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Motor vehicle accidents (1973–6) in a cohort of Montreal drivers

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SUMMARY In 1973–4 nearly 10 000 Montreal drivers, interviewed by telephone, provided information about medical and associated factors and about driving habits, in particular annual mileage. Records of accidents suffered by these drivers in the Province of Quebec over 39 months (1973–6) were also collected. The 7634 current drivers, with appropriate permits, and all of whose data passed reliability edits, were placed into nine sets—that is, three classes: women; men with the usual permit; and men with a chauffeur's permit to drive taxis, heavy vehicles, etc; further subdivided into three age groups. Accident rates depended on mileage, but after allowance for differences in mileage, accident rates still varied with sex, type of permit, and age. No association of the risk of accidents and a medical or related factor was consistent over all nine sets of drivers. Of the 7634 drivers, 347 had had at least one accident causing injury or death in the 39 months from 1 January 1973. These "cases" were compared with 347 "referents," closely matched for sex, type of permit, age, and reported mileage, but without accident causing injury or death. Cases included higher proportions who worked irregular shifts, who were overweight, and who reported smoking while driving. Relative to the chance of a referent suffering any accident in the 39-month period, a case had at least double the risk of having an accident in addition to the index accident.

For many years and in most countries traffic accidents have taken a heavy toll of life and caused immense suffering through injury. Many investigations of medically related factors in the driver have been restricted to simulated situations, while most observational studies have been and continue to be either descriptive, or retrospective without adequate controls. In fact, it is particularly difficult even to define such controls, and often impossible to obtain comparable information from drivers concerned and not concerned in accidents. Thus although *Cumulative Index Medicus* for the six years 1975–80 includes many scores of references to articles on traffic accidents, only one[1] appeared to use the tools of analytical epidemiology, and this was a cohort study. In such a study the denominators of accident rates are determined at entry without reference to accident experience, and the numerators are obtained during follow-up. A major advantage of this type of study is that direct and unbiased estimates may be obtained of risks at entry. The risk at the time of the accident, however, may be different because reported habits may have changed. Thus the period of follow-up should not be too long, which means that the cohort must be large if sufficient events are to be observed to permit reliable conclusions.

This project, one of the few to use this attractive but difficult design, had as its objectives: to determine whether medical and related factors, which might affect the chance of suffering motor vehicle accidents, could be identified by telephone inquiry of drivers; if so to investigate such factors in the causation of motor vehicle accidents among Montreal drivers.

Materials and methods

DEFINITION OF THE COHORT

During 1973, the Bureau des véhicules automobiles du Québec (BUVAQ) made available full identifying details of every person with a driver's permit whose address was recorded as being in Greater Montreal and whose birthday fell on one of six pre-specified dates, such as 8 January (regardless of year). The total cohort nominated in this way numbered 18 328. Certain other information from the permit, such as sex, height, and type of permit, was also provided.

TELEPHONE INQUIRY

We sought a telephone number for each member of the cohort but could locate only about two-thirds. The shortfall arose for several reasons: the driver did

not have a telephone; the driver was not in the directory, although spouse or other relative may have been; the number was listed under an old address; the number was "unlisted" or the address was outside the area of toll-free calls from central Montreal. In a further substantial proportion of cases with available numbers contact could not be made despite at least three attempts at different times of the day and additional attempts some weeks later. This proportion included some who had died or were in hospital and others who had left the district or were on extended vacations.

A questionnaire in French and English (copy of either available on request) had been developed during 1972. It had been designed with a 10-minute interview in mind, and was introduced as a survey of the respondents' health. The interviewer asked first about height and weight, and "obviously medical" questions concerning exercise, headaches, physical defects, periods in hospital, use of medications, etc; then, focusing on possible fatigue, about occupation, shift work, physical effort, and driving habits, including annual mileage; and, finally, the sensitive issues of smoking and drinking. These last questions did not probe deeply because we thought many respondents might rescind their co-operation, and illicit drugs were not mentioned. Accidents were not referred to at any time in the interview. The questionnaire was administered, during 1973 and early 1974, by telephone to all who could be contacted; very few refused.

NOTIFICATION OF ACCIDENTS

In 1975–6 we obtained information about all accidents during the 39-month period 1 January 1973 to 31 March 1976 in the Province of Quebec—that is, reported to BUVAQ or the City of Montreal; no overlap—suffered by drivers with the originally specified birth dates. Those occurring to the 18 328 drivers in the complete cohort were identified, but with an estimated 5% under-notification because of technical difficulties in the reporting and recording of permit numbers in the official accident files; we believe we eliminated all over-notification. The resolution of these technical difficulties turned out to be one of the most costly components of the investigation.

Accidents occurring outside the Province of Quebec were found to be few and were not considered further.

REPRESENTATIVENESS OF THE RESPONDENTS

Some response was obtained from 9799 subjects, which was 53% of the original cohort or over 80% of those whose telephone numbers were traced. For 6665 of these, questionnaires were complete and passed all edits; for 3134 there was some doubt about the reliability of the data obtained. These two parts of the original cohort, and the 8529 who did not respond, were all closely similar in sex, ages, types of permit, heights, and numbers of accidents. Further, the first two parts had similar distributions of mileage and of other questionnaire responses.

DEFINITION OF COHORT STUDIED

The cohort chosen for detailed study consisted of those 7634 current drivers whose questionnaires were complete or nearly so and about whom we had no identity doubts, but excluded the small proportion permitted to drive only motorcycles, mopeds, farm tractors, snowmobiles, or "other" vehicles. They were placed in three *classes:* (1) women (2374); (2) men (2912) with the usual operator's permit to drive "any vehicle, except (i) an autobus with passengers and (ii) any heavy (10 887 kg) vehicle"; and (3) men (2348) with chauffeur's permits or with operator's permits without the restrictions in the previous class.

The three classes of driver differed considerably in their age distributions and in annual reported mileage, which also varied with age (see table 1). Class 3 comprised two subclasses—those who drove daily in the course of their work, their vehicles including taxis, trucks, and buses, as well as cars, and averaged around 40 000 miles (64 000 km) a year and those who did not drive professionally although licensed to do so and averaged mileages similar to those of class 2. It did not prove feasible to examine these subclasses separately.

Table 2 gives the responses to some 18 questions by class. Not surprisingly, the women differed from the men in many respects. The differences between the two classes of men, however, were small for most factors.

Prospective analysis

A first analysis was carried out at a time when our files contained details of accidents occurring in 1973

Table 1 *The three classes of drivers in the cohort*

	Class 1 (women) (n = 2374)	*Class 2 (men with usual permit) (n = 2912)*	*Class 3 (other men) (n = 2348)*
Age distribution (% (years)			
Younger (≤ 34)	46·8	40·0	38·9
Middle (35 to 54)	44·6	39·0	48·0
Older (≥55)	8·5	20·9	13·1
Average reported miles driven annually (thousands)			
Younger (≤34)	4·9	14·3	17·5
Middle (35 to 54)	4·6	14·7	17·2
Older (≥ 55)	4·9	10·4	13·6

Table 2 *Questionnaire responses in the three classes of drivers**

	Class 1 (women) %	Class 2 (men with usual permit) %	Class 3 (other men) %
Overweight**	2·2	5·9	8·4
Warned against strenuous exercise	3·5	5·6	4·6
Suffer from headaches	23·4	9·7	10·8
Fainted within last month	0·8	0·4	0·5
With physical defect	1·9	3·5	2·9
Admitted to hospital within last year (except for check-up or childbirth)	12·4	10·5	11·9
Take insulin	0·2	0·5	0·6
On diet	16·9	11·1	10·5
Use tranquillisers	3·1	6·4	6·3
Take prescribed or other medicaments	28·2	10·8	9·9
Wear glasses for distant vision	34·0	40·0	26·4
Work non-sedentary†	31·8	39·3	46·1
Work other than days only†	16·6	21·9	28·3
Tired by driving	17·4	15·3	13·0
Use seat belts in town	28·7	26·9	19·9
Often smoke while driving‡	29·2	53·4	64·3
Drink socially or often‡	45·8	58·8	58·9
Occasionally or often drive after drinking§	3·9	11·2	15·1

*Percentages of each class reporting the factor present among 7634 drivers, except: † among 5789 drivers answering both questions, ‡ among 4663 drivers answering both questions, § among 3861 drivers answering this question.
**$((\text{Weight})/(\text{height})^2 \geq 6(\text{lbs})\,(\text{ft})^{-2}\,[29{\cdot}29(\text{kg})\,(\text{m})^{-2}]$.

and 1974 in the whole province, together with accidents occurring within the City of Montreal during the first 10 months of 1975. A total of 4209 accidents had been notified (72% from BUVAQ, 28% from Montreal) among the original cohort of 18 328, a rate of 23·0 per person; the 7634 drivers in the study cohort had 1791 accidents, a rate of 23·5 per 100 persons. The method was an adaptation of comparative composite cohort analysis,[2] with person-years replaced by driver-miles as the basis of accident rates, and using an internal standard of comparison.[3]

Although accident rates per 100 driver-years depended on mileage, this was by no means pro rata; when expressed per million driver-miles, accident rates were lower the higher the mileage (table 3).

Table 3 *Approximate accident rates according to reported annual mileage*

Average reported miles driven annually (thousands of miles)	Accidents per 100 driver-years	Accidents per million driver-miles
0– 4	4·8	23·8
5– 8	8·6	13·3
9–12	11·6	11·6
13–16	12·4	8·3
≥17	18·8	6·3

Table 4 gives the numbers of accidents observed among the nine *sets* of drivers (three classes by three age groups). Also given are accident ratios, crude and adjusted, by the "indirect" method[4 5] for mileage—definitions in the table. The adjustments conform with the mileages reported in table 1 but could not have been inferred directly from them. Adjustment reduced greatly the variation between sets, but important differences remained. Five sets—that is, women in all age groups and men with normal permits (class 2) in the two older age groups had very similar adjusted accident ratios (AARs) averaging 0·76. Three other sets—that is, younger men in class 2 and the two older age groups in class 3—also had similar AARs (1·09 to 1·11); the ninth set, the younger men in class 3, had AAR = 1·39.

We calculated the ratios of the AAR of drivers, in each of the nine sets who had reported the possible risk variables as in table 2, relative to the AAR of drivers in the same set who had not reported these risks; the variables were considered singly and in certain pairs, 25 "factors" in all. Because of small numbers the ratios were unreliable in themselves, so we looked for consistency over the nine sets. Only one pair of variables was associated, both alone and in combination, with a higher risk in the majority of sets; these were non-sedentary work and work other than on days. Table 5 illustrates this phenomenon—and its inconsistency. Of the (25 × 9=) 225 relative risks (RRs) evaluated, 106 were raised, but only 23 to an extent associated with a conventional level of statistical significance; of the 112 depressed RRs, 11 reached such a level—but

Table 4 *Accidents by sex, type of permit, and age of driver: crude ratios and ratios adjusted for annual mileage*

Age group	No of accidents and accident ratios	Class 1 (women)	Class 2 (men with usual permit)	Class 3 (other men)
Younger (≤ 34 years)	No of accidents*	128	339	378
	Crude accident ratio†	0·49	1·24	1·76
	Adjusted accident ratio‡	0·77	1·09	1·39
Middle (35 to 54 years)	No of accidents	115	233	372
	Crude accident ratio	0·46	0·87	1·41
	Adjusted accident ratio	0·73	0·75	1·11
Older (≥55 years)	No of accidents	22	115	89
	Crude accident ratio	0·46	0·81	1·23
	Adjusted accident ratio	0·72	0·84	1·10

*Reported to BUVAQ 1973–4 or to the City of Montreal 1 January 1973–31 October 1975, total 1791.
†Number of accidents per hundred drivers divided by the corresponding rate for the complete cohort (100 × 1791/7634 =) 23·46.
‡Number of accidents observed divided by those expected based on the accident rates, within mileage groups, for the complete cohort.

always with at least one "significantly high" RR of the same factor among the nine sets. Two RRs were equal to unity, and five could not be calculated because of void cells.

Retrospective analysis

When we had collected details of all accidents to end-March 1976, we carried out a further analysis using the case/referent approach. Roughly 0·4% of the reported accidents were fatal and a further 14% caused injury. Among the 7634 drivers in the first analysis were 347 who suffered at least one such accident in the period of the study. For each of these 347 cases, a referent who had not had such an accident was selected, matched for sex, age, reported mileage, and type of permit. Each referent was of the same sex as the case, and of the same year of age, except among the rather elderly where, rarely, a difference of one or even two years had to be accepted; these differences were balanced almost perfectly. Matching by mileage was usually to the same 1000, but, where mileage was great, differences, usually small in relative terms, had occasionally to be accepted but were more-or-less balanced out in the selection process. The type of permit was usually identical for case and referent. Where several members of the cohort met all the criteria to qualify as a referent, one was selected at random.

Cases were compared with referents in terms of the answers to some 14 questions. Comparisons were made separately for the three classes of drivers but are summarised in table 6 pooled over all case-referent pairs. The responses of cases and referents to nine questions (concerning having been warned about exercise; headaches; physical defects; use of insulin, tranquilisers, prescribed, or other medicaments; employment; and driving after drinking) were very similar. The wearing of glasses for distant vision was a little less common in the cases than in the referents. In each of the three classes of drivers slightly fewer cases than referents reported the use of seat belts on highways (from table 6, $\chi^2 = 3{\cdot}39$, 1 df, $p = 0{\cdot}066$, using the McNemar test[6] despite a possible small bias),[7] but there were only

Table 5 *Risks of accidents among non-sedentary workers, workers not on day shift only, and workers with both risk factors, relative to those with neither risk factor, by sex, type of permit, and age*

Class	*Age group (years)*	*A Non-sedentary work*	*B Did not work days only*	*People with factors A and B*
1 (women)	≤34	1·27	0·86	1·10
	35 to 54	1·43	0·54	0·90
	≥55	1·05	2·13	0·00
2 (men with usual permit)	≤34	1·44**	1·40*	1·49*
	35 to 54	1·56**	1·09	1·37
	≥55	0·84	1·10	0·70
3 (other men)	≤34	1·30**	1·38**	1·23
	35 to 54	0·78*	0·99	1·02
	≥55	1·03	1·25	0·79

*χ^2 >3·84, 1 df, p <0·05.
**χ^2 >6·64, 1 df, p <0·01.

Table 6 *Distribution of 347 case-referent pairs according to presence or obsence of certain factors in case and referent. (Figures in parentheses are numbers of pairs that could not be classified)*

Factor	*(a)*	*(b)*	*(c)*	*(d)*	*Relative risk*
Warned against strenuous exercise (2)	1	17	15	312	1·13
Suffer from headaches (0)	8	36	38	265	0·95
With physical defect (1)	0	13	14	319	0·93
Take insulin (1)	0	0	3	343	0·00
Use tranquillisers (3)	1	18	18	307	1·00
Take prescribed medicaments (0)	9	44	41	253	1·07
Take other medicaments (1)	3	18	17	308	1·06
Use glasses for distant vision (0)	40	65	80	162	0·81
Presently unemployed (0)	30	27	32	258	0·84
Work irregular shifts (84)	10	57	28	168	2·04
Seat belts not used on highways (28)	92	90	66	71	1·36
Seat belts not used in towns (28)	188	57	55	19	1·04
Often smoke while driving (198)	51	45	26	27	1·73
Occasionally or often drive after drinking (135)	5	27	24	156	1·13

(a) Factor present in both case and referent.
(b) Factor present in case, absent in referent.
(c) Factor absent in case present in referent.
(d) Factor absent in both case and referent.
*Discordant pairs: relative risk =(b)/(c).

miniscule differences in the use of seat belts in towns. Cases, particularly men, included a higher proportion who reported smoking while driving compared with their referents (over all pairs, $\chi^2 = 4{\cdot}56$, 1 df, $p = 0{\cdot}033$).

Drivers who had said they were employed at the time of interview had also been asked whether they worked days only, nights only, or on irregular or rotating shifts. In the 136 case-referent pairs in class 3, both of whom were employed, 44 of the cases (32%) reported work on irregular shifts, compared with 23 of the referents (17%); the "discordant' pairs" numbered 37 and 16 ($\chi^2 = 7{\cdot}55$, 1 df, $p = 0{\cdot}006$). A similar tendency, but with substantially fewer men on irregular shifts, was found for class 2, and again, but on tiny numbers, for women (from table 6, $\chi^2 = 9{\cdot}22$, 1 df, $p = 0{\cdot}002$).

For most subjects of both sexes the Quetelet/Davenport index of adiposity[8]—that is (weight)/(height)^2—was between 4 and 6 (lbs) (ft)$^{-2}$ (19·53 and 29·29 (kg) (m)$^{-2}$); taking these values as defining "normals," we found 25 cases and 19 referents were underweight, while 30 cases and 14 referents were overweight. Ignoring the matching, the 3×2 contingency table showed a difference ($\chi^2 = 7{\cdot}43$, 2 df, $p = 0{\cdot}024$).

In addition to the 347 index accidents the cases suffered 232 accidents in the period of the study, 21 of which caused injury or death (as had the index accidents). In the same period the referents had only 113 accidents in all, none, of course, causing injury. Compared with the chance of a referent suffering *any* accident, a case had a relative risk = 2·05 of having an accident *in addition to the index accident.* This relative risk was similar in all three classes of drivers, and did not appear to depend on mileage. The percentage distributions of cases and of referents according to the number of accidents suffered are in table 7.

Discussion

To analyse only 42% of the originally defined cohort needs justification. We have shown that respondents whose questionnaires were complete and passed all edits had many factors, including accident rates, similar to those among other respondents and among non-respondents, while most of the non-response was for reasons unlikely to create biases, and that it was almost certainly not a three-way interaction in response bias that might affect validity.[9] The 7634 drivers in the study cohort may therefore be accepted as an unbiased sample of all those with appropriate permits in the total original cohort. In turn, the method of sampling by birthdays ensured that that cohort was representative of the target population, all subjects living in Greater Montreal holding a current driving licence.

Table 7 *Percentage distributions of cases and referents by number of accidents*

No of accidents	*347 cases**	*347 referents†*
0	55·6	76·7
1	29·7	16·7
2	10·1	4·9
≥3	4·6	1·7
Total No of accidents	232	113

*Accidents in addition to the index accident.
†Any accident.

The first purpose of the interviews was to identify medical and other risk factors. Most of the accidents occurred after the interviews, and so could not have biased responses. The distribution of the answers to the various questions have been discussed with several doctors and other members of the department of epidemiology and health at McGill University, who found them self-consistent and in reasonable accord with their expectations. Several factors, however, could be identified only indirectly, while information on some matters (particularly driving habits in relation to consumption of alcohol and other drugs) was sketchy or non-existent. Nevertheless, it would appear that the first objective of the project was at least partially fulfilled.

For many drivers, the mileage reported during the interview would probably have been a fair indicator of the miles actually driven year by year throughout the period of follow-up. For others, it would have been a poor indicator, because it was inaccurate or because of changes from year to year. It remained the best available basis for comparison, for it is undoubtedly more appropriate to base epidemiological studies on driver-miles rather than on driver-years. It is also important that the dependence of accident rates on mileage was not pro rata; those with the highest mileage might well include the most experienced and "safe" drivers, but they were at risk for much longer periods during a year. It has to be appreciated that the use of million driver-miles as the basis, although necessary, is not sufficient to ensure the comparison of like with like, particularly as there were major differences in rates of accidents per million driver-miles by sex, type of permit, age, and annual mileage, with complex interactions: an important conclusion is that any attempt at the analysis of accident experience that does not take into account *at least* all these factors is vitiated, and could be grossly misleading.

The lack of consistent positive findings in the first analysis was disappointing, although some real effects may have been diluted in the consideration of all reported accidents, particularly as we had no

evidence as to whether the driver in the cohort was at fault or not. Again, the fact that the exposure variables were assessed from the interviews meant that the resulting relative risks would tend, by dilution, to be smaller than the "biological" relative risks. No further attempts were made to analyse by a priori reasoning, although several improvements could have been incorporated: not only was the budget overspent but we had by now become convinced of the major advantages of case/referent analysis of cohort studies.[3 10 11] Here, more than one referent could have been selected for almost every case, but the gain in efficiency would have been balanced by less perfect matching and the need for much more complex methods of analysis, only now readily available.[12]

In view of the many simultaneous inferences that have been made it is difficult to evaluate the finding that work on irregular shifts was more common in cases than in referents. Nevertheless, it is easy to postulate a simple hypothesis to explain the result. More complex hypotheses are, however, required in relation to the findings on adiposity, and on smoking while driving—if they are indeed more than "dredgings."[13] Many overweight drivers and many who smoke while driving may be drinkers, and the findings might be an indirect manifestation of the influence of alcohol on traffic accidents, even although we found no direct manifestation. That was despite treating reported driving after drinking as a risk factor in both analysis and, in the prospective analysis, considering drinking (socially or often) both by itself and in conjunction with smoking while driving. These findings, contrary to the generally accepted belief, could have arisen if impaired drivers who had had accidents were not identified by the questions posed because, for instance, they were those who drank only rarely but then to excess.

The demonstration that there were "accident repeaters", even after four major risk factors had been taken fully into account by close matching in a case/referent analysis, appears convincing.

The project was designed in such a way that continuing surveillance of the cohort would be possible at comparatively low cost. Further studies would be possible with only the accident file up-dated, but several possibilities are being evaluated. Meanwhile, there are many lessons to be learnt, not least from our mistakes, about a project of this nature.*

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*The methodological report to the granting agency could be made available to bona fide research workers.

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