J. chron. Dis. Vol. 15, pp. 811–826. Pergamon Press Ltd. Printed in Great Britain

A CONTROLLED STUDY OF FATAL AUTOMOBILE ACCIDENTS IN NEW YORK CITY*

JAMES R. MCCARROLL, M.D.,† and WILLIAM HADDON, JR., M.D., M.P.H.‡

Department of Public Health, Cornell University Medical College, New York and the Epidemiology Residency Program New York State Department of Health, Albany

(*Received* 15 *October* 1961)

AN ESTIMATED 1·4 *million* persons have been killed in motor vehicle accidents in the United States alone in the past sixty years (1901–1960) [1]. Despite this, only two adequately controlled investigations of the factors associated with the occurrence of such *fatal* accidents have been initiated and completed anywhere to date. The first of these, concerned with fatal, adult pedestrian accidents in Manhattan, demonstrated the feasibility of tightly controlled accident research under complex urban conditions. It found large differences between the characteristics of fatally injured pedestrians and those of non-involved, but similarly exposed individuals [2]. The second study, reported here, represents an extension to the driver-fatal accident of the design and technics developed and employed in the first.

In both of these controlled studies the objective was to compare those fatally injured with non-involved persons similarly exposed. This was accomplished by matching the exposure of the case and control groups by obtaining the latter in an arbitrary manner at the same sites, on the same days of week, at the same times of day. By thus matching for exposure, artifacts were avoided which had been introduced into other types of accident investigations because of case-control variations in exposure.

CASE SERIES

The case series consisted of forty-three (93 per cent) of the forty-six drivers of non-commercial automobiles fatally injured in New York City exclusive of Staten Island in the periods June 1, 1959–October 24, 1959 and June 1, 1960–October 24, 1960. The forty-six deaths represent all those known to the Office of the Chief Medical Examiner of New York, and to the Accident Investigation Squad (A.I.S.), New York City Police Department. Twenty-four of these, twenty-three of which were included in the forty-three in the series, occurred in 1959. Only one driver was killed in each of the forty-six accidents.

---

*This investigation was supported, in part, by research grants (RG-5937) and (2G-558) from the United States Public Health Service, and by the New York State Departments of Health and Motor Vehicles.

†Director, Division of Epidemiologic Research, Department of Public Health, Cornell University Medical College.

‡Director, Epidemiology Residency Program, New York State Department of Health: Formerly, Director, Driver Research Center, New York State Department of Health—State Department of Motor Vehicles.

Post-mortem inspections or examinations were performed in all cases. Analyses for alcohol, based either on brain, or on heart or great vessel blood, were performed by the Office of the Chief Medical Examiner using the method of Gonzales *et al.* [3] routinely employed by the Medical Examiner's Office in cases of violent death. Data with respect to the deceased and the circumstances of each accident were obtained from both the Office of the Chief Medical Examiner and from the A.I.S. It is pertinent that the characteristics of case-series members from the two years were not statistically significantly different, and that the numbers of such accidents have shown but little variation from year to year.

CONTROL GROUP

Each accident site was visited on a subsequent date, but on the same day of week and at the same time of day at which the accident had occurred. Site-visit dates were chosen days or weeks in advance without reference to probable weather, and all site visits were made in 1960, within a few weeks of the calendar week of occurrence.

Each site-visit team consisted of one or both of the authors, medical students and one to eight police. Routinely, on arrival, an n between 1 and 20 was chosen. Then each n^{th} non-commercial, passenger motor vehicle proceeding in the same direction as that driven by the case-series driver was stopped by the police until a total of six had been stopped and successfully interviewed. At many locations with low traffic density an n of one was chosen and the *first* six vehicles were stopped. At high-density sites a larger n was employed.

Each n^{th} driver on being stopped was requested, in a manner similar to that employed previously with pedestrians [2], to cooperate anonymously. Despite some initial apprehension and occasional hostility, and in one case an initial plea of diplomatic immunity, only one of 259 drivers stopped (0·4 per cent) refused complete interview and breath specimen. The remaining 258 (six from each of the forty-three site visits) constituted the control group. The breath specimens were collected in special Saran bags [4], processed as previously described [2], and analyzed in a 'Breathalyzer' [2, 5].

RESULTS

Figure 1 shows the distribution of cases in the four boroughs Manhattan, Queens, Brooklyn and Bronx. The Borough of Richmond (Staten Island) was omitted.

Prior to the analysis of the data each accident in which a member of the case series was fatally injured was placed in one of six categories based upon the type of accident in which he was involved:

I. Only one vehicle involved: Its driver fatally injured.

II. More than one vehicle involved, but only one in motion: Its driver fatally injured.

III. More than one vehicle involved and in motion: Driver in responsible vehicle fatally injured.

IV. More than one vehicle involved, but only one in motion: Driver of non-moving vehicle fatally injured.

V. More than one vehicle involved and in motion: Driver in non-responsible vehicle fatally injured.

VI. More than one vehicle involved and in motion: Not known whether fatally injured driver's vehicle was responsible or not.

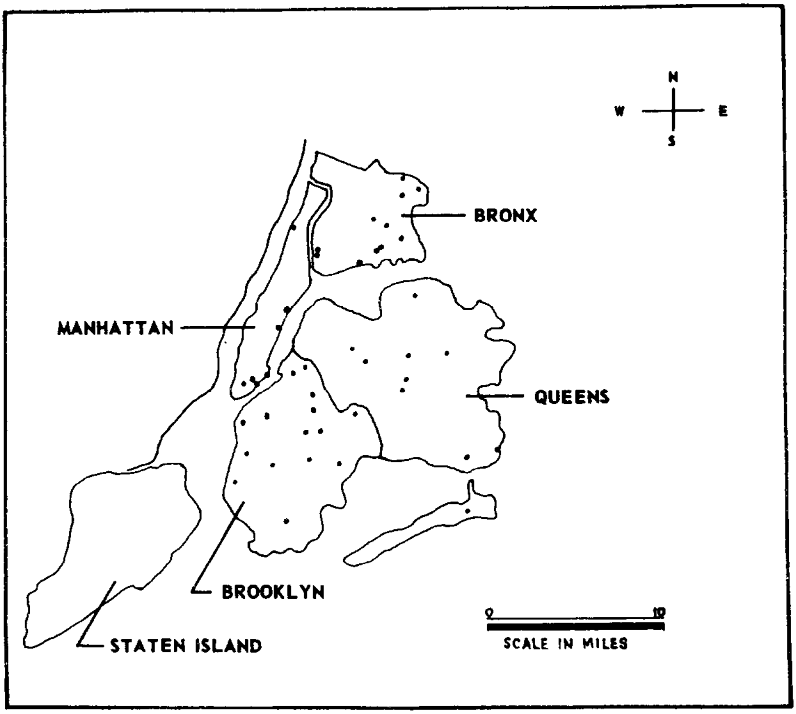

FIG. 1. Locations of forty-three accidents in which drivers of passenger cars were fatally injured in New York City exclusive of Staten Island.

TABLE 1. CATEGORIES OF ACCIDENTS FROM WHICH CASE-SERIES MEMBERS WERE DERIVED

Accident Category*	Number of Accidents in Category†
I	19
II	7
III	4‡
IV	1
V	1§
VI	11

*See text.

†Only one driver was fatally injured in each accident contributing to the case series.

‡One of these resulted in the death of the driver of a fleeing stolen car who went through a red light and hit another car broadside. A second accident in this category resulted when the vehicle driven by a case-series member crossed into the opposite lane on a Brooklyn to Manhattan bridge and hit an oncoming car head on. The third accident in this category involved a driver seen to be slumped over his wheel before hitting two pedestrians and another car. As the car approached the pedestrians its estimated speed was only 10–15 miles per hour. The fourth accident resulted when the case-series driver, a transit bus driver by occupation, was seen by two independent witnesses to slump over his wheel and lose control of the car he was driving. It is not known whether or not the drivers in the last two of these accidents were literally 'fatally injured,' but for lack of further evidence these accidents have been classified as listed. (See also footnotes Table 5.)

§This accident resulted when a car crossed a center island and hit an oncoming car the driver of which was killed. (See also footnotes Table 5.)

The category assignment was based on the A.I.S. report without reference either to the blood alcohol concentration of the case series member or to other post-mortem finding. Multivehicle accidents in which the only evidence as to responsibility was the disclaimer of a surviving driver were placed, because of the frequent unreliability of such statements, in category VI. As appropriate in the tabulations which follow, the thirty responsible drivers in accident categories I, II and III have been grouped together for analysis, as have the thirteen questionably responsible drivers in accident categories IV, V and VI (see Table 1 and Discussion). Cases in the first, responsible, group (I–III) comprised 70 per cent (30/43) of the case series. On the basis of the category of each accident the control subjects from the same site have been similarly categorized and grouped.

There were significantly ($P=0{\cdot}005$) more accidents (27/43) on weekends (Friday, Saturday and Sunday) than in the remainder of the week. There was also a significant association ($P=0{\cdot}05$) between time of day and accident occurrence, with more accidents from 6 p.m.–5 a.m. than from 6 a.m.–5 p.m. There was no statistically significant association ($P=0{\cdot}75$) between time of day of occurrence and accident category, comparing the time of day distribution (6 a.m.–5 p.m. and 6 p.m.–5 a.m.) of accidents in the responsible (I–III) group with that of those in the questionably responsible (IV–VI) group. In addition, there was no statistically significant association ($P=0{\cdot}38$) between road condition (wet or dry) and accident occurrence (see Table 2 and Discussion).

TABLE 2. ROAD CONDITION AT TIME OF ACCIDENTS AND AT SUBSEQUENT SITE VISITS*

	Accident	Site visit†	Total
Number wet	9	6	15
Number dry	34	37	71
Total	43	43	86
			$P=0{\cdot}38$

*Includes all sites at which the road was wet from any cause, for example, from concurrent or recent rain or from the use of street washing equipment.
†See text.

The case subjects were suggestively *older* in both responsible (I–III) and questionably responsible (IV–VI) groups. However, the differences were not statistically significant ($P>0{\cdot}05$) (Table 3). As a result, no age adjustment has been made in the case-control comparisons which follow. In this respect the analyses presented here differ from those of the pedestrian accident report [2], since in that instance a highly significant, seventeen year case-control age difference made age-adjusted case-control comparisons mandatory.

The ages of the vehicles, taken as the calendar year–model year difference, in the case and control groups were not significantly different ($P>0{\cdot}05$) in any of the groups studied (I–III, IV–VI, and I–VI), allowance being made in the case of the twenty-three 1959 accidents for the fact that their controls were obtained one year later (*q.v.*). Also, there was no statistically significant association between car age and time of day in either the accident responsible case ($P>0{\cdot}9$) or control ($P>0{\cdot}2$) groups. Further, there was no significant association ($P>0{\cdot}05$) between car age in case and control groups and drivers' blood alcohol concentrations. The difference

TABLE 3. MEDIAN AGE OF FATALLY INJURED AND CONTROL GROUP DRIVERS

Accident category*	Cases	Controls
I, II, III	37·0	34·5
IV, V, VI	47·5	35·0
Total I–VI	39·0	35·0
	$P>0{\cdot}05$ (Kolmogorov-Smirnov Test)	

*See Table 1 and text.

in the case group, however, was suggestive. The median age of the cars of the accident-involved drivers (I–VI) with blood alcohol concentrations (see below) of 100 mg % and higher was 4·5 yr in comparison with 3·3 yr in the case of case-series drivers with concentrations below 100 mg %. In the control group the age differences, although not significant ($P > 0{\cdot}05$), were reversed, 3·0 yr ($\geqslant$ 100 mg %) and 3·8 yr ($<$ 100 mg %).

Males were driving all but 11 per cent (29 female drivers/258 total) of the *non*-involved cars sampled at the times and places of the accidents (Table 4). They were nonetheless significantly overrepresented in the all male case group (I–III, $P=0{\cdot}04$; I–VI, $P<0{\cdot}01$). As far as race and place of birth were concerned, no significant case-control differences were found.

The *case*-series' alcohol concentrations by time of day and accident category are given in Table 5 with pertinent additional data, where available. High alcohol concentrations ($\geqslant$ 100 mg %) were found significantly more often in both the accident responsible group (I–III, $P<0{\cdot}03$), and in the total group of accident-involved drivers (I–VI, $P<0{\cdot}01$) in the evening, nighttime and early morning hours (6 p.m.–5 a.m.) than during the day. In all of the comparisons involving alcohol only the thirty-seven cases in which post-accident survival was less than 6 hr have been used—together with their 222 site-matched controls. This was done to avoid the artifacts which would have arisen from including cases in which prolonged

TABLE 4. SEX OF DRIVER

Accident category*		Male	Female	Total	P†
I, II, III	Cases	30	0	30	0·04
	Controls	160	20	180	
IV, V VI	Cases	13	0	13	0·23
	Controls	69	9	78	
I–VI	Cases	43	0	43	0·01
	Controls	229	29	258	
Total		272	29	301	

*See Table 1 and text.
†In each grouping the probability is the exact probability of obtaining 0 females.

TABLE 5. ALCOHOL CONCENTRATION OF FATALLY-INJURED DRIVERS DYING WITHIN 6 HR OF THEIR ACCIDENTS, BY TIME OF DAY AND ACCIDENT CATEGORY

Accident category [1]	a.m. 12–2	a.m. 3–5	a.m. 6–8	a.m. 9–11	p.m. 12–2	p.m. 3–5	p.m. 6–8	p.m. 9–11
I, II, III	+3[2]	+3	0	+3	0	0[5]	+3	+3
	+3	+3		No test	0	0	+1[7]	+3
	+3	+2				No test[6]	+1[8]	+3
	+3	0[4]						+1
	+3							
	+2							
	0[3]							
IV, V, VI	+3	+3		0	0	0	0	0[9]
		+3		No Rep				0
		0						

1. See Table 1 and text.
2. Within each 3-hr period equivalent alcohol concentrations have been grouped together. The semi-quantitative notation used here and the equivalent concentrations are those given by GONZALES *et al.*[2] See text. 0 = No alcohol detected; *tr* = >0, <20 mg per cent; +1 = ⩾20, <100 mg per cent; +2 = ⩾100, <250 mg per cent; +3 = ⩾250, <400 mg per cent.
3. Twenty-six-year-old driver of fleeing stolen car hit ramp divider. Driver thrown to pavement. The post-mortem examination report records no non-traumatic pathology.
4. Sixteen-year-old driver of fleeing stolen car fatally injured when he went through a red light and hit a second car broadside. The post-mortem examination report records no non-traumatic pathology.
5. Nineteen-year-old driver of following car in drag race hit puddle and went out of control. The post-mortem examination revealed no non-traumatic pathology.
6. Fifty-seven-year-old driver was seized with chest pains and collapsed. Examination revealed no external signs of trauma.
7. Fifty-nine-year-old driver was seen to be collapsed over wheel prior to collision with two pedestrians and another vehicle. Post-mortem examination revealed occlusive coronary arteriosclerosis, myocardial fibrosis and cardiac hypertrophy. Cause of collapse not known.
8. Fifty-two-year-old driver, by occupation a transit bus operator, was seen to slump prior to accident. Post-mortem examination revealed no pertinent non-traumatic pathology. Cause of collapse not known.
9. Fifty-nine-year-old driver found at post-mortem examination to have a ruptured cerebral aneurysm. As is commonly the case where medical factors are considered possible, the accident report attributed the accident to a 'heart attack.'[23]

post-accident survival had permitted substantial metabolic lowering of the alcohol concentrations present at the times of the accidents. This necessary precaution is seldom taken in the analysis of motor vehicle accident data [2, 6].

Alcohol was not detected in the case of the majority (76 per cent) of the 258 drivers in the entire *control* group (Table 6). However, 13 per cent (34/258) had concentrations in the 20–99 mg % range in which driving deterioration begins and 3 per cent (9/258) had concentrations in the high 100–249 mg % range.

The percentage of *case*-series members in the accident-responsible group (I–III) with blood alcohol concentrations in the very high 250 mg % and over range was 46 per cent (12/26) whereas *no* member of the six-times-as-large control group was in this range (Table 6). Using partial χ^2 the case-control difference among drivers with concentrations $\geqslant 100$ mg % was highly significant ($P < 0{\cdot}001$). In the entire group of accident-involved drivers (I–VI), which contained in categories IV–VI a number of drivers not responsible for their accidents and deaths, 41 per cent (15/37)

TABLE 6. BLOOD ALCOHOL CONCENTRATION OF FATALLY-INJURED DRIVERS DYING WITHIN 6 HR COMPARED WITH THOSE OF NON-INVOLVED DRIVERS AT THE SAME ACCIDENT SITES*

Accident category†	Blood alcohol concentration in mg (%)‡		00	<20	20–99	100–249	250–399	Lab. Loss No test No report	Total
I, II, III	Cases§	(#)	7	0	3	2	12	2	26
		(%)	27	0	12	7	46	8	100
	Controls	(#)	115	4	27	8	0	2	156
		(%)	74	3	17	5	0	1	100
IV, V, VI	Cases§	(#)	7	0	0	0	3	1	11
		(%)	64	0	0	0	27	9	100
	Controls	(#)	50	5	7	1	0	3	66
		(%)	76	8	11	2	0	5	102
Total	Cases	(#)	14	0	3	2	15	3	37
		(%)	38	0	8	5	41	8	100
	Controls	(#)	165(195)	9(14)	34(34)	9(9)	0(0)	5(6)	222(258)
		(%)	74(76)	4(5)	15(13)	4(3)	0(0)	2(2)	99(99)

*Cases in which post-accident survival was 6 hr or more have been omitted to avoid the artifacts introduced by post-accident, ante-mortem metabolic lowering of the alcohol concentrations present at the times of the accidents. However, for completeness with respect to the non-involved drivers the figures in parenthesis give the data for the drivers sampled at *all* accident sites, regardless of the duration of survival of the corresponding, fatally injured drivers.

†See text.

‡10 mg=0·01% by wt.=0·1 per mille.

§See footnotes, Table 5.

of those dying within six hours were in the 250 mg % and over range, in comparison with 0 per cent (0/222) in the corresponding control group, a highly significant difference. The case-control difference in the numbers of drivers in the accident-responsible group (I–III) with no detectable alcohol (negative) was not significantly different ($P=0·66$) from that of drivers with relatively low concentrations (> 0, < 100 mg %).

TABLE 7. MARITAL STATUS AND ALCOHOL CONCENTRATION OF FATALLY INJURED, ACCIDENT RESPONSIBLE DRIVERS, DYING WITHIN 6 HR OF THEIR ACCIDENTS, AND OF THEIR SITE-MATCHED CONTROLS

Marital status*		Alcohol concentration 0–99 mg %	≥100 mg %	Total
Married†	Cases	5	4	9
	Controls	103	5	108
Non-married‡	Cases	5	10	15
	Controls	43	3	46
Total§		156	22	178

*Two I–III group case-series members and two controls not tested have been omitted.

†The case-control difference in alcohol level within the married group is highly significant ($P<0·001$, partial χ^2).

‡The case-control difference in alcohol level within the non-married group is highly significant ($P<0·001$, partial χ^2).

§In the entire case-control group there was also a very significant ($P<0·01$, partial χ^2) association between marital status and alcohol concentration.

Within the married group there was a significant difference in blood alcohol concentration ($P < 0{\cdot}001$) between the accident-responsible case and control subjects (Table 7). The married *case*-series members more often had high concentrations (≥ 100 mg %) than the married control-group members. Within the non-married group (composed of the never married, widowed, separated and divorced) a similar difference was found ($P < 0{\cdot}001$). Marital status (married, non-married) was also significantly associated with alcohol concentration ($P < 0{\cdot}01$). The non-married in the entire case-control group more often had high blood alcohol concentrations (≥ 100 mg %). Also, unmarried persons, without reference to their alcohol concentrations were significantly ($P = 0{\cdot}02$) over-represented in the entire forty-three member case group in comparison with the 258 member control group. Forty-nine per cent of the cases were married, in comparison with 67 per cent of the controls.

No statistically significant difference ($P = 0{\cdot}20$) was found between accident-responsible drivers and their site-matched control drivers with respect to socioeconomic status, as classified using the U.S. Census Classification of Occupations. Also, no significant associations were found with respect to socioeconomic status in relation to alcohol concentration in the accident-responsible case ($P = 0{\cdot}17$) and

TABLE 8. PLACE OF RESIDENCE OF FATALLY INJURED AND CONTROL GROUP DRIVERS

	Cases		Controls	
	Number	Per cent	Number	Per cent
Residence and accident site in same borough	35(25)*	81(83)*	166(108)*	64(60)*
Residence in different borough of New York	6(4)	14(13)	44(35)	17(19)
Residence elsewhere in New York State	2(1)	5(3)	29(20)	11(11)
Other U.S.	0(0)	0(0)	19(17)	7(9)
Total	43(30)	100(99)	258(180)	99(99)

*The parentheses give the data from accidents in Categories I, II and III, and from their site-matched controls.

$P = 0{\cdot}04$ (χ^2) for the entire (I–VI) case-control residence difference.

$P = 0{\cdot}03$ (χ^2) for the accident-responsible (I–III) case-control residence difference.

$P < 0{\cdot}03$ (partial χ^2) for entire (I–VI) case-control residence difference camparing residence in New York City with residence elsewhere.

$P = 0{\cdot}02$ (partial χ^2)for the accident responsible (I–III) case-control residence difference comparing residence in New York City with residence elsewhere.

control ($P = 0{\cdot}60$) groups. Finally, Table 8, case drivers were significantly more often closer to their residences than were the non-involved, control-group drivers.

DISCUSSION

A seldom recognized problem in accident-causation research results from the inclusion in case groups of individuals not responsible for their accidents. To a corresponding extent, case series tend to include members whose characteristics are similar to those of the non-involved populations at risk [2]. This decreases the magnitude of case-control differences relative to those which would be observed if it were possible to compare uncontaminated groups of the accident responsible with the remainder of the population at risk. Hence, it is desirable when possible to subdivide case series according to probable responsibility. This has been done effectively, for example, in a previous study in which the distribution of a group of drivers' alcohol concentrations was compared with the distribution of their probable responsibilities, independently rated [7]. An additional reason for subdivision into more homogeneous groups stems from the fact that given factors may vary in importance from one such group to the next, as demonstrated by BARMACK and PAYNE [8–10].

The drivers (together with their vehicles) in accidents in categories I, II and III may reasonably be considered, on the basis of the available evidence, to have been responsible in most or all cases for their accidents. For this reason the case-series members from these accidents have been grouped together in the analyses of the data, and referred to as 'accident-responsible'. A second group comprised of the remaining case-series members, those from accidents in categories IV, V and VI, have been referred to as 'questionably-responsible'. It is recalled that the 'accident-responsible' group (I–III) constituted 70 per cent (30/43) of the case series. Further, since the accidents in the questionably-responsible group (IV–VI) involved some non-responsible drivers, the fraction of all the accident-responsible drivers in the *entire* case series derived from the I–III group was undoubtedly considerably higher than 70 per cent.

The inclusion in the questionably-responsible group (IV–VI) of some non-responsible drivers would be expected to have shifted the characteristics of drivers from this group to a position intermediate between those of the accident-responsible group and those of the corresponding controls. Insofar as the relatively small numbers in the questionably-responsible group permitted analyses, this was consistently found to be the case, as can be seen in several of the tables.

The very significant preponderance of Friday, Saturday and Sunday accidents is consistent with the distributions almost invariably observed elsewhere. The significant preponderance of evening, nighttime and very early morning accidents has also been often previously observed. It is worth noting, however, that the periods with the highest numbers of accidents, 12–2 and 3–5 a.m., have relatively light traffic. In contrast, the smallest number of accidents (one) in any 3-hr period occurred in the three hours ending at 9 a.m., a period during which the city's traffic greatly increases. These data are very similar to those obtained in the Manhattan pedestrian accident study, and suggest, as stated previously, that gross exposure *per se* is not the major determinant of such accidents, and that the factors of importance are more active at other times of day [2]. This also must lead to the questioning of the appropriateness of using the *unqualified* total of miles driven as the denominator of accident rates calculated for research and other purposes.

This predominance of evening, nighttime and early morning accidents again underscores the importance of emphasizing the same period in the organization of emergency medical care, 'a point of general relevance in the motor-vehicle accident picture' [2]. For example, only six of the forty-three member case series survived 6 hr or more and thirty-four were either dead on arrival at the medical facilities to which they were taken, or were dead within 1 hr of their accidents. Further, among the twenty-nine injured between 6 p.m. and 9 a.m., only three were alive at 9 a.m. Consequently, prompt medical care during these off-hours is essential.

However, since death was immediate in many cases, only the better packaging of the vehicle occupants could have contributed, once their accidents had been initiated, to the possible survival of many of those killed.

The lack of a significant association between road condition and accident occurrence (Table 2) was also seen in the pedestrian-accident study. However, as noted in that context, the design employed does not correct for possible weather-associated shifts in density [2].

It is generally accepted that young drivers have higher fatal, injury-producing and property-damage accident rates *per license holder* than do those in following decades [11]. This has been widely interpreted to indicate that such drivers drive more dangerously. However, such intergroup differences in rate per license holder can result: (1) exclusively from differences in the quantity *and* quality of exposure; (2) from differences in the risks assumed, exposure remaining constant; or (3) from a combination of both. Although the potential importance of such differences in the quality and quantity of exposure has been emphasized by some authorities, for example, by McFARLAND and MOORE [12], it has often been overlooked in the discussion of highway accidents and in the design of accident counter-measures.

If younger drivers tend to drive more dangerously under the same conditions of exposure the age of drivers in accidents should tend to be lower than that of the non-involved similarly exposed. In the investigation reported here the fatally-injured drivers were found to be *older* as a group, though not significantly so, than non-involved drivers similarly exposed (Table 3). This finding is consistent with the possibility that the age-associated differences in accident rates per license holder referred to above result primarily from age-associated differences in the quality and quantity of exposure, rather than from differences in risk per unit of exposure, for example, per mile driven, otherwise unqualified. The series reported here, however, is of only moderate size, consisting of forty-three cases and their 258 controls, and as such the data relative to this point should be regarded pending confirmation, as suggestive rather than conclusive.

This investigation was not designed to determine directly the role of the vehicle itself either from the standpoint of accident causation, or from the standpoint of crash-injury production. The lack of significant case-control differences in car age, however, does not lend support to the possibility that factors associated with vehicle aging contributed prominently to the caustion of the fatal accidents studied. This does not, however, rule out either vehicle factors of types which are less commonly contributory than the factors elicited or those which are not significantly associated with vehicle age. Since accidents which result from both use-associated, mechanical failures and faulty design and manufacture are known to occur [13], the determination of the role of such factors in caustion should be elicited by adequately controlled and designed studies in which such vehicle variables are directly studied. This was not the objective of the work reported here.

The most commonly observed characteristic of the drivers killed, other than maleness, was an extremely high alcohol concentration (Table 5). This was particularly the case during late evening and early morning hours. For example, of the fifteen killed in the 9 p.m.–5 a.m. period twelve had been drinking heavily (2, 3+), one moderately (1+) and only two, both drivers of stolen cars, not at all. In the accident-responsible case group (I–III) 14/26 (54 per cent) of all of the drivers had alcohol concentrations $\geqslant$100 mg % and 12/26 (46 per cent) had concentrations $\geqslant$250 mg %! To put these concentrations in perspective, a 155-lb man, for example, drinking within 1 hr or less and within 2 hr of eating an average meal would have to consume a minimum of approximately 5 oz of 80 proof (U.S.) spirits to reach a blood alcohol concentration of 50 mg %, 7·5 oz to reach 100 mg % and 15·5 oz to reach 250 mg % [14].

It is noteworthy that, despite the fact that the site visits were predominantly in the evening and nighttime 76 per cent (195/258) of the drivers in the entire control group had not been drinking to a measurable extent. Nonetheless a substantial minority, in addition to the drivers in the accidents, had been drinking, since 13 per cent had concentrations of 20–99 mg %, and 3 per cent 100–249 mg %. The conjunction of drinking and driving at the times and places of accidents must be regarded, as a result, as by no means rare. It is not the purpose of this report to discuss the considerable evidence that driving performance deteriorates with increasing alcohol concentration. However, it has been repeatedly demonstrated that the driving performance of some individuals begins to deteriorate at concentrations of less than 50 mg %, and that, in the words of an expert committee, '... as the blood alcohol concentration increases, a progressively higher proportion of such individuals are so affected until at a blood alcohol concentration of ... (100 mg %) ... all individuals are definitely impaired' [15]. Similarly, the report of a special committee of the British Medical Association stated, 'The committee considers that a concentration of 50 mg of alcohol in 100 ml of blood while driving a motor vehicle is the highest that can be accepted as entirely consistent with the safety of other road users. While there may be circumstances in which individual driving ability will not depreciate significantly by the time this level is reached, the committee is impressed by the rapidity with which deterioration occurs at blood levels in excess of 100 mg/100 ml. This is true even in the case of hardened drinkers and experienced drivers. The committee cannot conceive of any circumstances in which it could be considered safe for a person to drive a motor vehicle on the public roads with an amount of alcohol in the blood greater than 150 mg/100 ml' [16]. Such statements are derived from a large, well documented and internally consistent body of evidence derived from laboratory, field-trial and epidemiological investigations [7, 14, 17–21]. This evidence is reviewed elsewhere [22].

Several of the accidents in which alcohol was either present in low concentration or absent involved other circumstances which may reasonably be presumed to have been responsible for the deaths involved (Table 5). Aside from the issue as to whether or not an accident *preceded* by the death or incapacitation of the driver on another basis than drunkeness should be counted as a fatal motor vehicle accident, in the accident responsible group (I–III) the accidents involving very high alcohol concentrations ($\geqslant$250 mg %) (12), fleeing stolen cars (2), drag races (1), and presumably medical factors (3) totalled 69 per cent (18/26) of the accident-responsible group herein defined. Drunkeness of the marked degree present in the twelve cases ($\geqslant$250 mg %) referred to was not found in a single member of the control group (Table 6). Further, none of these other events were observed in connection with the control group or its collection. Consequently, the factors just listed, as a group, distinguished between cases and controls in 69 per cent (18/26) of the cases in the accident-responsible group. As a group these same factors, particularly drunkeness were also represented in the composite questionably-responsible group (IV–VI) but not in the corresponding control group (Tables 5, 6).

There is considerable evidence that a similar situation with respect to the importance of drunkeness in driver-fatal accidents exists in other areas. However, apparently only one previous study of driver-fatal accidents has used an adequately defined and collected case series [6], and the methods usually used, discussed elsewhere [6, 22], tend to result in substantial underestimates of the actual frequency and extent of alcohol involvement. In the one adequate study, descriptive of the alcohol concentration distribution of drivers fatally injured in single vehicle accidents in Westchester County, adjacent to New York City, 70 per cent had concentrations of 50 mg % or higher, 57 per cent, 100 mg % or higher, and 49 per cent, 150 mg % or higher. These data are similar to those now reported for the accident-responsible group, and should, together with the data from the non-involved drivers similarly exposed, leave little further doubt as to the genesis of a remarkably substantial portion of the heterogenous, fatal accident problem. There is also considerable evidence of the importance of alcohol in *non*-fatal motor vehicle accidents of various types [7–10, 21], but much further work remains to be done.

The presumably medical episodes noted in Table 5 are consistent with previous knowledge [23], but the fraction of the case series involved should not, because of the statistically small numbers involved, be taken as indicative of the prominence of such factors in the fatal-accident picture. Further, as pointed out elsewhere [23], although such accidents do occur, this knowledge should *not, per se*, be used as the basis of or justification for programs of medical license restriction. It is easily shown that the great rarity of such events in the huge driving population at risk and the practical difficulties inherent in medical screening programs of the types often proposed make such programs both theoretically and practically unreasonable on the basis of present knowledge [23, 24]. It is also of interest in connection with the proposals which have been made to restrict older drivers that none of the drivers in this group were sixty years of age or older.

Within both the married and unmarried groups the case-series members had significantly higher alcohol concentrations (Table 7). This is consistent with the data in Table 6 and with other evidence (*q.v.*) documenting the marked increase in risk associated with high alcohol concentration. The significant negative correlation between marital status and alcohol level and the significant overrepresentation of the non-married in the case group are of greater interest, and should be the subject of further research. It is very possible that these case-control differences would have been augmented if it had been possible to measure the stability of the marital and other social adjustments of those in the case and control groups. Considerable support for the importance of such social variables has come from the work of others. For example, TILLMANN and HOBBS [25] found in a controlled investigation of taxi drivers with high and low accident rates that those with high rates had less stable marital adjustments. Also, Tillmann, and McFarland *et al.* [11] found that among commercial operators those with high rates had significantly more frequent contacts with credit bureaus and with various social agencies. The importance of social and psychological variables in accidents among airmen has also been well documented by BARMACK and PAYNE [8, 10]. In addition to their relationship to such other reports, the present findings should also be considered in relation to the 'considerable body of literature dealing with alcoholism and marriage', recently reviewed by BAILEY [26].

It is not possible on the basis of present evidence to determine the extent to which the alcoholic, as opposed to the non-alcoholic drinker, is contributing to the substantial fraction of fatal, and apparently also non-fatal, accidents in which alcohol is involved. However, the fact that a very substantial proportion of the driver-responsible accidents in which alcohol was a factor involved exceptionally high alcohol concentrations (e.g. 46 per cent $\geqslant$ 250 mg %) suggests that something more than merely social drinking was involved in the same cases. Consequently, as noted in connection with the discussion of the same problem among pedestrians, many of the strategies implicit in present control measures may be inappropriate to the problem since the alcoholic would not be expected to be appreciably influenced by the approaches used [2, 22, 27].

There is great need for research with respect to the relationship both of drinkers who are not alcoholics, and those who are, to the motor-vehicle accident problem, since it is increasingly likely that the largely ignored problem of alcoholism in the modern community is accounting for substantial fractions of the totals of motor vehicle accidents and deaths. There is also a great need for research with respect to the circumstances under which the drinking which precedes alcohol-involved accidents takes place, and an excellent beginning in this respect has been made by BARMACK and PAYNE [8].

Despite the fact that alcohol-concentration distributions, similarly heavily weighted with exceptionally high values, have been reported previously, for example, from Westchester [6] and Baltimore [28], the impression is growing in the literature that the concentrations found among accident-responsible individuals are *usually* in the much lower range frequently reached by ordinary social drinkers. It is well documented that many accident-responsible drivers and pedestrians do have much lower concentrations, and that such individuals are significantly overrepresented in case series. Nevertheless, the assumption that persons with such low concentrations greatly predominate among accident-responsible drivers in most alcohol-involved accidents is not warranted by the present evidence, at least in so far as fatal accidents are concerned.

The question of whether men or women are safer drivers has long been argued, and lower accident rates per license holder among women are usually cited in favor of women drivers, without information as to whether or not women drive as much, or under the same conditions as men. It is noted that there were no women in the case series. Also, considering the time of day of many of the accidents in the series, it is not surprising that few women appeared in the control group (Table 4). Nonetheless, men were significantly overrepresented in the case series. Differences of this type may quite possibly be due to differences in the cultural, social and personal circumstances under which the members of the two sexes drive, as suggested, for example, by MCFARLAND and MOORE [12]. For example, it may be that very high alcohol concentrations are more common among men than among women similarly exposed and that this underlies one portion of the disparity observed. The question, however, is complex and will require much further research.

The significantly greater proximity of the case subjects than of the control subjects to their homes is of interest (Table 8) first, because it duplicates the same finding in the case of fatally injured pedestrians [2], and, second, because it confirms for an urban area the same finding obtained with respect to accidents in a group of rural areas [29]. Although the reasons for this greater proximity cannot be determined without further research, it might be expected that drivers drinking very excessively might be closer to home than other drivers in the same areas. The data in Table 8 are of further interest because they show that like the pedestrian-accident problem, the problem of the driver-fatal accident in New York is predominantly of very local origin. Unlike the non-accident-involved drivers similarly exposed, eighty-three per cent (25/30) of the drivers in the accident-responsible group were fatally injured in the same borough as their homes, and only one of the thirty accident-responsible drivers was from outside the city.

SUMMARY

Drivers of non-commercial automobiles fatally injured in accidents in New York City were compared with non-involved drivers passing the accident sites at the same times of day and on the same days of week. The greatest difference between the two groups was in the prior use of alcohol. Among drivers rated as probably responsible for their accidents 73 per cent had been drinking to some extent whereas only 26 per cent of the similarly exposed, but non-involved drivers had been drinking. Forty-six per cent of the accident-responsible group had blood alcohol concentrations in the very high, 250 mg % and over, range. In contrast, not a single one of the drivers in the large control group had a concentration in this range.

Also represented in the fatally-injured group, but not in the control group, were drivers of fleeing stolen cars, one driver killed in a drag race and a small group of drivers, all in the fifth decade of life, whose accidents resulted from the prior, medical incapacitation. It is pointed out that all of the drivers in these latter categories were sober, and that the occurrence of accidents in the medical group should not *per se* be used in justification of programs of medical license restrictions on the basis of present evidence.

Those fatally-injured were significantly closer to home than were the similarly exposed, but non-involved drivers, and almost none of those fatally-injured lived outside the city.

The case group was composed entirely of males. Although few women were driving at the times and places of the predominantly nighttime and early morning accidents, males were nonetheless significantly overrepresented in the case group. The fatally-injured were also significantly less often married, and in the entire case-control group those not married had significantly higher alcohol concentrations than those married.

The fatally-injured drivers were not significantly different in age or socioeconomic status from the similarly exposed but non-involved controls, and no association between accident involvement and vehicle age were found.

Finally, it is suggested that alcoholism rather than merely social drinking was involved in the case of the drivers with very high alcohol concentrations.

Acknowledgements—This work would not have been possible without the superb cooperation of Dr. MILTON HELPERN, Chief Medical Examiner, City of New York, and of the officers and men of the New York City Police Department. The authors particularly wish to thank former Police Commissioner STEPHEN P. KENNEDY; Assistant Chief Inspector JOHN J. KING, Commanding Officer, Safety Division; Captain MILTON ZARCHIN, Commanding Officer, Accident Investigation Squa d

Lieutenant JAMES DONNELLY, Commanding Officer, Accident Records Bureau; and Lieutenant HUGH A. CLEARY and Sgt. JOSEPH CEA of the Accident Investigation Squad.

In addition, BLAINE A. BRANIFF, ROBERT B. MCFADDEN and RICHARD M. SALLICK of Cornell Medical College, and ROBERT E. CARROLL, Albany Medical College, carried a large share of the burden imposed by the often inconvenient site visits, and this, together with the high level of professional competence with which they worked, are greatly appreciated. The authors also wish to thank Dr. ALAN M. GITTELSOHN, Director, Office of Biostatistics, New York State Department of Health, and Mrs. WILHEMINA CALHOUN for their very considerable assistance in the evaluation of the data, and the staffs of the Division of Epidemiologic Research and the Epidemiology Residency Program for their continued support.

REFERENCES

1. *Accident Facts* (1961 Edition) National Safety Council, Chicago, 1961.
2. HADDON, W., Jr., VALIEN, P., MCCARROLL, J. R. and UMBERGER, C. J.: A controlled investigation of the characteristics of adult pedestrians fatally injured by motor vehicles in Manhattan, *J. chron. Dis.* **14,** 655, 1961.
3. GONZALES, T. A., VANCE, M., HELPERN, M. and UMBERGER, C. J.: *Legal Medicine Pathology and Toxicology* (2nd. Edition) p. 1095, Appleton–Century–Crofts, New York, 1954.
4. SALEM, H., LUCAS, G. H. W. and LUCAS, D. M.: Saran plastic bags as containers for breath samples, *Canad. med. Ass. J.* **82,** 682, 1960.
5. FRIEDMANN, T. E. and DUBOWSKI, K. M.: Chemical testing procedures for the determination of ethyl alcohol, *J. Amer. med. Ass.* **170,** 47, 1959. Also published in: *Chemical Tests for Intoxication Manual,* Committee on Medicolegal Problems, *Amer. Med. Ass.,* Chicago, 1959.
6. HADDON, W., JR. and BRADESS, V. A.: Alcohol in the single vehicle fatal accident: Experience of Westchester County, New York, *J. Amer med. Ass.* **169,** 1587, 1959. Reprinted in: *Traff. Saf. Res. Rev.* **3,** 1959.
7. SMITH, H. W. and POPHAM, R. E.: Blood alcohol levels in relation to driving, *Canad. med. Ass. J.* **65.** 325, 1951.
8. BARMACK, J. E. and PAYNE, D. E.: Injury-producing private motor vehicle accidents among airmen: Psychological models of accident-generating processes, *J. Psychol.* **52,** 3, 1961.
9. BARMACK, J. E. and PAYNE, D. E.: Injury-producing private motor vehicle accidents among airmen: I. The role of drinking *Highw. Res. Bd. Bull.* **285,** 1961.
10. BARMACK, J. E. and PAYNE, D. E.: Injury-producing private motor vehicle accidents among airmen: II. Background correlates of the lost-time accident, *Highw. Res. Bd. Bull.* **285,** 1961.
11. MCFARLAND, R. A., MOORE, R. C. and WARREN, A. B.: *Human variables in motor vehicle accidents: A review of the literature.* Harvard School of Public Health, 1955.
12. MCFARLAND, R. A. and MOORE, R. C.: *Youth and the automobile,* presented at the White House Conference on Children and Youth, 1960, and reprinted by the Association for the Aid of Crippled Children.
13. *Comstock vs. General Motors et al.,* 358 Mich. 163, 99 N.W. 2d 627, 1959.
14. COLDWELL, B. B. (Editor): *Report on impaired driving tests,* Crime Detection Laboratory, Royal Canadian Mounted Police, Queen's Printer, Ottawa, 1957.
15. *Proceedings of the symposium on alcohol and road traffic, 1958,* Indiana University, 1959.
16. Alcohol and road accidents: Report of Special British Medical Association Committee, *Brit. med. J.* **1,** 269, 1960.
17. LOOMIS, T. A. and WEST, T. C.: The influence of alcohol on automobile driving ability: An experimental study for evaluation of certain medicolegal aspects, *Quart. J. Stud. Alcohol* **19,** 30, 1958.
18. DREW, G. C., COLQUHOUN, W. P. and LONG, H. A.: Effect of small doses of alcohol on a skill resembling driving, *Brit. med. J.* **2,** 5103, 1958. Reprinted in *Traff. Saf. Res. Rev.* **1,** 4, 1959.
19. BJERVER, K. and GOLDBERG, L.: Effect of alcohol ingestion on driving ability: Results of practical road tests and laboratory experiments, *Quart. J. Stud. Alcohol* **11,** 1, 1950.
20. COHEN, J., DEARNALEY, E. J. and HANSEL, C. E. M.: The risk taken in driving under the influence of alcohol, *Brit. med. J.* **15,** 1438, 1958.
21. LUCAS, G. H. W., KALOW, W., MCCOLL, J. D., GRIFFITH, B. A. and SMITH, H. W.: Quantitative studies of the relationship between alcohol levels and motor vehicle accidents, *Proceedings of the Second International Conference on Alcohol and Road Traffic, Toronto,* 139, 1953.
22. HADDON, W., Jr.: Alcohol and highway accidents: Read before the *American Medical Association Symposium on the medical aspects of automobile injuries and deaths, One Hundred and Tenth Annual Meeting, New York City* (27 June) 1961.
23. HADDON, W., Jr.: in *The heart in industry,* WARSHAW, L. J. (Editor) P. B. Hoeber, 406–407, New York, 1960.
24. HADDON, W., JR.: Drivers' licenses, *AMA News (Letters)* **4,** 1961.

25. TILLMAN, W. A. and HOBBS, G. E.: The accident-prone automobile driver: A study of the psychiatric and social background, *Amer. J. Psychiat.* **106,** 321, 1949.
26. BAILEY, M. B.: Alcoholism and marriage, A review of research and professional literature, *Quart. J. Stud. Alcohol* **22,** 81, 1961.
27. SCHMIDT, W. S. and SMART, R. G.: Alcoholics, drinking and traffic accidents, *Quart. J. Stud. Alcohol* **20,** 631, 1959.
28. FREIMUTH, H. C., SPENCER, R. W. and FISHER, R. S.: Alcohol and highway fatalities, *J. Forens. Sci. Soc.* **3,** 65, 1958. Reprinted in *Traff. Saf. Res. Rev.* **4,** 23, 1960.
29. ANONYMOUS: *The federal role in highway safety,* U.S. Government Print. Off., 1959.