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MEDICAL CONDITIONS AND THE SEVERITY OF COMMERCIAL MOTOR VEHICLE (CMV) DRIVERS' ROAD ACCIDENTS

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RÉSUMÉ

Dans cette recherche nous avons étudié les relations statistiques entre les conditions médicales des conducteurs de camion professionnels et la gravité des accidents dans lesquels ils étaient impliqués. La gravité des accidents a été mesurée par le nombre de victimes (blessés et morts). Des modèles Poisson et binomiale négative ont été estimés pour tenir compte de façon simultanée des caractéristiques des conducteurs, de leur état de santé et des circonstances des accidents. Ces dernières doivent être contrôlées pour isoler l'effet des conditions médicales sur la gravité des accidents. Elles ont un rôle similaire à l'exposition au risque pour estimer la fréquence d'accidents. Nos résultats montrent que les conducteurs de camion avec des problèmes de vision binoculaire et les conducteurs d'autobus avec des problèmes d'hypertension ont des accidents plus sévères que les conducteurs en bonne santé. Aucune autre condition médicale n'a un effet significatif. Plusieurs variables de circonstances d'accidents sont également significatives.

Mots clefs: Conditions médicales, accidents de conducteurs professionnels, gravité, circonstances d'accidents, régressions avec modèles de comptage.

ABSTRACT

In this research we studied the association between CMV drivers' medical conditions and crash severity. To our knowledge, no study has ever isolated this association. The severity of a crash was measured by the total number of victims (injured and dead). We estimated nonlinear regression models (specifically, Poisson and negative binomial) which incorporated, simultaneously, information on drivers' characteristics, crash circumstances and health status. We emphasized the fact that these variables had to be controlled adequately in order to isolate the association between health status and crash severity. They have a similar role than risk exposure for the estimation of accidents frequencies. Our results show that truck drivers with binocular vision problems and bus drivers with hypertension are involved in more severe crashes than healthy drivers. No other medical condition considered in this study had a significant effect on crash severity. Many variables describing crash circumstances were also significant.

Keywords: Medical conditions, CMV drivers' accidents, severity, crash circumstances, count data regression models.

INTRODUCTION

To our knowledge, no study has investigated the detailed relationship betwee severity of crashes and medical conditions (other than substance abuse, particularl alcohol) for commercial motor vehicles (CMV) drivers. CMV drivers are defined as bu or truck drivers according to their answer to a questionnaire on risk exposure (Dionn et al., 1995; Laberge-Nadeau et al., 1992). In other words, there is no article in th literature that can provide a satisfactory answer to the following question: Do truck o bus drivers with one of the following conditions (diabetes mellitus, coronary hear disease, hypertension or binocular vision problems) have more severe crashes than thos in good health?

A precise answer to this question is important for the setting of regulations by the public authority. In general, the severity of injury claims introduces private and social costs to the society. A negligent driver who does not respect the speed limits does not only influence the frequency of crashes but also the severity. He does introduce not only higher private costs to his insurance company but also creates externalities to other drivers, other insurers (particularly in no-fault systems) and to the whole society by generating supplementary monetary costs and other social costs associated with the value of life. Dionne et al. (1993) present an evaluation of social costs associated with road crashes taking into account both frequency and severity. For a discussion on externalities and road crashes, see Boyer and Dionne (1987).

The purpose of this article is to show how drivers' medical conditions are associated with the severity of crashes measured by the number of victims in each crash. Crashes of two groups of professional drivers were studied: truck drivers and bus drivers for which we had information on their medical conditions, including those in good health. These crashes were not restricted to those in which the commercial vehicle driver was considered at fault since in Quebec there is a pure no-fault insurance regime (Devlin, 1992). Our method, based on the estimation of count data regression models, permits the control of many explanatory variables which is a necessary condition in order to isolate adequately the links between medical conditions and crash severity.

As emphasized in Ékoé et al. (1991a et 1991b) and Dionne et al. (1995), taking into account risk exposure factors such as distance, hours, type of road and other qualitative and quantitative variables, provide a better measure of the statistical links between medical conditions and crash frequency. For example, Maag et al. (1994) show that controlling for risk exposure and the past driver's record results in a significant difference between the crash frequency of healthy taxi drivers and that of drivers with binocular vision problems. Without these exposure variables there is no significant difference between the two crash frequencies.

Here we face a similar methodological problem. For example, the severity of a crash is a function of: 1) the number and type of vehicles involved; 2) the presence or absence of several occupants or pedestrians on the crash site; 3) the type and condition of roads; etc. We define such variables as crash circumstances in contrast to the risk exposure used for the study of the crash frequency.

METHODS

This study is an extension of the article on the relationship between medical conditions and the frequency of truck drivers' crashes realized by Dionne et al. (1995). Count data regression models for the number of victims per crash were estimated in order to measure simultaneously the influence of individual characteristics, health status and the crash environmental conditions on the severity.

Data source and population studied: The data are part of a large sample (nested case control study aimed at the evaluation of the effects of medical and ophthalmologic conditions on safe driving) of 20,206 permit holders created by Laberge-Nadeau et al. in 1989. The anonymous file is the result of merging files of the Société de l'assurance automobile du Québec (SAAQ) that contain information on driver permits, crashes, and health status (medical conditions). Particularly for this study, the data from the acciden file contain information from the police report, i.e. the number of vehicles involved i the crash, date of crash, type of crash, number of victims, and characteristics of th vehicles at the crash site. The file on health status contains information on medical o ophthalmologic conditions of the professional drivers who were examined by a physicia or an ophthalmologist.

The medical conditions studied in this paper are diabetes mellitus (Type II, with no distinction between different treatments), coronary heart disease, hypertension (a diastolic pressure between 110 and 130 which is controlled by medication to be below 110), and binocular vision problems (non stereoscopic vision: >160 seconds or an acuity of at least 20/40 in the better eye and zero in the other). Drivers with multiple conditions were excluded.

In this study, the primary observations are the crashes of these drivers while driving a truck or a bus. The period considered covers January 1985 to December 1990. A total of 542 truck crashes and 579 bus crashes were analyzed. We now describe the variables that we retained for the multivariate analyses.

Variables: For each crash, we retained the following variables:

Victims: The total number of victims (dead and injured) in a crash involving a truck or a bus. Observations for this variable range from 0 to 3 for truck crashes and from 0 to 5 for bus crashes.

Age: This variable is bounded above by 65 for truck drivers and by 70 for bus drivers as of 1989. Age groups of the professional driver involved in the crash were created. No prediction is made for the age variables. These variables may capture the effect of being older than 25 years old for truck drivers, older than 30 years old for bus drivers. There were not enough bus drivers below 25 to have a specific class of 25 and below.

Year of the crash: This variable controls for different aggregate effects on severity. This variable should not be significant when many specific control variables are present in the regression. The reference year is 1990 for the interpretation of the different coefficients.
Class of driver's permit: Truck drivers were classified into two groups: those with a class 1 permit (articulated trucks and any other type of vehicle with the exception of busses) and others which includes mainly (79%) drivers of class 3 (straight trucks). Bus drivers were also classified into two groups: those with a class 2 permit (busses for more than 24 passengers) and those with a class 1 permit. For the bus drivers we had enough observations for each medical condition in order to build interaction variables between classes of drivers' permits and medical conditions. For the bus drivers the interaction variables are used to verify if the effect of a medical condition is significant whatever the class of driver's permit and to measure indirectly the effect of a class of driver's permit on the coefficient of a medical condition.
Medical condition: For the bus drivers we had information for only three levels of the medical conditions variable while six levels were studied for the truck drivers. All medical conditions were obtained from the different codes in the medical file of the SAAQ and were defined in a study by Laberge-Nadeau et al. (1992). The value "no evaluation" means that the truck drivers in this category were not examined by a physician and did not declare any medical condition. We predict more severe crashes for drivers with a medical condition (including "no evaluation" since it may contain drivers with medical conditions) when compared to drivers stated to be in good health after a medical and ophthalmic examination.

Information for all remaining variables was obtained from the police crash reports. They control for the crash circumstances in the sense that they measure technical and temporal information necessary in the measurement of the statistical relationship between health conditions and severity. Since these variables are not behavioral ones their descriptions and predictions will be straightforward.
Weight of the vehicle: This is the weight of the vehicle of the professional driver involved in the crash. The category "less than 5 000 kg" is the reference one.

Type of impact: This variable measures the position of the vehicles at the impact. Later frontal including frontal crashes is the reference category.

Type of crash: This variable identifies whether the crash was with a pedestrian, anothe vehicle or of any other type. Other type is the reference category.

Vehicle movement: This variable measures how the professional driver's vehicle wa moving at the moment of the impact. Straight ahead is the reference category.

Trimester: This variable is for seasonal effect. First trimester is the reference category.

Day of crash: Two groups of days: Week-end and week-days (reference category).

Time of crash: The period of the day (hours) when the crash occurred (9:00 a.m. to 3:59 p.m. is the reference category).

Condition of road: Road surface condition at the crash site with "dry" as the reference category.

Econometric model: We want to study, for each crash *i* where a professional driver was involved, the number of victims (Y_i) as a function of different explanatory variables (vector X_i) such as the driver's characteristics, his health status, environmental and other control variables. The objective is to find out, other things being equal, whether the driver's health status is related significantly to the severity of the crashes.

The dependent variable is naturally measured by non-negative integers. Many discrete probability distributions satisfy the requirement of non-negative integers, but the Poisson model is the simplest one to estimate.

If the number of victims (Y_i) for a crash *i* given the vector of characteristics (X_i) is Poisson distributed, the conditional mean $E(Y_i|X_i)$ is equal to the conditional variance $Var(Y_i|X_i)$. The probability of having *y* victims in a given crash is equal to

$$P(Y_i=y|X_i) = \frac{e^{-\exp(X_i\beta)}\,[\exp(X_i\beta)]^y}{y!}, \qquad y = 0,\ 1,\ 2... \tag{1}$$

where $\exp(X_i\beta) = E(Y_i|X_i) = Var(Y_i|X_i)$.

The exponential form of the Poisson parameter constrains expected values to be non-negative. Also, this form makes the relation between explanatory variables and the mean non-linear: the effect of one particular explanatory variable on the mean will depend of the value of all other explanatory variables, thus it will be different for different individuals.

In some circumstances, the hypothesis of equality of the conditional mean and variance may not be supported by the data. Following Gouriéroux, Montfort and Trognon (1984), Cameron and Trivedi (1986) and Boyer, Dionne and Vanasse (1992), one can add an additional noise in the distribution by allowing the Poisson parameter to be Gamma distributed. This leads to the negative binomial distribution. The probability of having y victims becomes

$$P(Y_i=y|X_i)=\frac{\Gamma(y+1/\alpha)}{\Gamma(1/\alpha)y!}\;\frac{[\alpha\ \exp(X_i\beta)]^y}{[1+\alpha\exp(X_i\beta)]^{y+1/\alpha}},\ y\ =\ 0,1,2,\ldots \qquad (2)$$

where $\alpha>0$ is called the dispersion parameter of the distribution and $E(Y_i|X_i)=\exp(X_i\beta)$ and $Var(Y_i|X_i)=\exp(X_i\beta)(1+\alpha\exp(X_i\beta))$ allowing for overdispersion; the conditional variance is greater than the conditional mean. The Poisson distribution is a special case of the negative binomial distribution (with $\alpha=0$) and one can test the Poisson hypothesis by a simple significance test of the α parameter. The parameters β of both Poisson and negative binomial regressions can be obtained by the maximum likelihood method. We used our homemade Fortran program for the estimations. However, the reader can find an equivalent method in the econometric software LIMDEP or in SAS.

Two sets of four models each are presented below. The first set (models 1 to 4) concerns crashes with trucks; the models differ in the number of explanatory variables used. Similarly, the second set (models 5 to 8) concerns crashes with busses. In each table, the χ^2 goodness of fits statistic indicates that each model fits the data at the confidence level of 95%.

RESULTS AND DISCUSSION

Tables 1 and 2 summarize the relationships between the number of crashes and th average number of victims by retained medical conditions for the two types c professional drivers studied.

Table 1: Number of truck crashes, average number of victims and standard deviation per crash for truck drivers, 1985 through 1990, Quebec.

Medical condition	Number of crashes	Number of victims	
		mean	std
Good health	114	0.123	0.402
Diabetes	93	0.204	0.563
Coronary heart disease	93	0.204	0.501
Hypertension	92	0.196	0.451
Binocular vision problems	34	0.265	0.710
No evaluation	116	0.190	0.455
TOTAL	542	0.186	0.491

We observe from Tables 1 and 2 that the average number of victims (dead and injured) is 0.186 for truck crashes while it is 0.254 for bus crashes. We also see that truck drivers with binocular vision problems have a higher average while bus drivers with hypertension register a greater average number of victims than those in good health. However these simple comparisons of means lack scientific rigor since they do not control for other important variables that may also affect the severity of crashes.

Table 2: Number of bus crashes, average number of victims per crash and standard deviation per crash for bus drivers, 1985 through 1990, Quebec.

Medical condition	Number of crashes	Number of victims	
		mean	std
Good health	279	0.161	0.397
Coronary heart disease	103	0.204	0.512
Hypertension	197	0.411	0.142
TOTAL	579	0.254	0.760

Tables 3 and 4 present the estimation results for the number of victims in crashes involving trucks. We observe that truck drivers with binocular visual problems have more severe crashes than those in good health. All other medical conditions do not show significantly more victims when compared to "good health". This result is not affected when more control variables are added to the first model. Moreover, many control variables are statistically significant: The day of the crash, the impact type, the road conditions at the impact site and some vehicle movement variables are significant when explaining the number of victims in a given crash. Age is not significant, neither are the permit class, the year, the trimester or the time of the day.

Table 3: Estimated count data models (negative binomial distribution) for the number of victims in a crash with a truck (Models 1 and 2).

Explanatory Variables	**Model 1**		**Model 2**	
	coefficient	**t-ratio**	**coefficient**	**t-ratio**
Intercept	-3.65	-4.87**	-3.81	-4.34**
Alpha	1.09	2.10**	1.05	2.04**
Year of crash				
1985	0.28	0.64	0.06	0.12
1986	0.71	1.67*	0.50	1.05
1987	0.06	0.11	-0.11	-0.23
1988	0.62	1.51	0.46	1.06
1989	0.77	1.84	0.69	1.63
1990	Reference category		Reference category	
No. of vehicles in the crash	0.22	1.78*	0.22	1.79*
Permit class				
Class 1	0.80	2.23**	0.71	1.93*
Class other	Reference category		Reference category	
Medical condition				
Good health	Reference category		Reference category	
Diabetes	0.58	1.44	0.56	1.37
Coronary heart disease	0.42	1.01	0.38	0.92
Hypertension	0.49	1.24	0.48	1.19
Binocular vision problem	1.45	2.43**	1.53	2.50**
No evaluation	0.42	1.09	0.38	0.98

Age group				
≤ 25 years	Reference category		Reference category	
26 to 30	-0.08	-0.14	-0.03	-0.06
31 to 35	-0.14	-0.25	-0.07	-0.13
36 to 40	0.58	1.01	0.59	1.02
41 to 45	-0.28	-0.47	-0.24	-0.39
46 to 50	0.44	0.77	0.47	0.82
51 to 55	-0.55	-0.85	-0.54	-0.84
more than 55 years	-0.51	-0.80	-0.43	-0.67
Vehicle weight				
3,000 to 4,999 kg			Reference category	
5,000 to 9,999 kg			0.16	0.34
10,000 to 14,999 kg			0.51	1.02
15,000 to 29,999 kg			0.34	0.67
≥ 30,000 kg			0.53	1.07
No. of crashes	542		542	
No. of variables	20		24	
Log-likelihood	-262.10		-261.07	
χ^2 Goodness of fit	0.689		0.716	
Log-likelihood ratio-test (vs Model 1)			$\chi^2_4 = 2.06$	

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* Significant at 10% ** Significant at 5%

We observe from Models 1 and 2 that the dispersion parameter is significant. This means that some important heterogeneity effect was not controlled in these two models. Models 3 and 4 were also estimated with the overdispersion parameter (the detailed results are available upon request from the authors). This parameter was not statistically greater than zero, hence the Poisson assumption cannot be rejected. We then estimated both models by assuming that the conditional mean is equal to the conditional variance (Poisson). The results are presented in Table 4 and are similar to those (not presented here) of the negative binomial.

Table 4: Estimated count data models (Poisson distribution) for the number of victims in a crash with a truck (Models 3 and 4).

Explanatory Variables	Model 3 coefficient	Model 3 t-ratio	Model 4 coefficient	Model 4 t-ratio
Intercept	-2.13	-2.28**	-2.99	-2.88**
Year of crash				
1985	-0.12	-0.27	-0.17	-0.35
1986	0.24	0.53	0.19	0.41
1987	-0.16	-0.34	-0.34	-0.70
1988	0.25	0.62	0.27	0.65
1989	0.42	1.06	0.53	1.29
1990	Reference category		Reference category	
No. of vehicles in the crash	0.15	1.52	0.58	1.61
Permit class				
Class 1	0.53	1.52	0.58	1.61
Class other	Reference category		Reference category	

Explanatory Variables	**Model 3**		**Model 4**	
	coefficient	**t-ratio**	**coefficient**	**t-ratio**
Medical condition				
Good health	Reference category		Reference category	
Diabetes	0.45	1.20	0.43	1.13
Coronary heart disease	0.33	0.86	0.32	0.83
Hypertension	0.38	1.04	0.33	0.88
Binocular vision problem	1.10	1.99**	1.24	2.14**
No evaluation	0.30	0.83	0.30	0.82
Age group				
≤ 25 years	Reference category		Reference category	
26 to 30	-0.10	-0.19	-0.26	-0.44
31 to 35	-0.26	-0.49	-0.06	-0.11
36 to 40	0.22	0.41	0.33	0.59
41 to 45	-0.41	-0.71	-0.46	-0.75
46 to 50	0.36	0.66	0.30	0.52
51 to 55	-0.66	-1.07	-0.62	-0.95
more than 55 years	-0.71	-1.18	-0.95	-1.48
Vehicle weight				
3,000 to 4,999 kg	Reference category		Reference category	
5,000 to 9,999 kg	0.14	0.33	-0.05	-0.11
10,000 to 14,999 kg	0.63	1.42	0.49	1.06
15,000 to 29,999 kg	0.27	0.60	0.29	0.61
≥ 30,000 kg	0.60	1.34	0.50	1.08
Type of impact				
Lateral frontal	Reference category		Reference category	

Explanatory Variables	**Model 3**		**Model 4**	
	coefficient	**t-ratio**	**coefficient**	**t-ratio**
Lateral same direction	-1.13	-2.48**	-1.12	-2.38**
Lateral opposite direction	0.16	0.43	0.20	0.51
Rear	-0.50	-1.71*	-0.49	-1.59
No collision	-1.29	-2.06**	-1.56	-2.42**
Other	-1.15	-3.48**	-1.25	-3.72**
Type of crash				
With a vehicle	-0.19	-0.43	-0.34	-0.75
Other	Reference category		Reference category	
Vehicle movement				
Straight ahead	Reference category		Reference category	
Turned right	-0.36	-0.79	-0.48	-1.05
Turned left	-0.10	-0.25	-0.02	-0.05
Joined the traffic, slowed down or stopped	-1.19	-2.23**	-1.30	-2.32**
Parked or quit parking area on the curbside	-0.13	-0.20	0.00	0.01
Reversed	-1.60	-2.67**	-1.55	-2.57**
Entered or left traffic or expressway overlook on the right or on the left, changed lanes, did a 180° turn, avoided an obstacle on the road, broke down, unknown	0.13	0.35	0.16	0.42
Trimester				
First			Reference category	

Explanatory Variables	Model 3		Model 4	
	coefficient	t-ratio	coefficient	t-ratio
Second			-0.26	-0.69
Third			0.21	0.59
Fourth			0.01	0.05
Day of crash				
Friday to Sunday			0.49	1.93*
Monday to Thursday			Reference category	
Time of crash				
6:00 am to 8:59 am			0.27	0.92
9:00 am to 3:59 pm			Reference category	
4:00 pm to 5:59 pm			0.34	1.00
6:00 pm to 9:59 pm			0.29	0.67
10:00 pm to 5:59 am			0.46	1.24
Road surface condition				
Dry			0.73	2.03**
Wet			1.21	3.14**
Snow-ice-mud and other			Reference category	
No. of crashes	542		542	
No. of variables	36		46	
Log-likelihood	-241.75		-232.15	
χ^2 Goodness of fit	2.632		1.523	
Log-likehood Ratio Test (vs Model 1)	$\chi^2_{16} = 40.7$**		$\chi^2_{26} = 59.9$**	

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* Significant at 10% ** Significant at 5%

Model 4 is the most interesting one. Based on the log-likelihood ratio test, it fits the data best. This result is due largely to the fact that more explanatory variables are significant. It is also important to observe that the driver's permit class variable is not significant when additional information on the crash circumstances are added. The same observation can be made for the year of the crash.

For the severity of the crashes involving a bus driver, the results differ in many aspects from those of truck drivers. First, we observe from Tables 5 and 6 that the estimated parameter α is significant in all four models. This means that we reject the Poisson assumption. Second, the drivers with hypertension have more severe crashes than those in good health. This is true for both permit classes. Since the coefficients are similar (statistically not different), the effect of hypertension does not depend on the permit class. We also observe that the coefficients of the hypertension variables increase when more information on the crash is included. This result is very important since it shows the appropriateness of taking environmental factors into consideration when we study the relationship between a medical condition and crashes. In Dionne et al. (1995), we have shown explicitly how a good control of risk exposure variable is necessary to derive conclusions on the effect of medical conditions on crash frequencies. Here we have a similar situation: The effect of health status is affected by controlling for the crash circumstances. This implies that the public decision makers who want to implement some regulation or other policy recommendations must have access among other things to both ingredients: detailed statistical information and adequate models.

Table 5: Estimated count data models (negative binomial distribution) for the number of victims in a crash with a bus (Models 5 and 6).

Explanatory Variables	**Model 5**		**Model 6**	
	coefficient	**t-ratio**	**coefficient**	**t-ratio**
Intercept	-1.114	-1.617	-0.663	-0.857
Alpha	1.841	3.768**	1.698	3.641**

Explanatory Variables	Model 5		Model 6	
	coefficient	t-ratio	coefficient	t-ratio
Year of crash				
1985	-0.263	-0.683	-0.001	-0.002
1986	-0.919	-2.226**	-0.578	-1.318
1987	-0.729	-1.729*	-0.634	-1.500
1988	-0.299	-0.884	-0.253	-0.753
1989	-0.047	-0.136	-0.070	-0.204
1990	Reference category		Reference category	
Age group				
≤ 30 ans	Reference category		Reference category	
31 to 35	-0.593	-0.807	-0.520	-0.707
36 to 40	-0.677	-0.948	-0.610	-0.853
41 to 45	-0.746	-1.095	-0.760	-1.116
46 to 50	-0.231	-0.361	-0.233	-0.364
51 to 55	-0.348	-0.539	-0.319	-0.493
More than 56	-0.267	-0.421	-0.252	-0.396
Permit class				
Class 1	0.130	0.303	0.190	0.444
Class 2	Reference category		Reference category	
Medical condition				
Class 1				
Good health	Reference category		Reference category	
Coronary heart disease	0.212	0.311	0.244	0.360
Hypertension	1.159	2.141**	1.080	1.996**

Explanatory Variables	**Model 5**		**Model 6**	
	coefficient	**t-ratio**	**coefficient**	**t-ratio**
Class 2				
Good health	Reference category		Reference category	
Coronary heart disease	0.158	0.434	0.150	0.416
Hypertension	0.810	3.075**	0.827	3.145**
Vehicle weight				
≤ 5,000 kg			Reference category	
5,001 to 10,000 kg			-0.438	-0.901
10,001 to 15,000 kg			-0.785	-1.558
15,001 to 20,000 kg			-1.414	-2.011**
Number of crashes	579		579	
Number of variables	17		20	
Log-likelihood	-343.60		-340.70	
χ^2 Goodness of fit	1.869		1.619	
Log-likelihood ratio test (vs Model 5)			$\chi^2_3 = 5.8$	

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* significant at 10%   ** significant at 5%

Table 6: Estimated count data models (negative binomial distribution) for the number of victims in a crash with a bus (Models 7 and 8).

Explanatory Variables	**Model 7**		**Model 8**	
	coefficient	**t-ratio**	**coefficient**	**t-ratio**
Intercept	0.745	0.906	0.495	0.567
Alpha	0.614	2.577**	0.430	2.139**

Year of crash				
1985	0.301	0.777	0.131	0.328
1986	-0.182	-0.431	-0.167	-0.396
1987	-0.315	-0.763	-0.416	-0.986
1988	-0.171	-0.523	-0.235	-0.714
1989	0.225	0.686	0.214	0.641
1990	Reference category		Reference category	
Age group				
≤ 30 ans	Reference category		Reference category	
31 to 35	-1.035	-1.452	-0.956	-1.325
36 to 40	-0.643	-0.944	-0.387	-0.567
41 to 45	-0.806	-1.238	-0.778	-1.203
46 to 50	-0.726	-1.193	-0.796	-1.314
51 to 55	-0.427	-0.701	-0.313	-0.519
More than 56	-0.415	-0.789	-0.221	-0.368
Permit class				
Class 1	0.166	0.383	0.142	0.332
Class 2	Reference category		Reference category	
Medical condition				
Class 1				
Good health	Reference category		Reference category	
Coronary heart disease	0.586	0.857	0.472	0.672
Hypertension	1.558	2.955**	1.741	3.365**
Class 2				
Good health	Reference category		Reference category	
Coronary heart disease	0.245	0.684	0.278	0.775

Hypertension	1.245	4.704**	1.205	4.494**
Vehicle weight				
≤ 5,000 kg	Reference category		Reference category	
5,001 to 10,000 kg	-0.386	-0.852	-0.626	-1.384
10,001 to 15,000 kg	-0.870	-1.814*	-1.059	-2.224**
15,001 to 20,000 kg	-2.226	-3.207**	-2.648	-3.834**
Type of impact				
Lateral frontal	Reference category		Reference category	
Lateral same direction	-2.298	-2.227**	-2.540	-2.442**
Lateral opposite direction	0.648	1.625	0.357	0.894
Rear	0.397	1.367	0.366	1.253
No collision	-0.084	-0.175	-0.225	-0.468
Other	-0.623	-2.010**	-0.752	-2.360**
Type of crash				
With a vehicle	-1.461	3.943**	-1.258	-3.299**
With a pedestrian	1.142	2.596**	1.294	2.824**
Other	Reference category		Reference category	
Vehicle movement				
Straight ahead	Reference category		Reference category	
Turned right	-1.020	-2.368**	-0.870	-2.053**
Turned left	-1.006	-2.421**	-0.868	-2.129**
Joined the traffic, slowed down or stopped	-0.673	-2.303**	-0.789	-2.634**
Parked or quit parking area on the curbside	-0.910	-1.525	-1.043	-1.718*
Reversed	-15.819	-0.014	-14.520	-0.023

Other	-1.175	-1.735*	-1.227	-1.761*
Trimester				
First			Reference category	
Second			0.631	2.002**
Third			-0.376	-0.889
Fourth			0.195	0.718
Day of crash				
Monday to Thursday			Reference category	
Friday to Sunday			-0.271	-1.056
Time of crash				
6:00 am to 8:59 am			0.608	2.197**
9:00 am to 3:59 pm			Reference category	
4:00 pm to 5:59 pm			0.470	1.756*
6:00 pm to 9:59 pm			0.311	0.746
10:00 pm to 5:59 am			1.249	2.591**
Road surface condition				
Dry			Reference category	
Wet			0.092	0.364
Snow-ice-mud			-0.489	-1.616
Number of crashes	579		579	
Number of variables	33		43	
Log-likelihood	-292.30		-280.01	
χ^2 Goodness of fit	2.79		3.486	
Log-likelihood ratio test (vs Model 5)	$\chi^2_{16} = 102.6$**		$\chi^2_{26} = 127.2$**	

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* significant at 10% ** significant at 5%

We also observe that the years 1986 and 1987 are significant in Model 5 but this effect disappears (Models 6 to 8) when additional information is included in the analysis, particularly the weight of the vehicle. In none of our models for the severity of bus crashes was the age variable significant.

We see that the severity effect for the driver of a large vehicle dominates the externality effect for other persons involved in the crashes since heavy busses have fewer victims per crash than busses weighing less than 5,000 kg. It seems that the advantages of greater momentum counterbalance the disadvantages of having (on average) more potential victims in busses. From Models 7 and 8, we also observe that crashes involving pedestrians result in a increased average number of victims while this number decreases when the crashes involve other vehicles.

Other environmental variables are added in Model 8; many of them have significant effects. For example, driving "in a straight line" at the moment of the crash increases the number of victims, possibly because the speed when driving straight ahead is higher than for other movements such as turning; having a crash in the second trimester is more dangerous in terms of victims than in the first one; and crashes during rush hours and during the night (between 10 p.m. and 6 a.m.) have more victims than those during the day (9 a.m. to 4 p.m.).

In summary, crashes involving bus drivers of both permit classes with hypertension have more victims than crashes involving bus drivers in good health whatever the crash circumstances included in the model. No other medical conditions have a significant relationship with the number of victims per crash.

CONCLUSION

This article shows that truck drivers with binocular vision problems and bus drivers with hypertension are involved in more severe crashes than healthy drivers. The other medical conditions considered in this study show no significant relationship with crash severity. Some crash circumstance variables such as direction of impact, state of the road surface and weight of the vehicle are also significant. Hypertension is usually not considered a risk to safe driving. Regulations might be concerned with severe hypertension or with additional complications. In our previous studies on truck drivers (Dionne et al., 1995) and bus drivers (Dionne et al., 1993) there was no significant relationship between hypertension and the frequency of accidents when compared to "good health". The present result on the severity of crashes is a new finding that calls for further studies. Overall, however, all the results were obtained from one data set and must be considered with precaution. We hope that some further replications will confirm their generality.

The results of this study are important for public policy purposes. They show that CMV drivers with two medical conditions are involved in more severe crashes than drivers in good health. We should repeat that we did not have information on crash responsibility since the Quebec automobile insurance regime is a pure no-fault system (Devlin, 1992).

Drivers with more severe crashes generate significant negative externalities and social costs by increasing the average number of victims per crash. Dionne et al. (1993) used the estimated parameters from count data regression models and survey data to calculate the private and social costs associated with the significant medical conditions.

REFERENCES

Boyer M.; Dionne G. The Economics of Road Safety. Transportation Research 21B(5): 413-431; 1987.

Boyer M.; Dionne G.; Vanasse C. Econometric Models of Accident Distributions in Dionne G. (ed.) Contributions to Insurance Economics, Boston, MA: Kluwer Academic Publishers; 169-213; 1992.

Cameron A.; Trivedi P.K. Econometric Models Based on Count Data: Comparisons and Applications of Some Estimators and Tests. Journal of Applied Econometrics 1: 29-53; 1986.

Devlin R.A. Liability vs No-Fault Automobile Insurance Regimes: An Analysis of the Experience in Quebec in Dionne G. (ed.) Contributions to Insurance Economics, Kluwer Academic Press; 1992.

Dionne G.; Desjardins D.; Laberge-Nadeau C.; Maag U. Medical Conditions, Risk Exposure and Truck Drivers' Crashes: An Analysis with Count Data Regression Models. Accident Analysis and Prevention (forthcoming, 1995).

Dionne G.; Laberge-Nadeau C.; Desjardins D.; Messier S.; Maag U. Analyse de l'impact économique des normes médicales et optométriques de conduite sur les coûts des transporteurs et sur les coûts sociaux des accidents routiers. Publication # 928; Laboratoire sur la sécurité des transports du CRT, Université de Montréal; 143 pages; 1993.

Ékoé J.-M.; Ghadirian P.; Hamet P.; Laberge-Nadeau C. Letter to the Editor. The New England Journal of Medecine 324(21): 1510-1511; 1991a.

Ékoé J.-M.; Laberge-Nadeau C.; Ghadirian P., et Hamet P. L'impact du diabète sucré sur la sécurité routière. Diabète et métabolisme 17(1): 61-68, 1991b.

Gouriéroux C.; Monfort A.; Trognon A. Pseudo Maximum Likelihood Methods: Application to Poisson Models. Econometrica 52: 701-720; 1984.

Laberge-Nadeau C.; Hamet P.; Desjardins D.; Ekoé J.-M.; Joly P.; Messier S.; Bergeron J.; Gagnon R.; Ghadirian P.;Joly M.-F.; Maag U.; Nadeau R.; Mathieu F.; Trudel G.. Impact sur la sécurité routière des normes médicales et optométriques pour la conduite d'un véhicule routier: Faits saillants des premiers résultats, méthodologie, publications. Rapport de la troisième année, cahiers I, II, III, V et VI. Publications # 823, 824, 825, 827 et 828 du Laboratoire sur la sécurité des transports du CRT, Université de Montréal, 1019 pages; Mars 1992.

Maag U.; Laberge-Nadeau C.; Dionne G.; Vanasse C. The high rate of taxi drivers' crashes: How severe are they in terms of number of victims? 38th Proceedings of the Association for the Advancement of Automotive Medicine, pp. 205-21, Lyon, France, September 21-23, 1994.

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