at baseline (yes)	86.4%	85.3%	0.691
Drives a vehicle with frontal driver airbag at baseline (yes)	43.0%	30.3%	0.536
Kilometers traveled during first two years of follow-up (on average)			
1,000 km/year	0.2%	0.0%	0.215
3,250 km/year	8.1%	5.6%	
7,500 km/year	34.2%	25.0%	
15,000 km/year	30.7%	25.0%	
25,000 km/year	26.8%	44.5%	
C4 completed	65.7%	72.2%	0.484
C6 completed	29.3%	30.6%	0.856
Years follow-up (average (*SD*))	4.1 (1.6)	2.6 (1.6)	<0.001

C4 = Four-year follow-up questionnaire.
C6 = Six-year follow-up questionnaire.

participants contributed three years, 7% contributed five years, and 2% of the participants contributed seven years each.

Thirty-six of the participants (0.3%) reported sustaining at least one hospitalization episode in relation to a motor vehicle during this follow-up time. The questionnaire does not allow for further precision into whether this occurred while being a pedestrian, a driver, or a passenger of any type of vehicle.

Table I summarizes their sociodemographic and travel patterns at baseline, by whether they reported an incident of hospitalization due to motor vehicle crash injuries at follow-up. Statistically significant differences between the two groups are also identified in the table, with participants reporting being hospitalized being more likely to be motorcycle riders at baseline, driving more kilometers per year at baseline, and having shorter periods of follow-up in the cohort. No differences in age, gender, use of protective measures such as safety belts or frontal driver side airbags, or drinking and driving habits were identified.

In total, 49,766 participant-years were available for analysis. They accumulated 389.6 million km traveled (average of 7,828 km per person-year and a range from 2,000 to 175,000 km). The median kilometers accrued per traveler over their follow-up—if they never reported a motor-vehicle-related hospitalization—was 30,000, whereas it was 22,500 for those 36 subjects reporting a first incident event. The mean (and *SD*) of their accu-

Table II. Change in Travel Over Time by SUN Participants

	C2 to C0* n = 12,369	C4 to C2 n = 8,014	C6 to C4 n = 3,323
Decreased exposure			
4 categories	–	0.2%	0.3%
3 categories	–	1.3%	1.4%
2 categories	–	4.2%	4.0%
1 category	10.3%	16.0%	18.7%
No change (i.e., remained in same category)	72.4%	51.5%	51.8%
Increased exposure			
1 category	17.3%	19.6%	17.2%
2 categories	–	5.1%	4.6%
3 categories	–	1.9%	1.4%
4 categories	–	0.4%	0.4%

*There was a change in available categories between C0 and C2, and for this reason we only present the percent increase and decrease opposed to a more disaggregated description, see text for more details.

Note: Travel was summarized in five categories averaging distances of 1,000, 3,250, 7,500, 15,000, or 25,000 km/year (n = 12,369).
C0 = baseline questionnaire.
C2 = Two-year follow-up questionnaire.
C4 = Four-year follow-up questionnaire.
C6 = Six-year follow-up questionnaire.

mulated kilometers were 37,650 (*SD* 30,384) and 23,930 (*SD* 20,082), respectively, a statistically significant difference ($P = 0.024$). In addition, reported distances traveled varied from follow-up questionnaire to follow-up questionnaire. Table II summarizes changes from C2 to C4 to C6, changes that are

	Hazard Ratio	*P*	95% CI	
Kilometers traveled (yearly estimates over each contributing year)	1.00005	0.015	1.00001	1.0001
Sex (male)	1.00431	0.992	0.45534	2.21509
At baseline (C0):				
Age	0.98337	0.350	0.94939	1.01857
Rides motorbikes (yes)	2.72985	0.017	1.19733	6.22388
Drives vehicle with frontal airbag (yes)	0.71998	0.405	0.33202	1.56122
Uses safety belt almost always	0.98003	0.967	0.38148	2.51774
Drinks and drives (on occasion)	1.04407	0.819	0.72118	1.511544

Table III. Multivariate Proportional Hazard Ratio with SUN Participants on the Hospitalization Due to Motor Vehicle Injuries ($n = 44{,}257$ Person-Years, 36 Incident Cases)
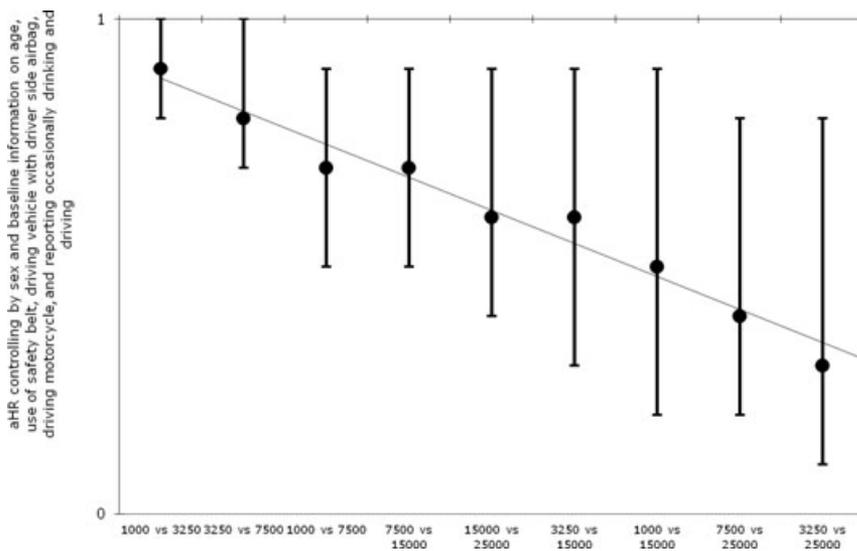

Fig. 1. Adjusted hazard ratios (aHR and 95% CIs) of suffering a hospitalization due to motor vehicle injuries among SUN participants associated with diminishing number of kilometers traveled per year ($n = 44{,}257$ Person-Years, 36 Incident Cases).

incorporated in the person-year exposure contribution in the multivariate models.

The univariate Cox model to predict the hazard ratio associated with kilometers traveled per year showed a hazard of 1.00005 (95% CI 1.000013 to 1.000086); a statistically significant ratio representing a 50% increase in risk of being hospitalized because of motor-vehicle-crash-related injuries per every additional kilometer traveled. This finding is not confounded by gender, age at baseline, "almost always" use of the safety belt, driving a vehicle equipped with a frontal airbag, or self-reported drinking and driving habits. Neither is it confounded by the reporting of driving motorcycles at baseline (Table III). However, unlike all other covariates that did not show statistically significant effects, the effect of riding motorcycles (any amount of travel) had a statistically significant hazard ratio of 2.7 (95% CI 1.2 to 6.2).

Using the results of the multivariate regression model shown in Table III, we computed the adjusted HR(aHR) and 95% CIs of lowering the amount of kilometers traveled per year from any particular amount to any other (e.g., from an average of 7,500 km per year to 3,250 km per year). The results are shown in Fig. 1. Even the smallest of reductions, going from an average of 3,250 km per year to 1,000, a 2,250 km reduction, showed a statistically significant protective effect in the likelihood of sustaining hospitalization in relation to motor vehicle injury with an aHR of 0.9 and a 95% CI from 0.98 to 0.78—however, since we are presenting estimates rounded to the first decimal point this shows in the figure as a 95% CI of 1 to 0.8. The largest reduction, shifting from 25,000 km to 1,000 km was associated with an aHR of 0.3 (95% CI of 0.8 to 0.1).

4. DISCUSSION

Our findings are the first individual-level assessment of the statistically significant impact on suffering motor vehicle injuries requiring hospitalization per each additional kilometer traveled. These

findings come from a prospective cohort study with the capability of recording shifting amounts of travel over a maximum eight-year period of more than 12,000 graduate adults never hospitalized before because of this kind of injuries.

In a controversial article, Peltzman in 1976 reported an ecological association where increase in vehicle miles traveled had a protective effect on fatality rates;[20] however, our study does not include fatal cases. Beck et al.[16] identified an ecological association of 10.4 and 754.6 per 100 million person-trips for fatal and nonfatal traffic injuries, respectively, in the United States. They also identified higher rates for motorcyclists, pedestrians, and bicyclists (which we cannot identify as such in our database). Our data were collected on a kilometer traveled basis as opposed to a per trip basis, which makes the comparison of the rates impossible. But we also report a statistically significant increase in the chance of being hospitalized due to a motor vehicle crash injury sooner if one reports driving motorcycles at baseline. Vehicle-mile-traveled-based increases in risk because of riding on motorcycles is also reported by Lin et al.,[30] where they report 34-fold increases in death risk per vehicle mile traveled when motorcyclists are compared to other road users in the United States. Beck et al.[16] further identified different rates by gender and age. The effect of age is documented by others too.[30–32] For example, Lyman et al.[32] report statistically significant increases in crash and fatal crash rates per mile driven at age 70. It is possible that the narrower age span of the SUN cohort participants (and the fact that they are all university graduates) prevents us from identifying any age-related impact on the risk of nonfatal events. And we did not find any relationship with gender either. Since our cohort excludes children, our findings cannot be compared to the child fatality rates per kilometer traveled reported in Reference 21.

Other exposure evaluations of the impact of injury outcome are not comparable to ours not only because they only measured fatalities but because they focused on the impact of either ethnicity—and our cohort does not collect information on ethnicity (and presumably almost 100% are Caucasian);[33] or children—and our cohort is based on adults.[34]

We could only identify two evaluations of the ecological impact of increases in road mileage on nonfatal road victims. In both cases, either direct measure of increases in travel[35] or proxy measures for such increased travel[36] related to increases in nonfatal crash risks. This finding is in consonance with the theoretical proposition that increased traffic intensity (derived from more travel in constant road lengths) leads to more but less lethal crashes.[19]

Even when individual-level data on both exposure and outcome have been available, the findings are not comparable to ours. For example, Yang et al.[37] report on nonfatal injury risks in Iowa's state (U.S.) school buses of 13.6 per 1,000 million bus miles traveled. And Cummings et al.[38] report an aHR of 2.2 per additional 100 miles traveled on the risk of being in a crash (even one without injuries) whereas our case definition involves hospitalization after the crash.

4.1. Strengths and Weaknesses of the Study

Our data collection questionnaire does not allow for distinction in travel mode (e.g., private passenger vehicles, or motorcycles) or in role (e.g., driver or passenger). Furthermore, although others have also used self-reported exposure (even using four-year time frames),[39] there are limited validation studies of the quality of this assessment, yet these present encouraging results.[40,41] To our benefit, the use of broad categories should minimize the errors in reporting and the assessment of a number of other variables in the SUN cohort have been reported as acceptable.[42–44] In fact, the quality of their reporting is one of the reasons to restrict the cohort participation to university graduates.[45]

On the "breadth" of the exposure category, it is worth mentioning that the coarsity of the original variable values and the fact that the possible variable values changed between the baseline and subsequent questionnaires, forced us to summarize all this information into a new exposure variable for this article. Despite it being a continuous variable in essence, such variable behaves more like a discrete one, since anyone is classified for any given year as traveling an average of 1,000, 3,250, 7,500, 15,000, or 25,000.

Obviously, not only the amount of travel is likely to be a significant risk factor in the occurrence of motor vehicle crashes, but also the types of roads where the travel takes place, the speeds at which one travels, etc., which unfortunately we cannot include in our analysis for lack of information in the cohort. It is known that urban driving is less likely to result in fatal crashes.[19] To our credit, the fact that we analyzed individual data over several years and that this is included in the analytical model implies that to some extent we are controlling for the possible confounding role of "experience" and "driving intensity,"[46]

that is, our findings are true regardless of whether the subject drove little and was more inexperienced in the past.

Nevertheless, we identify statistically significant effects in relation to increasing the timing of a motor-vehicle-related hospitalization when one additional kilometer is traveled in a new year. The opposite is possible, and one could project that reductions in the amount of travel "delay" statistically significantly such hospitalization in amounts ranging from 10%, when the reduction is as small as 2,250 km from one year to the next, to 70%, when the reduction is of 24,000 km in the same time period. This rough calculation implies that the risk per each kilometer traveled is equal, regardless of driving circumstances, but nevertheless, it is a first-point estimate of the expected benefit.

We attempted to compare the kilometers traveled annually by our cohort participants to those reported for the general Spanish population or other populations. Official statistics from Spain exclude travel in urban roads, which makes for an invalid comparison.[47] However, comparable data for 17 countries for which total vehicle kilometers traveled in 2003 were reported ranging from 3,281 km per year per person in the Czech Republic to 16,316 in the United States, suggest that our SUN participants fit in between the average travel of the Swiss population (7,743) and that of Great Britain (8,246).[48]

In addition, we derived the rates for nonfatal victims for the same populations as in the previous paragraph. Whether the operational definitions for the following figures are perfectly comparable is somewhat questionable, but it is worth pointing out that the 291 per 100,000 SUN participants compares to 324 per 100,000 population in Spain in 2006 as reported in a WHO publication[49] where the rates for the Czech Republic, United States, Switzerland, and Great Britain are indicated to be 226, 1,080, 357, and 435, respectively.

A 2006 publication using a Spanish population[50] pointed out gender- and age-based differences regarding safety belt use and motorcycle riding. Yet, in our analysis neither covariate had a statistically significant effect on the rate of motor vehicle hospitalization once exposure was included in the model. It is possible that those wearing safety belts also ride fewer kilometers on average (i.e., a comprehensive "safe behavior"). This warrants further investigation.

Whether our sample size was enough to allow for the effects of these other covariates to show is a valid question. A general rule of thumb is that there should be five to 10 outcomes for each independent variable when doing Cox regression models.[51] Our cohort participants reported 36 "first" hospitalization events, which should suffice to investigate between three and seven covariates; in our most populous model we had seven.

5. CONCLUSION

Others have raised the importance of measuring exposure.[21,52] Much is said about focusing on modifiable risk factors when thinking about preventive strategies to reduce injuries. However, when dealing with motor-vehicle-related prevention, the suggestion to reduce the amount of travel of subjects in-private means of transportation is hardly ever expressed, except for a few papers.[53–55] And this is even considering that some evidence points out that there exists a viable alternative for 40% of the car journeys.[8] This analysis is one of the first ones to include individual-level data on both exposure and outcomes and to allow for the calculation of hazard ratios related to this practice. In addition, it is the first one to report such ratios for working-age individuals. Our findings were robust to alternative modeling strategies such as repeating analysis stratifying by gender or including only some of the covariates in the models.

Motor vehicle transportation is a serious threat to health around the world. Motor vehicle crashes still are the leading cause of death for younger people worldwide and they rank fourth or fifth when compared to all causes of death for people of all ages combined.[11] It is estimated that for every dead person there are at least 10 to 15 hospitalization episodes, with estimates for nonfatal injured victims (hospitalized and not hospitalized) ranging from 20 to 50 million per year around the world.[49]

The identified relationship may not relate to symmetrical benefits if we were to propose reductions in the number of kilometers traveled since the reduction may disproportionally affect urban versus highway travel, work- or leisure-related travel, or many of the myriad of factors integrated into the once-called intensity of driving mode.[46] However, and for the sake of an example, if we were to get back to the Minnesota policy goal cited in Section 1, the proposed 50% reduction in miles traveled could lead to a reduction of between 30% and 20% of hospitalized nonfatal crash victims if one were to apply the findings of two 50% reductions in amount of travel in

our findings: a reduction from 15,000 to 7,500 or one from 7,500 to 3,250, respectively. We do not mean to curtail the mobility of the population, but support the recommendation of promoting alternative and safer means of transportation. The implications of such shift would indeed represent a substantial improvement to the health of the population.

ACKNOWLEDGMENTS

REFERENCES

1. Fuglestvedt J, Berntsen T, Myhre G, Rypdal K, Skeie RB. Climate forcing from the transport sectors. Proceedings of the National Academy of Science USA, 2008; 105(2):454–458.
2. Wilkinson P, Smith KR, Joffe M, Haines A. A global perspective on energy: Health effects and injustices. Lancet, 2007; 370(9591):965–978.
3. Bråbäck L, Forsberg B. Does traffic exhaust contribute to the development of asthma and allergic sensitization in children: Findings from recent cohort studies. Environmental Health, 2009; 8:17.
4. Lipfert FW, Baty JD, Miller JP, Wyzga RE. PM2.5 constituents and related air quality variables as predictors of survival in a cohort of US military veterans. Inhalation Toxicology, 2006; 18(9):645–657.
5. Tong S, Mackenzie J, Pitman AJ, FitzGerald G, Nicholls N, Selvey L. Global climate change: Time to mainstream health risks and their prevention on the medical research and policy agenda. Internal Medicine Journal, 2008; 38(6):445–447.
6. McMichael AJ, Woodruff RE, Hales S. Climate change and human health: Present and future risks. Lancet, 2006; 367(9513):859–869.
7. The Core Writing Team, Pachauri RK, Reisinger A. Climate Change 2007: Synthesis report. Intergovernmental Panel on Climate Change. Geneva, Switzerland: Intergovernmental Panel on Climate Change, 2008.
8. Chapman L. Transport and climate change: A review. Journal Transport Geography, 2007; 15(5):354–367.
9. Schmitt Olabisi L, Reich PB, Johnson KA, Kapuscinski AR, Suh S, Wilson EJ. Reducing greenhouse gas emissions for climate stabilisation: Framing regional options. Environmental Science and Technology, 2009; 43(9):1696–1703.
10. World Health Organization. The World Health Report: 2003: Shaping the Future. Geneva, Switzerland: World Health Organization, 2003.
11. World Health Organization. World Report on Road Traffic Injury Prevention: Summary. Geneva, Switzerland: World Health Organization, 2004.
12. Segui-Gomez M, Lopez-Valdes FJ. Recognizing the importance of injury in other policy forums: The case of motorcycle licensing policy in Spain. Injury Prevention, 2007; 13(6):429–430.
13. Chang HL, Jovanis PP. Formulating accident occurrence as a survival. Accident Analysis and Prevention, 1990; 22(5):407–419.
14. Jovanis PP, Chang HL. Modeling the relationship of accident to miles traveled. Transportation Research Record, 1986; 1068:42–51.
15. Elvik R, Vaa T. Controlling for exposure. In Elvik R, Vaa T (eds). The Handbook of Road Safety Measures. Oxford, UK: Elsevier, 2004.
16. Beck LF, Dellinger AM, O'Neil ME. Motor vehicle crash injury rates by mode of travel, United States: Using exposure-based methods to quantify differences. American Journal of Epidemiology, 2007; 166(2):212–218.
17. Lardelli-Claret P, Jiménez-Moleón JJ, Luna-del-Castillo JD, García-Martín M, Moreno-Abril O, Bueno-Cavanillas A. Comparison between two quasi-induced exposure methods for studying risk factors for road crashes. American Journal of Epidemiology, 2006; 163(2):188–195.
18. Lie A, Tingvall C, Krafft M, Kullgren A. The effectiveness of electronic stability control (ESC) in reducing real life crashes and injuries. Traffic Injury Prevention, 2006; 7(1):38–43.
19. Jokch HC. Review of the major risk factors. Journal of Studies on Alcohol, 1985; s10:47–53.
20. Peltzman S. The effects of automobile safety regulation: Reply. Accident Analysis and Prevention, 1976; 8:139–142.
21. Christie N, Ward H, Kimberlee R, Towner E, Sleney J. Understanding high traffic injury risks for children in low socioeconomic areas: A qualitative study of parents' views. Injury Prevention, 2007; 13(6):394–397.
22. Richter M, Pape HC, Otte D, Krettek C. The current status of road user injuries among the elderly in Germany: A medical and technical accident analysis. Journal of Trauma, 2005; 58(3):591–595.
23. Szklo M, Nieto J. Epidemiology. Beyond the Basics. Gaitherburg, MD: Aspen Publishers (US) 2000.
24. Segui-Gomez M, de la Fuente C, Vázquez Z, de Irala J, Martínez-González MA. Cohort profile: The "Seguimiento Universidad de Navarra" (SUN) study. International Journal of Epidemiology, 2006; 35(6):1417–1422.
25. Alonso A, Segui-Gomez M, de Irala J, Sánchez-Villegas A, Beunza JJ, Martínez González MA. Predictors of follow-up and assessment of selection bias from dropouts using inverse probability weighting in a cohort of university graduates. European Journal of Epidemiology, 2006; 21(5):351–358.
26. Alonso A, Laguna S, Segui-Gomez M. A comparison of information on motor vehicle crashes as reported by written or telephone interviews. Injury Prevention, 2006; 12(2):117–120.
27. Begg D, Langley J, Williams S. Validity of self reported crashes and injuries in a longitudinal study of young adults. Injury Prevention, 1999; 5(2):142–144.
28. Cox DR. Regression models and life tables. Journal of the Royal Statistical Society Series B (Methodological), 1972; 34(2):187–220.
29. Spruance SL, Reid JE, Grace M, Samore M. Hazard ratio in clinical trials. Antimicrobial Agents and Chemotherapy, 2004; 48(8):2787–2792.
30. Lin MR, Chang SH, Pai L, Keyl PM. A longitudinal study of risk factors for motorcycle crashes among junior college students in Taiwan. Accident Analysis and Prevention, 2003; 35(2):243–252.
31. Eberhard J. Older drivers' "high per-mile crash involvement": The implications for licensing authorities. Traffic Injury Prevention, 2008; 9(4):284–290.
32. Lyman S, Ferguson SA, Braver ER, Williams AF. Older driver involvements in police reported crashes and fatal crashes: Trends and projections. Injury Prevention, 2002; 8(2):116–120.

33. Baker SP, Braver ER, Chen LH, Pantula JF, MAssie D. Motor vehicle occupant deaths among Hispanic and black children and teenagers. Archives of Pediatrics and Adolescent Medicine, 1998; 152(12):1209–1212.

34. Sonkin B, Edwards P, Roberts I, Green J. Walking, cycling and transport safety: An analysis of child road deaths. Journal of the Royal Society of Medicine, 2006; 99(8):402–405.

35. Aguero-Valverde J, Jovanis PP. Spatial analysis of fatal and injury crashes in Pennsylvania. Accident Analysis and Prevention, 2006; 38(3):618–625.

36. Noland RB, Quddus MA. A spatially disaggregate analysis of road casualties in England. Accident Analysis and Prevention, 2004; 36(6):973–984.

37. Yang J, Peek-Asa C, Cheng G, Heiden E, Falb S, Ramirez M. Incidence and characteristics of school bus crashes and injuries. Accident Analysis and Prevention, 2009; 41(2):336–341.

38. Cummings P, Koepsell TD, Moffat JM, Rivara FP. Drowsiness, counter-measures to drowsiness, and the risk of motor vehicle crash. Injury Prevention, 2001; 7(3):194–199.

39. Laapotti S, Keskinen E, Hatakka M, Hernetkoski K, Katila A, Peräaho M, et al. Driving circumstances and accidents among novice drivers. Traffic Injury Prevention, 2006; 7(3):232–237.

40. Huebner KD, Porter MM, Marshall SC. Validation of an electronic device for measuring driving exposure. Traffic Injury Prevention, 2006; 7(1):76–80.

41. Leaf WA, Simons-Morton BG, Hartos JL, Shabanova-Northrup V. Driving miles estimates by teen drivers: How accurate are they? Injury Prevention, 2008; 14(1);59–61.

42. Alonso A, Beunza JJ, Delgado-Rodríguez M, Martínez-González MA. Validation of self-reported diagnosis of hypertension in a cohort of university graduates in Spain. BMC Public Health, 2005; 5:94–100.

43. Bes-Rastrollo M, Pérez JR, Sánchez-Villegas A, Alonso A, Martínez-González MA. Validación del peso e índice de masa corporal auto-declarados de los participantes de una cohorte de graduados universitarios [in Spanish]. Revista Española de Obesidad, 2005; 3:352–358.

44. Martinez-Gonzalez MA, López-Fontana C, Varo JJ, Sánchez-Villegas A, Martinez JA. Validation of the Spanish version of the physical activity questionnaire used in the Nurses' Health Study and the Health Professionals' Follow-Up Study. Public Health Nutrition, 2005; 8(7):920–927.

45. Tortosa A, Seguí Gómez M, De la Fuente C, Alonso A, Martínez-González MA. Diferencias en estilos de vida y calidad de la información autorreferida según nivel de estudios [Spanish]. Revista de Medicina de la Universidad de Navarra, 2008; 52(3):15–19.

46. Peltzman S. The effects of automobile safety regulation. J Political Economy 1975; 83(4):677–726

47. Dirección General de Tráfico. Observatorio de Seguridad Vial. Las principales cifras de la Seguridad Vial. España 2007. Madrid, Spain: Dirección General de Tráfico, 2008.

48. (OECD/ECMT) Organization for Economic Cooperation and Development European Conference of Ministers of Transport. Working Group on Achieving Ambitious Road Safety Targets. Country reports on Road Safety Performance. Geneva, Switzerland: Organization for Economic Cooperation and Development, 2006.

49. World Health Organization. Global Status Report on Road Safety: Time for Action. Geneva, Switzerland: World Health Organization, 2009.

50. Babio GO, Daponte-Codina A. Factors associated with seatbelt, helmet, and child safety seat belt use in a Spanish high-risk injury area. Journal of Trauma, 2006; 60(3):620–626.

51. Vittinghoff E, McCulloch E. Relaxing the rule of ten events per variable in logistic and cox regression. American Journal of Epidemiology, 2007; 165(6):710–718.

52. Waller PF. Challenges in motor vehicle safety. Annual Review of Public Health, 2002; 23:93–113.

53. DiGuiseppi C, Li L, Roberts I. Influence of travel patterns on mortality from injury among teenagers in England and Wales, 1985–95: Trend analysis. British Medical Journal, 1998; 316(7135):904–905.

54. DiGuiseppi C, Roberts I, Li L. Influence of changing travel patterns on child death rates from injury: Trend analysis. British Medical Journal, 1997; 314(7082):710–713.

55. DiGuiseppi C, Roberts I, Li L, Allen D. Determinants of car travel on daily journeys to school: Cross sectional survey of primary school children. British Medical Journal, 1998; 316(7142):1426–1428.